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An Examination of Several Variables Influencing the Efficacy of the Gateway in Street Sign Configuration on Motorist Yielding Behavior

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AN EXAMINATION OF SEVERAL VARIABLES INFLUENCING THE Efficacy OF THE GATEWAY IN-STREET SIGN CONFIGURATION ON MOTORIST YIELDING BEHAVIOR

by

Miles K. Bennett

A dissertation submitted to the Graduate College in partial fulfillment of the requirements for the degree of Doctor of Philosophy Psychology
Western Michigan University
August 2015

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AN EXAMINATION OF SEVERAL VARIABLES INFLUENCING THE EFFICACY OF THE GATEWAY IN-STREET SIGN CONFIGURATION ON MOTORIST YIELDING BEHAVIOR

Miles K. Bennett, Ph.D.
Western Michigan University, 2015

This study contains five different experiments that examine the effects of several variables influencing the effectiveness of the In-Street sign and various In-Street sign configurations. Experiment 1 and 2 compared the effects of the Gateway configuration using R1-6 signs to blank fluorescent yellow-green signs arranged in the Gateway configuration on motorist yielding to pedestrians in crosswalks. The results showed that the blank signs produced an increase in yielding from 7% to 33%, while the addition of the message and symbols to the sign increased yielding to 78%. Experiment 1, 2, and 4 examined the effects of different configurations of the In-Street sign on motorist yielding. The results showed the full Gateway was the most effective configuration, placement of the edge signs in the gutter pan was slightly more effective than placement of the edge signs on the curb face, partial installation of the Gateway was less effective than the full Gateway, and the substitution of a the City Post delineator for the lane line signs was slightly less effective than the full Gateway configuration with a yielding rate of 60%. Experiment 3 demonstrated that the full Gateway and
Gateway with City Post on the lane lines are effective at night. Experiment 5 demonstrated that the Gateway increased yielding at two single lane roundabouts.
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1 Introduction

1.1 A Brief History of Traffic Safety

Historical travel speeds were much lower than they are today. It would take months or years to travel the distance a car can now travel in hours. Roads were traveled together with carriages, horses, and walking. The idea of having a shared transit system continued for hundreds of years and can be seen as late as the 1920s. The rule was that all persons had equal rights in the highway and that exercising these rights required that each person take due care not to injure other road users.

Due to multiple factors not explored in this paper, ownership shifted subtly away from pedestrians to vehicles in first half of the 20th century. Pedestrians are designated to use sidewalks or to walk in the shoulder area facing traffic. In some cases pedestrian travel is completely restricted e.g., on highways or on-ramps.

Inevitably pedestrians have to cross from one side of the road to the other. This requires a pedestrian to negotiation space with oncoming vehicles. The scales are unfortunately uneven for pedestrians. Motorists have more mass, speed, and safety measures, which prevent injury and damage to themselves at the expense of their vehicles. Pedestrians are much more vulnerable than motorists and have no special protections available to them. Despite sciences’ best efforts, in 2013 the National Highway Traffic Safety Administration (NHTSA) stated that a pedestrian was injured every 8 minutes and a pedestrian was killed every 2 hours.
Researchers have developed technological countermeasures that have improved safety for pedestrians. Laws have also been created and enforced to provide additional protection and support for pedestrians. These work together to reduce pedestrian fatalities, but none can solve the problem alone. Some avenues have had more success than others. Only by examining each strategy and understanding how and under what conditions it works can we determine the best ways to improve pedestrian safety.

Attempts to improve pedestrian safety date back to ancient Rome. The 2,000-year-old ruins of Pompeii contained raised stones for pedestrians to use to cross roads. These raised crosswalks had gaps for the wheels of the cart to pass through. This design served as a form of traffic calming because the cart motorist needed to slow in order to align the card wheels with gaps in raised crossways. As technology advanced, both the sophistication of vehicles and the interventions used to increase pedestrian safety evolved.

### 1.2 The Crosswalk

Crosswalks are the most common pedestrian safety intervention in the United States. Crosswalks come in four different forms; marked and unmarked and controlled and uncontrolled. Marked crosswalks consist of pavement marked with white lines in one of the approved configurations in the Manual on Uniform Crossing Devices (MUTCD, 2009). These can be placed at intersections or at any point along a block. Unmarked do not have any paint, but rather are considered implied and therefore are not present outside of an intersection. Controlled crosswalks on state roads have a traffic signal or stop sign that explicitly controls motorist behavior (others may vary per local ordinances). At an intersection with
traffic signals, there may be additional signals present to indicate when it is the pedestrians’ turn to cross. Uncontrolled intersections do not have signals or signs present requiring motorists to stop.

The effectiveness of these types of crosswalks varies. Marked crosswalks for single lane roads with appropriate traffic volume are more effective than unmarked and controlled crosswalks are more effective than uncontrolled crosswalks (Zegeer, et. al. 2005). Research has shown that added markings and or signage at crosswalks increase motorist yielding (Van Houten, 1988; Van Houten et. al, 2004; Huybers et. al, 2004). Crosswalks that are over 60 feet in length often have raised pedestrian refuge islands. Areas with higher pedestrian activity, multiple lanes, or uncontrolled crossings are recommended to have higher visibility markings present.

Pedestrian fatalities still occur at locations with enhanced crosswalk features. Crashes, or near crashes, can still arise between pedestrians and motorists when vehicles movements’ conflict with a pedestrian crossing in a crosswalk. Innovations have been developed to increase motorist yielding right-of-way to pedestrians at crosswalks. Two new interventions that have become popular for uncontrolled marked crosswalks are the Rectangular Rapid Flashing Beacon (still under interim approval since 2008) and the Hybrid Beacon (formerly called the HAWK, added to the MUTCD in 2009). Installation of these devices has been shown to produce a marked increase in motorist yielding (Van Houten, 2008; Shurbutt et. al, 2009; Fitzpatrick, 2009). However, the use of these devices are limited due to their cost. Therefore, low cost interventions that can be used to
enhance the safety and utilization of crosswalks would likely have a large favorable impact on pedestrian safety and mobility.

1.3 Pedestrian Fatality Statistics

Overall pedestrian fatalities steadily decreased nationally from 5,801 pedestrian fatalities in 1991 to their record low of 4,108 in 2009 (NHTSA, 2013). Pedestrian fatalities began to rise in 2010 to 4,302 and continued to rise until 2012 when there were 4,818 pedestrian fatalities (NHTSA, 2013). 2013 saw a slight decrease of 2% in pedestrian fatalities with a total of 4,735 (NHTSA, 2013). Pedestrian deaths accounted for 14% of all traffic fatalities in motor vehicle accidents in 2013 (NHTSA, 2013). Urban locations accounted for 73% of all pedestrian fatalities while rural locations only accounted for 27% (NHTSA, 2013).

Michigan pedestrian fatalities have shown a similar trend as the national data according to the Michigan Department of Transportation. Overall pedestrian fatalities have decreased since their high of 175 in 1998 and continued to decline until 2008 with 124 pedestrian fatalities (MDOT, 2013). Fatalities have steadily risen in the following years. In 2009 there were 140, followed by 140, 152, 157, and finally 159 fatalities in 2013 (MDOT, 2013). Pedestrian fatalities in Michigan occurred 12% of the time while the pedestrian was using a crosswalk (MDOT, 2013). Similar to the national statistics, the most dangerous pedestrian behavior was crossing outside of an intersection. This accounted for 46 fatalities or 30.9% of the total pedestrian fatalities (MDOT, 2013).
1.4 Pedestrian Behavior

Statistics show crossing outside of an intersection to be consistently the most dangerous pedestrian behavior (NTHSA, 2013, MDOT, 2013). While intersections often have the most signalization, signage, and markings present, many pedestrians opt to cross at the middle of the block. This behavior often occurs outside of a crosswalk.

There are several reasons for why pedestrians may cross at unmarked and uncontrolled locations. One factor may be that motorist yielding is not reliably under the control of crosswalks. A US study found that motorists are the sole factor in 57% of all crashes and the sole or contributing factor in 94% of crashes (Evans, 1996). The percentage of motorists yielding for staged crossings at several unsignalized crosswalks was observed to be as low as 1% during the baseline condition in the preliminary Gateway research (Bennett et. al, 2014). A pedestrian may not perceive a sufficient enough increase in perceived safety to be incentivized to cross at a marked or controlled location.

Second, pedestrians may have to engage in additional effort by walking farther to use a crosswalk. As a result, pedestrians may cross outside markings because it is a shorter distance to the desired location. There is research that shows that younger pedestrians favor speed of passage over presences of signals or markings when compared to older pedestrians (Bernhoft, 2008). The top four rates of pedestrian injury and fatality per age group are for younger pedestrians (NHTSA, 2013).

Pedestrians might not have enough viable locations to cross. This could leave a high number of pedestrian crossing areas without adequate means to
safely cross the road. Therefore increasing the number of crosswalks at pedestrian generators, locations that produce high volumes of pedestrian traffic, could decrease pedestrian crossing outside of marked locations.

However, there are significant costs associated with creating and maintaining crosswalks. Any additions to crosswalks like signaling devices further increase the costs and time to create and maintain them. Engineers may desire to place installations where needed, but have a limited amount or resources available to do so. Also, a crosswalk is determined viable and necessary after a significant amount of data has been reviewed by traffic professionals to ensure that the crossing is safe and in a quality location. Therefore, adding quantity does not necessarily mean that it will increase safety for pedestrians.

The goal of this study was to examine low cost alternatives or additions to crosswalks at a variety of locations. A more effective and reliable crosswalk may in turn increase pedestrian utilization, increase motorist yielding, and decrease the number of pedestrian fatalities.

1.5 Pedestrian and Motorist Laws at Crosswalks

Vehicle laws vary significantly between states and cities nationally. The law may determine if a car must stop or yield, when they must stop or yield, at what distance, and what portion of the road the law applies to. The Michigan State Vehicle Code does not require vehicles to yield the right of way to pedestrians using a crosswalk. The Michigan Vehicle code defines a crosswalk as, “Any portion of a highway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface (Section 257.10 of
“Michigan Vehicle Code)”. Therefore any intersection marked or not, can be seen as a crosswalk.

Many cities, villages, and municipalities pass supplemental laws that afford pedestrians additional rights. The Michigan Department of State Police issued a set of Uniform Traffic Codes that may be passed and adopted at municipalities. The most recent version from 2003 states that, “(1) When traffic-control signals are not in place or are not in operation, the motorist of a vehicle shall yield the right-of-way, slowing down or stopping if need be to so yield, to a pedestrian crossing the roadway within a crosswalk when the pedestrian is on the half of the roadway on which the vehicle is traveling or when the pedestrian is approaching so closely from the opposite half of the roadway as to be in danger, but a pedestrian shall not suddenly leave a curb or other place of safety and walk or run into a path of a vehicle that is so close that it is impossible for the motorist to yield. (2) A person who violates this rule is responsible for a civil infraction. (R 28.1702 Rule 702.)”. Pedestrians also must yield the right-of-way to vehicles when crossing outside of a marked crosswalk at an intersection when it is not there to turn to cross (R 28.1706 Rule 706.).

The City of Kalamazoo has additional rules that apply to pedestrians. The Kalamazoo City Code goes on to state that the pedestrian must find an appropriate break in traffic to cross ([Traf. Code § 56]). Therefore a motorist is not required to yield to a pedestrian that is attempting to cross. Only after the pedestrian is in the crosswalk and traveling is the motorist required to stop for the pedestrian. When stopped, other vehicles are not allowed to change lanes to overtake or pass the
stopped vehicle. This law directly addresses the issue of a multiple threat scenario. If a motorist passes the stopped vehicle, the pedestrian does not have the necessary vantage point to see the passing car and the motorist does not have the necessary vantage point to see a crossing pedestrian. Additionally, the risk of colliding with vehicles in the adjacent lane increases while changing lanes.

The effects of governmental laws on the behavior of motorists and pedestrians vary significantly. Research has shown that a lack of motorist compliance and pedestrian compliance with laws at crosswalks are factors associated with pedestrian-vehicle collisions (Hunter et. al, 1996; Markowitz et. al, 2006). Poor compliance is likely the result of low levels of enforcement and education related to crosswalk compliance. Typically they are done in conjunction with each other and other elements of an intervention package. This makes it hard to determine which elements are most effective in increasing the target behaviors.

High-visibility enforcement campaigns have been successful at increasing motorist compliance with seatbelt laws and reductions in alcohol related crashes (Levy Shea, & Asch, 1988 and 1990; Lacey et. al, 1999; Milano et. al, 2004). This strategy was applied to pedestrian right of way laws with success across three cities in Canada (Van Houten et. al, 1990). A study in 1997 on 4 different campaigns in Washington State after a crosswalk law had been changed found that 2 campaigns had produced a significant increase in motorist compliance (TransSafety, Inc., 1997). However, they concluded that despite heavy ticketing, other environmental and perhaps behavioral factors are more salient to the motorists than enforcement concerns (TransSafety, Inc., 1997). They also found
that the threshold of ticketing necessary to achieve changes in motorist behavior is quite high (TransSafety, Inc., 1997).

In addition to enforcement campaign present in the Van Houten et. al study, there were a variety of educational pieces, low cost engineering additions, and feedback components used. Further study is needed to determine what elements are effective in enforcement campaign strategies.

1.6 Cultural Change and Educational Interventions

Educational interventions occur at different levels and in different forms. Educational campaigns can focus on national, state, city, or community levels. They can occur in waves or be maintained over long periods of time depending on the existence of funding. The education is delivered in a variety of different forms and media. The goals can also vary significantly. While some may take a target approach to raise awareness about a specific issue or law, others can focus on motorist training and learning. Some campaigns have attempted to combine these interventions with a variety of other measures as an attempt to change the culture of a given area. These interventions are higher intensity and higher cost and subsequently fewer in number.

Educational interventions utilize media in a variety of forms. Most take the form of ads with slogans and tag lines that are then strategically placed on the television, radio, billboards, and the Internet. A systematic review of randomized controlled trials showed that pedestrian safety education programs can change knowledge, but the effects on pedestrian crossing and motorist yielding are unknown or limited (Duperrex et. al 2002). An education and enforcement campaign that focused heavily on education was done in Washington, D. C. The
result was a significant increase in awareness, but no increases in the yielding of motorists (Street Smart, 2013). A study by Harré et. al, in 2004 designed to decrease the number of pedestrian signal violations and increase the number of motorists yielding to pedestrians when making turns into the crosswalk increased awareness, but did not affect motorist yielding. There is a lack of research on the cost and benefits available to compare the interventions effectiveness per dollar on motorist yielding (Elvik, 2000). Educational campaigns require further study to determine which programs are more cost effective and whether program awareness can produce changes in behavior over time.

Cultural change campaigns utilize community feedback signs, flyers in community areas, and officers providing warnings as well as citations. One study utilized publicly posted feedback to the community in the form of the percentage of motorists yielding to pedestrians, small signs prompting pedestrians to engage in appropriate crossing, and an enforcement program involving the use of warning tickets and feedback on community performance in the form of fliers. The results were more than double the percentage of motorists yielding to pedestrians and an increase in the number of pedestrians signaling their intention to cross by over 13% above baseline levels of less than 1% (Van Houten et. al, 1985). Many features were similar to the high-visibility enforcement campaign such as the use of educational and increasing police enforcement efforts (Malenfant and Van Houten, 1990). Feedback flyers, written and verbal warnings, and a two-week enforcement campaign were used in Miami Beach to increased motorist yielding
(Van Houten et. al, 2004). Follow up data showed the results maintained over a year and were associated with a reduction in pedestrian crashes.

A more recent study by Van Houten, et. al from 2013 evaluated strategies to change community safety culture by increasing motorist yielding to pedestrians on a citywide basis in Gainesville, Florida. The treatment consisted of high visibility crosswalk operations that included decoy pedestrian crossing, inexpensive engineering (advance yield markings, and in-street R1-6 signs), earned media, outreach efforts to stakeholders within the community, and large road signs that provided feedback on the percentage of motorists yielding right-of-way to pedestrians during the preceding week. Program effectiveness was evaluated along three different areas. First, there were weekly direct measurements of motorist yielding at a number of treated crosswalks and a number of untreated crosswalks located throughout the city. Second, strategy awareness was assessed through a survey on knowledge and attitudes about the program. Finally, a statistical analysis was performed on crash data from the sites.

The program occurred over the course of a year lead to a marked increase in motorist yielding to pedestrians in crosswalks from a baseline level of 32% to 62% at crosswalk with increased police enforcement for staged crossings using decoy pedestrians, and an increase from 54% to 83% for regular crosswalk users (unstaged crossings). At untreated crosswalk sites yielding to pedestrians increased from 37% to 59% for staged crossings and from 50% to 73% for regular crosswalk users. A time-series regression model showed that all treatment sites
(with the exception of one site with very high yield rates at the beginning of the study) showed a significant increase in yielding. At the untreated generalization sites, the increase in motorist yielding was somewhat less than those at the enforcement treatment sites. A comparison of results under staged and unstaged pedestrian crossing showed that unstaged crossings had a higher mean yielding level. One key element of the program developed by Van Houten et. al. was the use of community feedback on community performance provided on a weekly basis on large highway signs. The analysis of motorist awareness surveys indicates that feedback on motorist performance was the most frequently discussed and identified feature of the High Visibility Enforcement (HVE) study.

Informal information from the community indicated that the effects appeared to be maintained over time. A four year follow up funded by NHTSA has shown that motorist yielding was maintained or increased at all of the measurement sites and that there was a citywide reduction in vehicle-pedestrian collisions. The In-Street Sign was the most significant engineering intervention in the treatment package. Further research on the cultural efficacy of the components in the package would provide more insight on how it affects community safety culture.

1.7 Road Design and Design Speed

The design of the road has a significant impact on motorist speed and safety. Critical design elements typically examined are the type of road material, the grade of the road, the surface condition of the road, sight distance for motorists, number of lanes, the terrain, the edge control measures present, the posted speed limits, the distance from the adjacent horizontal curve, and the
distance from adjacent signals or signs (Fitzpatrick et. al, 2001). The design of the road is said to create the design speed of a given road, which is the speed for which roads are built (Parsons Transportation Group, 2003). The design speed may not be the same as the speed limit. Therefore, the design of the road controls the speed of the road. If a road is capable of a higher speed than posted, the road will likely see higher speeds. Signs, signals, and other measures can be put in place to alter the speed of the road, but a negligent design or facilities that no longer meet the design standards can be a critical feature in compliance and safety.

The speed of a vehicle is a key factor in pedestrian safety. There is a direct correlation with the speed of vehicles, the risk of crash, and the severity of injuries (Rosen and Sander, 2009). Motorists of a fast vehicle will have less time to react and less ability to react. As speed increases, motorist perceptions decreases because motorists’ visual field will narrow to only what is in front of them (Bartmann et. al, 1991). Measures have been developed to slow down the speed of a road or calm traffic. Traffic calming measures consist of humps, bumps, narrowing lanes, diverters, lane width, traffic circles, raised crosswalks, raised intersections, neckdowns, speed radar trailers, photo radars, and island or medians (Ewing, 1999). While design interventions are highly effective at mitigating motorist speed, they can also be expensive, time consuming, permanently alter landscapes, and therefore may not always be feasible.

The use of advance yield/stop lines can be seen as a type of road design intervention. Advance yield/stop markings used at a multilane uncontrolled
crosswalk have been shown to reduce the number of multiple threat conflicts by stopping vehicles well in advance of the crosswalk (Huybers et. al, 2004; Van Houten, 1988; Van Houten & Malenfant, 1992; Van Houten et. al., 2003; Van et. al, 2001; Retting et. al, 2000). Motorists yielding further from the crosswalk reduces the screening effect for vehicles traveling in adjacent lanes.

### 1.8 Street Sign Interventions

Unsignalized crosswalks are less effective than signalized crosswalks and account for the majority of crosswalks in the United States. Strategies to increase their effectiveness are a necessary component in reducing pedestrian fatalities. Several interventions have been developed to enhance the effectiveness of unsignalized crosswalks. As previously mentioned, the RRFB and pedestrian hybrid beacon have both produced significant increases in motorist yielding when used appropriately.

A series of studies have examined the effects of placing signs in and around the road, the R1-6 (Yield to Pedestrians) and R1-6a (Stop for Pedestrians) sign. These signs have been shown to significantly increase motorist yielding when placed on the center lane line of a two-lane road with one travel lane in each direction and less effective when used on a multilane road with two or more travel lanes in each direction (Turner, Fitzpatrick, Brewer, & Park, 2004). One study that examined the distance the sign was placed from the crosswalk showed placement at the crosswalk was more effective as compared to 20 feet and 40 feet away from the lines (Ellis et. al 2007). This study also showed that placing signs at all three locations was no more effective than placing a single sign on the crosswalk lines.
1.8.1 Gateway In-Street Sign Configuration

As a follow up to the previous In-Street Sign research, Bennett, Manal and Van Houten (2014), placed In-Street Signs on each side of a multi-lane road at uncontrolled crosswalks, on the lane lines and on the center line. The novel intervention was referred to as the Gateway In-Street Sign configuration. This configuration uses six signs for a four-lane road divided by a median or refuge island. The gateway treatment produced marked increases in the percentage of motorists yielding at a variety of sites across Michigan. Yielding increased from a baseline average of less than 25% to 79% at one site and from 23% to 82% at another site (Bennett et. al, 2014). The Gateway intervention also produced high yielding results when used in conjunction with two proven alternative interventions called the Rectangular Rapid Flash Beacon (RRFB), which uses emergency beacon flashers, and the Pedestrian Hybrid Beacon (Bennett et. al, 2014) which uses a shot solid red condition followed by red wig-wag indications. The price of the Gateway In-Street Sign configuration intervention is relatively low at (approximately $200 per sign and base) and could be more easily adopted by municipalities. The Bennett, Manal, and Van Houten study did not test the sign at a variety of different road configurations, the effects of narrowing the road using the signs, different types of signs in the same configuration, and the effects of the signs at different locations in the gateway configuration.

In many respects the Gateway configuration of the In-Street Sign is a road design feature because it produces a perceived narrowing of the roadway at the crosswalk. The Gateway configuration may serve as a type of traffic calming
device by perceptually narrowing the travel path of a motorist, by forcing vehicles to slow down when approaching the gap. The signs may also be more visible to motorists and thus more effective because of their position on the sides and center of the roadway. Pedestrians are often positioned near where the side signs are located in the Gateway configuration. The extent of the effects of the signs as a calming device could then be compared with the effects of the signs as a prompt for motorist yielding by manipulating a variety of sign features.

2 General Methods
2.1 Independent Variable

The Gateway intervention is a stimulus rich procedure. The goal of the present study is to examine the effects of the Gateway In-Street Sign configuration on motorist yielding in different types of roadway configurations, with different types of signs, at varying times of day, and at varying positions in the road. In order to understand how much each component of the treatment controlled motorist yielding right-of-way to pedestrians in crosswalks, the presence or absence of text, the type of sign, the location of the sign, and the number of signs were systematically controlled and varied. All signs were placed in the road with a temporary base. Double-sided signs were placed on centerlines so that both sides of traffic would be able to see the sign. Single sided signs were placed with the sign facing the direction of oncoming traffic on lane lines that separated traffic traveling in the same direction. Single sided signs were also placed in the gutter pan if it was utilized in the experimental configuration being tested. If there was no gutter pan present, signs were placed on top of the curb or on the roadway edge line.
2.1.1 Sign Types

Several sign types were examined based on the results of the previous research and suggestions from the Michigan Department of Transportation (MDOT). The R1-6 sign that states, “Local Law, Yield to Pedestrians” was used in this study. The utilization of these signs for experimentation is not approved by the Michigan Manual for Uniform Traffic Control Devices (MMUTCD). This is only allowed with special permissions from the Federal Highway Administration (FHWA). The signs were affixed to different posts. One set were attached to Impact Recovery posts. Impact recovery posts are designed to take several strikes and are made from a flexible plastic with an internal spring to allow them to return to their original position after being struck. Others were attached to ridged plastic poles and PVC piping.

A blank sign of the exact same size, sign sheeting color, and shape was used to determine if the language and symbols on the sign influenced the yielding rate of motorists. Both signs had a diamond grade reflective tape designed to increase visibility. They were attached to rigid plastic poles and PVC piping modified to fit into the bases.

The third sign used was a traffic-channeling device manufactured by Pexco. This product is called a City Post and is designed to take 100 impacts at 60 mph. This sign was used to address concerns about survivability of the intervention. MDOT was concerned that the signs placed on the lane lines would require frequent replacement. Even if the intervention was a cost effective intervention, frequent replacement would inflate the sign maintenance costs.
beyond their savings. There are currently no data on the survivability of the R1-6 signs.

2.2 Dependent Variable

The primary measurement was the percentage of motorists who yielded to researchers crossing at a designated crosswalk. One trial consisted of one completed crossing by the researcher. The number of motorists who yielded and did not yield to the researcher were recorded. A total of twenty crossings (trials) were averaged for each data point. The total number motorists who yielded were added to the total number of motorists who did not yield. The total number of motorists who yielded was then divided by the total number of motorists to obtain the percentage of yielding.

2.2.1 Staged and Unstaged Crossings

Crosswalks were publicly available during data collection. As a result, many pedestrians would cross while data were collected by researchers. These crossings were scored if the pedestrian utilized the crosswalk appropriately. If a pedestrian crossed outside of the markings or failed to follow appropriate procedures then they were not scored.

The crossings scored were divided into two different categories, staged and unstaged crossings. Staged crossings were any crossings performed by a researcher. Unstaged crossings were crossings by pedestrians using the crosswalk during the data collection periods. The motorist yielding was the target dependent variable for both types of crossings. Scoring and data calculation procedures were the same for both types. Pedestrian demographic information was not recorded.
2.3 General Scoring Procedure

A trial would begin when a research assistant put his or her foot in a crosswalk and looked towards the direction of traffic. The location of the dilemma zone was calculated by using the accepted engineering equation from the Institute of Transportation Engineers 1994 report titled “Determining Vehicle Signal Change and Clearance Intervals”. The formula is:

\[ y = t + \frac{v}{2a + 2Gg} \]

where \( y \) is the length of the yellow interval, \( t \) is motorist perception-reaction time (recommended as 1 second), \( v \) is the speed limit (feet per second), \( a \) is the deceleration rate (10 feet per second squared), \( g \) is gravitational acceleration (32 feet per second squared), and \( G \) is the approach grade, usually 0%. The time was used to calculate the location of the dilemma zone by multiplying the time by the speed limit in feet per second. The output distance reflects the minimum the distance a motorist requires to react and stop safely if a pedestrian entered a crosswalk. The interventions occurred at locations with a posted speed limit of 35 miles per hour. Thus the dilemma zone used at the experimental sites began 183 feet in advance of the crosswalk.

The dilemma zone was marked prior to any collection of data. This was done in pairs by the research assistants, a spotter and a walker. They would follow a protocol of having one research use a walking wheel to measure distances while the other would watch traffic. Both researchers would wear reflective vests and stay on the sidewalk if at all possible. There were times were the researcher would be required to walk in the shoulder of the road. If a car looked like it was going to be too close, the spotter would alert the measurer and they would both move away from the road until it was safe to continue setting up the zone. Markers of small
metal shafts with plastic flags were used or if there was a natural feature present at the site around the same distance such as a lamppost or sign it was used.

If a car inside the dilemma zone yielded to a pedestrian that initiated a crossing, the car would still be scored as yielding. This was possible because the formula used to calculate the dilemma zone provides a generous distance for vehicles to stop. It is also possible to yield inside the dilemma zone when the vehicles are traveling under the speed limit. If a motorist had to break hard to stop for a pedestrian it was also recorded. Hard breaking was recorded when a vehicle made a screeching noise, or the front bumper visibly dipped. These events were rare and not recorded on the data sheets. However, if the car did not yield within the dilemma zone, they would not be scored, as they did not likely have a safe amount of distance to safely yield. Yielding by vehicles within the dilemma zone when the pedestrian entered the crosswalk was separately measured at some sights.

Only the motorists approaching in the first half of the roadway were scored until the researcher was able to initiate a crossing for roads with two-way traffic. During all conditions, the research assistant approached the crosswalk and signaled an intent to cross by placing one foot in the roadway outside the travel way. The research then would wait at the crosswalk until a vehicle yielded or there was a large enough break in traffic that it was safe to cross. Yielding was defined as being able to walk at the researchers’ normal pace without threat of collision. The speed of the vehicle would have to be zero or below 5 miles per hour. Thus a vehicle dramatically decreasing speed would qualify as yielding so
long as the vehicle speed allowed for a safe gap to traverse the lane without
danger of collision. It was not feasible to test and verify the speed of the each
vehicle during the crossing; therefore researchers had to use their judgment to
determine if it was safe to cross. This is similar to what an actual pedestrian
would have to do in this situation. The motorist of a vehicle would occasionally
wave the researcher across or make other visible gestures to travel. This gesture
was only acted upon if the researcher felt it was safe to cross.

In the case of multiple lanes of traffic, the researcher would walk in front
of the vehicle that yielded and wait until the next lane yielded before continuing
to travel. This continued until the research assistant successfully traveled to either
the median of the road or a pedestrian refuge island. The lanes after this point
carry traffic moving in the opposite direction. If there was no island, the research
assistant would continue to proceed after each subsequent car yielded from the
new approaching direction. If there was a median or refuge island, the research
assistant had to initiate the crossing procedure again by placing one foot in the
crosswalk area on the other side of the island outside of the travel way. The
maximum number of yields depended on the maximum number of lanes present.
The highest number of lanes crossed for this study was four and the lowest was
two. If the crosswalk contained an island, then the crossing to the island was
scored as a single trial. The remaining lanes on the other side of the island were
scored as their own separate trial. However, if there was a turn lane or a double
yellow line separating the two directions of traffic the entire crossing was scored
as a single trial. If the road had multiple lanes all moving in the same direction (a one way street), then all vehicles were scored for all lanes.

Roundabout intersections have access lanes of traffic that enter and exit the circle and lanes of traffic within the circle. Researchers using the crosswalk scored motorists using the travel ways to exit and enter the circle and motorists who were in the circle itself. Motorists entering and exiting the roundabout were scored using the same procedures used at other intersection types. Motorists who were already in the circle were scored if they were outside of the dilemma zone prior to attempting to cross. Motorists who entered the circle from any of the access lanes would also then be counted. Motorists who were already in the circle and within the dilemma zone were not counted.

2.4 General Data Collection Procedure

In order to control potential confounding variables a variety of requirements were in place for researchers’ crossing. Researchers were not allowed to stand near the crosswalk in groups with other pedestrians or researchers. This was referred to as “stacking the crosswalk”. Researchers had to approach the crosswalk alone. When a naturally occurring pedestrian attempted to cross with the researcher, the trial counted if the naturally occurring pedestrian did not initiate the attempt to cross. If the pedestrian waited with the researcher or initiated the crossing, the trial was not counted. They were not allowed to make any motions prior to motorist yielding such as waving at the motorists, signs of emotional discomfort or frustration, yelling, pointing, etc. This was done because previous research indicated that pedestrians can influence motorist yielding by engaging in various behaviors to indicate intention to cross (Crowley-Koch,
However, researchers were allowed to smile, nod, and/or wave thanks to the motorists after they successfully yielded to the researcher.

Specific requirements were made for the behavior of approaching the crosswalk. The researcher could adjust the walking speed in order to time placing their foot in the crosswalk to when a vehicle was outside of the dilemma zone. Researchers could not run to the crosswalk in order to be in the correct measuring position for the oncoming group of traffic or walk at an overly slow pace. Researchers would stand away from the crosswalk in a place that would conceal their position or in a manner that was typical of other pedestrians. Researchers would identify a location at each site that could be used prior to an approach to appear natural and blend in with the surroundings. Researchers would take turns at these spots and wait for their turn to cross. Examples of these sites are a bench nearby, the façade of a building, an adjacent path, and alleyways. Researchers did not engage in conversation with actual pedestrians or motorists of traveling vehicles during the approach or while waiting.

Data were recorded on clipboards or on a cellular device. The researchers would either mark the behavior directly after finishing or would continue to move until they were not visible to motorists. The motorist behavior could not be recorded mid-crossing. Researchers typically recorded the motorist behavior for their own attempted cross. Measures were taken to reduce the risk of motorist reactivity to the appearance of a clipboard. Researchers would conceal the clipboards by placing themselves between the line of sight of the motorist and the clipboard. The clipboard would be held at their side or behind their back.
An alternative procedure was developed and used to increase the rate at which trials were completed. A single researcher recorded the behavior of motorists for a crossing initiated by a separate researcher. The researcher would stay in a single location or would participate in the crossings and record the motorist behavior for several other researcher crossings. During this alternative procedure, only one researcher would be scoring the motorist behavior.

Data were collected during daylight hours, between 7AM and 7PM, for all but one experiment. There was a single experiment that examined the effects of the various configurations during dusk and dark conditions. For all experiments, data collection was suspended if water was visible on the road or water was accumulating into puddles as the result of rainfall. Data collection would resume if raining stopped and roads were visibly dry. All data were collected during the spring, summer, and fall. Snow was never present when data were collected. There were no other weather conditions that warranted suspension of data collection.

2.4.1 General Sign Setup Procedures

When the temporary installation of signs were required for the intervention the researchers would finish up all data collection procedures for any remaining trials and not start a new trial until after the signs were properly placed. The researchers used the same roles employed during the creation of the dilemma zone, where one would spot and the other would place objects in the travel way. While wearing appropriate personal protective equipment, both or one would carry the signs and bases in or out of the roadway after there was safe break in
traffic or if the motorists yielded to them. They would then place the signs in their bases and exit the roadway. This would often require more than one trip to be made before all signs and bases were installed. When the signs and bases were not in use on site they were stored in the trunk of the researcher’s vehicle or they were laid flat on the side of the road. Because the signs have reflective sheeting, they were turned over or covered with a tarp to minimize reactivity from the motorists approaching the crosswalk.

2.5 Inter-Observer Agreement

Inter-observer agreement (IOA) was calculated for 25% of all data collected. Two independent researchers scored a crossing during inter-observer agreement sessions. A researcher could cross and score while the other did not cross and remained stationary or both would score from the same position while a third researcher performed the crossing. Each event that was scored the same by both observers counted as an agreement and each event that had differing scores counted as a disagreement. The percentage was calculated by dividing the total number of agreements on vehicles that yielded by the total number of agreements and disagreements \(\left(\frac{\text{Agreements}}{\text{Disagreements} + \text{Agreements}}\right) \times 100 = \% \text{ of Agreement}\).

2.6 Researcher Training

Researcher training occurred entirely on site. Candidates were shown how to use the equipment to mark the dilemma zone by a trainer. It was not necessary to test comprehension and retention of these procedures because no errors were observed after an initial training session. A selected candidate would observe a trained researcher model the appropriate crossing and procedures. The candidate
would then cross with the trainer and receive feedback until the candidate could consistently complete a crossing without any mistakes. The potential researcher and the trainer would score crossings together. Sometimes the trainer and candidate would score another researcher crossings or would cross together and score that trial. The person needed to obtain inter-observer agreement of 90% or higher for two data points (40 crossings) before being allowed to collect data. One candidate did not meet this requirement and was removed from the study. Either the primary investigator or the graduate student assistant researcher conducted all training. A total of ten different people collected data.

### 2.7 Participants

The participants of this study were the motorists at any of the given data collection site roadways. No demographic data were taken on any of the motorists. A motorist would become a participant simply by using the road where the researchers were collecting data. Motorists did not have to meet any criteria other than being physically present and currently operating a motor vehicle. No information about the motorist’s vehicles were recorded. Researchers were between the ages of 19 and 31 years old. Four were female and six were male. Researchers were not required to wear a uniform or meet any specific physical criteria.

### 2.8 Settings

Five different sites were used in this study. The posted speed limit for all sites was 35 mph on level terrain. Therefore the dilemma zone sizes were the same. Three sites were in Kalamazoo, MI and two sites were in Benton Harbor, MI. The sites in Kalamazoo, MI were: the intersection of Rose Street at Academy
Street, the middle of a block on Rose Street near the Kalamazoo Valley Community College Campus (KVCC), and the intersection of Westnedge Street and Ranney Street. The sites in Benton Harbor, MI were: the intersection of West Main Street and Riverview and the intersection of East Main and 5th street.

A total of five experiments were conducted across five different sites. One experiment was conducted at the intersection of Rose Street and Academy in Kalamazoo, MI. Two experiments were conducted at the midblock location of a section of Rose Street that runs through the downtown campus of Kalamazoo Valley Community College in Kalamazoo, MI. An experiment was conducted at the intersection at Westnedge and Ranney in Kalamazoo, MI. Last, a multiple baseline design experiment was conducted across two sites on a road that runs through downtown Benton Harbor, MI.

3 Experimentation

3.1 Experiment 1

Experiment 1 took place at a mid-block crossing in Kalamazoo, MI at the intersection of Rose Street and Academy. This site was a marked crosswalk located between two intersections with traffic signals with two lanes of traffic in each direction for a total of four travel lanes. The posted speed limit was 35MPH. The Annual Average Daily Traffic (AADT) for this section was 6,820 cars per day in 2013 (Stepek, 2013). There were parking spots on both sides of the road, making the travel lanes longer than normal. The crosswalk was located near a parking lot and city park with a high volume of pedestrian traffic. A total of six different sign configurations were used at this site.
3.1.1 Experiment 1 Sign Configurations

The first configuration was the Gateway In-street sign or Gateway configuration. Signs were placed at the point where the crosswalk lines intersected with the gutter pan, the dashed white lane divider lines, and the double yellow median line. These signs were placed on the crosswalk painted line intersection that was closest to the direction of oncoming traffic. The front of the sign pointed towards the direction of oncoming traffic and the middle signs were double sided. There were a total of five signs used (see Figure 1).

![Figure 1: The Gateway configuration.](image)

The second configuration used the same sign placement and orientation as the Gateway In-Street sign configuration, but each sign used was a blank sign of the exact same size and shape. This was referred to as Gateway with Blank signs configuration (see Figure 2).

![Figure 2: The Gateway with Blanks configuration.](image)

The third sign configuration had signs in the same positions and orientations as the previous two configurations. The R1-6 signs remained in the
gutter pan location and on the double yellow median line. The R1-6 sign in the dashed white lane divider position was replaced with a delineator referred to as the City Post. This configuration was referred to as the Gateway In-Street Sign configuration with the City Post (see Figure 3).

![Figure 3: The Gateway with City Post configuration.](image)

The fourth configuration varied the position of the signs on the edges. In the previous configuration the edge signs were placed in the gutter pan of the travel way. This configuration had the edge signs placed on top of the curb face. This position creates a wider area for vehicles to travel through. This is referred to as Gateway with Curb Signs configuration (see Figure 4).

![Figure 4: The Gateway with Curb Signs configuration.](image)
The fifth configuration utilized R1-6 signs in the gutter pan positions and centerline position alone. There were no other signs present. This was referred to as the Edge Signs with Centerline Sign configuration (see Figure 5).

![Figure 5: The Edge Signs with Centerline Sign configuration.](image)

The sixth configuration examined the R1-6 sign only on the white lane lines, referred to as the In-Street on White Lane Line sign configuration (see Figure 6).

![Figure 6: In-Street on White Lane Line Sign configuration.](image)

3.1.2 Design

The design used for experiment 1 was a reversal design that utilized multiple independent variables in different phases. The Gateway with Blanks and Gateway configuration were both examined and reversed in the initial phases. The
order was changed upon reversing to control for ordering effects. The next set of configurations introduced and reversed the Gateway with City Post configuration. This was followed by introducing and reversing the Gateway with Curb Signs configuration. The final set of configurations examined Edge Signs with Centerline Sign and the In-Street on White Lane Line sign configurations by introducing and reversing them in opposite order to control for ordering effects (See Table 1).

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<thead>
<tr>
<th>Conditions</th>
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<td>F-Edge Signs With Centerline Sign</td>
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<tr>
<td>G-In-Street Sign</td>
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</table>

*Table 1: A design table for experiment 1. An "X" indicates that the condition was present for that phase.*

### 3.1.3 Results

The first set of configurations compared the Gateway configuration with blanks and the Gateway In-Street Sign configuration. The Average Motorist Yielding for the baseline condition was 6%. This phase was followed by the Gateway In-Street sign configuration. An average of 74% of yielding was observed. Next the Gateway with Blanks configuration was introduced. A drop in average yielding to 28% was observed. Baseline was then briefly reintroduced. Motorist yielding decreased to 8%. Gateway configuration with Blanks
configuration was then introduced and yielding increased to 26%. The next phase was the Gateway In-Street sign configuration. Motorist behavior increased to 88%.

The second set of configurations examined was the Gateway configuration with City Posts compared to the Gateway In-Street sign configuration. The introduction of the Gateway with City Post configuration saw a reduction in motorist yielding to 65%. The Gateway In-Street sign configuration was reintroduced and yielding increased to 76%. The Gateway configuration with City Posts followed and was associated with a reduction of yielding to 55%.

The third set of configurations examined the positions of the signs using the Gateway with Curb Signs. Yielding increased to an average of 74% upon introduction of this condition. This was then compared to the Gateway configuration and yielding increased to 80% from the previous phase. The Gateway with Curb Signs was reintroduced and average yielding decreased to 70%.

The final set examined the Edge signs with Centerline sign configuration and In-Street on White Lane Line sign configurations. The Edge plus Centerline conditions were associated with 33% motorist yielding. This was followed by the In-Street on White Lane Line sign configuration. Yielding rose to 53%. The Gateway configuration was then introduced and yielding increased to an average of 81%. This was followed by the In-Street on White Lane Line sign configuration. Yielding dropped to 52%. The last phase for these configurations
and for this site was the Edge Signs with Centerline sign configuration. Yielding averaged 39% (see Figure 7).

A comparison of conditions indicates that the Gateway configuration was the most effective at increasing motorist yielding. The least effective configuration was the Gateway with Blanks. All conditions increased motorist yielding above baseline yielding levels (see Table 2).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Condition Averages</th>
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<td>A-Baseline</td>
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<tr>
<td>B-Gateway</td>
<td>79%</td>
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<tr>
<td>C-Gateway with Blanks</td>
<td>27%</td>
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<tr>
<td>D-Gateway with City Post</td>
<td>60%</td>
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<tr>
<td>E-Gateway with Curb Signs</td>
<td>72%</td>
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<tr>
<td>F-Edge Signs with Centerline Sign</td>
<td>36%</td>
</tr>
<tr>
<td>G-In-Street Sign</td>
<td>52%</td>
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</table>

Table 2: A table of the overall average motorist yielding for each condition in experiment 1.

The Inter-Observer Agreement for this experiment averaged of 92% with a range of 78% to 100%. The median value was 93% and the mode value was 95%. Of the total 80 data points collected, IOA was collected on 31, or 39%, of the data points.
Figure 7: The results of experiment 1.
3.1.4 Discussion

The initial hypothesis tested was that a perceived narrowing the road associated with the gateway sign treatment was responsible for the increase in motorist yielding and that the content of the signs would not matter. If this hypothesis was correct the Gateway with the R1-6 sign would yield similar results as the Gateway with Blanks configuration. The data showed that the content does have an effect on motorist yielding. The Gateway with Blanks configuration had an average motorist yielding of 27%. This configuration was the lowest tested configuration. The Gateway configuration with the R1-6 signs was comparatively higher at 80%. There was low variation during the Gateway with Blanks configuration and no overlap between the baseline condition and either Gateway configuration condition. These results suggest motorist yielding is controlled not only by the lane width afforded by the configuration, but also that the content of the signs.

The primary purpose of the City Post was to examine if the configuration would still be effective with a City Post instead of an R1-6. As mentioned earlier, although both signs are designed to withstand impacts, the City Post has more survivability and durability than the R1-6 signs. The Gateway with City Post proved to be a highly effective intervention and had an average of 60% yielding. There was low variability between the 2 phases of the condition. There was a slight overlap on a few points of the Gateway with all R1-6 signs configuration and the Gateway configuration with City Posts. The City Post did not have any writing on it and therefore can be seen as an extension of the hypothesis about the
content of the signs. The behavior is likely under the control of the content of the signs and the narrowing of the lanes. The yielding during the Gateway with City Posts condition was likely lower than the Gateway configuration because the lanes were slightly wider and there was less sign content.

The Gateway with curb signs configuration examined the relationship between the lane width and the content of the signs further. The amount of yielding was the second highest amount of all of the configurations at this site at 72%. This information seems to confirm that a narrower travel way will increase motorist yielding. What is surprisingly is that the curb position did not result in dramatically lower yielding, but rather a relatively small difference of 8% between the two configurations. This suggests that the behavior might not be as influenced by the narrowing as previously thought. This finding is important because signs placed on top of the curb are less likely to be struck then signs placed in the gutter pan. Gutter pan placement may also have drainage issues and could interfere with road sweepers.

The Edge Signs with Centerline Sign configuration and In-Street on White Lane Line sign configuration examined how important each position was in the Gateway configuration. The Edge Signs with Centerline Sign configuration resulted in 36% yielding which was the second lowest level of yielding, while the In-Street sign centerline configuration was moderately successful with yielding of 52%. The data reaffirms that signs on the centerlines have the most influence on behavior and introduces the Edge Sign plus Centerline Sign configuration as another effective configuration above baseline yielding.
3.2 Experiment 2

Experiment 2 took place in Kalamazoo, MI at a mid-block crossing on Rose street further north near the Kalamazoo Valley Community College campus. The posted speed limit was 35MPH. The crosswalk had a pedestrian island between the four lanes of traffic. Sign configurations were examined during the day and at night at this site. There were functioning streetlights present along the side of the road.

3.2.1 Experiment 2 Sign Configurations

The first configuration used was the Gateway with Blanks configuration (see Figure 8).

![Gateway with Blanks configuration](image8)

*Figure 8: The Gateway with Blanks configuration.*

The second configuration examined was the Gateway configuration (see Figure 9).

![Gateway configuration](image9)

*Figure 9: The Gateway configuration.*
The Third configuration was the Gateway with City Posts on Lane Lines configuration (see Figure 10).

![Figure 10: The Gateway with City Post configuration.](image)

There was not enough room for gutter pan installation on both sides. Therefore one sign was placed on the curb face and one in the gutter pan. The centerline signs were placed on the curb and the edge signs were placed in the gutter pan. The Michigan law does not permit placing signs in the travel way of vehicles.

### 3.2.2 Design

This design was similar to the previous study and utilized a reversal design with several different independent variables. This study examined the effects of the Gateway, Gateway with Blanks, and Gateway with City Post conditions.

Multiple replications were performed with the Gateway and Gateway with City Post. This is because the Gateway with City Post condition had more applied value than the Gateway with Blanks condition (see Table 3).

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<tr>
<th>Condition</th>
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*Table 3: A design table for experiment 2. An "X" indicates that the condition was present for that phase.*
3.2.3 Results

The experiment began with a baseline condition that had a yielding averaging of 8%. This was followed by the Gateway with Blanks configuration. Yielding increased to 36% during this condition. This was followed by the Gateway configuration with the R1-6 signs. Yielding increased to 76% during this condition. This phase was followed by the Gateway with City Post configuration and yielding dropped to 68%. The Gateway configuration with all R1-6 signs was introduced next and yielding increased to 81%. The next phase was the Gateway with City Post configuration and yielding dropped to 49%. The Gateway was reintroduced again and yielding increased to 77%. This was followed by the Gateway with the Gateway with City Posts and yielding declined again to 56%. Baseline condition was reintroduced and yielding dropped to 6%. Gateway with Blanks was introduced next and yielding increased to 41%. This was followed by Gateway with City Post condition and yielding increased further to 65%. The final phase was the Gateway with all R1-6 signs configuration and yielding increased to 75% (see Figure 11). The total average IOA was 98%.

The overall conditions indicate that the Gateway configuration was the most effective intervention. The Gateway with Blanks was the least effective configuration. All configurations were more effective than baseline conditions (see Table 4).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Condition Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td>7%</td>
</tr>
<tr>
<td>B-Gateway</td>
<td>77%</td>
</tr>
<tr>
<td>C-Gateway with Blanks</td>
<td>39%</td>
</tr>
<tr>
<td>D-Gateway with City Post</td>
<td>60%</td>
</tr>
</tbody>
</table>

*Table 4: A table of the overall average motorist yielding for each condition in experiment 2.*
Figure 11: The results of experiment 2.
3.2.4 Discussion

Baseline had a mean of 7% of motorists yielding and remained stable. The Gateway with Blanks configuration had yielding of 39%. This number was higher than what was seen at the previous site by 12%. This is likely due to the differences in the travel way widths. There was no gutter pan present on the inside road and there was a pedestrian island separating the two lanes of traffic. This resulted in a travel way that was significantly narrower than what was present for experiment 1. The narrower road probably enhanced the narrowing effects on motorist yielding.

The percentage of motorists yielding for the Gateway configuration was 79%, which was very similar to the yielding level in experiment 1. Motorist yielding right-of-way to pedestrians for the Gateway with City Post condition averaged 60% which is identical to the percentage obtained for this condition in experiment 1. This further adds support to the conclusion that motorist yielding is not solely under the control of the perceived narrowing of the roadway. The content of the signs remains a key variable in producing the highest percent of motorist yielding. Because the road way was as narrow as possible and the yielding produced was nearly equivalent, there seems to be a limit to the amount that narrowing can control motorist yielding.

3.3 Experiment 3

Experiment 3 examined the Gateway configuration and the Gateway with City Post configuration in Kalamazoo, MI at the mid-block crossing on Rose Street at a KVCC campus. The purpose was to specifically examine the effectiveness of the interventions in low light scenarios. Data began during dusk
and carried over into nighttime. The road was lighted with street lamps and the signs have reflective tape that reacts to vehicle head lamps.

3.3.1 Experiment 3 Sign Configurations

Two different sign configurations were used. The first was the Gateway configuration. The second was the Gateway with City Post configuration. There were no special adjustments made to the configurations when they were setup at night.

3.3.2 Design

The experiment utilized an ABCA design. Each independent variable studied was introduced once and the experiment concluded in the baseline condition (see Table 5).

<table>
<thead>
<tr>
<th>Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>B-Gateway</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>C-Gateway with City Post</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Table 5: A design table for experiment 3. An "X" indicates that the condition was present for that phase.*

3.3.3 Results

The first phase was the baseline condition. The percentage of motorists yielding right-of-way to pedestrians was 7% during baseline. The Gateway configuration was associated with an increase in yielding to 59%. This was followed by the Gateway with City Post configuration and yielding decreased to 39%. The experiment concluded with the baseline condition and yielding dropped to 2% (see Figure 12). The total average IOA was 100.00%. Overall condition averages are listed in Table 6 (see below).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Condition Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td>1%</td>
</tr>
<tr>
<td>B-Gateway</td>
<td>60%</td>
</tr>
<tr>
<td>C-Gateway with City Post</td>
<td>39%</td>
</tr>
</tbody>
</table>

*Table 6: A table of the overall average motorist yielding for each condition in experiment 3*
Figure 12: The results of experiment 3.
3.3.4 Discussion

All percentage of motorists yielding to pedestrians was lower for each configuration at night. This echoes the importance of visibility in pedestrian safety that has been identified as a key factor in pedestrian-vehicle collisions. Baseline yielding of 1%, was 7% lower than during daylight hours. The Gateway configuration proved to be the most effective configuration again with yielding of 60%. The Gateway with the City Post also proved to be an effective intervention with yielding of 39%. The results suggest that while lighting is a critical variable for motorist yielding, sign configurations can still play a key role in improving pedestrian safety at night. However, the addition of lighting alone to a high-volume crosswalk cannot be the only intervention made available to pedestrians, as baseline yielding was less than 2%.

3.4 Experiment 4

Experiment 4 took place in Kalamazoo, MI at the intersection of Westnedge and Ranney Street. This was a two lane one-way street with parking at a T-Intersection of a two lane one-way street. The site had a posted speed limit of 35 MPH. There was a signalized intersection at the end of the block. There were various restaurants and stores near the crosswalk and there was a high amount of pedestrian traffic and vehicle traffic.

3.4.1 Experiment 4 Sign Configurations

The site had the Gateway In-street sign configuration (see Figure 13), Gateway configuration with City Post, Edge Signs configuration (see Figure 14), and the In-Street on White Lane Line sign configuration. The road had parking spaces on both sides. This was used as a measurement for the In-Street sign
placement. The signs were not placed in the gutter pan for any configuration, but rather in line with the parking spaces.

![Figure 13: The Gateway configuration.](image)

![Figure 14: The Edge Signs with Centerline Sign configuration.](image)

### 3.4.2 Design

This experiment employed a reversal design. Not all of the independent variables were reversed. The Gateway configuration and the In-Street on White Lane Line sign intervention had the R1-6 sign on the centerline position. A vehicle came into contact with the sign and while minimal damage was done to the vehicle, the sign was made unusable. As a result, those configurations were not re-introduced to prevent any further to prevent damage to the signs (see Table 7).

<table>
<thead>
<tr>
<th>Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-Gateway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-Gateway with City Post</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-Edge Signs</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-In-Street Sign</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

*Table 7: A design table for experiment 4. An "X" indicates that the condition was present for that phase.*
3.4.3 Results

The experiment began with the baseline condition. Motorist yielding right-of-way during this condition averaged 0% for five data points. This was followed by the Edge Signs configuration and yielding increased to 10%. The next phase was one In-Street on White Lane Line Sign located at the lane divider. Yielding during this condition averaged 17%. The Gateway configuration was then introduced and yielding increased to 89%. The next phase was the Gateway with City Post configuration. Yielding during this condition decreased to 58%. This was followed by a return to the baseline condition and a decline in motorist yielding to 0%. After this the Gateway configuration was introduced and the sign was struck, only 4 trials were run before data collection was discontinued. The Edge Signs configuration was tested next and yielding dropped to 10%. The final phase was the Gateway with City Post configuration and yielding increased to 61% (see Figure 15). The total average IOA was 96% during this condition.

Overall, the Gateway configuration was the most effective at producing motorist yielding. The least effective was the Edge Signs configuration. All conditions produced motorist yielding levels above baseline (see Table 8).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Condition Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td>0.18%</td>
</tr>
<tr>
<td>B-Gateway</td>
<td>89.11%</td>
</tr>
<tr>
<td>C-Gateway with City Post</td>
<td>59.41%</td>
</tr>
<tr>
<td>D-Edge Signs</td>
<td>9.79%</td>
</tr>
<tr>
<td>E-In-Street Sign</td>
<td>17.46%</td>
</tr>
</tbody>
</table>

*Table 8: A table of the overall average motorist yielding for each condition in experiment 4.*
Figure 15: The results for experiment 4.
3.4.4 Discussion

Baseline yielding at this site was lower than any other experimental site. There was zero yielding observed for five consecutive points and less than one percent for the fifth data point. The Edge Signs with Centerline Sign configuration, In-Street on White Lane Line sign configuration, and Gateway with City Post configuration all had lower yielding levels than obtained in the other experiments. The Edge Signs and In-Street on White Lane Line sign configuration in particular were much lower than the yielding that was produced at experimental site 1. Conversely, the Gateway configuration had the highest yielding level at this location than all of the other experimental sites. Three data points had 100% motorist yielding, which was not seen in any other experiment. Thus this site saw both the worst and best average motorist yielding.

It is difficult to identify why some configurations were more or less effective at this particular site and not others. The road does have slightly larger gutter pans due to the parking available on the left and right, but this was also present at experimental site one at Rose Street and Academy Street. Therefore, it cannot solely be due to a reduction in the narrowing effects on motorists or parked vehicles screening the visibility of the signs.

Some differences observed at this site were a larger volume of traffic, a closer proximity to a traffic signal, and the appearance of a consistently higher travel speed than the posted speed limit. The larger volume of traffic may be a disincentive to stopping behavior by increasing concern of being rear ended by another motorist. Thus a motorist would be more likely to avoid this outcome by
maintaining their present speed rather than slowing down or stopping for a pedestrian attempting to cross. The closer distance to a traffic signal may make stopping less rewarding because it may be more punishing to rapidly decelerate after rapidly accelerating. The increased travel speed affects the dilemma zone size and thus the reaction time of motorists. The dilemma zone was calculated by the posted speed limit and not the speeds traveled by the motorists using the road. The interruption of maintaining a present speed could serve as a punishing consequence that increases in severity as the speed increases. Motorists would be less likely to yield to a pedestrian because it would interrupt their driving.

However, these differences seem to disappear upon the utilization of the Gateway and the Gateway with City Post configurations. The threshold for yielding resulting from narrowing of the roadway may be different at this site and require a larger amount before it affects behavior. This would be different than other experimental sites where the yielding was higher with a similar amount of narrowing present. Therefore the site may not be as sensitive to narrowing and/or behavior may not be affected until a threshold or tipping point is achieved with narrowing.

The content of the signs seemed to be a key determining factor at other experimental sites, while at this site content seemed to control behavior less. The increased number of signs could prevent any gaps in the motorist’s vision tracking path and thus prompt responding. Whatever factors are present that weaken the other configurations are overwhelmed by the Gateway and Gateway with City Post configurations.
3.5 Experiment 5

Experiment 5 took place across two different sites in Benton Harbor, MI., at two roundabouts locations. Each roundabout had pedestrian islands separating the traffic. As a result, there were eight different crosswalks available. In order to reduce the complexity of the experiment, only yielding on the main line road was measured for each site. There were a total of four crosswalks used. The posted speed limit was 35MPH. There was little pedestrian traffic at each site, but a large amount of vehicle traffic because the roads were connecting to the downtown and provided a business route to the highway.

3.5.1 Experiment 5 Sign Configurations

Only the Gateway In-Street sign configuration was examined at these sites. This is the first time it has been used on this type of road (see Figure 16).

![Figure 16: The Gateway configuration.](image)

3.5.2 Design

This configuration was staggered across both sites using a Multiple Baseline Design. At the first site, W. Main and Riverview, the baseline condition was measured for five data points and then the intervention was introduced. The baseline condition was measured for eight data points at the second site, E. Main
and 5th Street. The introduction of the intervention at the second site was staggered by three points.

3.5.3 Results

The baseline condition at the first site had a motorist yielding right-of-way to pedestrians of 9%. The introduction of the Gateway configuration increased yielding to 43%. The second site’s baseline condition yielding was 19%. The introduction of the Gateway configuration was staggered by 3 data points. It increased yielding to 45% (see Figure 17). The overall conditions averages are listed in Table 9 (see below). The total average IOA was 99%.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Condition Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Baseline</td>
<td>14%</td>
</tr>
<tr>
<td>B-Gateway configuration</td>
<td>44%</td>
</tr>
</tbody>
</table>

Table 9: A table of the overall average motorist yielding for each condition in experiment 4.
Figure 17: The results of experiment 5.
3.5.4 Discussion

Baseline behavior remained stable across both sites at slightly different levels. The yielding for W. Main was 10% lower than E. Main. While the roads were identical in design, they were in different parts of the town. W. Main was located downtown and E. Main was located farther outside of town near roads that had higher travel speeds. Thus, like experimental site 4, travel speeds may have affected compliance.

The yielding for the Gateway configuration was very similar across both sites. E. Main yielding increased to 45% and W. Main yielding increased to 43%. Although other configurations were not examined at the site, it is likely that the other configurations would have been less effective.

The yielding level produced by the Gateway configuration for this site was lower than all other experimental sites (including the night time study). Several reasons may explain the weaker effect. Motorists exiting the circle were less inclined to yield to pedestrians because they were engaged in accelerating their vehicles. This may make braking more effortful and therefore more aversive. The data shows that motorists entering the inner circle had an average motorist yielding rate of 22% and motorists exiting the inner circle had a yielding rate of 3%.

The shape of the circle itself may not be as conducive to the Gateway configuration as other sites. A motorist entering the roundabout sees the signs directly in front of them while someone exiting is would see the signs at a later time.
3.6 Additional Measures

3.6.1 Roundabout Yielding

Initially researchers were not marking whether a motorist was exiting or entering the roundabout. After collecting several data points, the researchers identified a potential characteristic of motorist behavior that could be related to motorist yielding. There appeared to be subtle consistencies between the point of travel for a motorist using the circle and yielding of the motorist. Researchers at a site added a new measure to their data collection procedures. The researchers began to mark whether the vehicles were entering or exiting on their data sheets for each trial.

These trials were then separated into their respective categories of motorist who yielded and were entering the roundabout and motorists who yielded and were exiting the inner circle of the roundabout. There was only enough data on yielding to examine one of the two sites. The data were separated by baseline and intervention for the exiting and entering data.

There is a relationship between the likelihood of a motorist yielding and the course of the roundabout. The average number of motorists who yielded to a pedestrian when entering the roundabout for the baseline condition was 26%. The average number of motorists who yielded while exiting the roundabout was 15%. Upon the introduction of the Gateway configuration, entering yielding increased to 52%. While yielding also increased in motorists exiting the roundabout to 32%, the percentage is almost twenty percent lower (see Table 10 and Figure 19).
Table 10: A table showing the average exiting and entering motorist yielding.

<table>
<thead>
<tr>
<th></th>
<th>Entering</th>
<th></th>
<th>Exiting</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1</td>
<td>Phase 2</td>
<td>Phase 1</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Averages</td>
<td>26.44%</td>
<td>51.73%</td>
<td>15.37%</td>
<td>31.68%</td>
</tr>
<tr>
<td>Ranges</td>
<td>37.18%</td>
<td>35.97%</td>
<td>17.59%</td>
<td>27.27%</td>
</tr>
<tr>
<td>Median</td>
<td>27.47%</td>
<td>50.00%</td>
<td>11.96%</td>
<td>28.57%</td>
</tr>
</tbody>
</table>

Both of the conditions showed that motorists entering appeared to be more likely to yield to pedestrians than motorists exiting the circle. This suggests that a critical variable for motorist yielding is related to the momentum of the behavior being engaged in. If the motorist was reducing speed to enter the circle, the motorist was more likely to yield. If the motorist was accelerating and exiting the roundabout, the motorist was less likely to yield. Interestingly, this even affected the Gateway configuration. Again, visibility of the signs was also greater for motorists approaching the roundabout than those exiting it.

However, experimental conclusions fall short of showing causation because the data that were mined resulted from an AB design. The intervention phase, while having higher averages also had only three data points. The data points
showed relatively moderate variability and had overlap with some baseline points. The entering data appeared to be in an upward trend. Therefore more research needs to be done to verify these findings empirically.

### 3.6.2 Unstaged Pedestrian Crossing

The unstaged pedestrian crossing data indicates that many of the same interventions that were effective for staged crossings were also effective when used in an unstaged setting. Baseline appears to be similar to that of the staged crossings and has the largest sample size of all other conditions. This adds strength to the staged crossings findings about low baseline yielding. The Gateway with Blanks configuration, Gateway with City Post, and Gateway configuration yielded similar results, but had substantially lower sample sizes. The sample sizes continue to drop off until the Gateway with R1-6 narrow was utilized. Interestingly, it had the largest sample and the largest effect. Furthermore, the effect observed was higher than that at the other sites. This could be due to the fact that many of the protocols and procedures were put in place to provide the most protection for the researchers. As a result, researchers used a more conservation approach and refrained from engaging in gambits with oncoming traffic or forcing a yield. Rather, researchers only crossed when they felt safe. Thus the numbers were skewed partially because of the methodology.

No statements can be made about the unstaged pedestrian crossing data because there is not an adequate sample size. Unstaged crossing data were not the primary focus of this study. The purpose of the study was primarily to examine the interventions using the same conservative methodology that had been
approved in the past. It is recommended that the study or pieces of the study be replicated using purely unstaged crossing data (see Table 11).

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Sum of # Cars Yielded</th>
<th>Sum of # Cars Not Yielded</th>
<th>Yield %</th>
<th>Count of Trial #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1</td>
<td>59</td>
<td>1.7%</td>
<td>64</td>
</tr>
<tr>
<td>Gateway with Blanks</td>
<td>12</td>
<td>29</td>
<td>29.3%</td>
<td>28</td>
</tr>
<tr>
<td>Gateway with City Posts</td>
<td>16</td>
<td>11</td>
<td>59.3%</td>
<td>19</td>
</tr>
<tr>
<td>Gateway with R1-6</td>
<td>23</td>
<td>8</td>
<td>74.2%</td>
<td>36</td>
</tr>
<tr>
<td>Gateway with R1-6 and City Post</td>
<td>21</td>
<td>5</td>
<td>80.8%</td>
<td>29</td>
</tr>
<tr>
<td>Gateway with R1-6 and City Post Narrowing</td>
<td>4</td>
<td>0</td>
<td>100.0%</td>
<td>2</td>
</tr>
<tr>
<td>Gateway with R1-6 Narrow (Gutter Pan)</td>
<td>99</td>
<td>11</td>
<td>90.0%</td>
<td>76</td>
</tr>
<tr>
<td>Gateway with R1-6 Wide (Curb)</td>
<td>39</td>
<td>0</td>
<td>100.0%</td>
<td>33</td>
</tr>
<tr>
<td>R1-6 Centerline</td>
<td>9</td>
<td>53</td>
<td>14.5%</td>
<td>19</td>
</tr>
<tr>
<td>R1-6 Edge</td>
<td>0</td>
<td>15</td>
<td>0.0%</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 11: A table of the unstaged crossing results.

The total IOA for each study never dropped below 90% (see Table 12). IOA likely fluctuated due to the obstructions present at each site and the effects of parallax.

<table>
<thead>
<tr>
<th>Inter-Observer Agreement</th>
<th>Average Total IOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>92%</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>98%</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>100%</td>
</tr>
<tr>
<td>Experiment 4</td>
<td>96%</td>
</tr>
<tr>
<td>Experiment 5</td>
<td>99%</td>
</tr>
</tbody>
</table>

Table 12: A table of the average IOA for each experiment.

4 General Discussion

The goal of the study was to examine the effects of the different variations on the Gateway configuration on motorist yielding. Each of the configurations and sign positions was more effective than baseline conditions. No configuration matched the effectiveness of the complete Gateway configuration. While baseline
conditions and the effects of configurations varied among sites, the effects of the Gateway configuration were similar across different site types.

The results indicate that motorist yielding is a complex behavior that is under the control of multiple critical variables. A single yield may be the result of one or more of these variables operating in the environment. The study was not able to determine how much control each variable was responsible for, but it was able to show that the variables seem to work together. This is evidenced by the Gateway configuration, which contained the largest number of critical variables producing the largest effect size.

The configuration analysis showed that the position of the sign is a critical factor for motorist yielding. Not all positions resulted in the same degree of motorist yielding. The center position alone had more control over yielding than the edge positions alone at all sites. This also shows that the number of signs alone is not a critical variable. The Edge Signs and Edge Signs with Centerline Signs configuration had more signs in the road, but it consistently performed lower than all but one of the configurations tested. The variations in the edge sign position in the Gateway configuration suggest that the edge signs gain their controlling effects through perceived narrowing. When the configuration was widened, yielding dropped slightly. The position of the sign increased in significance when it was placed in conjunction with a centerline sign to create the perceived narrowing effect.

The initial hypothesis tested was that the content of the signs would not be a critical variable for motorist yielding. This was incorrect; the blanks
configuration was significantly less effective than the Gateway configuration with the sign message present. The Gateway with Blanks configuration was the least effective configuration. Therefore, content is a critical variable for controlling motorist yielding. This indicates that the position of the signs and the number of the signs work together with the content of the sign to give the Gateway configuration its effectiveness. The results suggest that the effects of narrowing accomplished by placing the critical number of signs in their critical location accounts for between 27% and 38% of the motorist yielding achieved by the Gateway condition. It cannot be determined how much of the Gateway configuration yielding is due to the addition of the content because the content was not experimentally controlled in each position.

The content of the signs was slightly varied from the previous study because the words, “State Law” were covered. This suggests that not all of the content may be critical in controlling motorist yielding. The Gateway with City Post configuration, unintentionally tested the effects of removing the content from the center position, which was identified as the most effective sign position. This configuration had the second highest yielding rate when tested at most sites. It was out performed by the Gateway with Curb signs configuration and Signs on the lane line alone configuration. The effects of the content are therefore likely amplified by being present on a sign in the critical centerline position. This indicates that the effects of the center position are likely related to the narrowing of the field of vision. As a motorist’s vehicle moves faster, the signs on the sides are harder to detect, thus the content on these signs become less effective at
controlling behavior. The narrowing may cause a motorist to reduce the speed. This would increase the field of view because slower speeds increase the locus of focus for a motorist. The edge signs would then be within the field of vision for the motorist and have the opportunity to affect the behavior of the motorist. This may also explain why edge signs are less effective than centerline signs placed on white lane lines.

The effect of the sign content suggests that motorist yielding may be rule governed. It is likely that the motorist has a complex learning history with both the writing on the sign and the symbols on the sign. The yielding behavior may also be evoked by the signs symbols as a result of respondent conditioning. When a motorist sees certain shapes and writing, the behavior may have been paired with a natural occurring event like a pedestrian attempting to crossing or a police officer in close proximity to a sign with a yield symbol. Thus over time, the sign itself may have gained the evocative properties through consistent pairing. This may explain why motorist yielding was similar even with some of the content covered.

The Gateway with City Post configuration did not directly test the effects of the content because the sign shape was varied along with the removal of content when a different type of sign was used. A blank would need to be present at the center position while the edges have content and the reverse of having blanks on the edges with a centerline sign with content in order to determine the effects of the content directly on the configuration.
The Gateway with City Post configuration was tested as a more viable form of the Gateway configuration alone because the City Posts were designed for endurance. The results show that the longevity provided comes at a modest cost in effectiveness. While it was still a considerably more effective than baseline and one of the top interventions, it still cannot match the effects of the complete Gateway configuration.

The effects of the narrowing seen from the various configurations are the result of an implied theoretical avoidance contingency. The motorist would reduce the risk of striking the sign by reducing speed. This may reduce the threshold for yielding enough for a motorist to engage in it when prompted by the signs. However, the speed reduction may also increase the field of vision for the motorist. A motorist may then be able to visually attend to a pedestrian attempting to utilize a crosswalk. This identification may serve as a prompt for motorists to yield further. A motorist might experience an aversive emotional condition if they see a pedestrian and do not yield. It may also be the case that the pedestrian symbol on the sign serves as a prompt to motorists who increases the motorist’s probability of seeing a pedestrian. This was not possible to test in these experiments.

There was some informal evidence of an increase in scanning during the study. Researchers at the Westnedge and Ranney intersection noticed a large number of motorists looking at them before they were able to place their foot in the crosswalk to activate it. Upon further inspection, motorists seemed to be engaging in more scanning when an intervention was present than during baseline
condition. Scanning consisted of the motorist moving their head from side to side while approaching the crosswalk. This occasionally was accompanied by a speed reduction. Unfortunately, these behaviors were not the target of the study and were not recorded.

Another critical variable that may be in effect is motorist social comparison feedback. Motorists may be more or less likely to yield based on another motorist’s yielding. It was observed that during certain conditions, multiple consecutive vehicles would pass in groups and that after a sufficient break a motorist might yield. This was dubbed, “following the leader”. If this effect is present, the Gateway configuration seems to be powerful enough to eliminate it almost entirely. A potential way to study this variable would be to examine the number of motorists who yield without any other motorists present and the reverse. This would not control for motorists who respond differently to social comparison feedback, that is to say, a motorist who is less reactive to other motorist behavior. The rest of the yielding would appear to come from the critical number of signs, the critical position of the signs, and the critical content on the signs.

There are a limited number of stimuli that reward behavior yielding without an intervention present. The feedback that a motorist would receive from a pedestrian may be rewarding or punishing. A motorist yielding to a pedestrian would increase the wear on the vehicle, increase risk of being rear ended, increase travel time and effort, and could receive punishing feedback from other motorists. The motorist yielding might be reward by a pedestrian’s emotional response, for
following rules, helping other people, or removing fear producing stimuli. The Gateway configurations and the various configurations tested do not seem to be adding any additional forms of positive reinforcement, but rather adding additional opportunities to avoid the potential for punishment.

For the Gateway configuration, the design of the road was largely irrelevant. The Gateway was the most effective intervention across all of the sites and had very similar percentages at each site. This demonstrates the robustness of the Gateway configuration design. Previous research had only examined the configuration on multilane roads crossing at the midblock. The Gateway configuration performed similar given a variety of road designs. The lowest performance was seen at the roundabout. The other configurations were more affected by the road design, as their effects seemed to diminish if the road was wider.

The results of the nighttime experiment indicate that lighting alone cannot be the only intervention used to prevent pedestrian fatalities. Pedestrian fatalities occur more during night time and the addition of street lights were shown to be an effective intervention in reducing pedestrian fatalities. However, the baseline yielding rates were nearly identical to daytime. It is clear that the addition of signs would increase yielding during nighttime. This provides another solution to a critical factor in pedestrian fatalities.

Reducing pedestrian crossings at unmarked locations is another strategy for increasing pedestrian safety. Several studies have examined the factors associated with pedestrian crossing at unmarked locations. The results of these findings
could be used as other measures for the Gateway configuration in order to understand the effects on pedestrian crossings. One factor could be associated with the reliability of the markings to produce the desired results for the pedestrians. A pedestrian may not perceive an increase in safety by crossing at a marked location if it is not reliably producing the desired results. Pedestrians may then opt to cross at an unmarked location instead. Baseline yielding was low across all sites. However, installing the Gateway configuration at marked locations would increase motorist yielding. A more effective crosswalk could increase crossing at marked locations and reduce the number of crossings at unmarked locations. A decrease in crossing at unmarked locations and an increase in motorist yielding will decrease the total number of pedestrian fatalities and provide a cost effective solution to communities across America.
References

Bennett, M. K., Manal, H. and Van Houten, R. (2014), A comparison of gateway In-Street Sign configuration to other motorist prompts to increase yielding to pedestrians at crosswalks. Jnl of Applied Behav Analysis, 47: 3–15.
doi: 10.1002/jaba.103

doi:10.1016/j.trf.2007.08.004


Elvik, R. (2000). Which are the relevant costs and benefits of road safety measures designed for pedestrians and cyclists? *Accident Analysis and Prevention, 32*(1), 37–45. doi:10.1016/S0001-4575(99)00046-9


Administration, ATSSA/ITE/AASHTO. Publication Number MUTCD-10,
0000/Curtis1000/0310.

countdown signals: Experience with an extensive pilot installation. *ITE
Journal (Institute of Transportation Engineers)*, 76, 43–48.

media strategies in high visibility enforcement campaigns. *Journal of

Washington, D.C. Downloaded from http://www-
hrd.nhtsa.dot.gov/Pubs/811625.pdf

at Signalized Intersections: Results of a Field Evaluation. *ITE Journal*. 70,
47-54.


Effects of Stutter Flash LED Beacons to Increase Yielding to Pedestrians
Using Multilane Crosswalks. *Transportation Research Record*, 2073, 69-
78.


Van Houten, R. & Malenfant, L. (1992). The Influence of signs prompting motorists to yield 50 feet (15.5 m) before marked crosswalks on motor vehicle-pedestrian conflicts at crosswalks with pedestrian activated flashing lights. Accident Analysis and Prevention, 24, 217-225.


Appendix

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: October 21, 2013
To: Ron Van Houten, Principal Investigator
Miles Bennett, Student Investigator for dissertation
From: Amy Naugle, Ph.D., Chair
Re: HSIRB Project Number 13-10-28

This letter will serve as confirmation that your research project titled “Comparison of Alternative Pedestrian Crossing Treatment” has been approved under the exempt category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., you must request a post approval change to enroll subjects beyond the number stated in your application under “Number of subjects you want to complete the study”). Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

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