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Evaluation of R1-6 Gateway Treatment Alternatives for Pedestrian Crossings: Follow-Up Report

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Final Report

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16. Abstract (Limit: 250 words)

Monthly follow-up data confirmed that permanent in roadway installations of the R1-6 gateway treatment led to an increase in the percentage of drivers yielding to pedestrians at midblock and multilane urban and suburban locations from 15% to 70% and that these increases endured without any decrement over the spring, summer and fall of 2016. Speed data collected at each site showed 4 to 5 mph reduction in mean when motorists traversed the crosswalk when pedestrians were absent. These speed changes persisted over time. An additional study showed that placing the signs between 5, 10, 20, 30, and 50 ft in advance of the crosswalk were equally effective and they enticed drivers to yield further ahead of the crosswalk. Data on sign survival showed that signs mounted on a curb type mount with a flexible rubber attachment all survived while only 58% of the flush mounted signs with a pivoting base survived. Data showed that none of the signs mounted on top of the edge of a curb on a refuge island or median island, curb extension, or the curb on the edge of the roadway under FHWA permission to experiment were destroyed or damaged.

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FINAL REPORT

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List of Acronyms

Average Daily Traffic	ADT
Baseline	BL
Federal Highway Administration	FHWA
Institute of Transportation Engineers	ITE
Manual on Uniform Traffic Control Devices	MUTCD
Michigan Department of Transportation	MDOT
Miles per Hour	mph
Minnesota Department of Transportation	MNDOT
National Cooperative Highway Research Program	NCHRP
National Highway Traffic Safety Administration	NHTSA
Pedestrian Hybrid Beacon	PHB
Rectangular Rapid Flashing Beacon	RRFB
Western Michigan University	WMU

Executive Summary

A gateway installation of the R1-6 signs can be installed at a crosswalk by placing them on the edge of the road and on all lane lines. This requires all drivers to drive between two signs. The gateway configuration has been documented to produce a marked increase in the percentage of drivers yielding right-of-way to pedestrians (2,5,6). The primary purpose of the follow up study was to examine the long-term efficacy of hard installations of the gateway. This research was conducted to determine whether the effects of the gateway on driver yielding persist over time, the effect of the gateway on driver speed when pedestrians are not in the crosswalk and to how to increase the durability and survival of the gateway treatment.

The results of the first series of studies examined whether the effects of the gateway treatment persisted over time. The results showed that the effects of the treatment continued to remain in force with no sign of a reduction in efficacy over a spring, summer, and fall season. These results confirm that the results shown in the primary study (6) were not a novelty effect and can be expected to persist over time. The results also indicated that gateway treatments that lose one element (for example one sign on a lane line) can still provide useful improvements in the percentage of drivers yielding right-of-way to pedestrians and that it may not be necessary to replace these elements until the following year when the treatment is reinstalled after the winter snowplow season. The average percentage of drivers yielding to pedestrians across all 12 intersection sites and midblock crosswalks sites increased from 15% before the gateway was installed to 70% after the gateway was installed

The second chapter reported the effect of the gateway on vehicle speed when pedestrians were not present in the crosswalk. This simulates what drivers would do if they were approaching a crosswalk but did not see a pedestrian. Driver speeds were measured when drivers traversed the dilemma zone (the distance in advance of a crosswalk calculated using the ITE signal timing formula beyond which a driver can safely yield to a pedestrian) and when they traversed the crosswalk. On roads where operating speeds were 25 mph or greater, speed was reduced by 4 to 5 mph as drivers traversed the crosswalks when pedestrians were not present. Drivers also began slowing at the dilemma zone with average speed reduced by 2 mph. It is important to note that the speed reduction began at the dilemma zone well in advance of the crosswalk. This reduction in speed should also be expected when a pedestrian is present but not initially seen by the driver and should allow the driver to successfully avoid a crash with a pedestrian. The speed distributions at the crosswalk showed a clear shift in speed after the gateway was installed, with marked reductions in the parentage of drivers over the speed limit.

Previous work (5) comparing the efficacy of the gateway treatment at sites where the gap between signs were of different widths has shown that the narrower the gap between signs the larger the percentage of drivers yielding to pedestrians. In this study, the gap between the signs in a gateway was systematically manipulated by moving the sign on the right side of the road to vary the width of the gateway gap. The results showed that the increase in yielding produced by installing a gateway is far larger than the increase in yielding produced by narrowing the gateway (varying the gap size).

The study reported in the fourth chapter showed that systematically moving the gateway back from the crosswalk from 5 ft to 50 ft in 10 ft increments had little effect on the percentage of drivers yielding to pedestrians. Data also indicated that drivers yielded farther back from the crosswalk when the signs were placed 30 to 50 ft. in advance of the crosswalks. Placing the sign ahead of the crosswalk on multilane roads would entice drivers to yield farther back than when the gateway was placed at the crosswalk reducing the probability of the most serious type of pedestrian crash, the multiple threat (or screening) crash. The findings from this site show that placing the gateway 30 to 50 ft. in advance of the crosswalk can produce a larger effect than advance stop or yield markings. Moving the sign back at intersection locations would also reduce the likelihood that the sign would be struck by a turning vehicle.

The last chapter examined the survival of elements of the treatment over time. The results of this study showed that signs with a curb type base and a flexible rubber connector rather than a hinged spring loaded pivoting base were much more likely to survive over the course of this study. In fact, none of these signs were lost while 43% of the signs with a pivoting base attachment were sheared from their base within the first 10 months. Data also showed that none of the signs placed in the gutter pan, on top of the curb at the edge of a curb extension, a refuge island or a median island, or on top of a curb at the right side of the road under permission to experiment as part of a gateway were destroyed. It is also likely that signs placed 30 to 50 ft. in advance of a crosswalk at an intersection will be more likely to survive because they are out of the path of turning vehicles.

CHAPTER 1: INTRODUCTION

Pedestrian fatalities and injuries represent a growing percentage of all traffic fatalities and injuries (1). For example, pedestrian fatalities comprised 10.9 percent of all traffic deaths nationwide in 2004, but 14.5 percent in 2013. In 2013, the Michigan Department of Transportation (MDOT) initiated a multi-year study with Western Michigan University (WMU) in order to: 1) evaluate factors related to the efficacy of a gateway treatment using R1-6 signs, 2) determine the long-term effects of permanent installations of the gateway treatment, and 3) examine configurations that contribute to the effectiveness of the treatment. Because the signs were installed late in the season (August and September), it was not possible to collect data on the long-term effects of the gateway treatment and sign survival. This paper reports follow-up data collected the following year (2016) to address these issues. It should be noted that pedestrian fatalities in the US increased to almost 6,000 in 2016.

As MDOT would like to increase its focus on reducing the number of pedestrian crashes in Michigan as part of the Toward Zero Deaths statewide safety campaign, the WMU team (hereafter referred to as the "WMU team") conducted a study with the following objectives:

> Determine whether the effects of the gateway on the percentage of drivers yielding right-of-way to pedestrians persist over an entire season in Michigan between May and November (note signs in vulnerable locations for being struck by snowplows need to be removed during the late fall in Michigan and reinstalled in the spring).
>
> Determine the influence of the gateway treatment on vehicle speed when pedestrians are not present in the crosswalk and whether these effects persist over an entire season.
>
> Determine which gateway elements have the greatest probability of long-term survival.
>
> Determine whether placing the gateway 30 to 50 ft in advance of the crosswalk (compared to placing it at the crosswalk) increases the percentage of drivers yielding in advance of the crosswalk.

To address these objectives, the WMU team conducted a number of studies; each is captured as an individual chapter of this report. The following provides an outline of the individual chapters and thereby the actions taken as part of this multi-year study:

Chapter 3: Evaluation of the Gateway's Effect on Driver Yielding Right-of-way Over Time.

Chapter 4: Evaluation of the Effect of the Gateway on Driver Speed

Chapter 5: Evaluation of the Gateway Gap Size on Yielding Behavior.

Chapter 6: Effects of Placing the Gateway in Advance of the Crosswalk on Yielding Distance.

Chapter 7: Evaluation of the Survival of Gateway Elements

Chapter 8: Conclusions.

CHAPTER 2: LITERATURE REVIEW

2.1 EVALUATION OF A GATEWAY INSTALLATION ON MULTILANE ROADS

The purpose of this review is to summarize the results of research reported in the MDOT report major report No. RC-1638. Bennett, Manal, and Van Houten (2) used a gateway configuration of the in-street sign (the use of a sign on the white lane line and two roadway edge signs in each direction on a four lane roads). This gateway treatment produced a marked improvement in yielding at multilane uncontrolled crosswalks that was comparable to those produced by a Rectangular Rapid Flashing Beacon (RRFB) or Pedestrian Hybrid Beacon (PHB) (3, 4). One reason the gateway in-street sign configuration was so effective may have been the perceived narrowing of the roadway produced by adding signs on both sides of the road outside the lanes, even though the width of the travel way itself was not actually narrowed. It is also likely that three signs were more visible than one sign, particularly if vehicles ahead of a motorist approaching the crossing blocked the motorist's view of the location of the single sign.

Bennett and Van Houten (5,6) examined the effects of several variables influencing the effectiveness of the in-street sign used in a gateway configuration. At two multilane sites with two travel lanes in each direction, the R1-6 gateway sign treatment was compared with the sign message present with the gateway treatment with the sign message absent (the use of the fluorescent yellow green background without the symbol message). The results showed that the use of yellow green blanks without the sign message produced an average increase in yielding (to pedestrians) from 7% to 33% while the addition of the message increased yielding to 78%. These data showed that lane narrowing alone is not responsible for the efficacy of the gateway treatment.

Data were also collected comparing various configurations of the in-street sign on drivers yielding right-of-way to pedestrians at three sites. Edge signs alone, centerline signs alone, and lane line signs alone were all associated with increased driving yielding to pedestrians, but a gateway made up of edge signs, lane line signs and centerline signs together was most effective. These data showed that the gateway treatment maintained some of its efficacy even when some elements were removed, as would be the case if one of the signs was damaged during a season.

The results of another series of studies demonstrated that signs placed on top of the curb at the right edge of the road were also effective (conducted under FHWA permission to experiment), but not as effective as signs placed in the gutter pan. Since signs currently may be placed on the curb of refuge islands, median islands, and curb extension, this is one way to increase the survival of the signs and may allow these elements of the gateway to remain in place over the winter months because they would be located outside the path of the snow plow blade.

Another study showed that the substitution of a flexible delineator the same color of the R1-6 background on the lane line led to better driver yielding than edge signs alone but not as much yielding as a R1-6 sign placed on lane line. Data also documented a 10 mph speed reduction associated with a gateway when pedestrians were not in the crosswalk at one of the treatment sites. Observers consistently noticed that drivers appeared to scan back and forth looking for pedestrians as they approached the gateway, and speed data confirmed that motorists began to slow at the dilemma zone well in advance of the gateway (the dilemma zone is calculated using the ITE signal timing formula and takes into account reaction time, the speed of the roadway, a safe deceleration rate and the grade of the roadway).

Together, these studies demonstrate that the R1-6 sign is effective because it reminds drivers of their responsibility to yield to pedestrians. The Gateway is more effective as a reminder, probably because of the multiple placements of signs in the roadway. Because drivers need to drive between the elements of a gateway it was difficult for them not to notice this reminder. Data also indicated that the signs were more effective at increasing driver yielding to pedestrians on straight line segments such as crosswalks at intersections and midblock locations than at or near a curved segment such as crosswalks on a traffic circle or adjacent to a roundabout.

Because the data reported by Bennett and Van Houten (6) was collected for two months at Ann Arbor Sites and for three months at other Michigan sites with permanent in-road installation of signs, they also captured the effectiveness of the intervention over time. However, it is not known whether these results would be sustained over longer periods of time. Research was needed to address this question, as well as sign survival and whether the gateway produces consistent speed reductions. The purpose of this research was to address these questions.

CHAPTER 3: PERSISTENCE OF THE GATEWAY'S EFFECT ON DRIVER YIELDING TO PEDESTRIANS OVER TIME

3.1 INTRODUCTION

In the original study (6) data were collected after permanent installations for a period of two months at some sites and three months at other sites. The results appeared to persist for these relatively short periods of time. The purpose of the present study was to determine whether the results would persist over the spring, summer and fall season.

3.2 METHODOLOGY

3.2.1 Site Selection

Sites were selected from several locations in south Michigan with good pedestrian activity and community requests to improve driver yielding at crosswalks. Four sites were located in the city of Grand Rapids Michigan. Because local law had a yield requirement at these sites, the R1-6 signs included a yield sign. Four sites were located in Ann Arbor Michigan. Because local law had a stop requirement in this city, the R1-6 signs included a stop sign. The remaining signs were located in various areas in southwest Michigan suggested by MDOT. Appendix A shows the characteristics of each of the sites included in this study.

3.2.1.1 Dependent Variables

The number of motorists who did and did not yield to pedestrians in crosswalks was measured in the same way as reported in the original study (6). Driver yielding was measured in reference to an objective dilemma zone (a location beyond which a driver can easily yield if a pedestrian enters the crosswalk). This distance was calculated using a formula that takes into account driver reaction time, safe deceleration rate, the posted speed, and the grade of the road used to calculate this interval for the yellow traffic light.

Motorists who had not passed the outer boundary of the dilemma zone when a pedestrian entered the crosswalk were scored as yielding or not yielding because they had sufficient time and space to stop safely for the pedestrian. Motorists who entered the dilemma zone before the pedestrian placed a foot in the crosswalk could be scored as yielding, but could not be scored as failing to yield because the motorist did not have adequate distance to yield based on the calculated distance. However, the signal timing formula is relatively lenient; hence, many vehicles that passed the dilemma zone could yield safely, particularly those traveling below the speed limit.

Drivers in the first two travel lanes nearest the pedestrian were scored for yielding after the pedestrian had entered the crosswalk. This procedure was used because it conforms to the obligations of motorists specified in the Universal Vehicle Code and local ordinances in Kalamazoo, Ann Arbor, and Grand Rapids, regarding who has the right-of-way at what time. Drivers in the second half of the roadway were scored as a separate trial if there was a pedestrian refuge or median island separating the travel way. If there was no island, drivers in the second half of the road were scored when the pedestrian approached the center of the last travel lane adjacent to the yellow centerline separating opposing lanes of traffic. Motorists were then scored using the same method as the crossing for the first half of the roadway.

Each data sheet (a data point) consisted of 20 pedestrian crossings when drivers were present who could yield or fail to yield to the pedestrian. A minimum of five data points were collected during the baseline period at each site. A minimum of three data sheets was collected at each site when the temporary gateway installation was in place. A temporary installation was not installed at two of the sites prior to installing the permanent gateway, the Monroe Midblock location and the N Main Street midblock location in Three Rivers. Three data sheets were collected each month at each of the sites during daylight hours after permanent installations and during the return to baseline at the end of the 2016 season.

3.2.1.2 Inter-observer Agreement

Inter-observer agreement was calculated in the field for at least 34% of all observations in this experiment, and data were independently collected during each condition of each experiment in order to validate the observational data. Each event that was scored the same by both observers was counted as an agreement, and each event that was scored differently by each observer was scored as a disagreement. Inter-observer agreement was calculated by dividing the number of agreements during each session by the sum of agreements plus disagreements for that session.

Inter-observer agreement on the percentage of drivers yielding to pedestrians averaged 96.8% over all of the studies completed in this research with a range of 87.5% to 100%.

3.2.2 Apparatus

Three types of traffic control devices (TCD)s were used in this study. The first TCD device was the R1-6 in-street sign with a curb type base with a flexible rubber connector between the paddle and the curb type base. The second was a flexible delineator and the third was a R1-6 sign with a flush mounted base and a spring loaded pivot at the base.

Figure 3.1. Figure 3.1a (above left) shows an R1-6 sign installed on a removable curb base. Figure 3.1b (middle) shows a flexible delineator installation. Figure 3.1c (above right) shows an R1-6 sign mounted on a flush mounted base.

3.3 RESULTS

3.3.1 Midblock and Intersection Sites

The percentage of drivers yielding right-of-way to pedestrians at each site located at midblock and intersection locations is shown in Table 3.1. Each cell is color-coded. Yielding measured between 0% and 19% were colored red. Yielding measured between 20% and 39% were colored orange, yielding between 40% and 59% were colored yellow, yielding between 60% and 79 percent were colored green, and yielding between 80% and 100% were colored blue. The installation of the temporary gateway led to an increase in the percentage of drivers yielding to pedestrians at each site. During baseline conditions, yielding averaged 15% with a range of 0 to 40%. A temporary installation was evaluated after the baseline condition at each site except two. When the temporary gateway treatment was evaluated, yielding increased to 75% with a range of 50% to 94%.

Once the permanent gateway treatments were installed yielding remained consistently high at all sites with little evidence of decline unless most of the signs were damaged (this only occurred at one site, Westnedge at Ranney – a two lane one way street with on street parking). The first month an edge sign was lost, the second month the lane line sign was lost, the remaining sign was an edge sign on the right of the road that was often obscured by a parked car in front of a popular restaurant). One out of four signs was lost at the Monroe site. This reduced the level of yielding, but yielding still stayed well above baseline. The sign on Huron at Ingalls was missing lane line signs because of the traffic engineer felt they would not last with construction and truck traffic on that route.

Table 3.1 The percentage of drivers yielding.

Crosswalk Location	Percent of Drivers Yielding											
	Baseline	Temporary Installation	Permanent Installation 2015			Permanent Installation 2016						
Follow up Period	X	X	Aug	Sept	Oct	May	Jun	July	Aug	Sept	Oct	Nov
Midblock refuge island or median												
Monroe RRFB Off	6	X	82	*50	*56	*57	*73	*54	*51	*46	*50	removed
Stadium @ High School	15	54	X	64	70	73	80	70	65	64	63	77
E. Huron St. W of Ingalls	40	86	X	X	X	X	X	*74	*64	*88	*72	*85
Midblock without refuge or island												
N. Main St. Three Rivers	6	X	64	53	50	55	41	45	53	69	51	59
Intersection												
S. Westnedge at Ranney	0	59	33	29	**NA	X	X	X	X	X	X	X
Nixon Rd. at Bluett Rd.	40	86	X	93	89	87	78	*81	*79	*85	*81	*92
Division St. at Jefferson	3	94	X	94	93	89	90	78	*73	*82	*92	construct
Wealthy at Cass	33	73	X	X	X	X	X	X	71	75	80	88
Lake at Carroll	4	50	X	X	X	X	X	X	X	X	X	X
Intersection with Ciub Extension												
Cherry at Hollister GR	8	92	X	X	X	76	76	79	67	73	69	74
Wealthy at Henry GR	6	68	X	X	X	62	62	62	67	56	84	75
Cherry at Warren GR	13	88	X	X	X	69	69	80	*65	*69	*65	*70
Mean all sites	15	75	60	67	76	73	67	69	66	71	71	78
*Gateway element was identified as damaged or destroyed												
**Two Gateway elements were destroyed												

The percentages in Table 3.1 correspond to motorists yielding the right-of-way to pedestrians during baseline, when the temporary sign was in place, and each month after the permanent signs were in place. An Asterisk marks the loss of a sign at a site. Two asterisks indicate the loss of two signs.

Figure 3.2, and 3.3 show the percentage of drivers yielding at each of the midblock and intersection crosswalk sites with a straight approach across all sites as line graphs. The blue diamond shows the average percentage of drivers yielding during baseline before the gateways was installed. The red square shows the average level of yielding behavior during days when a temporary gateway configuration was installed. The green diamonds show the percentage of drivers yielding during each month after the permanent gateway was installed.

The final figure shows the average for all sites. These data show that the gateway treatment produces a marked and obvious sustained increase in the percentage of drivers yielding right of way to pedestrians at each of the sites, Furthermore, the effect sizes are similar to those produced by a rectangular rapid flashing beacon (RRFB)(3). Another important finding is that the effects persisted over time. This shows that the increased yielding behavior produced by the gateway treatment is not a novelty effect. It should be noted that the effects are larger at midblock and intersection sites and smaller at sites with curvature such as roundabout and traffic circle sites. Note that approaching vehicle speeds are considerably lower at roundabouts and traffic circles and that sight distance is typically poorer.

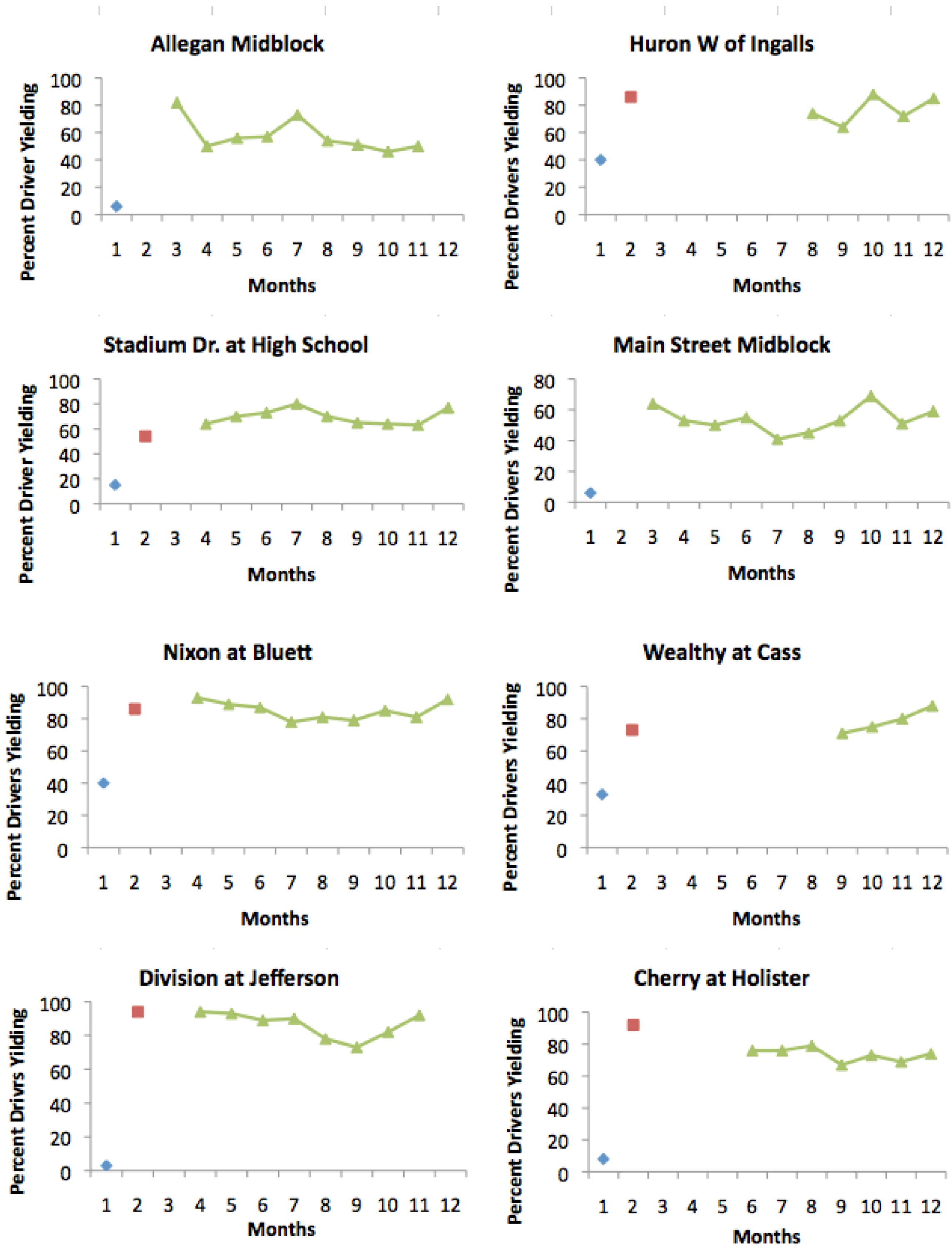

Figure 3.2 The percentage of drivers yielding at midblock and intersection sites.

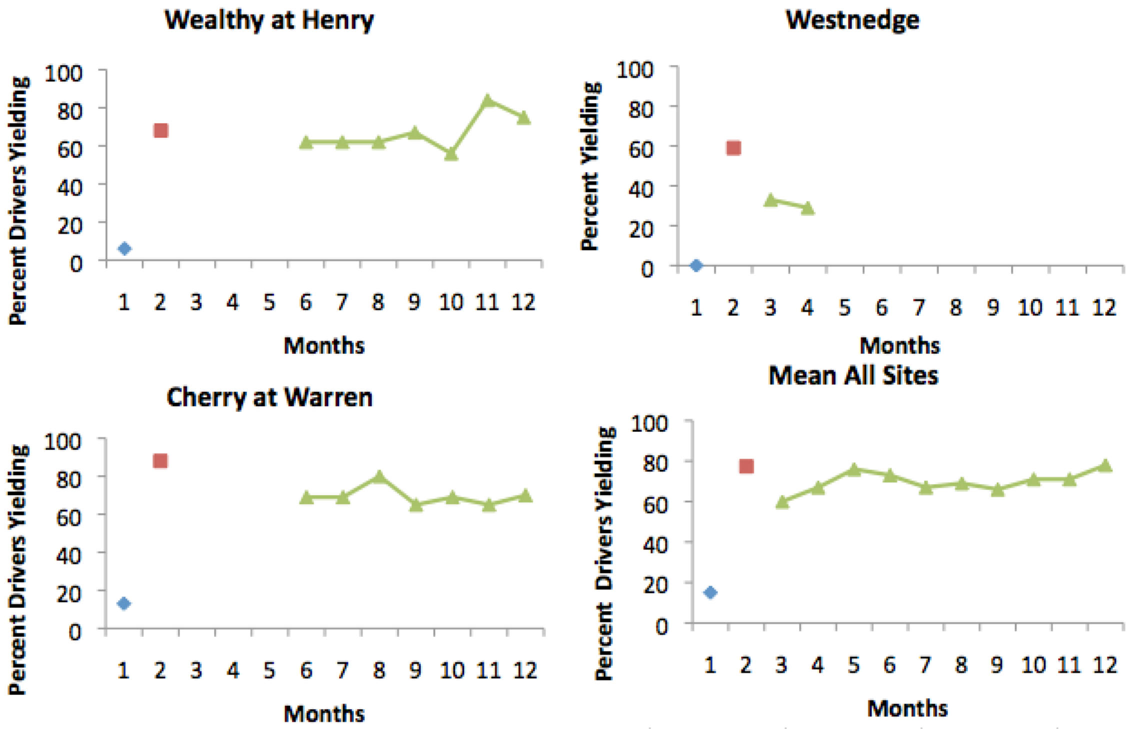

Figure 3.3 The percentage of drivers yielding at three additional midblock and intersection sites. The graph on the bottom right is the average across all sites.

3.3.2 Traffic Circle and Roundabout Sites

The percentage of drivers yielding right-of-way to pedestrians at each site located at either traffic circle or roundabout locations when the temporary sign was in place, and each month the permanent signs were in place is shown in Table 3.2. Each cell is color-coded. Yielding measured between 0% and 19% were colored red. Yielding measured between 20% and 39% were colored orange, yielding between 40% and 59% were colored yellow, yielding between 60% and 79 percent were colored green, and yielding between 80% and 100% were colored blue.

The installation of the temporary gateway led to an increase in the percentage of drivers yielding to pedestrians at each site. During baseline conditions, yielding averaged 13% with a range of 9 to 19%. A temporary installation was evaluated after the baseline condition at each site. When the temporary gateway treatment was evaluated, yielding increased to 43% with a range of 29% to 54%. Once the permanent gateway treatments were installed yielding remained consistent at the one site where no sign was damaged (Marshal Circle SE Leg) and declined at two of the sites that lost a sign element Marshall NW Leg and the roundabout at East Main at 5th Street.

Table 3.2 The percentage of drivers yielding to pedestrians at roundabout and traffic circle locations. An asterisk marks indicates the loss of a sign at the site.

Crosswalk Location	Percent of Drivers Yielding											
	Baseline	Temporary Installation	Permanent Installation 2015			Permanent Installation 2016						
Follow up Period	X	X	Aug	Sept	Oct	May	Jun	July	Aug	Sept	Oct	Nov
Traffic circle												
Marshall Circle NW Leg	13	54	71	71	50	46	32	*40	*44	*37	*33	*46
Marshall Circle SE Leg	11	29	26	38	34	36	34	25	25	38	39	24
Roundabout												
E. Main St. at 5th St.	19	45	61	60	*33	40	*24	*39	*38	*45	*49	*43
E Main at Riverview Dr.	9	43	44	44	44	67	47	*42	*34	*51	*51	*45
Mean all roundabout sites	13	43	51	53	43	47	34	37	35	43	41	40
*Gateway element was identified as damaged or destroyed												
**Two Gateway elements were destroyed												

Figure 3.4, shows the percentage of drivers yielding at each of the sites as line graphs. The blue diamond shows the average percentage of drivers yielding during baseline before the gateways was installed. The red square shows the average level of yielding behavior during days when a temporary gateway configuration was installed. The green diamonds show the percentage of drivers yielding during each month after the permanent gateway was installed. Note that one of the edge signs forming the one lane gateway was destroyed during the third month at the Marshall NW Leg site and at the E. Main at 5th site.

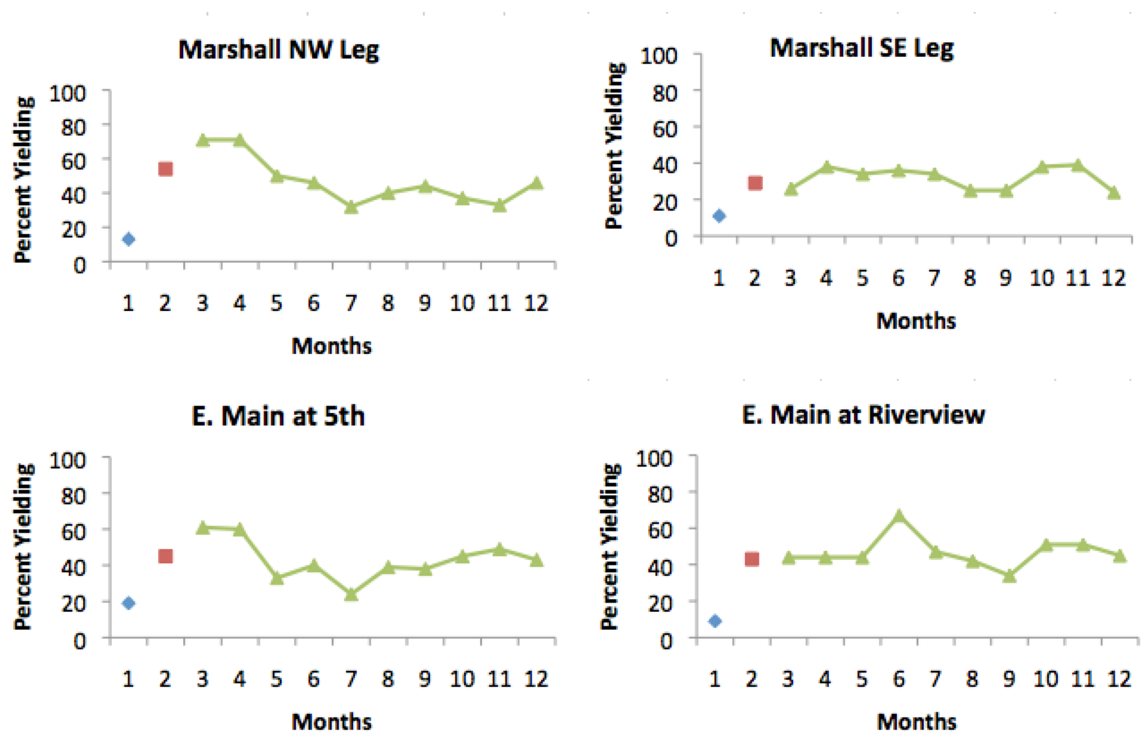

Figure 3.4 The percentage of drivers yielding at two traffic circle sites (top frames) and at the two roundabout sites (bottom frames).

3.4 DISCUSSION

The results of the study on the persistence of the effect produced several interesting findings. First, the introduction of the gateway treatment was associated with a large increase in the percentage of drivers yielding right-of-way to pedestrians at each of the fifteen sites. Second, the increase in yielding was greater at intersection and midblock crosswalks than at crosswalks at a roundabout or traffic circle locations. It is quite likely that this difference is related to the poorer sight distance drivers have when exiting a roundabout or when traversing a traffic circle. Third, increases in yielding were maintained over time. This shows that the increase in yielding produced by the sign was not a novelty effect.

Another interesting finding was that the gateway effect was partially maintained when one element of the gateway was lost. This result suggests that maintenance may not be immediately required when a sign element is lost. In almost all cases when a sign was lost it was a sign with a flush mounted base with a spring loaded hinged pivoted return. Future research should study how well these signs survive over a longer period of time to more accurately determine long time costs.

It is important to note that the increase in drivers yielding right-of-way to pedestrians is not the only benefit of the gateway treatment. Driving speed at the crosswalk also influences pedestrian safety. The purpose of the next chapter is to explore this issue.

CHAPTER 4: EFFECT OF THE GATEWAY TREATMENT ON DRIVER SPEED

4.1 INTRODUCTION

In the original study (6) speed data were collected at one temporary gateway installation site when pedestrians were not present in the crosswalk because the research team members noticed obvious slowing when drivers traversed the crosswalk when pedestrians were not present in or at the crosswalk. The research team also noticed that drivers appeared to visually scan for pedestrians by looking from side to side while traversing the crosswalk. Therefore, speed data were collected in the presence and absence of the gateway treatment at this site in the absence of pedestrian crossings.

When the gateway was introduced at that site average speed decreased from 26.8 mph to 23.1 mph at the dilemma zone and from 28.3 mph to 18.1 mph at the crosswalk, a 10 mph drop. A single R1-6 sign located on the yellow line at the center of the road was associated with a very small reduction in speed similar to that reported in research that only used one sign (7). Not only was the magnitude of the reduction clearly visible, but it also reduced vehicle speed below the speed associated with fatal crashes (8). Speed reductions can reduce both the probability of a pedestrian crash by giving drivers more time to react, and also reduce the tunnel vision associated with higher vehicle speeds. Reduced speed can also decrease the severity of injuries should a crash occur. Therefore the purpose of this study was to collect speed study at a number of additional sites, in order to determine whether these results can be expected at typical gateway sites, and to determine whether the reductions in speed persist over time.

4.1.1 Apparatus

Speed was measured with an Ultra Lyte LTI 20-20 laser speed measuring system donated by Kalamazoo Public Safety. Prior to each data collection session the LIDAR unit was calibrated by one of the research assistants in the manner described in the manual. The surveyor tripod was set up between 3 and 4 ft. from the curb, depending on the location, and between 120 ft. and 150 ft. beyond the crosswalk in reference to approaching traffic in order to eliminate any significant cosine error. The person collecting data was dressed as a surveyor with a helmet and vest and radar unit was mounted on a surveying tripod in order to conceal speed data collection.

4.2 METHODOLOGY

4.2.1.1 Dependent Variables

Vehicle Speeds

Speed data were collected during baseline in May of 2016, after the gateway treatments were installed at the end of June (after one month), the end of August (the end of three months), and the end of October (at the end of 5 months). Data were then collected a month after the treatment was removed for winter at the end of November. During each speed measure data were collected on a sample of 400 vehicles. Drivers were excluded if they changed lanes after their speed was read at the dilemma zone and if they parked just before traversing or just after traversing the crosswalk. It is important to note that drivers were excluded if pedestrians were attempting to enter or were within the crosswalk and if motorists were turning or attempting to turn while a driver was in the dilemma zone. Thus these data show the effect of the gateway in the absence of pedestrians and other reasons for slowing such as parking or turning movements.

The dependent variable was the vehicle's speed as it traversed the dilemma zone (calculated using the ITE signal timing formula), which begins 104 ft. in advance of the crosswalk at sites with a speed limit of 25 mph, 141 ft. in advance of the crosswalk at sites with a 30 mph speed limit and 183 feet in advance of the crosswalk on roads with a 35 mph speed limit, and a second speed measure was taken on the same vehicle as it traversed the crosswalk. Data were not collected on cars slowing to park before or just after the crosswalk. Two people collected data. One person operating the LIDAR unit would state the speed of the of the vehicle as it traversed the dilemma zone then state the speed of the same vehicle as it traversed the crosswalk. A second recorder entered the speeds onto a recording sheet. Then the radar operator would then select the next car approaching the dilemma zone.

When multiple cars were approaching the crosswalk, the observer would measure the speed of the first car in the platoon of vehicles. At each site, data were collected from the same side of the street and speed was only measured for cars going in one direction. This procedure was kept constant for each site. For example, if we collected traffic going east at one site, we continued to measure traffic going east for all data points at that site. Each data point consisted of 400 cars.

Hard Braking

In order to determine whether the Gateway increased the percentage of hard braking, data were recorded on hard breaking at two sites in Ann Arbor, MI: Nixon Rd. at Bluett Rd., and S. Division St. at E. Jefferson, St. Hard braking was defined as the driver swerving or braking hard as defined by audible braking or the rear of the car making a sudden upward displacement during deceleration.

4.3 RESULTS

4.3.1 Speed at the Crosswalk and Dilemma Zone

Table 4.1. Shows the baseline speed measure, and the speed measures obtained after the gateway was introduced in June, August, and October. These data show that driving speeds decreased after the gateway was installed at all 10 crosswalk locations where speed was measured. The speed reductions were small at three of the sites, the roundabout sites at Main Street and Riverview, the site at Main Street in Three Rivers, and the location at Wealthy and Henry. Mean baseline speeds on all three of these streets were less than 25 mph. The speed at

the roundabout site was less than 20 mph. These three streets had the lowest mean baseline speeds and would therefore be expected to have the lowest speed reductions.

Table 4.1 Vehicle speed at the Dilemma Zone and the Crosswalk at each site during baseline and each of the three post treatment measures.

	Baseline		Jun		Aug		Oct	
	Mean Speed		Mean Speed		Mean Speed		Mean Speed	
SW Michigan	*Dillema Zone*	*Crosswalk*	*Dillema Zone*	*Crosswalk*	*Dillema Zone*	*Crosswalk*	*Dillema Zone*	*Crosswalk*
Westnedge & Ranney	27.6	29	24.3	23.0	NA	NA	NA	NA
Three Rivers N.Main	23.9	22.6	22.8	21.6	21.5	14.0	20.5	19.7
Benton Harbor	29.4	19.2	27.6	18.8	27.4	15.7	27.2	16.4
Allegan	27.2	28.1	25.9	25.4	27.2	27.1	26.9	26.9
Grand Rapids								
Cherry & Hollister	25.6	25.2	22.8	21.9	21.5	20.5	21.5	20.5
Wealthy & Henry	24.8	24.4	24.4	22.0	24.7	23.6	23.0	22.3
Ann Arbor								
7th & Stadium	34.1	30.6	31.6	27.6	32.1	28.9	29.6	28.4
Division & Jefferson	28.1	27.4	25.4	19.1	22.6	19.5	NA	NA
Nixon & Bluett	32.8	32.3	28.5	27.1	31.6	29.3	29.9	28.8
Huron	32.8	32.9	29.4	28.3	24.6	23.5	23.4	22.6

Mean speed reductions as the vehicle traverse the crosswalk for all sites with a baseline mean speed of 25 mph or more are shown in Table 4.1 and Table 4.2. These data show that the speed reductions at these sites averaged around 4 mph and remained consistent over the 5-month measurement period. The one site with consistently smaller speed reductions, Monroe in Allegan, lost one of the two curbside gateway signs after the June speed reading and driver yielding also was reduced at this site. Speed data are missing for Westnedge because most of the gateway at this site had been destroyed after June. Speed data were not collected at division in October because of construction.

Table 4.2 Speed reductions at the crosswalk and at the dilemma zone at each site during June, August and October.

	Speed Redution at Crosswalk			Speed Reduction Dilemma Zone		
Location	**Jun**	**Aug**	**Oct**	**Jun**	**Aug**	**Oct**
Monroe	2.7	1	1.2	1.3	0	0.3
Stadium	3.2	1.9	2.4	0	0	1
Huron	4.6	9.4	8.3	3.4	8.2	7.4
Westnedge	6.1	NA	NA	3.3	NA	NA
Nixon	3.6	3	3.5	2.4	1.9	3
Division	8.3	7.9	NA	3	5	NA
Cherry	3.3	4.7	3.3	2.8	4.1	3.5
Mean	4.5	4.7	3.7	2.3	3.2	3.0

Mean speed reductions as the vehicles traverse the dilemma zone for all sites are shown in Table 4.2. These data show that drivers began to slow at the dilemma zone and that the mean reduction in speed varied between 2 and 3 mph. This would imply that drivers might not be expected to engage in hard braking because they begin slowing at a reasonable distance when approaching the gateway.

4.3.2 Hard Breaking

At the Nixon Rd. crosswalks 758 vehicles that slowed at the crosswalk were observed and no instances of hard braking were observed. At the S. Division crosswalk 912 vehicles that slowed were observed and only one instance of hard braking was observed. These data were collected several weeks after the permanent installations.

4.3.3 Speed Distribution at the crosswalk

4.3.3.1 Speed Distributions

The speed distributions for the Nixon Rd. crosswalk at Bluett is shown in Figure 4.1 for baseline and after the treatment was introduced in June. It is clear that the entire distribution of speeds at the crosswalk (orange bars) shifted to the left after the treatment was introduced. The data remained shifted to the left when measured in October. The speed distributions for Huron are shown in Figure 4.2. The entire distribution also shifted toward slower speeds at this site. The treatment distributions also look flatter than the baseline distribution. The speed distributions for Division are shown in Figure 4.3. The distribution also shifted at this site and considerable flattening of the distribution was observed at this site. The speed distribution for the crosswalk on Stadium Drive is shown in Figure 4.4. The treatment produced a shift toward lower speeds after the treatment was introduced that was sustained 5 months after the treatment was introduced. The speed distribution for Stadium Drive shows a sustained shift in the speed distribution toward lower speed. A similar sustained shift is shown at Wealthy and Henry in Figure 4.5 and at Cherry St. at Hollister in Figure 4.6 in the city of Grand Rapids.

The speed data at the midblock crosswalk on Monroe in Allegan shows a shift toward slower speeds when the treatment was first introduced. However, even though one of the flush mounted signs was lost at this site, the distribution obtained in October showed an even larger shift toward slower speeds.

Figure 4.8 shows the speed reductions entering one of the roundabouts in Benton Harbor. At this site a similar progressive shift toward slower speeds was observed with a larger shift in October than in June. Figure 4.9 shows a similar progressive shift in speed after the gateway was introduced at a midblock site in Three Rivers.

The final graft shows the speed distribution during baseline before the gateway was introduced at the crosswalk on South Westnedge Avenue (a one-way street). The introduction produced a large shift in speeds toward lower speeds. Data were only shown at this site for June because two flush mounted signs were lost after the June speed data were collected. Because there were only three signs at this site, and parked vehicles often screened the remaining sign, data collection was suspended at this site.

The gateway treatment produced sustained speed reductions at all sites. Because the data set included many different types of sites, it is clear that this effect had considerable generality.

Figure 4.1 Speed distribution at the crosswalk for Nixon at Bluett. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

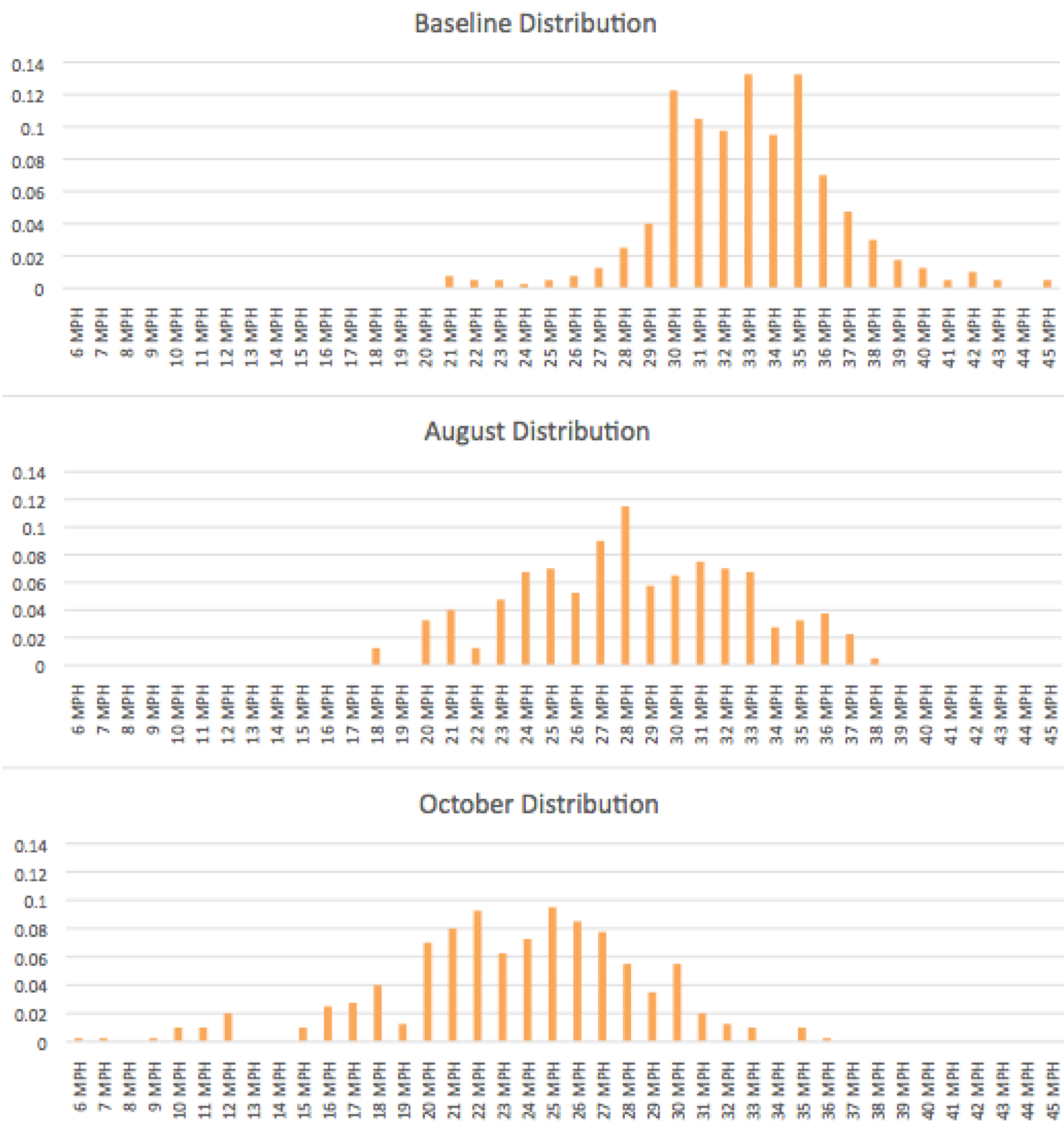

Figure 4.2 The speed distribution at the crosswalk for Huron. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in July and the bottom frame shows the distribution in August (The treatment was not introduced until July at this location).

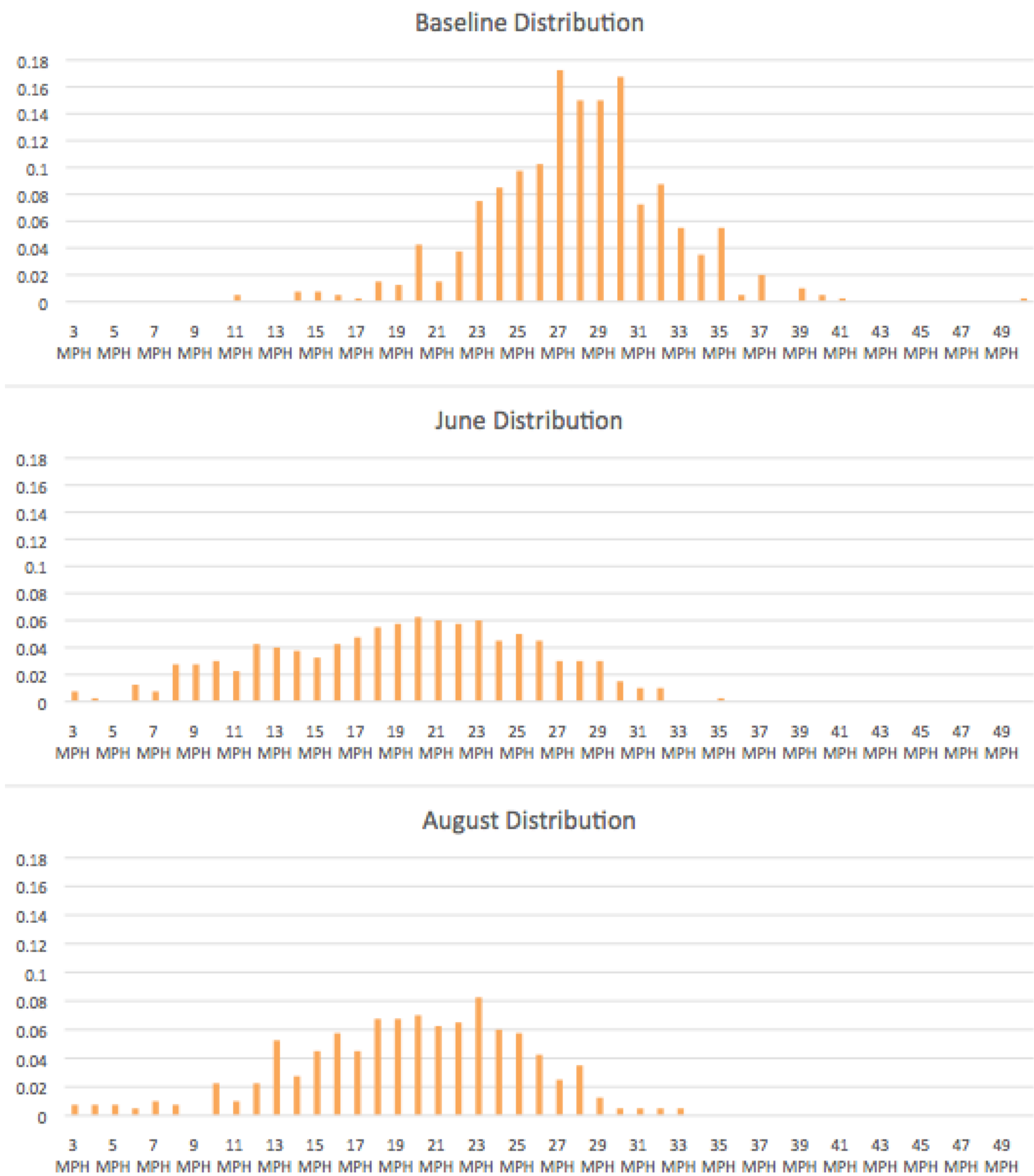

Figure 4.3 The speed distribution at the crosswalk for Division. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in August (data were not collected in October because of road construction).

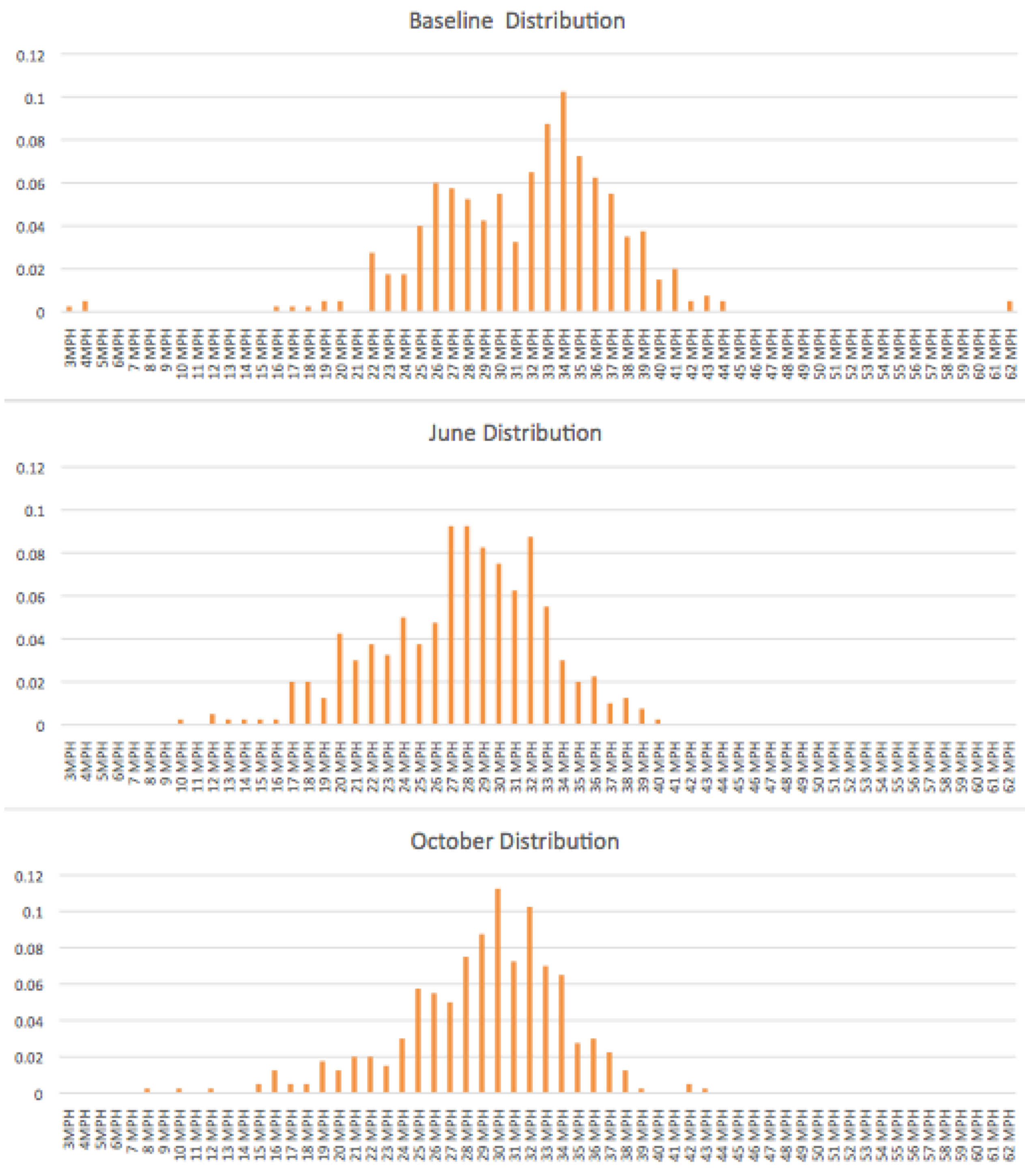

Figure 4.4 The speed distribution at the crosswalk for Stadium Drive. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

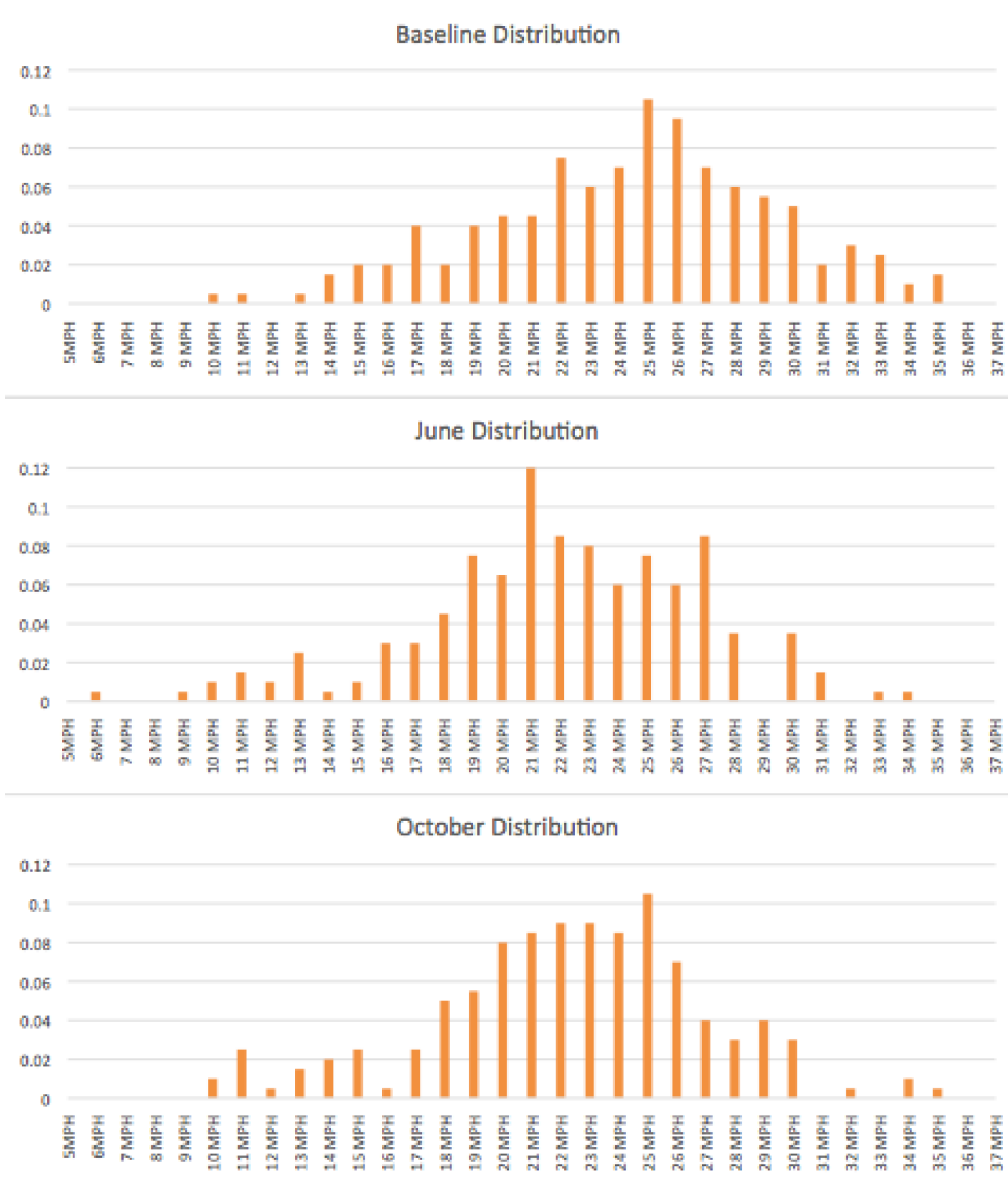

Figure 4.5 The speed distribution at the crosswalk for Wealthy at Henry. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

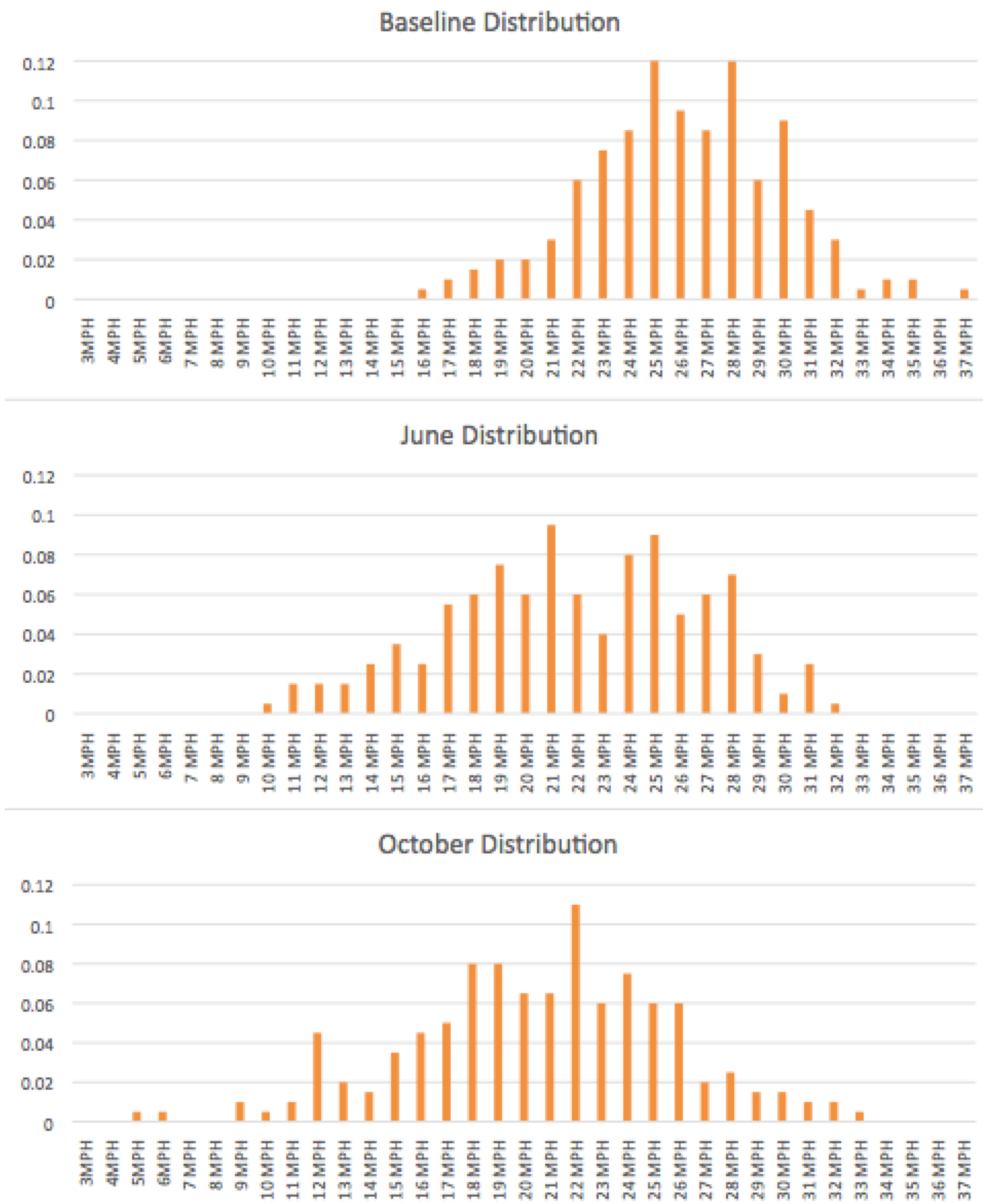

Figure 4.6 The speed distribution at the crosswalk for Cherry Street at Hollister. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

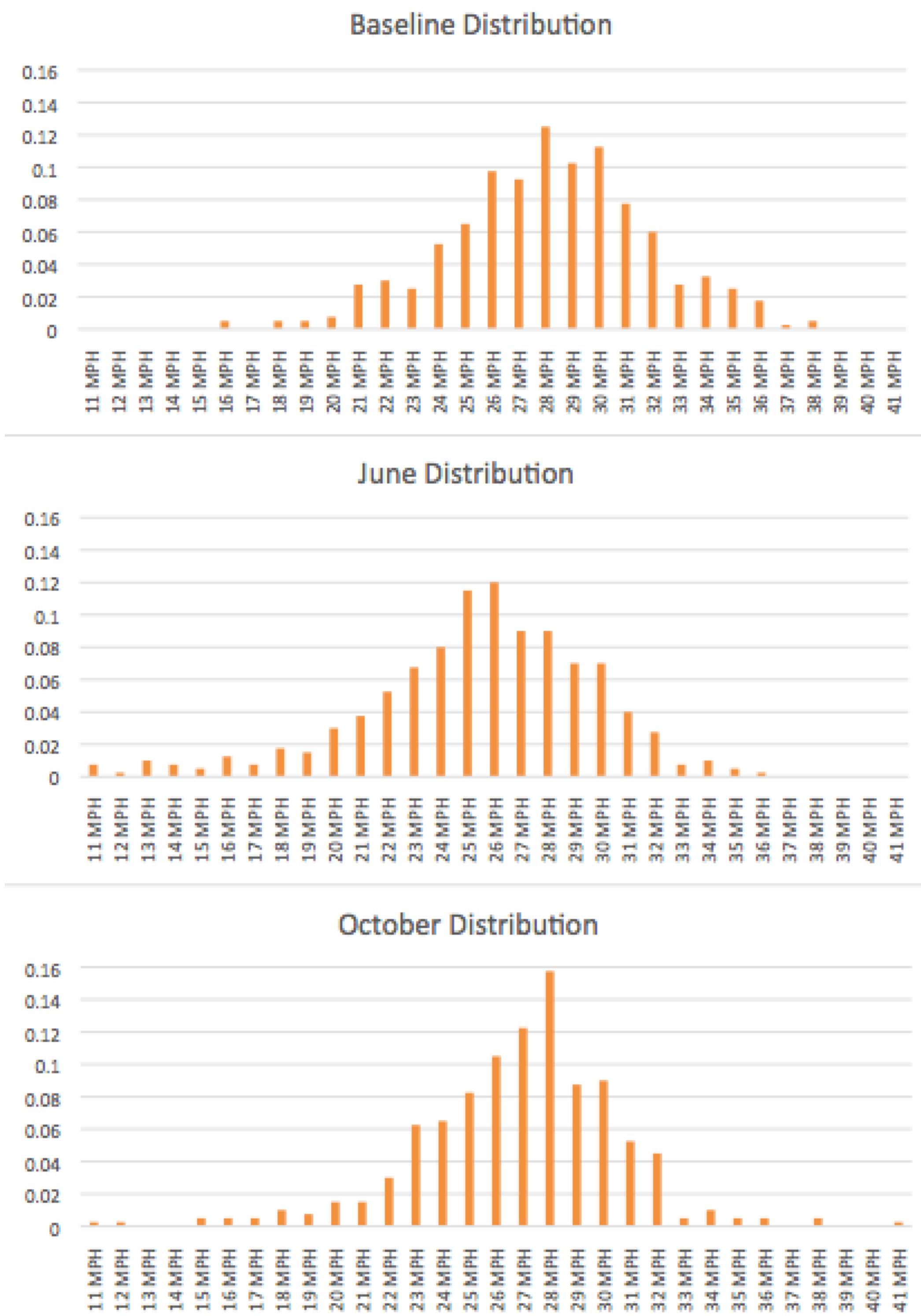

Figure 4.7 The speed distribution at the midblock crosswalk on Monroe in Allegan. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

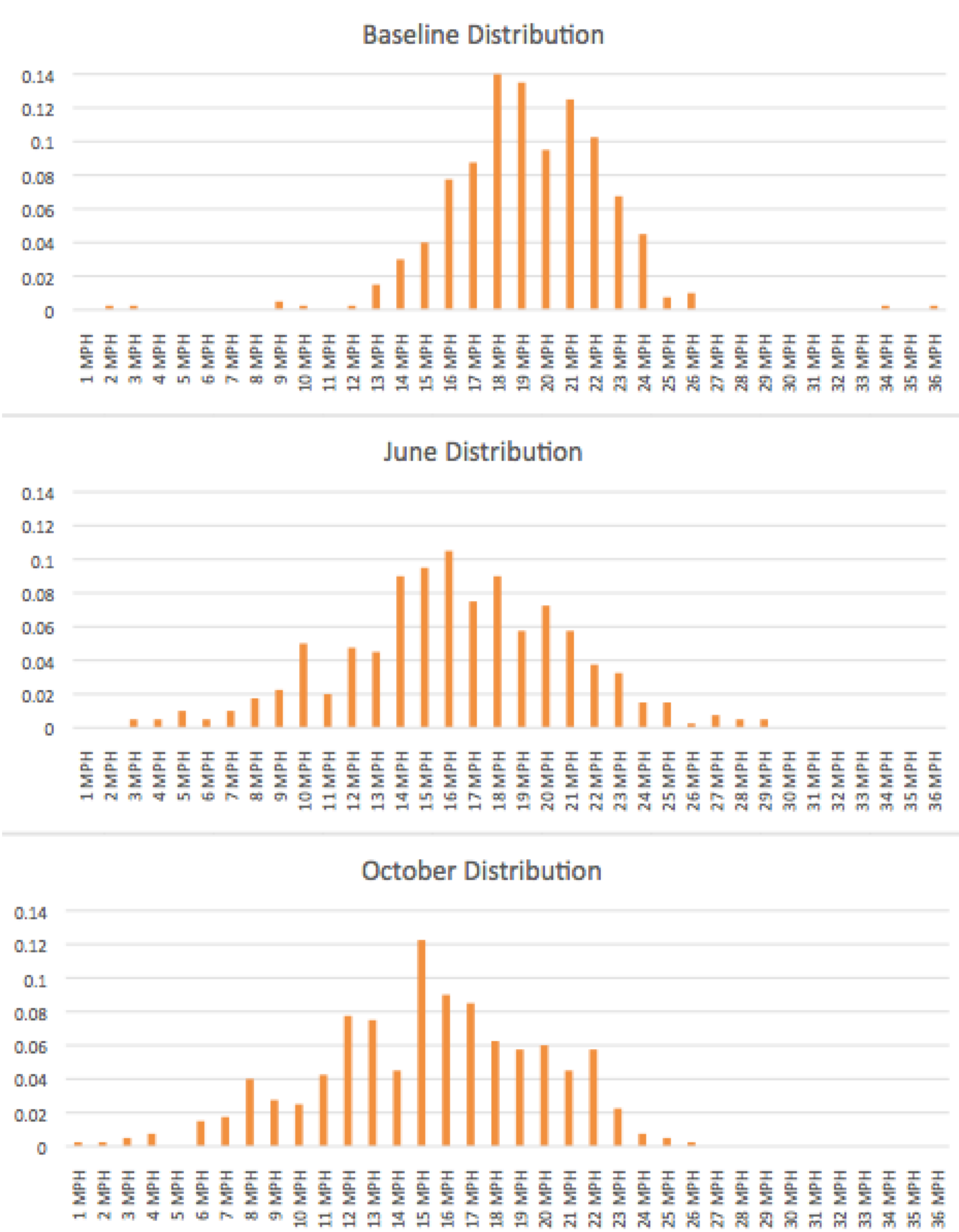

Figure 4.8 The speed distribution at the crosswalk at the approach to the roundabout on W Main St. at Riverview Dr. in Benton Harbor. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

Figure 4.9 The speed distribution at the midblock crosswalk on Main Street in Three Rivers. The top frame shows the distribution of speeds for baseline, the middle frame shows the distribution in June and the bottom frame shows the distribution in October.

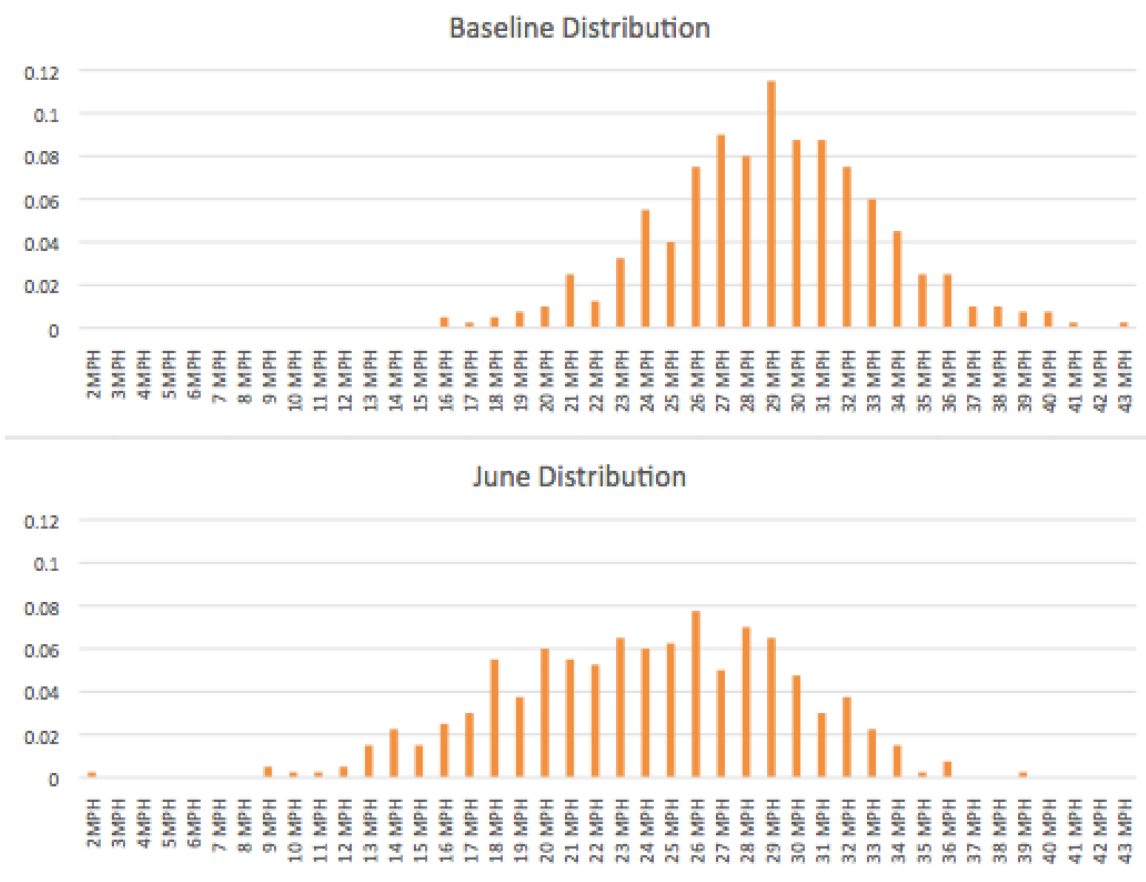

Figure 4.10 This Figure shows the speed distribution at the crosswalk on South Westnedge at Ranny. The top frame shows the distribution of speeds for baseline, the bottom frame shows the distribution in June. Two out of three gateway elements were destroyed at this site after the June speed measures. Parked cars often screened the third element.

4.3.4 Discussion

The results of the study on the effects of the gateway treatment on driver speed as they traverse the crosswalk when pedestrians were not present produced several important findings. First, the reduction in mean driver speed was relatively robust and equal to or better than most practical traffic calming methods. This is important because driver speed is related to the probability of a pedestrian crash as well as the seriousness of a pedestrian crash. The speed a driver crosses when a pedestrian is not present is important because it is also the speed present when a driver does not see a pedestrian in a crosswalk, or does not see the pedestrian until there is less time to react. However, it should be noted that slower speeds are associated with more time to react and given limited braking time, a lower impact speed should a crash occur. These factors clearly benefit the pedestrian.

Second, drivers began slowing at the dilemma zone when the gateway treatment is used. This finding is important because early gradual slowing decreases the probability and potential severity of a rear-end crash when the following driver is inattentive. It is interesting to note that data on hard braking obtained at two sites with large speed reductions confirm that hard braking conflicts does not appear to be an issue with the gateway treatment.

Third, the speed reduction at each site persisted for nearly a year. This is an important because it shows that the effects are not produced by the novelty of the treatment. Fourth, the changes in speed were associated with large shifts from the high end of the speed distribution. This is important because crashes of vehicles traveling at a higher speed are most likely to be associated with an incapacitating or fatal pedestrian crash and the shape of this function is known to be exponential.

Fifth, although not specifically tested, these data also suggest that the gateway treatment at crosswalks in small communities located on MDOT trunk routes could also function as a traffic calming feature. Additional research should examine this use for the gateway treatment.

CHAPTER 5: EFFECT OF GAP SIZE ON DRIVING YIELDING BEHAVIOR

5.1 INTRODUCTION

In the original study (6) there was an inverse relationship between the width between the gateway signs and the percentage of drivers yielding right-of-way to pedestrians. In other words, greater yielding was found in situations where the gateway signs were closer together. However, this effect was considerably smaller than the difference in the percent of drivers yielding comparing the gateway with the widest sign spacing vs the before or baseline condition.

Data also showed that a gateway constructed with blank Ra-6 signs without the message was markedly less effective than a gateway constructed from Ra-6 signs with the message. These data show that the presence of the objects in the road alone were not responsible for the effect of the gateway treatment. Because the comparison between different gateway widths were typically between different sites in the previous research, the research team decided to conduct a parametric analysis, where gateway width was varied over several widths at the same site.

5.2 METHOD

5.2.1 Setting

All data were collected at Garden Lane trail crossing, in Portage, Michigan. Data collection occurred between the months of July and November, 2016.

5.2.2 Design

The present study utilized a mixed design, incorporating both a reversal and alternating treatments design. The sign was placed at different distances on different days and each distance was replicated several times.

5.2.3 Conditions

The present study used the R1-6 in-street sign in a gateway configuration (Bennett, Manal, & Van Houten, 2014). The distance between the signs was manipulated in 2ft increments, and the change in driver yielding to pedestrians was measured (see Figure 5.1).

Figure 5.1 Photographs of different Gateway widths: (Top left) 12ft, (top right) 14ft, (bottom left) 16ft, and (bottom right) 18ft.

Initially, data were planned to be collected on widths ranging from 16ft to 10ft, as well as baseline (i.e., no gateway treatment)., however when the signs were placed at the 10ft interval, one experimenter became concerned that this might increase the probability of a sign being struck. In response to this, it was agreed to make the fourth sign width 18ft. Taped lines were placed on the ground at the set distances, and the signs moved to these positions with each change in conditions (see Figure 5.2).

Figure 5.2 Photograph of crosswalks with tape lines marking placement of sign for each gateway width.

The alternating treatments embedded within the reversal design was added to explore and control for any effect that time of day might have on yielding. A Latin Square (4x4) generator was used to counterbalance the order of widths by time of day. The times of day represented were 10:00AM, 11:00AM, 12:00PM, and 1:00PM, and no combination of condition and time of day was repeated.

5.2.4 Inter-observer Agreement

Inter-observer agreement (IOA) was collected on more than 30% of all trials. Average IOA was 97.8%, with a range of 92.5% to 100%.

5.3 RESULTS

The results of the study are presented in Figure 5.3. During baseline 29.6% of drivers yielded right-of-way to pedestrians in the crosswalk. The introduction of the gateway treatment was associated with an increase in yielding at all distances, with the percentage of yielding inversely related to the narrowness of the gateway. In other words the narrower the gateway the higher the percentage of drivers yielding to pedestrians. When the distance between the gateway signs was 18 ft., 72.6 percent of drivers yielded to pedestrians, when the distance between the signs was 16 ft., 74.8 percent of drivers yielded to pedestrians, when the distance was 14 ft., 79% of drivers yielded and when the distance was 12 ft. 85% of drivers yielded.

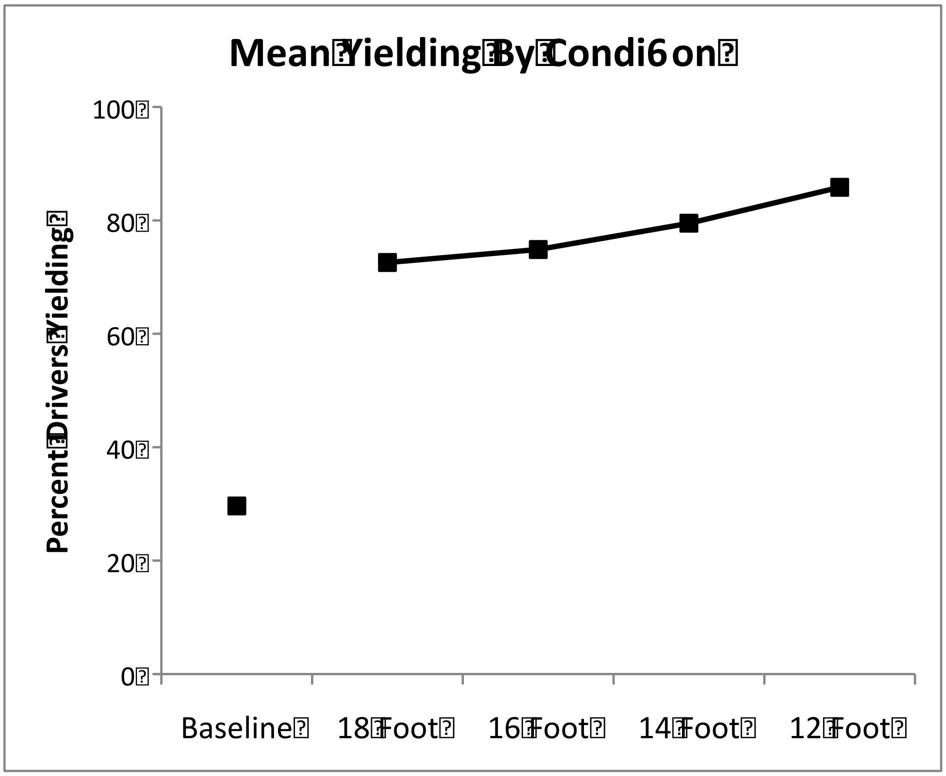

Figure 5.3 The percentage of drivers yielding to pedestrians at each of the gateway gap distances. The black square shows baseline (i.e., no gateway treatment present), yielding and red line shows the function between gap width and yielding behavior.

5.4 DISCUSSION

This study replicated the previous finding that the percentage of drivers yielding right of way to pedestrians is inversely proportional to the narrowness of the gateway. That is, more drivers yield to pedestrians as the distance between the signs becomes narrower. However, the presence of a gateway produces a larger effect than the difference between the wide and narrow conditions. These data lend further support to the theory that the prompting effect of the gateway is more important in inducing drivers to yield right-of-way to pedestrians, than the narrowness of the gateway, although the width of the gateway is a factor influencing yielding behavior.

CHAPTER 6: EFFECTS OF THE ADVANCE GATEWAY PLACEMENT ON YIELDING AND YIELDING DISTANCE

6.1 METHOD

6.1.1 Setting

All data were collected on the northbound crosswalk at Bennett and North Main St., in Three Rivers, Michigan. All data was collected between the months of October and November 2016.

6.1.2 Design

This study utilized a mixed design, which incorporated both a reversal and alternating treatments design.

6.1.3 Conditions

The present study used the R1-6 in-street sign in a gateway configuration (Bennett, Manal, & Van Houten, 2014). The distance the signs were placed in advance of the crosswalk was varied between the following (5ft, 10ft, 20ft, 30ft, and 50ft). A measuring wheel was used to determine all 5 distances from the crosswalk, as well as tape lines to denote those distances in the gutter. Small sprinkler flags were then placed on the curb in the grass to help experimenters accurately measure how far in advance of the crosswalk drivers yielding right-of-way to pedestrians.

The alternating treatments design embedded within the reversal design was added to explore and control for any effect that time of day might have on yielding. To counterbalance the order of distances from the cross walk by the time of day, a Latin Square (4x4) generator was used. The times of day represented were 10:00AM, 11:00AM, 12:00PM, 1:00PM, and 2:00PM, and no combination of conditions and time of day was repeated.

6.1.4 Inter-Observer Agreement

Inter-observer agreement (IOA) was collected on more than 25% of all trials. The average IOA was 98.08%, with a range of 96.25% to 100%

6.2 RESULTS

6.2.1 Percentage Drivers Yielding Right-of-Way to Pedestrians

The results of this study are presented in Figure 6.1. During the baseline condition 7.5% of drivers yielded right-of-way to pedestrians. When the gateway was 5 ft. in advance of the crosswalk, 50.1% of drivers yielded, when it was installed 10 ft. in advance of the crosswalk 55.9% of drivers yielded. When the sign was 20 ft in advance of the crosswalk 55.4% of drivers yielded to pedestrians, when the signs were installed 30 ft. in advance of the crosswalk 54% of drivers yielded to pedestrians, and when the signs were 50 ft. in advance of the crosswalk 52.3% of drivers yielded to pedestrians.

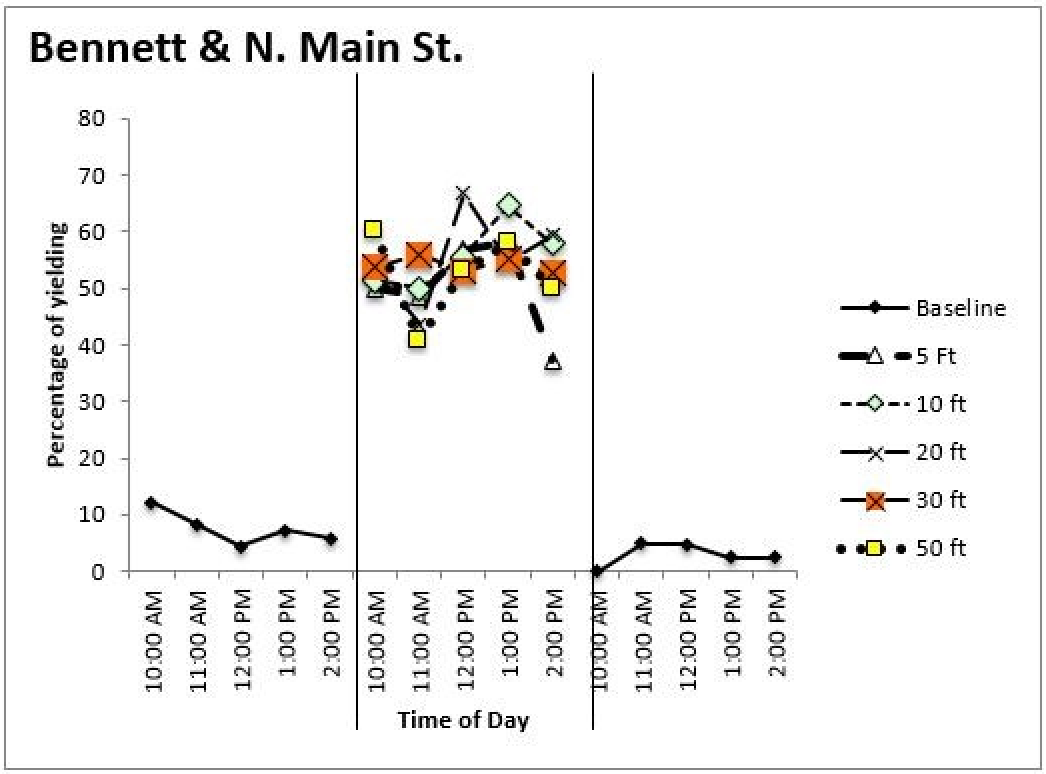

Figure 6.1 The percentage if drivers yielding right-of-way to pedestrians when the sign was placed 5 ft, 10 ft., 20 ft. 30 Ft. and 50 ft. in advance of the crosswalk.

6.2.2 Yielding distance

Figure 6.2 shows the percentage of drivers yielding more than each distance from the crosswalk.

These data show that the use of the gateway produces a very large in advance of the crosswalk increases the distance that drivers yield in advance of the crosswalk. When the gateway was placed 50 ft in advance of a crosswalk not only did yielding increase but drivers also yielded further back from the crosswalk.

Because multiple threat (or screening crashes) are the most likely type of pedestrian crash to lead to a fatality or incapacitating injury these data take on a special significance. In the past advance stop/yield lines (9, 10, 11) located along with the R1-5 and R1-5b sign have been the only tool to available to reduce the occurrence of multiple threat crashes. The data from this experiment suggest that the gateway treatment placed 30 to 50 ft in advance of the crosswalk may be an even more effective countermeasure for reducing multiple threat crashes, as compared to advanced yield lines.

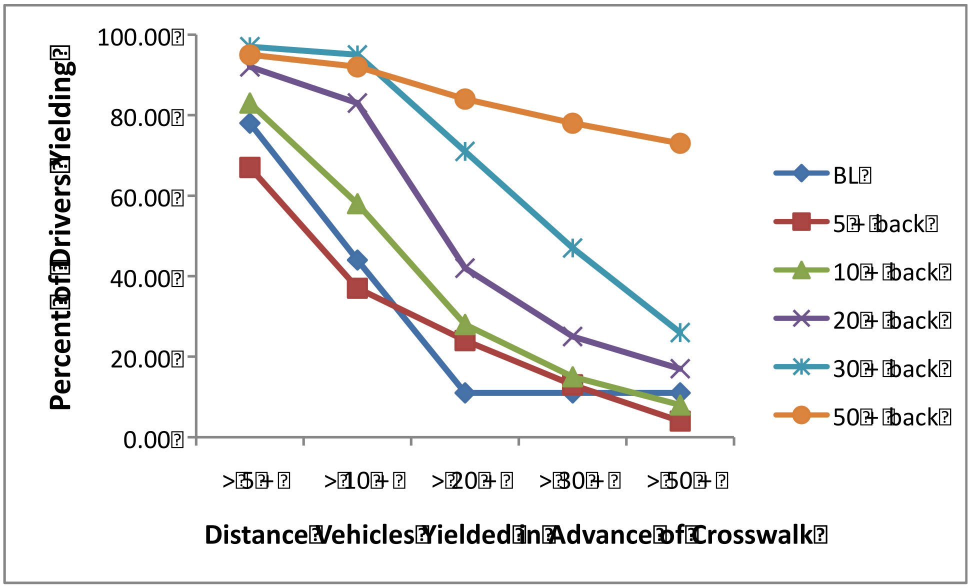

Figure 6.2 The percentage of drivers yielding greater than 5, 10, 20, 30 and 50 ft in advance of the crosswalk during Baseline, and when the gateway is placed 5, 10 20, 30 and 50 ft. in advance of the crosswalk.

6.3 DISCUSSION

The results of this study show two important findings. First, placing the gateway between 5 ft and 50 ft in advance of the crosswalks lead to very similar levels of driving yielding behavior. This finding is important because placing the gateway in advance of the crosswalk provides better protection from turning movements at crosswalks located at an intersection with minor road controlled by a stop sign.

The second finding was that drivers are more likely to yield right of way to pedestrians at a distance further in advance of the crosswalk when the gateway is placed further in advance of the crosswalk. This finding is particularly important at crosswalks on four lane multilane roads, where there is a danger of a driver attempting to pass a vehicle stopped for a pedestrian in the crosswalk. If the driver stops close to the crosswalk, the stopped vehicle can screen the view of the approaching driver in another vehicle as well as screen the view of the pedestrian of the vehicle approaching in the next lane. This situation can lead to what is referred to as a multiple threat crash. This type of crash is often fatal because there is little or no time for the driver to brake or alter their course, and the impact speed is often quite high. It should be noted that the gateway could also reduce the seriousness of such a crash because of the decrease in speed and the increase in driver vigilance associated with the gateway treatment. Further research should examine the consistency of the effect of gateway placement on yielding distance at crosswalks on multilane roads.

CHAPTER 7: EVALUATION OF THE DURABILITY OF GATEWAY ELEMENTS

7.1 SIGN DURABILITY

Signs were checked for damage on each month prior to collecting yielding data. Upon arrival to the site researchers would take photos of the signs and look for any sign damage and log it on the data sheet. All flush mounted signs were mounted on the side of the road or on curb tops locations. None were mounted in the centerline of the road. Signs on a curb type base and signs flush mounted on a pivoting base were counterbalanced for placement on the lane line on the right side of the road.

Table 7.1 shows the number of each type of sign installed along with the number of each type of sign destroyed and Figure 7.1 shows the percentage of each type of sign destroyed. Generally, signs mounted on a curb type base affixed to a detachable flexible rubber boot that support the sign panel in a vertical position, and capable of restoring the sign to the vertical position if struck by a vehicle, installed on the right lane line showed little evidence of being struck and only one was damaged although it continued to work in its damaged state (see Figure 7.2 a for a picture of the only damaged curb type mounted sign). Forty two percent of the signs installed in on the right lane line with flush mounted bases and a spring loaded pivoting connector were destroyed. In all cases these signs were sheared from their base, see Figure 7.2b for a picture of a base where the sign has been sheared off. It is important to note that all of the signs destroyed were located on the right side of the road and were mounted on the lane line. No signs mounted in the gutter pan or on a curb top were destroyed.

Only one of the flexible delineator posts was destroyed (at Westnedge and Ranney) and this was at the site with the highest number of strikes. The use of the flexible delineator post looks like it can survive, however these data show that this device can be destroyed if it is struck on a regular basis. Observational data indicated that this delineator was placed at a location where motorists frequently changed lanes increasing the chance it would be frequently struck. These data suggest that signs mounted flush to the street are less robust than the signs mounted on curb type bases. It is unlikely these signs would have been damaged if they were placed on top of the curb.

Table 7.1. The number of each type of sign installed at each site along with the number of each type of sign destroyed at each site. All of the flush mounted sign on Huron were mounted on the curb on either the refuge island or on the side of the road under permission to experiment. Therefore, they were not counted in the analysis.

Table 7.1 The number of each type of sign installed at each site along with the number of each type of sign destroyed at each site. All of the flush mounted sign on Huron were mounted on the curb on either the refuge island or on the side of the road under permission to experiment. Therefore, they were not counted in the analysis.

Site	Curb Mounted	Curb Mounted Destroyed	Flush Mounted	Flush Mounted Destroyed	Flexible Delinators Mounted	Flexible Delinators Distroyed
Roundabout						
Roundabout East Main and 5th Street, Benton Harbor	2	0	2	1	0	0
Roundabout East Main and Riverview, Benton Harbor	2	0	2	1	0	0
Marshall Traffic Circle, Marshall, SE by City Hall	1	0	1	0	6	0
Marshall Traffic Circle, Marshall, NW	1	0	1	1	6	0
Hybrid Beacon/ RRFB						
Midblock RRFB Monroe St., Allegan	2	0	2	1	0	0
Midblock Crosswalk						
Stadium Drive at	3	0	1	0	1	0
North Main St. Three Rivers	1	0	2	0	4	0
Lake at Carroll	X					
E. Huron St. West of Ingalls	0	0	4*	0	0	0
T Intersection						
S. Westnedge and Ranney St. Kalamazoo	1	0	1	1	1	1
Full Intersection						
Nixon Rd. at Bluett Rd.	3	0	0	0	1	0
Division St. at Jefferson	2	0	0	0	1	0
Cherry at Warren	3	0	0	0	0	0
Cherry at Hollister	3	0	0	0	0	0
Wealthy at Cass	3	0	0	0	0	0
Weatlhy at Henry	6	0	0	0	0	0
TOTAL	**33**	**0**	**12**	**5**	**20**	**1**
X = Not yet installed						
Impact Recovery Curb Top *						

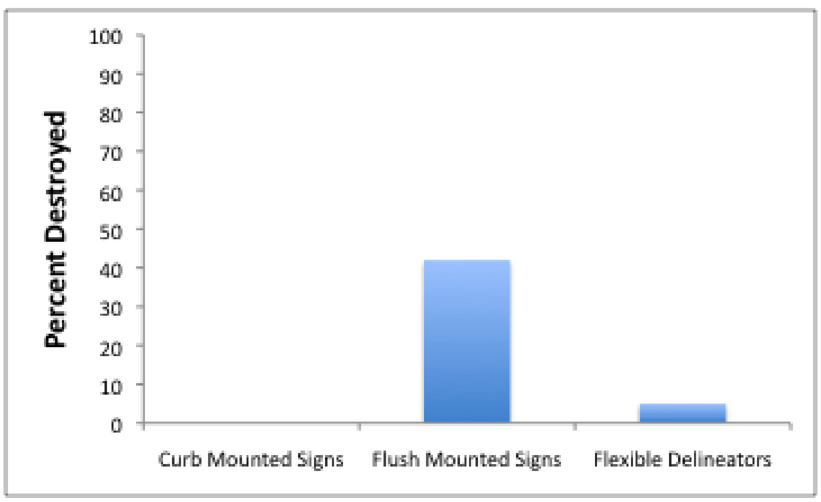

Figure 7.1 The percentage of curb type base mounted signs, flush type base mounted signs and flexible delineators destroyed in 2016 during the study period.

Figure 7.2. Figure 7.2a (above left) shows an R1-6 sign installed on a removable curb base that was damaged during the study. Figure 7.2b (above right) shows a sheared base of a flush mounted sign.

7.2 DISCUSSION

One type of R1-6 mounting (Flush mounted with a spring loaded pivot performed less well that the others. All of the R1-6 signs lost were of this type. Those mounted with a flexible rubber linkage on a curb type base all survived although one of the paddles was bent on one of these signs. It was decided not to replace lost signs to determine if the partial gateways offered some degree of effectiveness. The results indicated partial effect if one element was lost. At one site (Westnedge and Ranney) two out of three signs were lost and yielding returned to close to baseline levels.

It was also noted that signs placed on top of a curb extension, on top of a refuge island or median, or on top of the curb on the right side of the roadway under FHWA permission to experiment were more likely to survive, as none of these signs were lost over the study period. The flexible delineators and curb type base signs placed on lane lines or centerlines were also likely to survive.

Even if these signs do not survive, pedestrian activity is typically greater during the spring, summer and fall than during winter months, particularly in areas with high tourism exposure. This is key because the only signs that would likely survive in winter are those mounted on the top of the curb at the right side of the road and those mounted on top of the curb on a refuge or median island. However, it is not certain whether the snow loading from the plow could damage the signs if it pushes them to the side. One type of curb-mounted signs uses a flexible rubber boot to connect with the base that allows it to bend to the side as well as back. This type of sign is most likely to survive side pressure caused by snow loading resulting from plowing.

CHAPTER 8: CONCLUSIONS

The results of this study confirm that the gateway treatment is more effective at intersection and midblock crosswalk locations than at locations that involve curvature such as roundabouts and traffic circles. The results of the first series of studies examined whether the effects of the gateway treatment persist over time. Data from the preceding year confirmed that the effects of a permanent installation of the gateway persisted for up to three months. The results reported in Chapter 1 of this report show that the effects of the treatment continue to remain in force with no sign of decay over a spring, summer, and fall season. These results confirm that the results shown in the primary study (6) were not the result of a novelty effect and can be expected to persist over time. The results also indicated that gateway treatments that lose one sign element can still provide useful improvements in driver yielding right-of-way and that it may not be necessary to replace these elements until the following year when the treatment is reinstalled.

The second chapter examined the effect of the gateway on vehicle speed when a pedestrian was not present in the crosswalk. This replicates what drivers would do if they were approaching a crosswalk but did not see a pedestrian. Driver speeds were measured when they traversed the dilemma zone in advance of the crosswalk and when they traversed the crosswalk. On roads where operating speeds were 25 mph or more, speed was reduced by 4 to 5 mph as drivers traversed the crosswalks. Drivers also began slowing at the dilemma zone with average speed reduced by 2 to 3 mph. It is important to note that the speed reductions begin at the dilemma zone well in advance of the crosswalk. Because drivers begin slowing well in advance of the crosswalk, they can also be expected to increase scanning for pedestrians, and they are less likely to need to engage in hard braking to yield right-of-way to pedestrians.

The data collected on hard braking at two sites when pedestrians were not present serve to confirm this hypothesis. This reduction in speed should also be expected when a pedestrian is present but not initially seen by the driver and should allow the driver to successfully avoid a crash with a pedestrian. Another important finding was that the changes in the speed distribution at each site involved a marked reduction in the percentage of drivers traveling at higher speeds. Because the relationship between driver speed and the likelihood of a pedestrian fatality is exponential, the gateway can be expected to reduce both the probability of a crash and the severity of a crash. These data also suggest that the gateway treatment at crosswalks in small communities located on MDOT trunk routes could also function as a traffic calming feature.

Previous work (6) comparing the efficacy of the gateway treatment at sites where gap width between signs varied between sites. These data showed that the narrower the gap between signs the greater the percentage of drivers yielding to pedestrians. In the third chapter the gap between the signs was systematically manipulated at a single site. These results show that the effect of installing a gateway is far larger than the increase produced by varying the gap size. These results are consistent with the larger effect of a gateway with the sign message than the gateway without the sign message in the original report (6).

The study reported in the fourth chapter showed that systematically moving the gateway back from the crosswalk from 5 ft to 50 ft in 10 ft increments had little effect on the percentage of drivers yielding to pedestrians. Moving back the sign at intersection locations would reduce the likelihood that the sign would be struck by a turning vehicle, which should increase long-term survival of the treatment. A more important benefit of moving the sign back is that it decreases the percentage of drivers that stop close to the crosswalk. This finding has great practical importance given the severity and frequency of multiple threat crashes.

The last chapter examined the survival of elements of the treatment over time. The results of this study showed that signs with a curb-type base and a flexible rubber connector rather than a pivoting base were much more likely to survive. In fact none of these signs were damaged or sheared from their base. Data also showed that none of the signs placed in the gutter pan, on top of the edge of the curb of a curb extension, a refuge island or a median island, or on top of a curb at the right side of the road under permission to experiment as part of a gateway were destroyed. It is also very likely that signs placed 30 to 50 ft. in advance of a crosswalk at an intersection are more likely to survive because they are out of the path of turning vehicles. This finding is particularly important at crosswalks on multilane roads where there is a danger of a driver attempting to pass a vehicle stopped for a pedestrian in the crosswalk. If the driver stops too close to the crosswalk, the stopped vehicle can screen the view of the approaching driver as well as screen the view of the pedestrian of the vehicle approaching in the next lane. This situation can lead to what is referred to as a multiple threat crash. This type of crash is often fatal because there is little or no time for the driver to brake or alter his or her course.

In climates that require plowing snow in winter, it is necessary to install the signs after the snow season ends and to remove the signs before the start of the snow season. Because the initial cost of installation is greater than the cost of removal and reinstallation, removal for winter operations is not likely a major burden for the use of these signs. However, the data from this study shows that a gateway with a single missing element can still increase yielding behavior. The city of Grand Rapids and Ann Arbor have decided to test whether some of the gateway elements can survive through the winter. Signs mounted on the curb of a refuge island and on the curb of a curb extension using a curb-type base show a potential for survival during the winter months. The rubber connecting boot, which allows the sign to bend back when struck and then recover to its erect position, can withstand side loadings that might occur when snow is piled on the side of the roadway. These cities are also testing some on the center line because the signs with a curb type of base are used in MI at approaches to railroad crossings and have survived the winter plowing season. Because pedestrian exposure is less during winter months, the absence of the more vulnerable elements of the gateway in winter should be somewhat mitigated. Data this past winter show that the partial gateway survives over the winter months.

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APPENDIX A

Table A-1. shows the site characteristics for each experimentation sites where gateway installations were installed. The data do show some trends. The gateway seems to work best at midblock crosswalks and uncontrolled crosswalks at an intersection with a minor street with stop sign control. It does not seem to matter whether the site has a refuge island or median, but it is known that the presence of these features is associated with a crash modification factor. It is also the case that a more robust gateway can be installed at a midblock site with a refuge island and a curb extension and it is likely that the side elements of such a gateway can survive the winter plowing season in parts of the country with significant snow fall.

Table A-1. Select roadway characteristics for each of the treatment sites.

Location	*Number of lanes*	*parking*	*Island or Median*	*ADT*	*Posted Speed*
Midblock refuge island or median					
Monroe Midblock Allegan	2	No	Yes	9,200	30
Stadium in Ann Arbor	3	No	Yes	12,500	35
Huron Midblock	4	No	Yes	20,100	30
Mean					
Midblock without refuge island or median					
N Main St. Three Rivers	2	Yes	No	7,500	*30
Mean					
Intersection					
Westnedge @ Ranney One -Way	2	Yes	No	17,254	35
Nixon @ Bluett, Ann Arbor	3	No	No	9,734	30
Division @ Jefferson One-Way	2	Yes	No	9,284	25
Wealthy at Cass GR	4	No	No	11,328	25
Lake at Carroll GR	3	Yes	No	15,650	25
Mean Speed Intersection No Curb Extension Sites					
Intersection with curb extension					
Cherry at Hollister GR	2	Yes	No	7,7,571	25
Wealthy at Henry GR	2	Yes	No	13,274	*25
Cherry at Warren GR	2	Yes	No	7,571	25
Mean Yielding and Mean Speed All intersection Sites					
Traffic Circle and Roundabouts					
Roundabout @ Riverview	2	No	Yes	9,400	*35
Roundabout @ 5th St.	2	No	Yes	6,900	*35
Traffic Circle Wide	1	No	Yes	14,400	*35
Traffic Circle Narrow	1	No	Yes	14,000	*35
Mean All Sites					
Flexible Delineator on lane lines					
* Baseline speeds below 25 mph					