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# A Comparison of the Efficacy of Gutter Pan and Curb Top Placement with a Full Gateway Configuration of the In-Street Sign on Driver Yielding to Pedestrians

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# A COMPARISON OF THE EFFICACY OF GUTTER PAN AND CURB TOP PLACEMENT WITH A FULL GATEWAY CONFIGURATION OF THE IN-STREET SIGN ON DRIVER YIELDING TO PEDESTRIANS

by

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Driver yielding behavior at crosswalks directly affects pedestrian safety. In this study we examined whether the placement of the signs in the gutter pan or on top of the curb, while using a full gateway configuration of the in-street sign, influenced the efficacy of the treatment. Data were collected at sites using both in gutter and on top of curb full gateway configurations. The gutter pan configuration resulted in a higher percentage of driver yielding behavior to pedestrians in the crosswalk. The gateway treatment was shown to be more effective in the gutter pan configuration than the curb top configuration at all three of the sites, though the difference in effects were minimal. This suggests that placing the signs on the curb, though shown to be less effective, is still effective in prompting driver yielding to pedestrians. This finding is important because placement on top of curb would allow for proper sewage drainage, plows not being impeded during the winter months, street sweepers not being impeded, etc. Perhaps most important, signs mounted on top of the curb would be less likely to be struck and damaged by vehicles or plows than signs placed in the gutter pan area. Contextual variables appeared to be related to whether the gutter pan or the curb configuration was more effective. Behavioral principles were used to interpret these data with edge signs mounted on top of the curb vs. in the gutter pan on driver yielding to pedestrians in the crosswalk.

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# INTRODUCTION

Everyone has experienced the feeling of being a pedestrian at some moment in time; whether walking to the grocery store or to the mailbox. Most trips begin and ends as a pedestrian. Pedestrians have to share the roadways with many forms of motorized vehicles. Along with bicyclists, pedestrians are the most vulnerable road users. According to the National Highway Traffic Safety Administration (2018), there were 37,133 people killed in motor vehicle traffic crashes on U.S. roadways during 2017, a 1.8 percent decrease from 37,806 people killed in 2016, which came after two yearly consecutive increases in 2015 and 2016. While pedestrian fatalities remain high, there was 1.7 percent decrease in the number of pedestrians killed in traffic crashes in 2017 from 2016, totaling 5,977 deaths (NHTSA, 2018) and an increase in pedestrian crashes to 6,283 in 2019, a 3.4 percent increase (NHTSA, 2019).

There have been many different ways to increase pedestrian safety. The engineering of roads to increase pedestrian safety dates to ancient Rome, where raised crosswalks with gaps in them for the cart wheels forced cart drivers to slow. Since that time, traffic engineers have utilized a variety of interventions to increase safety for pedestrians (Bennett & Van Houten, 2015). One traffic safety interventions that has shown to be effective at increasing driver yielding behavior towards pedestrians at the crosswalk is a sign designed for in-street use. This sign is called the R1-6 or R1-6a.  The R1-6 is described in the Manual for Uniform Traffic Control Devices, which reads "STATE LAW YIELD TO PEDESTRIANS", (Federal Highway Administration [FHWA], 2009). The R1-6a sign states “STATE LAW STOP FOR PEDESTRIANS”, (Federal Highway Administration [FHWA], 2009).

Bennett, Manal, and Van Houten (2014) ran an experiment using a novel configuration of the in-street sign, called a gateway. In the gateway configuration, an R1-6 sign is placed in each gutter pan (i.e., the flat, concrete portion adjacent to the base of the curb), or on the lane line marking the edge of the road where applicable, and on each subsequent lane line in the road, including the centerline. This configuration requires a vehicle to pass between two R1-6 signs flanking their travel lane when traversing a pedestrian crosswalk. The authors assessed these configurations at two locations. At one location, they found that yielding increased from a baseline average of 25%, to 56% in the centerline only condition, and 79% in the gateway condition. They found similar results at a second location, with average yielding in baseline of 23%, increasing to 45% in the centerline only configuration, and 82% in the gateway configuration (Bennett, Manal, & Van Houten, 2014). The authors concluded that the gateway configuration produced greater levels of yielding than a single sign, that it produces comparable levels of yielding to much more expensive interventions, and that it can improve the effectiveness of other crosswalk interventions when used in concert with them (Bennett et al., 2014).

Bennett and Van Houten (2015) examined several additional factors involving the R1-6 sign. They assessed the influence of the sign symbol and message, replacing some of the R1-6 signs in the gateway configuration with fluorescent, durable, polyurethane, traffic delineator posts, and comparing the gateway configuration to alternatives which used fewer in-street signs. The experimenters started by finding an average baseline yielding of 7% at two sites. Yielding at the sites increased to 79% and 77% in the gateway R1-6 sign condition. They also measured the effects of the sign placed only on the edge of the road, or on the centerline only, and compared yielding under those conditions to the gateway at two of these locations. Edge sign placement alone produced an average yielding of 36% and 10%, while centerline sign placement alone produced 52% and 18% yielding. The R1-6 signs were then replaced with identical, yellow-green blank signs, 4 which had no symbols or messages, in the full gateway configuration. This resulted in the average yielding decreasing to 27% and 39%. When the authors replaced the most vulnerable signs in the gateway configuration (i.e., those in the roadway, unprotected by the curb), with fluorescent traffic posts, they saw a slight reduction in average yielding compared to a gateway which used only R1-6 in-street signs. At both locations, Bennett and Van Houten found that in this gateway with delineator condition, average yielding was 60%. At a third location they found average baseline yielding was 0%, which increased to 59% in the gateway with traffic post condition, and to 89% in the gateway with all R1-6 signs condition. Bennett and Van Houten (2015) concluded that it was not merely the presence of the in-street sign which produced the increase in yielding, but that the message on the sign was also important. This was shown to be true given that the blank signs produced much less benefit in yielding. However, they also demonstrated that the placement of the signs in the road is an essential factor in the efficacy of an in-street sign configuration, and the center vs. edge sign comparison suggested that the distance between signs might be a variable of interest. Additionally, they raised the question of durability of a gateway installation. The authors began to address this question by examining the effects of replacing certain elements of a gateway with more durable components (Bennett & Van Houten, 2015).

A longitudinal study (August to October 2015, and May to November 2016) was conducted to examine the R1-6 sign durability. This study examined the cost and survivability of various elements of the gateway configuration and determined that certain types of sign mounts were more vulnerable than others, regardless of their position in the road (Van Houten, Hochmuth, Dixon, & McQuiston, 2018). However, even less durable sign-mount units were capable of surviving when placed on top of a curb. When signs were damaged or destroyed, and the gateway treatment remained partially intact, yielding did decrease at these sites, though not to baseline levels (Van Houten et al., 2018). The more frequently signs are damaged or destroyed, the more frequently they must be replaced. This results in treatment becoming more expensive and inconvenient the more frequently signs need to be replaced. However, mounting a sign on a curb necessarily increases the width of the gap between signs, because the top of the curb is often as much as 2 ft removed from the edge lane line, or further yet if there is a dedicated bicycle lane. Thus, the relationship of driver yielding to the distance between signs in a gateway configuration is an important variable to investigate when balancing sign survival, cost, and efficacy (Hochmuth, 2018).

Hochmuth (2018) examined the effects of wide and narrow gateway configurations of the in-street sign on drivers yielding the right of way to pedestrians. Two locations were studied. Hochmuth (2018) found that in regard to the R1-6 sign, the use of a gateway configuration at any width has the greatest effect on yielding. That said, the width of the gap between two in-street portions of a gateway does influence the degree of driver yielding to pedestrians. The narrower the gap between the signs the higher yielding, however, the gain in yielding may not outweigh the possible reduction in survivability of the signs at a given location. The variable of width between signs has practical implications for survivability of permanent installations. This factor should be considered not only because of cost, but also because damage to the signs may result in a further reduction in yielding; while damaged sign configurations do not always fall to baseline levels, their performance is lower than an undamaged gateway (Van Houten, & Hochmuth, 2016).

The present study examined the effects of gutter pan and curb top placement of the R1-6a sign in a full gateway configuration on driver yielding to pedestrians in the crosswalk at three locations. The variable of gutter pan and curb top sign placement has practical implications for survivability of permanent installations. The effectiveness of each configuration on driver yielding behavior was assessed.

## GENERAL METHOD

### Participants

The participants were motorists who were driving through the crosswalk when pedestrians were present at the crosswalk locations during data collection periods. All data was anonymously recorded. There was no identifying information collected on any of the participants. The yielding behaviors of the motorist were publicly observable.

### Settings

Three sites were assessed in Ann Arbor, Michigan. Two of the locations in the study featured an unsignalized pedestrian crosswalk. One site featured a pedestrian activated Rectangular Rapid Flashing Beacon (RRFB) (Shurbutt, Van Houten, Turner, and Huitema, 2009), but the activation button was not used during the experiment. If a natural pedestrian chose to activate the beacon, the motorists' behavior was not measured. Lane measurements at each site were also recorded. The first site was a crosswalk located at the North leg of Nixon at the intersection with Bluett.  Nixon road had three motor vehicle travel lanes and allowed for northbound and southbound travel. One of the lanes was a left turning lane. This lane was on the southbound side. Both the northbound and southbound lanes included a designated bicycle lane. The southbound lane measured 17.5 ft. wide including the bicycle lane. The left turn lane, which was also southbound, measured 16.66 ft. wide. The northbound lane at this site had a width of 14 ft. The posted speed limit on this road was 30 mph. The flow of traffic appeared to frequently exceed the posted limit during observations. There was a posted speed limit sign in close proximity to the site. At each end of sidewalk before the start of the bicycle lanes there was a yellow pedestrian crossing sign signifying a crosswalk. R1-6 Signs were located on the centerline, on the lane line and on both bicycle lanes.


*Figure 1.* Nixon Road Site

The second site was a crosswalk on North 7th Street, adjacent to Pioneer High School. The speed limit at this site was 35 mph. Observation periods were conducted when school was not in session. On the southbound side of the crosswalk was an entrance to a wooded trail. This site has a large volume of pedestrian and motor vehicle traffic. The crosswalk included a median that separated the two directions of travel. This site was comprised of one travel lane and a bike lane going north and one travel lane, a turn lane, as well as a bike lane going south. One of the lanes was a left turning lane. This lane was on the southbound side. There was also a buffer area between the motorist lanes and bicycle lanes. The southbound lane measured 20.75 ft. wide including the bicycle lane. The southbound left turn lane measured 12.25 ft. wide. The midblock median separating the direction of travel measured 9.5 ft. wide. The northbound lane measured 18.25 ft. wide. The buffer area between the motorist lane and bicycle lane measured 3.5 ft. on both the southbound and northbound lanes. At each end of sidewalk before the start of the bicycle lanes on the grass near the curb there was a yellow pedestrian crossing sign signifying a crosswalk. There was also the same sign in the midblock. This site featured a RRFB which could be activated by pressing the button on the pedestrian crossing sign pole. Since the other two sites did not have a RRFB, beacon was not used during the experiment.

*Figure 2.* Nixon Road Site

The third site was Huron Street. This was a busy location with a lot of motorist and pedestrian traffic. The speed limit at this location was 35 mph. This site was located next to a University of Michigan dormitory and two blocks away from the main campus. Huron Street had two-way traffic with two lanes in each direction and pedestrian refuge island separating the direction of travel. Huron road carried traffic traveling in an eastbound and westbound direction. There were no bicycle lanes on this street. There were yellow pedestrian crossing signs on both ends of the crosswalk near the sidewalk. The midblock contained a keep right sign, but did not have any pedestrian crossing signage. The eastbound lane was 21.83 ft. wide. The westbound lane was 21.75 ft wide.


*Figure 3.* Huron Street Site

**Apparatus**

This study used an in-street pedestrian crossing sign called a R1-6a sign. This sign contained a written command that clearly was designed to serve as a prompt for motorists to come to a complete stop when pedestrians are present in or near the crosswalk. The sign consisted of a fluorescent yellow-green reflective sheeting. In the middle of the sign there was a white background with a red stop sign, with the words "for" below that, and a black pedestrian symbol below that. It was also clearly stated on the sign that this is local law. Each sign was attached to a portable rubber base. They were not bolted or attached to the surface of the road, the position of the sign could be changed during different conditions of the experiment. During the study we would place the signs in various configurations and collect data. Being able to relocate and reconfigure the signs was needed to conduct the study.

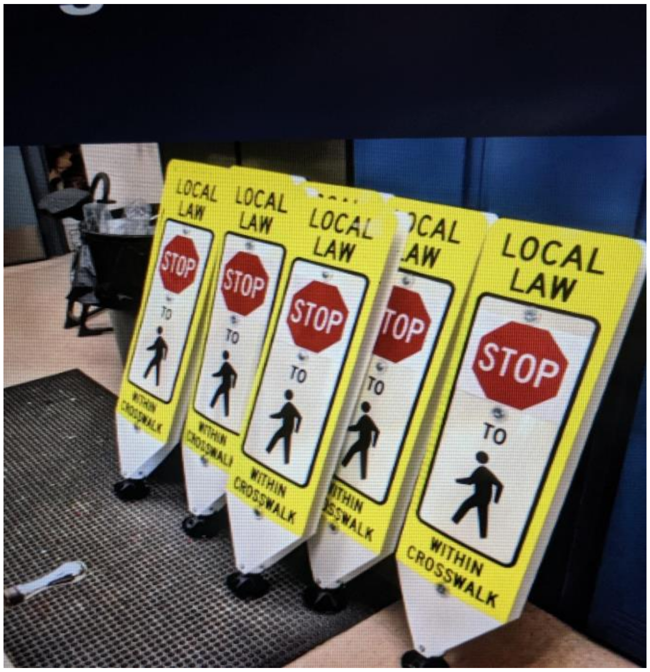


*Figure 4.* R1-6a sign with portable base.

**Dependent Variables**

We observed and measured the public behavior of motorists. We specifically measured the number of motorists who yielded or stopped and failed to yield or stop for pedestrians in or entering the crosswalks. The study used the same measuring techniques as Bennett et al. (2014) and Hochmuth (2018). An objective dilemma zone (DZ) was established to have a consistent measuring point in reference to driver yielding to pedestrians in the crosswalk. An objective dilemma zone is a location beyond which a driver can easily stop if the crosswalk has active pedestrians or pedestrians are entering the crosswalk. A formula created by traffic engineers was used to calculate the yellow light duration, the time required to allow a vehicle to safety stop when a traffic signal went from green to red. (Institute of Transportation Engineers, 1989). The formula: $y = t + (v/2a + 2Gg)$ takes into account the reaction times of drivers, safe deceleration rate, the posted speed, and the grade of the road to calculate the interval for the yellow traffic light (Hochmuth, 2018). This formula was used to determine the distance to the dilemma zone boundary by multiplying the time (y) by the posted speed limit in feet per second: where t = the perception and reaction time in seconds (1s); v = the speed of approaching vehicles in feet per second (we substitute the posted speed limit in feet per second); a = the deceleration rate, recommended at $10ft/s^2$; G = acceleration due to gravity ($32ft/s^2$); and g = the grade of the approach (Bennett et al., 2014). Orange lawn flags were placed in the ground adjacent to the road, along with orange duct tape which was placed from the top of curb and extended into the gutter pan. This was done to help observers know where the dilemma zone began. This resulted in a DZ of 141 feet at Nixon, 183 feet at 7th Street, and 183 feet at Huron Street.

Motorists who had not passed the outer boundary of the DZ when a pedestrian entered the crosswalk were scored as yielding or not yielding because they had sufficient time and space to stop safely for the pedestrian. Motorists who entered to dilemma zone before the pedestrian placed a foot in the crosswalk could be scored as yielding but could not be scored as failing to yield because the motorist was not legally required to yield at this distance. However, the signal timing formula is relatively lenient; hence many vehicles that passed the DZ yielded safely, particularly those traveling below the speed limit (Hochmuth, 2018).

**Procedures**

Researchers were trained to use the operational definition of yielding behavior. They practiced recording together until they obtained inter-observer agreement of 90% or better for two consecutive sessions (a total of 40 observations). Researchers were also trained on how to use a walking wheel to measure the distance to the DZ, and how to place the small lawn flags or lay the tape to delineate the DZ.

The researchers set up the DZ before beginning trials. A walking wheel was used to measure the distance from the nearest crosswalk line to the DZ. During the marking process, one of the researchers served as a spotter to ensure that the person using the walking wheel was clear of any oncoming traffic. Both researchers wore yellow, reflective vests during the marking process to make themselves more visible to drivers. The researchers then marked the location with the necessary flags or tape. On two lane roads with one lane in each direction, only drivers in the first travel lane were scored for yielding after the pedestrian entered the crosswalk. This procedure was used because it conforms to the obligations of motorists specified in most vehicle statutes regarding who has the right of way at what time. At 7th Street and Huron Street, motorists in the second half of the roadway were scored as a separate trial, because there was a median island (i.e., a raised section of pavement) separating the travel way, however, if no vehicles were in the second lane the crossing was completed and that portion was not considered a trial. At Nixon Road, there was no midblock or median island. Drivers in the second lane of the road were scored only when the pedestrian had entered the second half of the first lane preceding the yellow centerline, if they were beyond the DZ for the travel lane, and were scored in the same trail as the crossing for the first lane. This procedure conforms with the law requiring motorists to yield to pedestrians in a crosswalk.

Each session consisted of 20 trials (pedestrian crossings). A trial, or staged crossing, began when a researcher placed one foot within the crosswalk with their head turned in the direction of the approaching vehicle, and ended when that researcher safely stepped out of the street. A research assistant recorded the results of the trial on the data sheet immediately following the cessation of each trial.

The percentage of drivers who yielded the right of way to pedestrians was calculated for each session by dividing the number of drivers that yielded the right of way during that session by the number of drivers that yielded the right of way during that session by the number of drivers that yielded plus the number of drivers that failed to yield during that session. Data were collected between April 2015 and August 2015, and no data were collected when it was raining.

Inter-observer agreement was calculated for all three experiments, and data were collected during each condition of each experiment. Each event that was scored the same by both observers was counted as an agreement, and each event that was scored differently by each observer was scored as a disagreement. Inter-observer agreement was calculated within each session by dividing the number of agreements by the number of agreements, plus the number of disagreements. The result of this calculation was then converted to a percentage. At the beginning of inter-observer agreement sessions, one observer was designated as the primary observer: it was this observer's final yielding percentage which is represented in the data set.

During sessions in which inter-observer agreement data were collected, each observer stood several meters apart at a location with an unobstructed view of the crosswalk. They then independently recorded motorist yielding behavior and did not discuss with each other how they scored any of the trials. This procedure controlled for potential observer bias.

## EXPERIMENT

Two different configurations of the gateway were assessed at each location (on curb top and in gutter pan), and compared to baseline levels of yielding. At Nixon Road, the curb top configuration consisted of an R1-6a sign placed on the left side, on top of the curb adjacent to the pedestrian island, and a second R1-6a sign was placed on the right side on top of the curb. The gutter pan gateway configuration involved an R1-6a sign placed on the left side, in the gutter pan adjacent to the pedestrian island, and a second R1-6a sign was placed on the right side, in the gutter pan. A R1-6a sign was placed on the centerline and left turn lane for both configurations.

At 7th Street, the curb top configuration consisted of an R1-6a sign placed on the left side, on top of the curb adjacent to the pedestrian island, and a second R1-6a was placed on the right side of on top or the curb. A R1-6a sign was also placed on top of the curb on the median island. The gutter pan configuration involved an R1-6a sign placed on the left side, in the gutter pan adjacent to the median island, and a second R1-6a sign was placed on the right side, in the gutter pan. A R1-6a sign was placed in the gutter pan on the right and left side of the median. A R1-6a sign was placed on the centerline and left turning lane for both configurations.

At Huron Street, the curb top configuration consisted of an R1-6a sign placed on the left side, on top of the curb on each side of the pedestrian island, and an R1-6a was placed on the top the lane line on each side of the road. A R1-6a sign was also placed on the curb on the right side of the road in each direction. The gutter pan configuration involved an R1-6a sign placed on the left side, in the gutter pan adjacent to the pedestrian island, and a second R1-6a sign was placed on the right side, in the gutter pan in each direction. A R1-6a sign was placed on the centerline for both directions of travel. In each case, the particulars of these sign configurations were dictated by the existing characteristics of the sites in terms of sign placement and the resulting widths between the signs.

**Results**

The percentage of driver yielding right of way to pedestrians in the crosswalk under each condition at the Nixon Road were assessed. Baseline yielding at this location averaged 39.6%, while the curb top configuration of the R1-6 sign increased average yielding to 86.4%. However, the gutter pan configuration produced average yielding of 93.2%. A center lane only probe was conducted which resulted in a yielding percentage of 68.3%.

The percentage of driver yielding right of way to pedestrians in the crosswalk under each condition at the 7th Street site were assessed. Baseline yielding at this location averaged 15.2%, while the curb top configuration of the R1-6a sign increased yielding to 59.1%. However, the gutter pan configuration produced a higher average yielding of 69.9%.

The percentage of driver yielding right of way to pedestrians in the crosswalk under each condition at Huron Street were assessed. Baseline yielding at this location averaged 61.8%. The curb top configuration of the R1-6a sign increased yielding to 92.0%. The gutter pan configuration of the R1-6a sign at this site produced an average yielding of 97.6%. At this location, both the curb top and gutter pan configurations produced comparable high levels of yielding.

Inter-observer agreement on the percentage of drivers yielding to pedestrians was calculated for 30% percent of all observations, and averaged 95.8% across all three sites, with a range of 90% to 100%.

Across all three locations, the R1-6a gateway configuration produced an increase in drivers yielding over baseline. Additionally, gutter pan configurations produced greater levels of average yielding compared to the curb top configuration. Across all three sites, the average yielding for the curb top configuration was 75.7% and the average yielding for the gutter pan configuration was 83.3%.

## DISCUSSION

The results of the present study demonstrated that R1-6a signs used in a full gateway configuration at all three sites has the greatest effect on yielding in the gutter pan configuration. The present study and Hochmuth (2018) found that the width of the gap for in-street sign full gateways configurations does influence the amount of driver yielding to pedestrians. However, the gain in yielding with the smaller width gateway configuration may not outweigh the possible reduction in survivability of the signs at a given location. This factor should be considered not only because of cost, but also because damage to the signs may result in a further reduction in yielding; while damaged sign configurations do not always fall to baseline levels, their performance is lower than an undamaged gateway (Hochmuth, 2018).

Though the gutter pan placement was shown to be more effective in prompting driver yielding to pedestrians at the crosswalk, there are a variety of factors as to why the curb top placement of the edge sign may be a better permanent option. Curb top placement allows for proper water-drainage and snow-removal. The gutter pan placement of the edge sign could possibly impede plows during the winter months and street sweepers year-round. It could also interfere with sewers collecting drainage water and waste matter on the roadways by serving as a dam. Another disadvantage of the gutter pan placement is that it cannot be installed if a bicycle lane is present. The bicycle lane must be absent of signs and markers to allow the bicyclist to have a safe and unobstructed lane of travel. For all of these reasons, the curb top placement of the R1-6a edge sign may be a better permanent option for a full gateway configuration than the R1-6a edge signs being located in the gutter pan.

Future research is needed to determine the long-term durability of the gateway treatment with the edge sign placement on the curb top. Vehicles may be less likely to strike in-street signs that are placed at the edge of the roadway. The signs on the lane line are most vulnerable and may limit the application of this device on higher speed road (Bennett, 2014). The outlook for such research should be promising. The gateway configuration produces comparable levels of yielding to more expensive treatments (i.e. the rectangular rapid-flashing beacon) (Bennett et al., 2014), and reductions in speed which is associated with a crash modification factor (Zegeer et al., 2017). A crash modification factor is a multiplier which estimates the expected number of crashes if a particular countermeasure is used (Hochmuth, 2018). For instance, if a location has 10 crashes per year of a certain type, implementing a countermeasure with a CMF of 0.5 would estimate 5 crashes, while a CMF of greater than 1.0 would predict an increase in crashes of that type. The long-term survivability of the full gateway configuration with the curb top placement needs to be studied in terms of damage from roadway use and through vandalism.

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