CONTRIBUTING FACTORS OF DRIVER YIELDING BEHAVIORS AT UNCONTROLLED INTERSECTIONS

by

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ABSTRACT

CONTRIBUTING FACTORS OF DRIVER YIELDING BEHAVIORS AT UNCONTROLLED INTERSECTIONS

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Under the Supervision of Professor Xiao Qin

The present study aims at analyzing driver yielding behaviors to pedestrians' right of way, who are attempting to cross at uncontrolled crosswalks. Three types of variables were identified to be collected for this research including characteristics of the locations as well as demographic, and behavioral characteristics of pedestrians and drivers. The behavioral characteristics of drivers and pedestrians are recorded only when a pedestrian arrives at the crosswalks trying to cross and a vehicle is approaching the intersection; so, the driver makes a decision whether or not yield to the pedestrian waiting to cross. Some behavioral characteristics of pedestrians include pedestrians' assertiveness, standing location and waiting time at the crosswalk to find a gap in traffic to be able to cross. The demographic characteristics also include age, gender, race. Some location specific variables include the presence of marked crosswalks, pedestrian crossing sign, near side bus stop, right turn lane, whether or not the location has had pedestrian-vehicle crash, type of land use surrounding the un-signalized intersections, crossing distance, AADT, the distance of last car parked from the intersection, the distance difference between the un-signalized intersection to the downstream and to the upstream signalized intersection, and the last location specific variable is the distance of uncontrolled intersection from the Atwater park locates in eastside of the city nearby the Lake Michigan. After identifying the variables and instructing the data collection process, the location studies were investigated. Twenty un-signalized intersections were selected

that specific characteristics were similar among them to maintain consistency across all locations. Ten different uncontrolled intersections are selected as study locations, which each has had at least two pedestrian crashes in 2010 to 2014, and the other ten are selected as comparison locations, which none of them has had any crashes history in the same period of time.

To analyze the collected data, five different models are proposed using logistic regression and random effect models. Ultimately, the preferred model that has a better goodness of fit is selected. This model well displays that what variables are most statistically significant with the driver yielding behavior. Based on the final model, each variable may have a positive or negative impact on the driver yielding behavior. The variables that cause drivers yield to the pedestrians at crosswalks include the assertiveness of pedestrians to cross, standing in the street, and the pedestrians' race with the ethnicity of white as well as the second crosswalk marked, nearside bus stop, and the distance of uncontrolled intersection from the Lake Michigan. Some other independent variables that cause drivers not yield to the pedestrian at crosswalks are the type of land use (commercial area), having a crash history, AADT, crossing distance, and the distance difference between the downstream and upstream signalized intersection to the un-signalized intersection. Note that many professionals cited the importance of land use (proximity to commercial districts, downtown,.etc) on driving yielding behavior because of its relationship with pedestrian volumes. This study does not include a variable representing pedestrian volumes, so that could be explored in future studies.

To better illustrate the effect of the variables on the likelihood of the driver yielding, the elasticity analysis was conducted. So, depends on the type of data, they were categorized into continuous and categorical variables. The elasticity from the continuous variable represents that 1% change in crossing distance variable reduces the driver yielding by 15.469%. For categorical variables, the sensitivity of the driver yielding variable is made by pseudo –elasticity. It represents that the existence of the near side bus stop at uncontrolled intersections increases the probability of drivers yielding by 0.54% while the existence of crash history at the intersections reduces the probability of drivers yielding by 0.82%. It means that drivers still not tend to yield to pedestrians at crashes locations.

Eventually, to improve the drivers yielding behaviors at uncontrolled intersections, five E approaches including engineering, enforcement, education, encouragement and evaluation are recommended. The engineering treatments with the minimum cost have a capability of being implemented in a short period of time. Simultaneously, a designed program for applying the law enforcement and for increasing people's awareness and education in a longer run is anticipated to have a significant impact on improving the drivers yielding behaviors to pedestrians' right of way at crosswalks. At the end of the program, through evaluation and comparison of the before and after implementation of the engineering, enforcement, education and encouragement strategies, we can determine if the desired result have been met.

As part of the focus on enhancing traffic safety and reducing fatal crashes at the assigned locations, High Visibility Enforcement pilot program is also recommended. HVE combines highly visible and proactive law-enforcement strategies to target the violated drivers not yielding to the pedestrian right of way at crosswalks. It offers law enforcement agencies a proven alternative for preventing many of the unsafe driving practices that passenger and drivers engage in roads. By targeting passenger and drivers, they raise everyone's awareness of the joint responsibility that we all have to drive carefully and share the road safely.

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1. INTRODUCTION

In a few past decades, pedestrians has been one of the road user categories that is the most exposed to high-risk levels. Globally 1.25 million people lose their life in traffic crashes including more than 270,000 pedestrians which constitutes 22% of all road deaths (WHO, 2015). In some countries, this proportion has been steady and in some countries, it has been decreasing or increasing.

In the United States, the pedestrian fatalities has declined steadily since 2001, reaching 4109 pedestrian fatalities in 2009 (FHWA, 2004). Then, the annual pedestrian fatalities had increased by 30% in just six years, reaching nearly up to 5400 in 2015, the highest number of pedestrian fatalities since mid-1990s (FHWA, 2011). Figure (1) clearly shows this trends and compares it with the overall road fatalities.

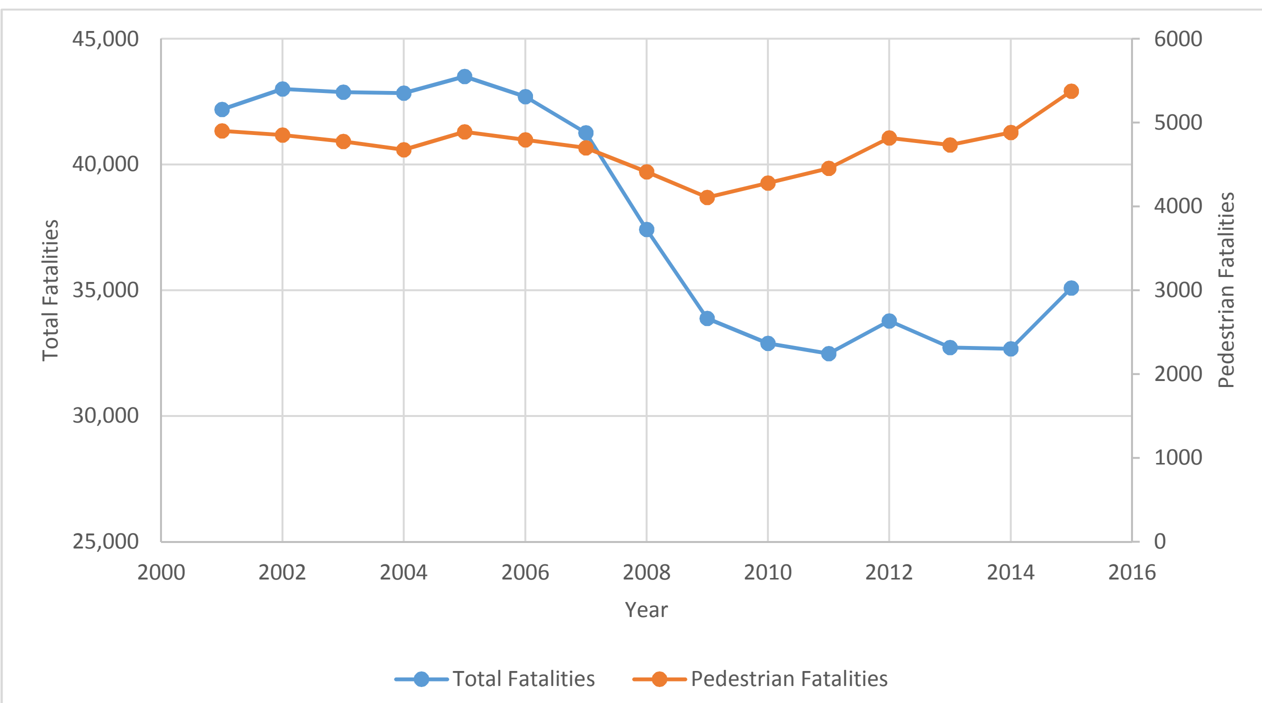


Figure 1: Total fatalities and pedestrian fatalities (2001-2015)

This incremental change in pedestrian fatalities' trend in the U.S. is due to many factors, which are crucial to be recognized particularly those that have not been explored enough in the previous studies. These factors are being used for assessing the pedestrian safety situation in a given setting and how to select, design, implement and evaluate effective interventions to prepare an action plan.

Some of the explored factors that expose risk to pedestrians are; drivers behaviors particularly in relation to speeding as well as drinking and driving; infrastructure in terms of lack of dedicated facilities for pedestrians such as sidewalk, crossings and raised medians; and vehicle design in terms of solid vehicle fronts that are not forgiving to pedestrians should they be struck.

In addition to the above items that increase the risk of pedestrian-vehicle crashes, the intersections' safety characteristics and drivers' responsibilities to yield to pedestrians are also effective. Many of the pedestrian-vehicle crashes are associated with a lack of driver compliance that drivers often fail to yield to pedestrian especially in mid blocks and uncontrolled intersections (Mitman, Cooper, & DuBose, 2010). Of the pedestrian fatalities, 29% were related to improper crossings and 15% to failure to yield right-of-way at crossings (Bertulis & Dulaski, 2014).

Each state has certain rules for drivers yielding to pedestrian right of way at crosswalks. Generally, drivers and pedestrians have certain safety responsibility that depend on both circumstances. In Wisconsin, drivers must yield to pedestrians who are crossing the highway within a marked or unmarked crosswalk at an intersection where there are no traffic lights or control signals (Wis_DOT, 2001-2002). On the other hands, pedestrians also must yield to drivers when crossing a road where there is no intersection or crosswalk or where the pedestrian does not have a green or "walk" signal and where vehicles have a green signal. Additionally, pedestrian must not suddenly move into the path of a closely approaching vehicle that does not have sufficient time to yield for a pedestrian. Any unusual movement by pedestrians and drivers cause accident and severe crashes. Pedestrian crashes most often occur within urban and suburban areas and on college campuses because these areas experience the highest levels of pedestrian activity and traffic volume. Recently, pedestrian safety concerns are more at un-signalized intersections locations where there is no stop lights, stop sign, yield signs, blinking traffic signal or other clear safety instruction regarding right of way or driver responsibility.

Noting the above information, we can conclude that the capacity to improve pedestrians' safeties on roads is an important component of the agencies' efforts to prevent pedestrian-vehicle crashes and fatalities. Recent US researches in road safety underscore the need for national and international efforts to improve pedestrian safety. A variety of pedestrian safety treatments are available for implementation at such locations including pedestrian traffic signals, signage,.etc. The United Nations also seeks to reduce traffic fatalities by 50% by 2020 (Assembly, 2015) and Pillar 2 of the United Nations Decade of Action for Road Safety emphasizes the need for the safety of vulnerable road users, including pedestrians and bicyclists (Commissions, 2010).

This research complements the previous efforts and stresses the importance of the specific contributing factors on drivers yielding behavior at uncontrolled intersections. It particularly addresses the demographic and behavioral characteristics of the pedestrians and drivers at uncontrolled crosswalks as well as the location specific-variables that have not been investigated enough in the previous researches. The demographic characteristics include age, gender and race; the behavioral specific variables include the pedestrians' assertiveness, standing locations, pedestrian group size; the locational specific variables include the presence of second crosswalk marked, existence of the nearside bus stop and right turn lane, type of land use (commercial district), annual average daily traffic (AADT), whether or not the intersection has a crash history, crossing distance, distance difference from the next upstream and downstream signalized intersections to the uncontrolled intersection, and lastly distance from the Atwater park locates on east side of the city of Milwaukee nearby the lake Michigan. The study evaluates the effects of each factor on drivers yielding behaviors at assigned locations across the city. The ultimate goal of this research is to contribute towards strengthening national and local capacity to implement pedestrian safety measures in settings worldwide

Note that this study builds off of the previous research in Portland, OR (Goddard, Kahn, & Adkins, 2015) and Gainesville, FL (Van Houten, Malenfant, Blomberg, Huitema, & Casella, 2013).

2. THESIS OBJECTIVE OUTLINE

The main goal of this research is to improve the pedestrians' safety at uncontrolled intersections when they attempt to cross. To meet this goal, I try to identify the new and high statistically significant contributing factors that affect drivers yielding compliance to pedestrians' right of way at crosswalks. In this research, a few objectives are outlined to increase the clarity of this goal. These objectives are as follow:

1. Design/conduct data collection to quantify pedestrian and driver behaviors.
2. Identify important factors that affect driver yielding decisions at crosswalks.
3. Apply regression models to find the highly correlated factors with driver yielding behaviors.
4. Recommend safety treatments to increase driver yielding behaviors at crosswalks.

Three types of variables were identified to be collected for this study; including demographic, behavioral and location specific variables. The behavioral characteristics of drivers and pedestrians is recorded only when a pedestrian arrives at the crosswalks trying to cross and a vehicle is approaching the intersection; so, the driver makes a decision whether or not yield to the pedestrian waiting to cross. At the same time, the demographic characteristics of the pedestrian and the driver such as age, gender, race as well as a few more behavioral characteristics specific to the pedestrian including physical disability (Y/N), group size, whether or not the pedestrian is assertive and his/her standing location were recorded.

To quantify the intersections' characteristics, some specific features of the locations were recorded including the presence of marked crosswalks, pedestrian crossing sign, near side bus stop and right turn lane as well as whether or not the location has had pedestrian-vehicle crash, type of land use surrounding the un-signalized intersection, crossing distance, AADT, the distance of last car parked from the intersection, the distance difference between the un-signalized intersection to the downstream and to the upstream signalized intersections, and the last location specific variable was the distance of uncontrolled intersection from the Atwater park locates in eastside of the city nearby the Lake Michigan [1].

After collecting all these data, the goal is to find the correlation between each of these independent variables with the driver yielding variable by using the statistical descriptive analysis, and logistic regression model.

Note that a few variables were dismissed from the analysis due to the lack of time and due to the lack of occurrences and due to a high correlation with the other independent variables.

Ultimately, the efficient strategies are outlined to target the most contributing factors on drivers yielding behaviors. Recognition of these contributing factors on driver yielding behaviors can help inform education, enforcement, and engineering treatments for uncontrolled intersections to improve the safety of pedestrians and drivers.

[1] For more information about the definition of each variable and the data collection process please refer to appendix A.

3. LITERATURE REVIEW

3-1- Contributing Factors on Drivers Yielding Behaviors

Researchers have found that many factors affect drivers yielding behaviors to pedestrian right of way at crosswalks such as cultural and geographical characteristics of the area, traffic control features, and roadway geometric design of intersections. Previous studies have commonly focus on the relationship between drivers yielding behaviors with roadway specific variables including crosswalk's marking, sign, signal, crosswalk length, road's speed limit, turning movement lanes,.etc,

The study performed by Huybers et al., found that the use of road markings alone is more effective than the use of signs alone (Huybers, Van Houten, & Malenfant, 2004). Surprisingly, the study also shows that the use of road markings alone is as effective as the use of signs and road markings together, which means markings alone plays an important role in increasing yielding behavior. Nonetheless, the markings consisting of a series of white triangles was the type that was used in the study. Depending on the location of the site, vehicles yielding rates at white triangles crosswalks varied from 72% to 81%. Figure (2) and (3) show an example of pedestrian sign along and pedestrian marking alone respectively.

Figure 2: Pedestrian sign (Sandy, 2012)

Figure 3: Marked Crosswalks *(SERA, 2011)*

In another study by Van Houten et al, it is shown that placing markings and signs 15 m and 25 m in advance of the crosswalk reduce the percentage of motor-vehicle pedestrian conflicts (Van Houten, R; Malenfant, E L; McCusker, D, 2001). Figure 4 and 5 are such examples.

Figure 4: Advance yield marking [2]

Figure 5: Advanced stop lines (PBIC, 1999)

The overhead sign (Figure 6) also resulted in increased vehicles yielding to pedestrian at one location in Tucson (Hang, Zegeer, Nassi, & Fairfax, 2000). In New York, cones and in Seattle

[2] Figure 4 source: http://www.raepaint.com/Preformed_Thermoplastic_Legend_YIELD_90_mil_p/pr-th-3628.htm

use of signs were highly effective in increasing the number of drivers who stop for pedestrian at crosswalks. However, it is essential to use these devices together with enforcement, education, and standard geometric design to produce a friendlier pedestrian environment at the outset.

Figure 6: Overhead pedestrian sign (Pang, 2010)

Duduta et al has shown in his study that the length of crosswalks is inversely correlated with the probability of crossing on red (Duduta, Zhang, & Kroneberger, 2014). He also found that certain signal phases such as protected left turns is highly correlated with probability of crossing on red and the most common conflict occurs at right turning vehicles movement. Ultimately, the three factors that affect a pedestrian's decision to cross on red are long waiting time, the pedestrian's compliance level, and a sufficient gap in traffic.

Ross et al study has focused on rectangular rapid flash beacons (RRFBs) and their impact on yielding rates (Ross, Serpico, & Lewis, 2011). The study especially looked at before and after data for RRFBs and found that the average yielding rate before installation is %18 while it jumps to 80% in after installation. Finally it concludes that RRFBs should be considered for high-speed roads where posted speed limits are greater than 35 mph and if there is a history of pedestrian crashes with vehicles. Figure (7) shows an example of RRFB at midblock crosswalk.

Figure 7: A rectangular-shaped rapid flash LED beacon system (Systems, 2009-2013)

Turner et al. investigated vehicles yielding rates to pedestrians at high-visibility crosswalks with emphases on speed (Fitzpatrick, et al., 2006). The study found that at a speed limit of 35 mph, yielding rates are around 20% and for a speed limit of 25 mph it jumps to 91%. It also shows that in- street crossing signs placed in the middle of streets with posted speed limits in the range of 25 to 30 mph led to yield rates of 90%.

Bertulis and Dulaski in their study show that there is an inverse correlation between speed and tendency of drivers to yield to pedestrians (Bertulis & Dulaski, 2014). It shows that of the eight two lane roadways, the range is from a 75% yield rate for the 20 mph street to a 17% yield rate for the 37 mph street. The one street that was four lanes wide had only a 9% yield rate, a significantly lower yield rate.

Schneider et al at his study found that the rate of drivers yielding to pedestrian in marked crosswalks are related to characteristics including social norm, cultures, roadway design, law enforcement, and pedestrian volume (Schneider & Sandres, 2015). However the data shows significant geographic differences in yielding cultures.

Goddard in his study found that black pedestrians were passed twice as many as cars and experience waiting times about 32% longer than white pedestrians (Goddard, Kahn, & Adkins, 2015). The results of his study supports the hypothesis that minority pedestrians experience discriminatory treatments by drivers at crosswalks.

The two other studies showed that drivers may be more likely to yield to pedestrians holding a cane (Salamati, Schroeder, Geruschat, & Rophail, 2013), (Harrell A. W., 1992) and who are wearing brighter clothing and entering crosswalk more assertively (Harrell, W A, 1993). Drivers owning expensive cars also may be less likely yield to pedestrians than other drivers (Piff, Stancato, Mendoza-Denton, Keltner, & Coteb, 2012).

3-2- Methodology Used for Measuring the Effect of Contributing Factors on Drivers Yielding Behaviors

Each study has used a specific method for collecting and analyzing the drivers yielding – related data. Below, we will mention some of the methodologies that have used.

In the study performed by Bertulis et al, a methodology was designed to measure how driver speed affects yielding rates (Bertulis & Dulaski, 2014). They selected different sites with similar characteristics and used the experimental selective method, as the police would perform a sting operation. In this method, the pedestrian steps into the street as a driver is approaching, but with enough lead time for the driver to notice and brake. The AASHTO guidelines was also used to calculate the stopping sight distance to ensure that nothing obstruct the drivers and pedestrians visibility at a standard distance away from the marked crosswalk, where the pedestrians are asking to step into the street. A driver was considered to be yielding if he or she slowed enough to let pedestrian cross. Simultaneously, observers stay out of sight so as not to influence the drivers yielding behavior and try to measure the speed of at least a dozen vehicles and obtain its 85^{th} percentile speed. The yielding rates and speeds recorded at each site. Ultimately, by using statistical descriptive method on the data, the study shows that drivers yielding trend was inversely related to speed. The study found that the yielding rates varied in each site depending on specific site characteristics such as on-street parking, dense residential land use and trees or even the direction of sun. In some streets, as the sun is beginning to set; drivers may have sunlight in their eyes and less likely yield if they can't see the pedestrian.

In a research accomplished by Fitzpatrick et al, a negative binomial mixed-effects model was used to analyze the effect of contributing factors on drivers yielding (Fitzpatrick, K; Brewer, M A; Avelar, R, 2016). The researchers combined the characteristics data related to drivers yielding from previous Texas Department of Transportation and Federal Highway Administration projects. The results from this research show that the intersections configuration (number of legs), presence of median refuge, crossing distance, approach for the crossing, and direction of vehicle travel (i.e., one way or two way) were statistically significant for drivers yielding. Several variables were expected to be statistically significant but were not, including posted speed limit, supplemental traffic control devices, distance to transit, presence of a school within 0.5 mile, location of the beacons and legend on the face of the crossing sign.

In a study performed by Stapleton et al, the logistic regression modeling results found that the type of crosswalk treatment (e.g. unmarked, standard only, continental only, in street R1-6 sign, and pedestrian hybrid beacon) has a strong influence over driver yielding compliance (Stapleton, Kirsch, Gate, & Savolainen, 2016). The study suggests that compliance improves as drivers become more familiar with these devises. The study also found that yielding compliance variable is statistically significant to the roadway cross-section and lane position of the vehicle relative to the location of the crossing pedestrian. Drivers were less likely to yield to the staged pedestrian waiting at the nearside curb lane compared to encounters that occurred when the pedestrian is approaching any other lane. That is because, the pedestrian is in a less conspicuous and less vulnerable position when waiting near the curb. Additionally, the results show the low curb-lane compliance across the observed types of roadway cross sections (two lane, multilane undivided, and multilane divided), and it was particularly low on median divided roadways. This may be due to a potential obstruction within the median that reduce the visibility of pedestrians waiting to cross.

Each contributing factor may have a positive or negative impact on drivers yielding behaviors. Some of the contributing factors that are related to roadways' engineering can also be addressed in engineering treatments of the roadway safety. Since the engineering-related contributing factors have been already studied and their impacts on drivers yielding behaviors have been already tested, they can be targeted in engineering treatments as a part of the improvement of pedestrians' safety.

3-3- Pedestrians Safety Treatments at Intersections

How to increase driver yielding compliance to pedestrian right of way at crosswalks? The studies show that the implication of the three E approaches including engineering, education and enforcement over a course of time increase the trend of driver yielding compliance to pedestrian right of way at crosswalks and therefore, the pedestrian-vehicle collisions reduce over time.

The study performed by Houten et al, evaluated the effect of a high-visibility enforcement operation on drivers perception of enforcement and driver yielding right-of-way to pedestrian (Van Houten, Malenfant, Blomberg, Huitema, & Casella, 2013). It found that to establish a perception of a high level of enforcement, a broad attention of a community is essential; therefore, the police department needs to widely publicize the enforcing pedestrian right-of-way laws at crosswalks. So drivers, who pass a stopped vehicle knows that the stop is for a pedestrian crossing and if they pass the stopped vehicle they will receive ticket and citation.

In a study conducted by Waller et al, high visibility enforcement in conjunction with media attention increase the public perception about the risk of being stopped by the police if they violate the pedestrian-right-of way law (Waller P, Li, Stewart, & Ma, 1983). So, raising the perceived probability of apprehension is an essential effective factor in the program of drivers yielding enforcement

The Van Houten and Malenfant's study was on a multifaceted high visibility countermeasure described as a pedestrian decoy operation to improve the pedestrian right-of-way enforcement operation (Van Houten , R; Malenfant, L; Rolider, A, 1985). In the decoy operation study typically a police in plainclothes steps into the roadway at marked or unmarked crosswalks while following a defined protocol carefully, which provides ample opportunity for drivers to yield right-of-way. This study incorporated the feedback signs which shows weekly information of the percentage of vehicles yielding to pedestrians along with the record (best level achieved to date); and outreach materials distributed to member of the community which includes description of the law, request for cooperation in making the program a success, and information about the impending enforcement operations. Subsequent interactions of this program included installation of in street signs and reminding pedestrians and drivers the law to increase public awareness at the start of enforcement.

The institute for Transportation Research and Education (ITRE) seeks to find out "how much enforcement is needed to change driver yielding behavior to pedestrian in a crosswalk?" (Findley, Palmer, Searcy, Jackson, & Nye, 2016).The study found that in addition to site-level characteristics, the enforcement at medium-intensity, long duration and low-intensity, low duration scenarios at assigned crosswalks have a sustained effect on driver yielding behavior during time periods when it appeared that the driver population utilizing the corridors do not change.

In a project conducted by Dunckel et al, an education campaign program is used for each high incidence area (HIAs) (Dunckel, Haynes, Conklin, Sharp, & Cohen, 2014). Demographic analysis of the HIAs, pedestrian- vehicle crashes history and informal knowledge were developed for the outreach program and education campaigns. Community member were also involved to reach a wider audience. The strategic education campaign last for a period of 24 months at each HIAs and the efforts more focused on the moment of impulse, that instant when, without thinking, a pedestrian steps into traffic. Retraining behavior requires a disruptive approach. Therefore, the strategic plan for each campaign focused on public events, street level activity and information dissemination.

Engineering treatment is the last approach of three E elements that includes the improvement of the roads' infrastructures. In Van Houten et al (2013) study, the engineering elements includes advance yield markings and in street signs warning drivers and in Dunckel et al (2014) study, installing countdown pedestrian signals, lighting upgrades, sidewalk improvement, midblock pedestrian crossing with high intensity beacons and bus stop and shelter consolidation. In addition to engineering treatments, the traffic calming is also constructed to build a pedestrian friendly environment and reduce the vehicles' speed. Such traffic calming as curb extensions, road diets, median or pedestrian refuge island. These engineering treatments have been also targeted in school's program along with education to increase the public perceptions comprehensively.

At the end, the studies suggest that to increase the effects of high-visibility enforcement to pedestrian right-of way, the three E elements should implemented in conjunction with each other.

4. METHODOLOGY

4-1- Empirical Explanatory Data Analysis:

The EEDA method is used to visualize the data to get a general idea about how the data is distributed, and what the mean of each variable is. These information will enable us to see the pattern, do some comparison between variables, and help us make some pre assumptions before running any model.

4-2- Two-Sample T-tests Allowing Unequal Variance

A t-test is the statistical hypothesis test in which the test statistic follows a t-distribution under the null hypothesis. T test can be used to determine if two sets of data are significantly different from each other.

The null hypothesis [3] for the independent t-test is that the population means from the two unrelated groups are equal: H0: u1 = u2

In most cases, we are looking to see if we can show that we can reject the null hypothesis and accept the alternative hypothesis, which is that the population means are not equal: HA: u1 ≠ u2

To do this, we need to set a significance level (also called alpha) that allows us to either reject or accept the alternative hypothesis. Most commonly, this value is set at 0.05.

4-3- Logistic Regression Model: General Form Explanation

A driver yielding compliance is a binary (yes/no) outcome. The binary logit regression model was used in previous studies for predicting a binary dependent variable as a function of the

[3] https://statistics.laerd.com/statistical-guides/independent-t-test-statistical-guide.php

predictor variables in transportation engineering (Xu & Tian, 2008), (Hubbard, Bullock, & Mannering, 2009) and (Liu, Wang, Lu, & Sokolow, 2007).The probability of the occurrence of each independent variable can be estimated using the logit regression as follows:

$$P(x_i) = \frac{1}{1 + e^{-g(xi)}} \qquad (i = 1,2, \ldots, n)$$

Where P(xi) denotes the probability of the occurrence of an independent variables and g(x) is the multiple linear combination of explanatory variables, which can be expressed as:

$$g(X) = Ln \left[\frac{P(x_i)}{1 - P(x_i)}\right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki}$$

Where X_{ki}denotes the value of variable k for sample i and β_k is coefficient of variable k. Among all variables, those that are statistically significant at a p-value of 0.05 or better have a strongest relationship with the dependent variable. Note that if the sample size would be quite small, this could lead to insignificant p-values.

The absolute value of the z-score shows how many standard deviations are away from the mean. Some z-scores will be positive whereas others will be negative. If the variable's z-score is positive, it means that the variable performs better than the group mean. Very high or very low (negative) z-scores, associated with very small p-values. If the number of elements in the set is large, about 68% of the elements have a z-score between -1 and 1; about 95% have a z-score between -2 and 2; and about 99% have a z-score between -3 and 3. In general, if the absolute value of the Z-value is bigger than 2.0, the variable is significant (which means that there is statistical evidence that X is related to the Y variable). Z score formula is computed as below:

$$Z_i = \frac{X_i - \mu}{S}$$

Where X is a variable, μ is a mean and S is a standard deviation.

The standard error of a statistic is the standard deviation of the sampling distribution of that statistic and it is important because it reflects how much sampling fluctuation a statistic will show. In general, the larger the sample size the smaller the standard error. The standard error formula is computed as below.

$$SE = \frac{S}{\sqrt{n}}$$

Where SE is standard error, S is the standard deviation and n is the sample size.

4-4- Random Effect Logistic Regression

To explore whether or not there is any variation in driver yielding behavior from location to location, a random effect logistic regression will be developed considering random effect for each location. The generic random effect formula is as below:

$$g(X) = Ln \left[\frac{P(x_i)}{1 - P(x_i)}\right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + U_{ik}$$

Where U_{ik} is the additional independent variable. Generally, the random effects are used in the analysis of the data when no fixed effect is assumed. There are two common assumptions made about the individual specific effect including the random effects assumption and the fixed effects assumptions. The random effects assumption is that when the individual specific effect is uncorrelated with the independent variables. The fixed effect assumption is when the individual specific effect is correlated with the independent variables. If the random effects assumptions would be significant. It is more efficient to be used than the fixed effects model. However, if this assumption does not hold, the random effects model is not consistent. Such model is used for controlling the unobserved variables which are correlated with the indicator factor.

4-5- AIC

To evaluate the goodness and the performance of the models, the null/residual deviances, and AIC will be considered. Null deviance indicates the response predicted by a model with nothing but an intercept. Lower the value, better the model. Residual deviance indicates the response predicted by a model on adding independent variables. Lower the value, better the model; means, the variable performs better than the group mean. AIC (Akaike Information Criteria) is the analogous metric of adjusted R^2 in logistic regression. It is the measure of fit which penalizes model for the number of model coefficients. Therefore, always model with minimum AIC value is preferred.

4-6- Elasticity and Pseudo-Elasticity

To better understand the effect of each contributing factor on the likelihood of the driver yielding behavior, the elasticity analysis was conducted. The elasticity represents the percentage change in the independent variable resulting from a 1% change in an independent variable (Washington , Karlafts , & Mannering, 2003). The elasticity for continuous variables are computed as below:

$$E_i = \frac{\delta\lambda_i}{\lambda_i} * \frac{X_{ik}}{\delta X_{ik}} = [1 - P_i)]\, \beta_i X_i$$

Where E represents the elasticity, Xik is the value of the kth independent variable for observation i, β is the estimated parameter for the kth independent variable and $\boldsymbol{\lambda}$ is the drivers yielding dummy variable. Although each observation in the dataset has an elasticity that depends on the value of Xi and the estimated probability of driver yielding P(i), it is customary to report the average elasticity in the sample.

Note that for categorical variables, pseudo-elasticity is computed. Following equation is one form of pseudo elasticity that shows the sensitivity of the indicator variable x_i.

$$E_i = \left[\frac{\text{Exp}\,[\Delta(x'\beta)]\,[1 + \text{EXP}(x_i\beta_i)]}{\text{Exp}[\Delta(x'\beta)][\text{EXP}(x_i\beta_i)] + 1} - 1\right] * 100$$

Because the categorical independent variables are binary, the pseudo elasticity is used to examine the change in estimated likelihood of driver yielding when an independent variable switches from 0 to 1. Following equation is another form of pseudo elasticity where X ik is the kth independent variable for the ith observation (Islam & Hernandez, 2012).

$$E_i = \frac{P[\,given\; x_{ik} = 1] - P[given x_{ik} = 0]}{P\;[given\; x_{ik} = 0]}$$

5. DATA COLLECTION

5-1- Site Selection

This study is to evaluate the drivers yielding behaviors at uncontrolled intersections. Prior to site selection, a preliminary criteria was identified to maintain the consistency across all locations. Below is the list of those criteria:

- Two way streets
- Four legs intersections
- On street parking

- Two lane roadways with no median
- No crosswalk sign in advance of the intersection
- No curb extension in the direction of pedestrian crossing

The process of the site selection is done based on crash or non-crash sites. Therefore, the pedestrian crash data[4] was geocoded and visualized for each aldermanic area to see which uncontrolled intersections have had the most crashes from 2010 to 2014, and which ones have had no incidents in the same period. Figure (8) displays the pedestrian-vehicle crash spots on uncontrolled intersections with the radius of a quarter mile. Red and yellow areas are where the concentration of crashes are high and light and dark green areas are where the concentration of crashes are less.

[4] Wisconsin Traffic Operations and Safety Laboratory website. https://transportal.cee.wisc.edu/

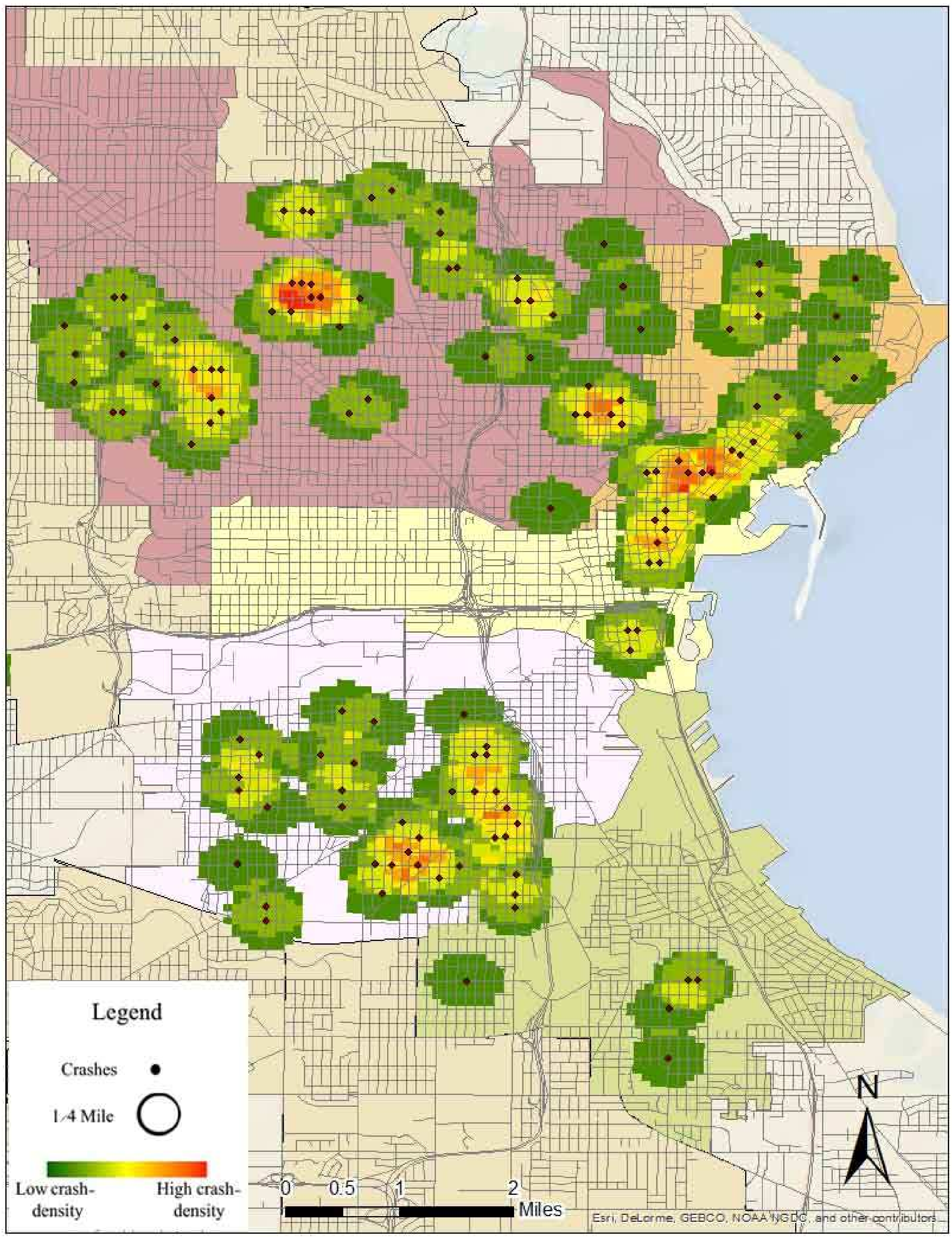


Figure 8: A quarter mile radius around crash spot at un-signalized intersections of the study zones

Ultimately, ten uncontrolled intersections were selected as study locations, which have at least 2 pedestrian- vehicle crashes occurred in 2010 to 2014 round year, and ten uncontrolled intersections were selected as control locations, which have no pedestrian-vehicle crash reported in 2010 to 2014.

To maintain consistency and extend the study throughout the city, the team selected each pair of study and control locations in each aldermanic area. Figure (9) illustrates the locations of study and control locations in the city. Each intersection is given a specific ID number to be compared with its pair.

Note that control locations are selected as a comparison of the study locations with the closest AADT (Annual Average Daily Traffic), and in the same area zone (table 1).

Table 1: Study locations vs. control locations

	Study Locations	**Major Road AADT***	**Study Area**		**Control Locations**	**Major Road AADT**	**Study Area**
1	Downer Ave-E Park PL	7200	East Zone	**11**	Downer Ave-Linnwood Ave	5100	East Zone
2	E North Ave-N Palmer St	16400	North Zone	**12**	North Ave-1st St	16400	North Zone
3	Brady St-Franklin PL	10100	North Zone	**13**	Mitchell-8th St	9000	South Zone
4	W Center St-N 5th St	10000	North Zone	**14**	W Center & 9th st	9100	North Zone
5	W North Ave-N 44th St	13200	North Zone	**15**	North Ave-N 45th St	11000	North Zone
6	N 20th St- W Melvina St	4900	North Zone	**16**	20th St-W Meinecke Ave	6800	North Zone
7	W Becher St- N 7th St	9600	South Zone	**17**	W Becher St- S 15th St	6600	South Zone
8	35th St-Garfield Ave	14500	North Zone	**18**	N 35th St-W Meinecke Ave	13800	North Zone
9	Historic W Mitchell-12th St	6300	South Zone	**19**	W Historic Mitchell- 10th St	8400	South Zone
10	Lincoln Ave- 15th St Pl	14200	South Zone	**20**	Lincoln Ave- 17th St	13000	South Zone

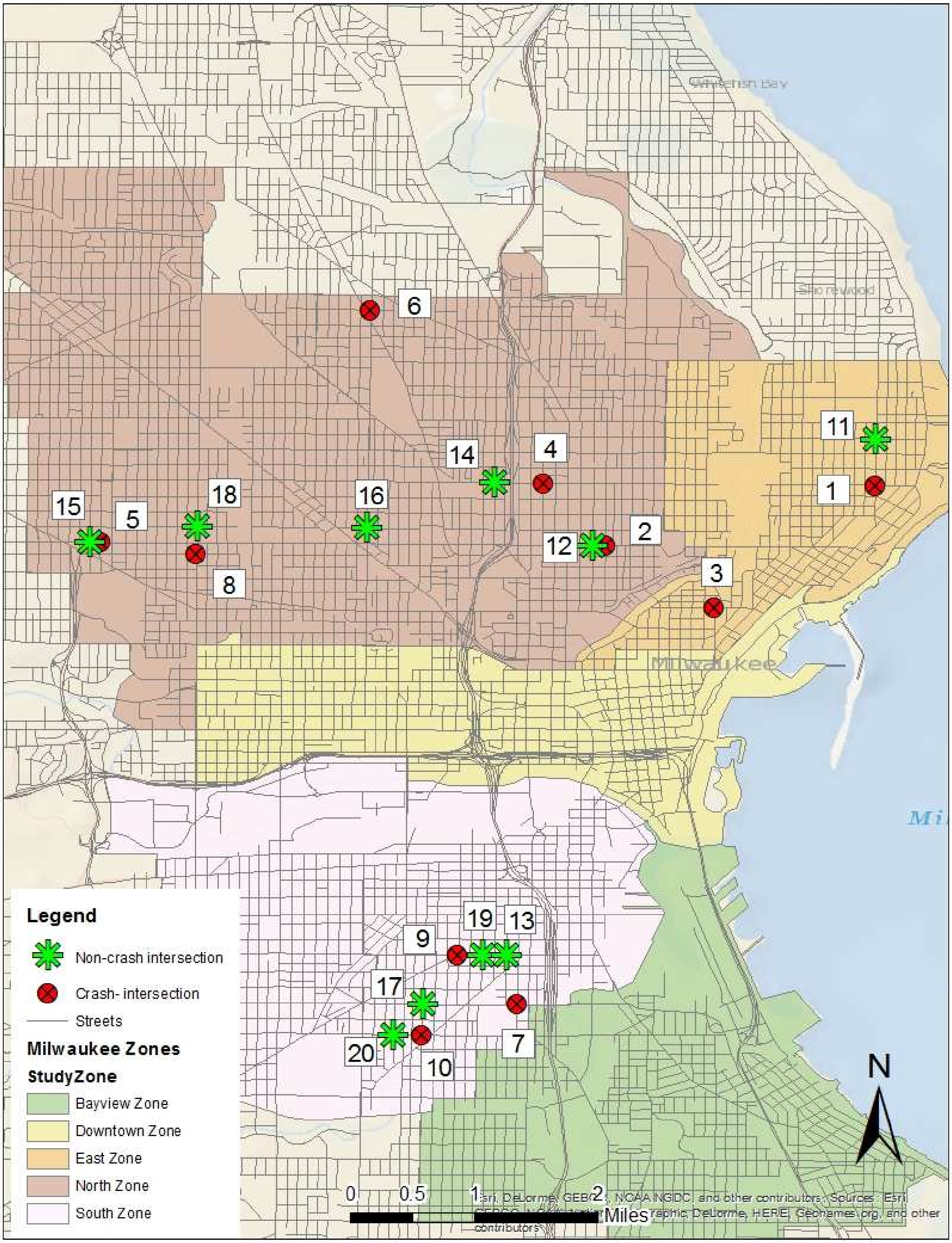


Figure 9: Locations of crashes and non-cashes uncontrolled intersections in study zones

5-2- Process of Data Collection

Three observers attended at each location and collected data during the peak hours (4:30-6:30 PM or 5:00- 7:00 PM) from Sept. to Nov. 2016. Data collection was done at a single crosswalk, when a pedestrian arrives at a crosswalk and try to cross in a single direction on the major street, Data were collected in four sheets at every intersections. Sheet 1 was designed to record the characteristics of the intersections. The first observer focuses on whether or not drivers have the opportunity to yield and whether or not they yield (Sheet 2), the second (optional) observer records a driver's speed, gender, race, and age of every fifth car in each vehicle direction on a major street (Sheet 4), and the third observer focuses on a pedestrian characteristic(Sheet 3).

5-2-1- Intersections Characteristics (sheet1)

Table below includes all the information of the first sheet that can also be collected prior to actual data collection time.

Table 2: Intersection Characteristics

Categorical variables	**Summary statistics**
One crosswalk is marked, [Crosswalk_1 marked]	
Both crosswalks are marked [Crosswalk_2 marked]	
Crosswalk sign at the intersection	
Nearside bus stop near the intersection [NS_Bus]	
Farside bus stop near the intersection (Y/N)	
Right- turn lane in the direction of the traffic at the intersection	
Left- turn lane in the direction of the traffic at the intersections	
Land use: Commercial [LU_Comm]	
Crash/ non crashes	
Continuous variables	
Traffic volume (AADT)	
Crosswalk crossing distance (feet) [Crossing_Dist]	
Distance from the last car parked from the intersection (feet) [Parking_Dist.]	
Speed limit (mph)	
Signal distance Difference (feet) [Sig_Dist_Diff]	
Distance from Lake (mile) [Dist._Lake]	

For more information about the description of each variable and the data, please refer to appendix A and B and to see the picture of each site please refer to appendix C.

5-2-2- Driver Yielding Behavior and Demographic Characteristics (Sheet 2)

The purpose of sheet (2) is to document the characteristics of drivers who either yield or not yield when a pedestrian is at the crosswalk. A driver observation should be made for the first car that approaches the crosswalk after a pedestrian arrives at the crosswalk. Then, if the first car does not yield, the data collector should observe the next car that they can feasibly observe if there is a yielding opportunity. All the information in table 3 should be recorded for each driver. To see the format of sheet 2 please refer to Appendix A.

Table 3:Driver Yielding and Demographic Characteristics

Driver Characteristics	
Direction	Eastbound /Westbound
Time stamp (when ped. arrives)	H:Min:Sec
Yielded	Yes/No
Number of Pedestrians waiting to cross	
Gender	F/M
Race	Black
	White
	Latino
	Asian
	Other
Age	(Est.)
Speed	(Radar)
Where the car yielded	In crosswalk
	Within 5ft
	5-10 ft
	10-15 ft
	>15ft
	Didn't stop (slowed/rolled)

5-2-3- General Information for Sheets 2 and 3

General information were also provided at the top of the sheets (2) and (3). This includes the name of the observer, intersection location, travel characteristics, and environmental characteristics.

- Name of observer: ………………………..
- Intersection location: Major roadway …….. Minor roadway……….
- Crosswalk leg (e.g., North, South, East, West)
- Vehicle travel direction (e.g., Southbound/Northbound)
- Posted speed limit in direction of travel (mph)
- Pedestrian travel direction (e.g., Eastbound/Westbound)
- Location of observer at intersection (Observers can stand in any safe place at intersections where can have a good view to pedestrians crossing and drivers yielding)
- Time period of data collection: Start time …………… End time …………
- Day of week: ……………………
- Date (e.g., 6/27/16): ……………..
- Weather (e.g., sunny, partly, cloudy, rainy, snowy): ………………
- Temperature (F):

5-2-4- Pedestrian Behavior and Demographic Characteristics (Sheet 3)

Sheet 3 was designed to collect the pedestrians' behaviors and demographic characteristics when they are attempting to cross the major street. Please refer to appendix A to see the sheet. Each row in this sheet represents a pedestrian crossing in a single direction in a single crosswalk. The first pedestrian that arrives at the crosswalk in any group should be observed. No additional pedestrians need be recorded until all members of that group complete crossing. All the information that should be recorded in sheet 3 is shown in table (4). Note that the time stamp allows the pedestrian characteristics to be matched with the driver characteristics.

Table 4: Pedestrian Behavior and Demographic Characteristics

Pedestrian Characteristics	
Pedestrian direction	(Northbound/Southbound)
Crosswalk location	(East/West)
Time stamp	H:Min:Sec
Yielding opportunity	Yes/No
Gender	Female
	Male
Race	Black
	White
	Latino
	Asian
	Other
Age	(Est.)
Physical disability	Wheelchair
	Walker
	Other
Standing location	On the curb
	On the street
Assertive to cross	Yes
	No
Group	Size
Waiting time to cross	<10 sec
	>10 sec
Number of Cars drove through crosswalk	number
Driver	Yielded (Y/N)

5-2-5- Overall Driver Demographic Characteristics (Sheet 4- Optional)

The purpose of this sheet is to capture the characteristics of the total population of drivers, including gender, race, age, and speed. The demographic characteristics are the same as described in Sheet 3. Speed requires using a radar gun and recording the speed in the right-hand column. The driver of every fifth car should be observed, and the data collector should alternate approach directions.

Sheet 4 is for collecting data of the whole drivers' characteristics approaching crosswalks. For more information please refer to appendix A.

Table 5: Overall Driver Demographic Characteristics

Driver Characteristics	
Direction	EB/WB or SB/NB
Time	H:Min:Sec
Gender	F/M
Race	Black
	White
	Latino
	Asian
	Other
Age	(Est.)
Speed	(Radar)

6. ANALYSIS AND DISCUSSION

This chapter includes two levels of data analysis. In the initial step I used statistical descriptive analysis for the collected data and then I used the logistic regression and random effect models to investigate more accurately the correlations between the variables. Eventually, I will select the more statistically significant model.

6-1- Primary data analysis

6-1-1- Refining the data

After completing the data collection, my team entered the whole data from the field worksheets into an electronic database. Prior to do any analysis, all data need to be cleaned and refined. During data cleaning process, a few variables were dismissed including vehicle and pedestrian direction, speed, crosswalk location, where the car yields to the pedestrian, and number of cars not yielding as well as pedestrian disability and waiting time. Also, some variables were not exist at any intersections such as left turn lane and farside bus stop.

The remaining data were refined and converted into dummy variables for the next steps of the analysis.

6-1-2- Drivers yielding rate

In total, 474 observations was completed that 364 was related to the existence of yielding opportunity, which includes the number of drivers yielding and non-yielding.

$$\text{Driver yielding rate} = \frac{\text{Driver yielded}}{\text{Yielding oppurtunity}}$$

The driver yielding rate for each site is calculated by the number of yielding vehicles over the total number of yielding opportunity. Of the total yielding opportunity, 66.75% of drivers yielded at control intersections and 34.25% yielded at study intersections (Figure 10).

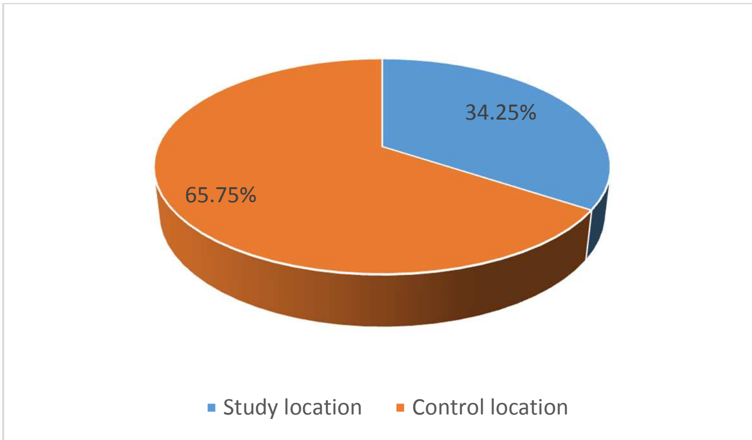


Figure 10: yielding rate at study and control intersection

6-1-3- Race and Drivers Yielding Behavior

As discussed in Goddar et al study, the minority pedestrians experience discriminatory treatment by drivers at crosswalks. According to the U.S. Census Bureau, the city of Milwaukee is one of the most segregated cities in the country. Approximately 40% of the population in Milwaukee are African-American. Disparities in education, housing and incarceration are so extreme. High percent of the African-American population reside on south and west side of the city. In general, as you go further west or south, the environment and people's culture noticeably change which can be a reason for drivers yielding behaviors and pedestrians' assertiveness. It is more appear that east side and downtown of the city get more percentage of drivers yielding than west and south side as shown in Figure (11). The numbers from 1-10 are the study locations and numbers from 11-20 are the control intersections.

Although race could be in associated with drivers yielding behavior, other factors may have an impact as well. We will discuss the effect of other variables later in this research.

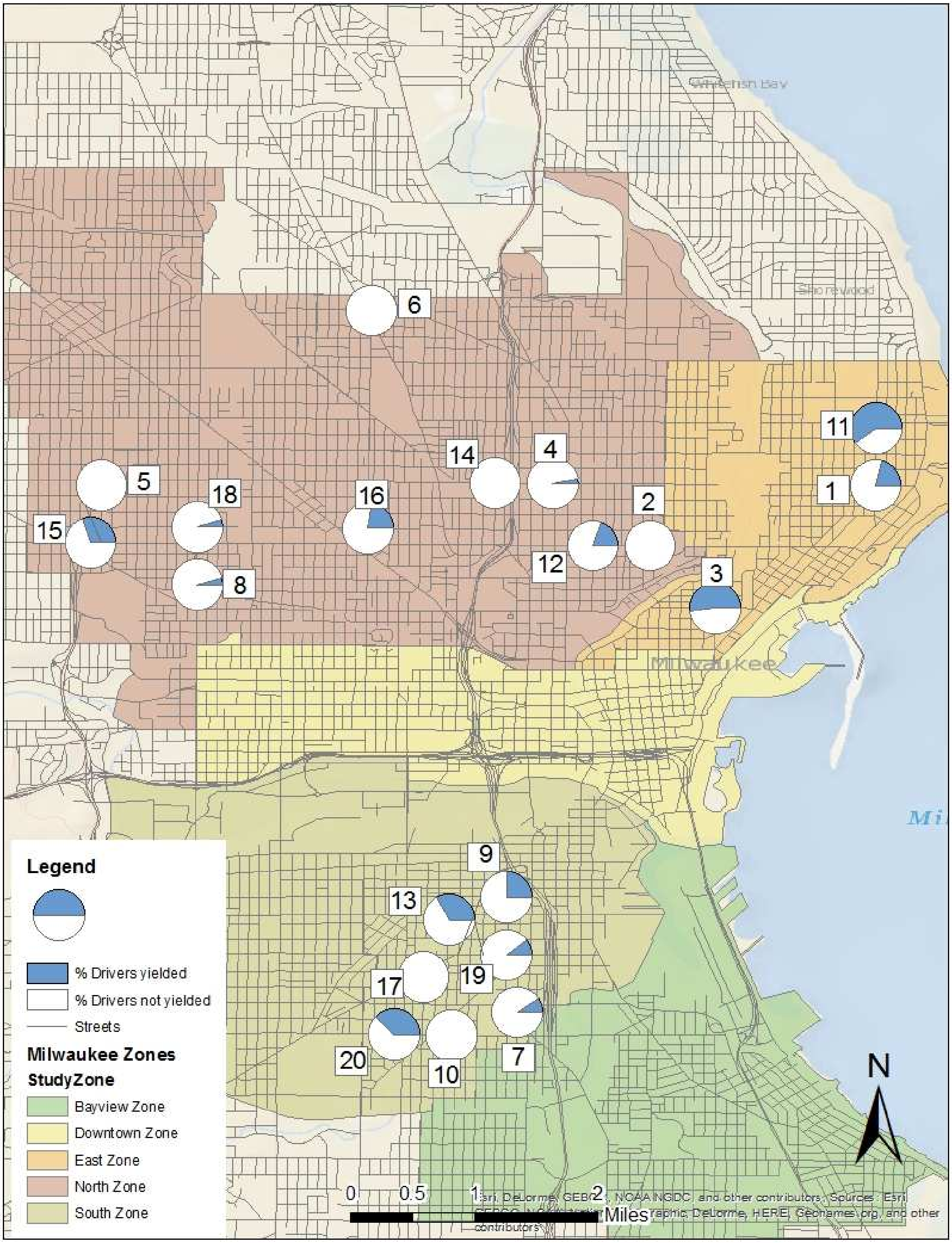


Figure 11: Drivers yielding rate at selected un-signalized intersections

6-1-4- Yielding Rates and Pedestrian Flow Rates at Study and Control Intersections

To compare the yielding percentage and pedestrian flow rate in crashes and non-crashes locations, the two sample t- test for independent variable allowing unequal variance was run through the SPSS software. According to the mean of yielding percentage in table (6), drivers most likely yield to pedestrian at non-crashes locations even though the number of pedestrians are more at crashes locations.

The variance of the drivers yielding is also greater in non-crashes locations, which means that the yielding percentage is not evenly distributed among all non-crashes locations. On the other hand, the variance of the pedestrian flow rate in non-crashes locations is lower, which means the pedestrian flow rate in all non-crashes locations were almost similar.

The null hypothesis for yielding variable states that there is no relationship between crashes and non- crashes locations in drivers yielding. At the confidence interval of 90%, since p value for one tail and two tail is larger than 0.1, then the null hypothesis can be accepted. So, there is no relationship between crashes and non-crashes locations.

The null hypothesis for pedestrian flow rate also states that there is no relationship between crashes and non-crashes locations in pedestrian flow rate. If the confidence interval is considered at 90%, then the null hypothesis is rejected. So, there is a relationship in pedestrian flow rate between crashes and non-crashes locations.

Table 6: Yielding percentage at study locations and control locations

	Locations	Mean	Variance	Observations	df	t Stat.	P(T<=t) one-tail	t Critical one-tail	P (T<=t) two-tail	t Critical two-tail
Yielding (%)	**crashes location**	11.37	284.13	10	18	-1.29	0.11	1.73	0.21	2.10
	non-crashes location	21.82	369.08	10						
Pedestrian flow rate	**crashes location**	10.65	21.45	10	16	1.75	0.05	1.75	0.10	2.12
	non-crash locations	7.55	9.86	10						

6-1-5- Location Specific Characteristics

Categorical Variables

The physical characteristics of each intersection were recorded to evaluate their association with the drivers yielding behaviors. To ease the analysis perception, we classified the location specific characteristics into categorical and continuous variables. Table (7) indicates the percentage of driver yielding for the categorical variables at crashes and non-crashes locations. The highest percentage of yielding for each variable at each locations has been bold in the table (7) for a better interpretation.

Table 7: Yielding percentage of intersections' characteristics

Categorical variables		Total		Crashes locations		Non- crashes locations	
		Total Yielding Opportunity (Count)	**Yielding Percentage (%)**	**Total Yielding Opportunity (Count)**	**Yielding Percentage (%)**	**Total Yielding Opportunity (Count)**	**Yielding Percentage (%)**
Crosswalk 1 marked	No	92	13.04%	69	1.45%	23	**47.83%**
	Yes	272	**17.65%**	144	**18.06%**	128	17.19%
crosswalk 2 marked	No	142	9.15%	96	2.08%	46	23.91%
	Yes	222	**21.17%**	117	**21.37%**	105	**20.95%**
Nearside bus stop	No	238	15.58%	127	**14.96%**	104	16.35%
	Yes	126	**18.05%**	86	9.30%	47	**34.04%**
Crosswalk sign	No	248	15.70%	129	4.65%	113	**28.32%**
	Yes	116	**18.03%**	84	**25.00%**	38	2.63%
Right turn lane	No	176	**17.88%**	104	**19.23%**	75	16.00%
	Yes	188	15.14%	109	6.42%	76	**27.63%**
Land Use Type	Commercial	256	15.63%	156	18.83%	100	12.00%
	School	48	**22.92%**	17	0.00%	28	**21.43%**
	Residential	60	15.00%	27	**25.93%**	36	13.89%

Drivers most likely yield to a pedestrian at marked crosswalks particularly when the second crosswalk is also marked. Surprisingly, non-crashes locations with no marking in either crosswalks, have received the higher percentage of yielding. The presence of some variables such as nearside bus stop, crosswalk signs and schools especially at non crashes locations positively affect drivers yielding behavior. On the contrary, some other variables such as right turn lane does not have much effect on drivers yielding.

Pedestrians and drivers race is another factor that highly correlated with yielding behavior particularly in non-crashes locations, pedestrians and drivers with the ethnicity of white have more yielding compliance especially at non-crashes locations.

The pedestrians and drivers race interaction will be explored later in this research.

Personal Observations for Roadway Geometry Level

- Roadways with bike lane and parking lane usually dissolves to a single combined area near the intersection. If any vehicle is waiting to turn left on the major road of the uncontrolled intersection, following drivers often use the combined area for passing
- The combined area mentioned above is hazardous for pedestrians waiting on the street.
- Drivers tend not to yield to pedestrian if there is no pedestrian crosswalk sign at the intersection.
- Parking of large/ utility vehicles close to intersection restricts drivers' view of pedestrian. This happens a lot at uncontrolled intersections in or near downtown area.
- Lighting condition at crosswalk affects the driver's identification of pedestrian at night.

Continuous variables

Table (8) indicates the descriptive statistics of the continious variables of the intersections's characterisitcs. The table below gives a general idea about the number of observations, range, minimum and maximum number and mean of each continious variable in associated with the driver yielding behavior. It appears that the drivers yielding percentage is the highest for AADT variable and it is the lowest number for the distance from the last car parked variable. Note that the range of driver yielding precentag is smaller for Dist. Parking variable compare to other variables.

Table 8: Descriptive Statistics for location specific variables

Continuous variables	**Descriptive Statistics**				
	N	Range	Min	Max	Mean
AADT	19	11500	4900	16400	9958
Driver Yielding Percentage	19	60	0	60	16.8
Crossing_ Distance	11	19	40	59	51.82
Driver Yielding Percentage	11	60	0	60	16.63
Dist._ Parking	12	482	18	500	156.9
Driver Yielding Percentage	12	53.333	0	53.3333	15.93
Sig_Dist_Diff	19	1433	1	1434	617.9
Driver Yielding Percentage	19	60	0	60	16.5
Distance_ Lake	20	5.55	1.15	6.7	4.421
Driver Yielding Percentage	20	60	0	60	16.59

6-1-6- Behavioral Characteristics of Intersections

Table (9) indicates the complete information about the pedestrians' and drivers' behavioral characteristics at crashes and non-crashes locations. The highest yielding percentage in each category has been bold to be easily evaluated.

Table 9: Data summary of yielding opportunity and yielding percentage of all intersections

Categorical variables		**Total**		**Crash**		**Non crash**	
		Total Yielding Opportunity (Count)	**Yielding Percent age (%)**	**Total Yielding Opportuni ty (Count)**	**Yielding Percentag e (%)**	**Total Yielding Opportuni ty (Count)**	**Yielding Percenta ge (%)**
Pedestrian Gender	Male	230	**35.40%**	131	12.21%	99	**24.24%**
	Female	98	24.24%	61	**14.75%**	37	18.92%
	Both	36	13.79%	21	9.52%	15	0.13%
Pedestrian Race	White	106	**29.25%**	86	**24.42%**	20	**50.00%**
	Other	258	11.24%	127	4.72%	131	17.56%
Ped_Dom_Race_ White*	No	281	12.10%	140	5.00%	141	19.15%
	Yes	83	**31.33%**	73	**27.40%**	10	**60.00%**
Pedestrian Age	Age =< 20	65	15.38%	31	**25.81%**	34	5.88%
	20< age < 50	278	**16.55%**	152	16.45%	126	**18.75%**
	age >=50	21	19.05%	17	23.53%	4	0.00%
Physical Disability	Yes	4	0.00%	3	0.00%	1	0.00%
	No	360	**18.69%**	210	**12.86%**	150	**22.00%**
Standing Location	On Curb	66	9.09%	35	**11.43%**	31	6.45%
	In Street	298	**18.12%**	178	0.13%	120	**25.83%**
Assertiveness	Yes	157	**23.57%**	82	**24.39%**	75	**22.67%**
	No	207	11.11%	131	5.34%	76	21.05%
Group Size =1	Size=1	266	35.90%	149	10.74%	117	**22.22%**
	Size>1	98	**52.94%**	64	**17.19%**	34	20.59%
Waiting Time	<10 sec	274	**20.80%**	165	**16.36%**	109	**27.52%**
	>10 sec	90	3.33%	48	0.00%	42	7.14%
Driver Gender	Male	238	**16.88%**	141	**14.18%**	95	21.05%
	Female	126	15.75%	72	9.72%	56	**23.21%**
Driver Race	White	136	**26.47%**	83	**22.89%**	51	**33.33%**
	Other	228	10.53%	130	6.15%	100	16.00%
Driver_Dom_Rac e_White*	No	254	12.60%	123	5.69%	131	19.08%
	Yes	110	**25.45%**	90	**22.22%**	20	**40.00%**
Driver Age	Age =< 20	12	16.67%	10	20.00%	3	0.00%
	20< age < 50	332	15.66%	182	17.03%	147	13.61%
	age >=50	20	**30.00%**	8	**37.50%**	14	**21.43%**

*Ped_Dom_Race_White: The intersection that pedestrians' population with the ethnicity of white is more than 50%

* Driver_Dom_Race_White: The intersection that drivers' population with the ethnicity of white is more than 50%

According to table 9, male pedestrian has received the highest percentage of drivers yielding. Additionally, drivers tend to yield to pedestrian with the ethnicity of white at crash and non-crash locations and also drivers with the ethnicity of white most likely yield at those locations. It is hypothesized that there is a relationship between the pedestrians and drivers race in yielding which will be more explored later in this research.

As table (9) indicates, pedestrians standing on curb at crashes locations have received a higher number of drivers yielding while the pedestrians standing in street at non-crash locations received the higher percentage of yielding. Nonetheless, pedestrian who are assertive and waiting less than 10s to cross get the higher percentage of yielding at crashes and non-crashes locations.

Pedestrians with no physical disability get the higher yielding rate at both locations. The pedestrians with the group size of more than 1 received the highest percentage of yielding especially at non crashes locations.

Regarding age, drivers with the age of more than 50 most likely yield at crashes and non crashes locations, and pedestrians with the age between 20 and 50 received the highest percentage of yielding especially at non-crashes locations.

Personal Observations for Pedestrian Level

- Pedestrian who use cellphone while attempting to cross the street, usually has a higher waiting time.

- A high number of pedestrians tend to wait for the vehicles clearance from the roadway to start crossing
- A significant portion of pedestrians do not use the crosswalks.
- A few number of pedestrians cross the street diagonally.
- Most of the pedestrians usually do not show assertiveness for crossing the intersection.

Personal Observations for Driver Level

- Drivers tend not to yield to pedestrians when their speed is high.
- Drivers usually drive faster than the speed limit on roadways that connects arterial or any other major roadway.
- A portion of drivers use cellphone while driving. Drivers using cellphone do not look for roadside objects or any pedestrian waiting to cross.
- A few uncontrolled intersections are situated in a considerably large distance away from the signalized intersections. Drivers usually speed up from the signalized intersections and do not tend to slow down or yield to pedestrian while approaching the uncontrolled intersections.
- Drivers tend to yield to pedestrian if the downstream signal is Red and a traffic queue is visible from the upstream intersection.
- Drivers tend not to yield to pedestrian if the downstream signalized intersection is a short distance away from the uncontrolled intersection and if the traffic signal is green at downstream signalized intersection.

- Drivers tend not to yield when pedestrians stand on the curb showing no willingness to cross the street.
- A few aggressive drivers even don't yield when they almost reach the pedestrians' waiting spots.

6-2- Logistic Regression Models

6-2-1- Correlation Matrix

Before running any models on data, the correlation between independent and dependent variables should be explored by correlation matrix. In the target dataset, all the behavior specific variables are converted as binary dummy variables and the dependent variable itself is also a binary outcome. In statistics, the correlation coefficient between two binary variables is called **Phi Coefficient.** The phi coefficient is a measure of the degree of association between two binary variables. This measure is similar to the correlation coefficient in its interpretation. A general rule of thumb for correlation coefficients is provided below and the same rule can be used for the Phi coefficient.

- (-1.0 to -0.7) strong negative association.
- -0.7 to -0.3 weak negative association.
- -0.3 to +0.3 little or no association.
- +0.3 to +0.7 weak positive association.
- +0.7 to +1.0 strong positive association.

Table 10: Estimate of Phi Coefficient between Dependent Variable and Behavior-specific Variable

Phi Coefficient	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9
Yielded (Y)	1	0.03	0.22	-0.01	0.09	0.17	-0.03	0.02	0.21	-0.01
Pedestrian Gender: Male (X1)	0.03	1	-0.02	-0.12	0.03	0.09	0.31	-0.05	-0.06	0.07
Pedestrian Race: White (X2)	0.22	-0.02	1	-0.03	-0.09	0.1	-0.01	0.06	0.36	0.02
Pedestrian Age<=20 (X3)	-0.01	-0.12	-0.03	1	-0.08	-0.02	-0.2	0.13	0.05	-0.05
Standing Location: Street (X4)	0.09	0.03	-0.09	-0.08	1	0.17	0.07	0	-0.1	0
Pedestrian Assertiveness: Yes (X5)	0.17	0.09	0.1	-0.02	0.17	1	0	0.06	0.07	0.06
Group Size=1 (X6)	-0.03	0.31	-0.01	-0.2	0.07	0	1	-0.03	-0.09	-0.01
Driver Gender: Male (X7)	0.02	-0.05	0.06	0.13	0	0.06	-0.03	1	0.05	-0.06
Driver Race: White (X8)	0.21	-0.06	0.36	0.05	-0.1	0.07	-0.09	0.05	1	-0.08
Driver Age<=20 (X9)	-0.01	0.07	0.02	-0.05	0	0.06	-0.01	-0.06	-0.08	1

Few behavior specific variables such as waiting time, pedestrian disability etc. are excluded from dataset due to low sample size and effect on dependent variable. As table (10) indicates, the phi coefficient values between the dependent variable and the explanatory variables are all fallen within -0.3 to +0.3. It means that based on the general thumb rule, a little or no association between yielding behavior and driver behavior-specific variables exist. However, a week positive association is observed between some explanatory variables such as pedestrian race and driver race. This correlation will be more explored later in this research.

Next table also provides phi coefficient for binary variables and Pearson correlation coefficient for the continuous and categorical variables in related to intersections characteristics.

Table 11: Estimate of Phi/Correlation Coefficient between Dependent Variable and Location-specific Variable

Correlation/ Phi Coefficient	Y	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11	Z12	Z13
Yielded (Y)	1	0.16	0.03	0.03	-0.04	0	0.22	0.16	-0.12	-0.2	-0.21	-0.14	0	-0.12
Crosswalk 2 Marked: Yes (Z1)	0.16	1	0.25	0.15	-0.34	0.26	0.3	-0.01	-0.15	0	-0.31	0.13	0.08	-0.24
Crosswalk Sign (Z2)	0.03	0.25	1	-0.19	0	-0.1	0.63	0.24	0.15	0	-0.49	0.13	0.5	-0.42
NS Bus (Z3)	0.03	0.15	-0.19	1	0.43	0.24	0.12	0.11	0.09	-0.03	0.3	0.25	-0.17	-0.49
Right Turn Lane (Z4)	-0.04	-0.34	0	0.43	1	-0.13	0.18	0.32	0.01	0.15	0.36	-0.2	-0.09	-0.23
Land Use: Commercial (Z5)	0	0.26	-0.1	0.24	-0.13	1	-0.03	0.17	0.36	0.1	0.03	-0.15	-0.51	0.09
Ped. White Dominated: Yes (Z6)	0.22	0.3	0.63	0.12	0.18	-0.03	1	0.58	0.32	-0.17	-0.53	-0.3	0.11	-0.72
Driver White Dominated: Yes (Z7)	0.16	-0.01	0.24	0.11	0.32	0.17	0.58	1	0.31	-0.01	-0.34	-0.39	0.12	-0.33
Crash Site:Yes (Z8)	-0.12	-0.15	0.15	0.09	0.01	0.36	0.32	0.31	1	0.15	-0.24	-0.24	-0.23	-0.21
AADT (Z9)	-0.2	0	0	-0.03	0.15	0.1	-0.17	-0.01	0.15	1	0.18	0.28	-0.07	0.25
Crossing Dist. (Z10)	-0.21	-0.31	-0.49	0.3	0.36	0.03	-0.53	-0.34	-0.24	0.18	1	0.33	-0.35	0.3
Parking Distance (Z11)	-0.14	0.13	0.13	0.25	-0.2	-0.15	-0.3	-0.39	-0.24	0.28	0.33	1	0.33	0.06
Signal distance Difference (Z12)	0	0.08	0.5	-0.17	-0.09	-0.51	0.11	0.12	-0.23	-0.07	-0.35	0.33	1	-0.11
Distance from Lake (Z13)	-0.12	-0.24	-0.42	-0.49	-0.23	0.09	-0.72	-0.33	-0.21	0.25	0.3	0.06	-0.11	1

The correlation and phi coefficients provided in Table (10) and Table (11) illustrates that the maximum value of correlation/phi coefficient between yielding behavior and other explanatory variable is 0.22. This value represents little or no association between variables based on general thumb rule. To explore the statistical relationship between variables, a series of logistic regression model was developed. The next section provides the model outputs from logistic regression

6-2-2- Model Development

In this section, five models will be proposed that based on their performances, the preferred model will be selected to identify the correlation between variables.

Model with Behavior-Specific Variables and Location ID (ID=20)

Table 12: behavior-specific variables and location ID (model 1)

Coefficients:	Estimate	Std. Error	Z-value	Pr(>|z|)
(Intercept)	***-4.570***	***1.256***	***-3.638***	***0.000***
Behavior Specific Variables				
Pedestrian Gender: Male	0.412	0.397	1.040	0.299
Pedestrian Race: White	0.863	0.587	1.470	0.142
Pedestrian Age<=20	-0.039	0.501	-0.078	0.937
Standing Location: Street	***1.357***	***0.600***	***2.263***	***0.024***
Pedestrian Assertive ness: Yes	***1.151***	***0.455***	***2.528***	***0.011***
Group Size=1	0.139	0.426	0.326	0.744
Driver Gender: Male	-0.014	0.376	-0.038	0.970
Driver Race: White	0.234	0.414	0.565	0.572
Driver Age<=20	0.106	0.386	0.273	0.785
Location ID				
Downer:E Park PL	0.141	1.092	0.129	0.898
E North Ave:N Palmer St	-18.438	2443.337	-0.008	0.994
Brady:Franklin	1.731	1.056	1.640	0.101
W Center:5th St	-0.976	1.365	-0.715	0.475
W North:44th St	-17.313	2627.556	-0.007	0.995
Downer:Linnwood	**2.234**	**1.254**	**1.781**	**0.075**
North:45th	1.440	0.997	1.445	0.148
35th:Garfield	-1.036	1.355	-0.765	0.444
20th St:W Melvina	-17.456	4072.816	-0.004	0.997
Becher:7th St	0.280	1.430	0.196	0.845
Mitchell:10th	**1.990**	**1.104**	**1.802**	**0.072**
35th:Meinecke	-1.079	1.355	-0.796	0.426
Becher:15th	-17.743	3951.089	-0.004	0.996
Mitchell:12th	1.266	1.089	1.162	0.245
Mitchell:8th	-0.152	1.415	-0.108	0.914
Lincoln:17th	1.009	1.031	0.978	0.328
Lincoln:15th	-17.786	1763.612	-0.010	0.992
W Center:9th	-16.749	2481.538	-0.007	0.995
20th:Meinecke	0.86	1.09	0.79	0.43
North Ave:1st	NA	NA	NA	NA

[Note: Variables significant at 95% C.I. are presented in Bold and Italic font.

Variables significant at 10% C.I. are presented in Bold font.]

Table 13: Model performance for model 1

Null deviance	325.85 on 363 degrees of freedom
Residual deviance	216.38 on 335 degrees of freedom
AIC	**274.38**

A dummy binary variable was created for location ID and used in the above presented model. From the model output, it can be noted that none of the location ID is statistically significant in 95% C.I. Only two of the location ID is statistically significant in 90% C.I. Based on the model output, it is clear that the location ID cannot be used as an explanatory variable in the model.

Random Effect Logistic Regression with Random Effect for Each Location ID (ID=20)

To explore whether or not there is any variation in driver yielding behavior from location to location, a random effect logistic regression was developed considering random effect for each location. The random effect logistic regression model output is given below:

Table 14: Random effect logistic regression with random effect for each location ID (model2)

Random effects			
Groups	Name	Variance	Std. Dev.
ID	(Intercept)	1.783	1.335

Fixed Effects	**Estimate**	**Std. Error**	**Z-value**	**Pr(>|z|)**
(Intercept)	***-4.643***	***0.883***	***-5.258***	***0.000***
Pedestrian Gender: Male	0.381	0.384	0.992	0.321
Pedestrian Race: White	***1.068***	***0.494***	***2.161***	***0.031***
Pedestrian Age<=20	-0.026	0.483	-0.054	0.957
Standing Location: Street	***1.362***	***0.579***	***2.354***	***0.019***
Pedestrian Assertiveness: Yes	***0.928***	***0.411***	***2.258***	***0.024***
Group Size=1	0.019	0.412	0.047	0.963
Driver Gender: Male	-0.009	0.360	-0.025	0.980
Driver Race: White	0.491	0.389	1.261	0.207
Driver Age<=20	0.028	0.363	0.078	0.938

[Note: Variables significant at 95% C.I. are presented in Bold and Italic font.]

The results of random effect logistic regression clearly illustrate that there is a variation in driver yielding behavior from location to location. To explain this variation, a series of location-specific variables were collected. The correlation/phi coefficient of these location-specific variables are provided in Table (13).

Table 15: Model performance for model 2

AIC	BIC	LogLik	Deviance	df.resid
286.2	329.1	-132.1	264.2	353

Logistic Regression Model with Behavior-Specific Variable, Location-Specific Variable and Location IDs

To explain the location-specific variance in driver yielding behavior, another logistic regression model was developed using behavior-specific variables, location-specific variables and location IDs as explanatory variables. The model output is provided below:

Table 16: behavior-specific variable, location-specific variable and location IDs (model3)

Coefficient	**Estimate**	**Std. Error**	**Z-value**	**Pr(>|z|)**
(Intercept)	-6.59E+14	3.49E+14	-1.885	0.059
Behavior Specific Variables				
Pedestrian Gender: Male	1.68E-01	4.50E-01	0.373	0.709
Pedestrian Race: White	1.44E+00	8.02E-01	1.800	0.072
Pedestrian Age<=20	-1.16E-01	5.35E-01	-0.218	0.828
Standing Location: Street	1.15E+00	6.81E-01	1.693	0.090
Pedestrian Assertiveness: Yes	1.53E+00	4.90E-01	3.131	0.002
Group Size=1	3.83E-01	4.82E-01	0.795	0.426
Driver Gender: Male	1.93E-01	3.93E-01	0.492	0.623
Driver Race: White	3.53E-02	4.41E-01	0.080	0.936
Driver Age<=20	1.88E-01	4.13E-01	0.455	0.649
Location-Specific Variable				
Crosswalk_2	1.18E+15	6.04E+14	1.952	0.051
Crosswalk_Sign	-2.44E+13	3.96E+14	-0.062	0.951
NS_Bus	-5.70E+14	6.16E+14	-0.926	0.354
RT_Lane	9.82E+14	4.01E+14	2.451	0.014
LU_Comm	-8.23E+14	5.18E+14	-1.590	0.112
Ped_Dom_Wh	-1.29E+15	9.07E+14	-1.423	0.155

Driver_Dom_Race_Wh	-7.97E+13	6.70E+14	-0.119	0.905
Crashes.non.crash	4.40E+14	2.89E+14	1.522	0.128
AADT	-6.08E+10	4.72E+10	-1.288	0.198
Crossing_Dist	3.60E+13	2.01E+13	1.796	0.072
Dist_Parking	5.27E+11	1.15E+12	0.458	0.647
Sig_Diff	2.79E+11	4.39E+11	0.635	0.526
Distance_Lake	-2.36E+14	1.38E+14	-1.709	0.087
Location Variable				
Downer:E Park PL	-4.12E+14	4.15E+14	-0.992	0.321
E North Ave:N Palmer St	-9.82E+14	9.04E+14	-1.087	0.277
Brady:Franklin	8.40E+14	5.76E+14	1.459	0.144
W Center:5th St	-1.31E+14	5.41E+14	-0.242	0.809
W North:44th St	9.53E+14	5.62E+14	1.695	0.090
Downer:Linnwood	NA	NA	NA	NA
North:45th	-4.21E+14	4.07E+14	-1.033	0.302
35th:Garfield	NA	NA	NA	NA
20th St:W Melvina	-5.79E+14	5.34E+14	-1.084	0.278
Becher:7th St	NA	NA	NA	NA
Mitchell:10th	2.41E+14	5.07E+14	0.476	0.634
35th:Meinecke	NA	NA	NA	NA
Becher:15th	4.30E+14	4.81E+14	0.894	0.371
Mitchell:12th	-2.21E+14	7.02E+14	-0.315	0.752
Mitchell:8th	1.94E+14	4.98E+14	0.389	0.697
Lincoln:17th	NA	NA	NA	NA
Lincoln:15th	4.91E+14	8.87E+14	0.553	0.580
W Center:9th	-1.39E+15	6.14E+14	-2.259	0.024
20th:Meinecke	-1.47E+15	7.51E+14	-1.958	0.050
North Ave:1st	-1.51E+15	9.74E+14	-1.545	0.122

[Note: Model did not converge with location-specific variables and location ID]

Model developed with location-specific variables and location ID together in the model did not converge and the predicted probability numerically occurred as 0 or 1 in the model output. One major reason of this non-convergence can be multi- collinearity due to location-specific variables and location IDs.

Logistic Regression Model with Behavior-Specific Variable, Location-Specific Variable

The next model was developed using behavior-specific variables and location-specific variable but without location IDs. The model output is provided below:

Table 17: Logistic regression model with behavior-specific variable, location-specific variable (model4)

Coefficients	**Estimate**	**Std. Error**	**Z-value**	**Pr(>|z|)**
(Intercept)	14.128	5.319	2.656	0.008
Behavior-Specific Variables				
Pedestrian Gender: Male	0.469	0.381	1.232	0.218
Pedestrian Race: White	***1.174***	***0.502***	***2.341***	***0.019***
Pedestrian Age<=20	0.129	0.489	0.264	0.792
Standing Location: Street	***1.273***	***0.578***	***2.204***	***0.028***
Pedestrian Assertiveness: Yes	***0.817***	***0.421***	***1.942***	***0.052***
Group Size=1	0.038	0.411	0.094	0.925
Driver Gender: Male	-0.055	0.355	-0.156	0.876
Driver Race: White	0.485	0.383	1.266	0.205
Driver Age<=20	0.090	0.356	0.252	0.801
Location-specific variables				
Crosswalk 2 Marked: Yes	1.038	0.699	1.484	0.138
Crosswalk Sign	0.086	1.322	0.065	0.948
NS Bus	2.330	1.900	1.226	0.220
Right Turn Lane	-0.299	1.544	-0.194	0.846
Land Use: Commercial	-1.058	1.205	-0.878	0.380
Crash Site:Yes	***-2.030***	***0.572***	***-3.549***	***0.000***
AADT	-0.00016	9.44E-05	-1.653	0.098
Crossing Dist.	***-0.322***	***0.100***	***-3.229***	***0.001***
Parking Distance	-0.002	0.004	-0.413	0.680
Signal distance Difference	***-0.002***	***0.001***	***-2.428***	***0.015***
Distance from Lake	0.324	0.295	1.097	0.273

[Note: Variables significant at 95% C.I. are presented in Bold and Italic font.]

Table 18: Model performance for Model 4

Null deviance	325.85 on 363 degrees of freedom
Residual deviance	236.54 on 335 degrees of freedom
AIC	**278.54**

In model 4, still many behavior and location specific variables are not statistically significant in confidence interval of 95%. More exploration on this model is needed to improve the performance of the model and make more variables significant at 90% and 95% confidence interval. Therefore, the stepwise method will be used in the next model. But before that, the interaction effect of some independent variables need to be explored.

Exploration of Variable Interaction Effect (Race and Gender)

To explore the effect of racial interaction on driver yielding behavior, the observation-level interaction term was included in the regression model. In similar way, the intersection-level racial interaction also need to be explored. To do that, two new explanatory variables were created: "***Dominating Pedestrian Rac***e" and "***Dominating Driver Race***" at intersection level. To test whether there will be a multi-collinearity issue by incorporating both observation level pedestrian and, driver race and intersection-level racial interaction, Variance Inflation Factor (VIF) was conducted. The VIF result output (***VIF= 2588.6 >10***) shows that incorporating both individual level racial variable and intersection level racial interaction will create serious multi-collinearity issue in the model. To avoid multi-collinearity, separate models were explored for individual and intersection level racial interaction.

Table 19: Variable Interaction Effect (Race and Gender)

Coefficients	Estimate	Std. Error	Z-value	Pr(>|z|)
(Intercept)	14.109	5.318	2.653	0.008
Pedestrian Gender: Male	0.470	0.381	1.233	0.218
Pedestrian Age<=20	0.128	0.489	0.263	0.793
Standing Location: Street	1.275	0.579	2.203	0.028
Pedestrian Assertiveness: Yes	0.820	0.421	1.945	0.052
Group Size=1	0.038	0.411	0.091	0.927
Driver Gender: Male	-0.056	0.356	-0.159	0.874
Driver Age<=20	0.084	0.361	0.231	0.817
Pedestrian Race: White	***1.137***	***0.625***	***1.820***	***0.069***
Driver Race: White	***0.456***	***0.478***	***0.954***	***0.340***
Crosswalk 2 Marked: Yes	1.050	0.711	1.477	0.140
Crosswalk Sign	0.071	1.331	0.053	0.957
NS Bus	2.317	1.905	1.216	0.224
Right Turn Lane (Z4)	-0.285	1.551	-0.184	0.854
Land Use: Commercial	-1.057	1.206	-0.876	0.381
Crash Site:Yes	-2.024	0.575	-3.519	0.0004
AADT	-0.00016	9.45E-05	-1.646	0.099674
Crossing Dist.	-0.322	0.100	-3.231	0.001
Parking Distance	-0.002	0.004	-0.408	0.683
Signal distance Difference	-0.002	0.001	-2.427	0.015
Distance from Lake	0.326	0.296	1.101	0.271
Race Interaction	***0.079***	***0.804***	***0.099***	***0.921***

The race interaction at individual observation level is not statistically significant at 95% confidence interval. Similar exploration was also conducted for intersection-level race interaction. But the racial interaction at intersection-level also do not have any statistically significant association with driver yielding behavior although it is against the previous hypothesis.

Similar exploration was also conducted to explore the interaction between pedestrian and driver gender at observation level. But similar to variable level statistical significance, the gender interaction was also found statistically insignificant to predict driver yielding behavior.

Stepwise Variable Selection Model

The model selection algorithm determine which variables significantly improve model fit. For final model development, one variable selection procedure was conducted using ***Stepwise variable selection***. Stepwise variable selection procedure is a well-known and widely used variable selection procedure and regression and generalized regression analysis. A stepwise variable selection procedure was also implemented along with variable selection using random forest to validate the output of random forest. In stepwise variable selection procedure, most significant variables were selected based on overall model performance. The stepwise variable selection output is provided below:

Table 20: Stepwise Variable Selection

Variable	**Df**	**Deviance**	**AIC**
Intercept		240.19	264.19
Land Use: Commercial	1	243.01	265.01
Distance from Lake	1	243.51	265.51
Crosswalk 2 Marked: Yes	1	244.29	266.29
Pedestrian Assertiveness: Yes	1	244.31	266.31
Standing Location: Street	1	245.99	267.99
Pedestrian Race: White	1	248.23	270.23
AADT	1	248.75	270.75
NS Bus	1	251.31	273.31
Signal distance Difference	1	254.01	276.01
Crash Site: Yes	1	257.95	279.95
Crossing Dist.	1	264.35	286.35

Based on both variable selection output, the following variables were selected for final model development:

Behavior Specific Variable: Pedestrian Race: White, Standing Location: Street, Pedestrian Assertiveness: Yes,

Location Specific Variable: Crosswalk 2 Marked: Yes, NS Bus, Land Use: Commercial, Crash Site: Yes, AADT, Crossing Dist, Signal Distance Difference, Distance from Lake,

Using selected variables, final model was developed. The final model parameter estimates are provided below:

Based on final model output, Parking distance and Driver Race: White variables were excluded from the final model. An updated final model parameter estimates are provided below:

Table 21: Behavior specific and location specific (model 5)

Coefficients	**Estimate**	**Std. Error**	**Z-value**	**Pr(>|z|)**
(Intercept)	16.803	4.521	3.717	0.000
Behavior-specific Variable				
Ped_Race_White	1.289	0.459	2.810	0.005
Standing_Street	1.248	0.559	2.234	0.025
Assertive	0.800	0.400	2.000	0.045
Location-specific Variable				
Crosswalk_2	1.177	0.613	1.921	0.055
NS_Bus	2.174	0.703	3.092	0.002
LU_Comm	-1.154	0.706	-1.635	0.102
Crashes.non.crash	-2.051	0.533	-3.850	0.000
AADT	-0.00017	6.1E-05	-2.841	0.005
Crossing_Dist	-0.361	0.086	-4.208	2.57E-05
Sig_Dist_Diff	-0.002	0.001	-3.398	0.001
Distance_Lake	0.312	0.174	1.8	0.072

Table 22: Model performance for model 5

Null deviance	325.85 on 363 degrees of freedom
Residual deviance	240.20 on 335 degrees of freedom
AIC	**264.2**

6-3- Models Comparison

The null/ residual deviances and AIC are the measures of goodness of fit of a model. Higher numbers always indicates bad fit. Table (23) indicates the overall comparison of all models. Model 1 and 3 were rejected due to the logic explanations that discussed before. In model 2, the additional of 28 (363 -335) independent variables decreased the deviance from 325.85 to 264.2; a significant reduction in deviance. The residual deviance reduced by 89 (325.85-264.2) with a loss of 10 degrees of freedom. In model 4, it decreases by 98.46 with a loss of 28 degrees of freedom and in model 5, by 95 with a loss of 28 degrees of freedom. By the comparison of the residual deviances of the models, model 4 appears to be the best fit. However, with the comparison of the AIC of the models, model 5 has the least value of AIC compared with other models. The AIC of the model 5 is almost 14 units less than the model 4's while its residual deviance is almost 4 units more than the model 4. Overall, with the comparison of the residual deviances and AICs, we can conclude that model 5 is the best model to analyze the research's data.

Table 23: Comparison of the models

	Model description	**Model situation**	**Null deviance**	**Residual deviance**	**AIC**
Model 1	Model with behavior-specific variables and location ID	Rejected	325.85 on 363 degrees of freedom	216.38 on 335 degrees of freedom	**274.38**
Model 2	Random Effect Logistic regression with random effect for each location ID	Accepted but incomplete	353 on 363 degrees of freedom	264.2 on 353 degrees of freedom	**286.2**
Model 3		Rejected			
Model 4	General behavior-specific variable, location-specific variable	Accepted	325.85 on 363 degrees of freedom	236.54 on 335 degrees of freedom	**278.54**
Model 5	behavior-specific variable, location-specific variable	Accepted	325.85 on 363 degrees of freedom	240 on 335 degrees of freedom	**264**

7. CONCLUSION

7-1- Final Model

In the final model (model 5), the pedestrians' race, standing location and assertiveness are statically significant at the confidence interval of 95% (p value <0.05). Thus, we can conclude that drivers tend to yield to pedestrians who are classified as an ethnicity of white and are assertive, and standing on the street to cross. Among all behavior-specific variables, pedestrian race with the estimate of 1.289 and z value of 2.81 is the most correlated variable with the driver yielding decision.

Among all location-specific variables, the nearside bus stop, crash site, AADT, crossing distance and signal distance difference are statically significant at the confidence interval of 95%. At the confidence interval of 90%, the crosswalk_2 marked, land use (commercial) and distance from lake are statistically significant with the p value of less than 10%. According to the p- values of the location-specific variables, the crossing distance is the most correlated factor with the driver yielding behavior.

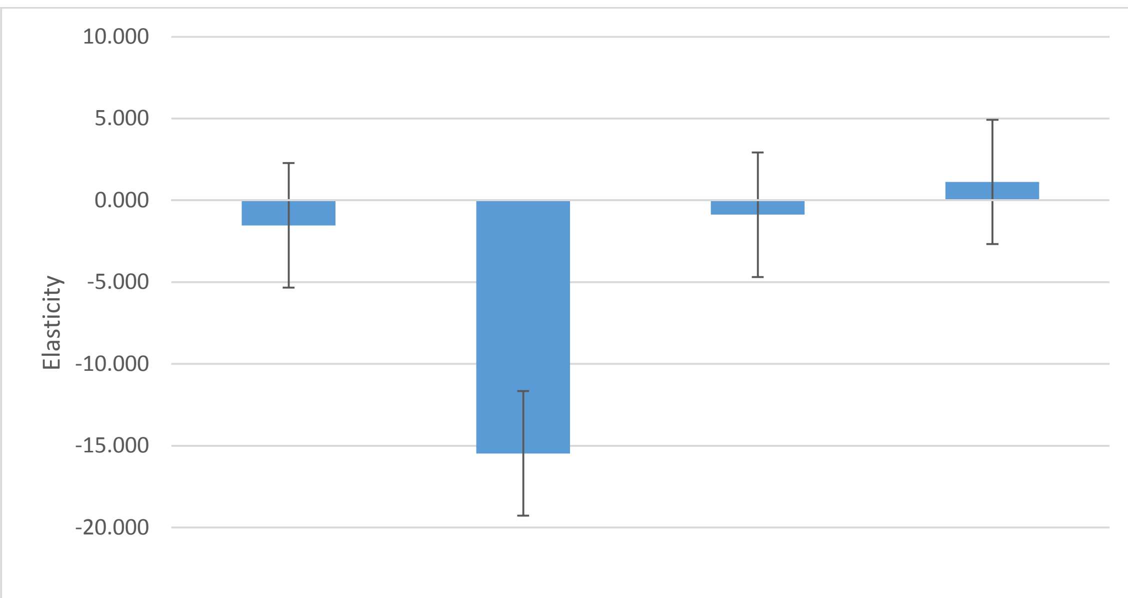
7-2- Elasticity and Pseudo Elasticity

To better illustrate the correlation between explanatory variables with the driver yielding factor, the elasticity for continuous variables and pseudo elasticity for categorical variables are used. Figure (12) shows the elasticity of driver yielding behavior on each continuous variable. As it appears, 1% increase in the expected frequency of AADT would reduce driver yielding by 1.53%. It means, as the traffic volume on a road is higher, drivers less likely yield to a pedestrian waiting to cross.

The great change in driver yielding caused by 1% change in crossing distance. In fact, 1% increase in crossing distance would reduce driver yielding by 15.4%. Respectively, 1% increase in the distance difference between the downstream and the upstream signalized intersections to the uncontrolled intersection would reduce driver yielding by 0.88%. That is because when this distance gets longer, drivers less likely brake and reduce speed for a pedestrian waiting to cross at uncontrolled intersection.

The distance from lake is the only continuous variable that with 1% increase, the driver yielding decision also increase by 1.129%.

Figure 12: Elasticity of the continuous contributing factors



	AADT	Crossing_Dist	Sig_Diff	Distance_Lake
Elasticity	-1.530	-15.469	-0.881	1.129

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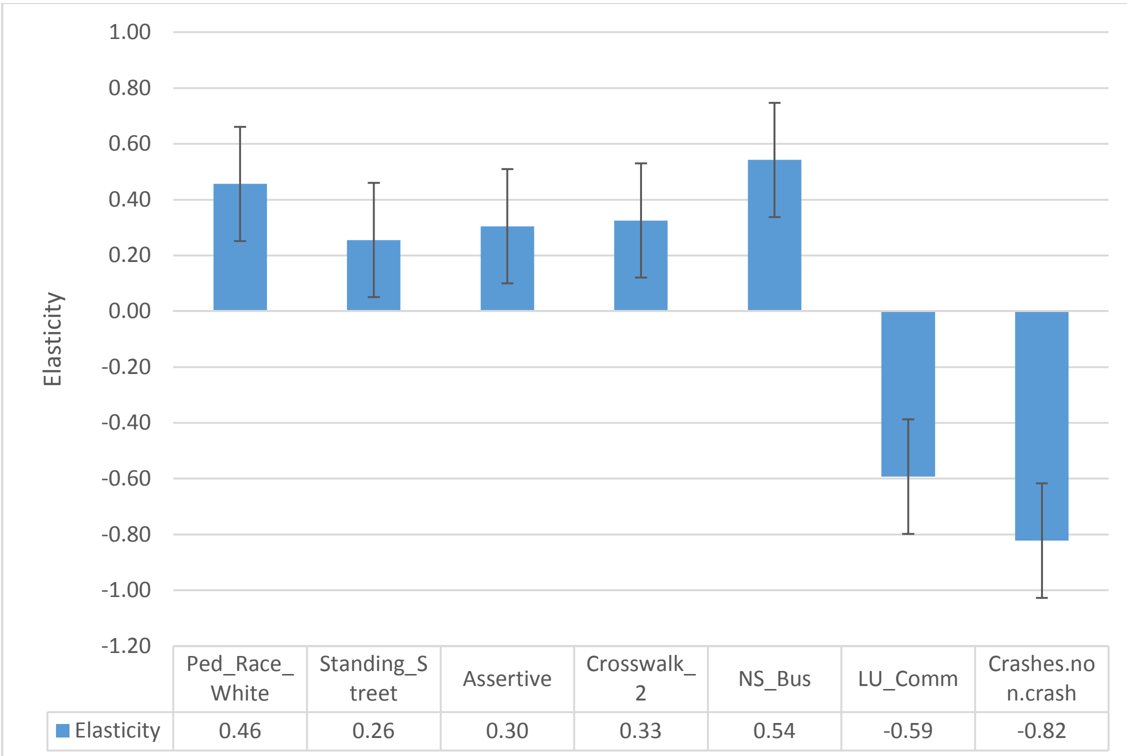
Figure (13) indicates the pseudo elasticity of the categorical variables. It is used to examine the change in estimated likelihood of driver yielding when any of the independent variable exists. According to the figure above, the presence of nearside bus stop has the most positive impact on driver yielding decision. It means that if a nearside bus stop exists at the intersection, the probability of driver yielding would increase by 0.9%.

The presence of other explanatory variables including pedestrian with an ethnicity of white, pedestrian standing in street, assertiveness, and crosswalk_2 marked would increase the likelihood of driver yielding decision by 0.46%, 0.26%, 0.30% and 0.33% respectively.

On the contrary, if the intersection has had a crash and locates in commercial district, the probability of driver yielding would be reduced by 0.82% and 0.59% respectively. Obviously in commercial district because the pedestrian volume on street is usually higher, drivers tend to drive slower; so, the chance of yielding would be higher. However, in this study with the presence of commercial area surrounding the intersection, the driver yielding would decrease.

Figure 13: Pseudo elasticity of the categorical contributing factors



From the elasticity result of the yielding behavior for categorical variables, I can conclude that driver yielding compliance at crosswalk to pedestrian right of way is more when a nearside bus stops exists and both crosswalks are marked. Moreover, drivers tend to yield to pedestrians with an ethnicity of white and who are assertive and standing in the streets to cross. On the contrary, drivers less likely yield when the surrounding land use is commercial and the sites have had a pedestrian-vehicle crashes before.

7-3- Recommendation

To improve driver yielding behaviors at uncontrolled intersections, five E approaches including engineering, enforcement, education, encouragement, evaluation are recommended (PBIC, 1999). Engineering treatments strategy is effective in a shorter period of time while education and enforcement become more effective over time.

Engineering Treatments

1. **To Increase Crosswalk Visibility**

- Crosswalk marking: Motorists most likely fail to yield to pedestrians at unmarked crossings, but, marked crosswalks warn motorists to expect pedestrian crossings and indicate the preferred crossing locations for pedestrians. Ideally, crosswalks should be used in conjunction with other measure such as curb extensions, to improve a pedestrian safety particularly with AADT above 10,000.
- Surface treatment: Designing streets surface with materials such as color bricks to enhance the visibility of the crosswalks as well as create an aesthetic environment.

2. **To Increase Pedestrian Visibility To Driver And Vice Versa**

- Parking restriction at intersections that provides a clearer view of oncoming vehicles for a pedestrian waiting to cross
- Roadway lighting upgrade: Proper street lighting illuminates pedestrian crosswalks and reduces glare to motorists. It can also enhance commercial districts and improve nighttime security.

3. **To Reduce Pedestrian Crossing Distance At Crosswalk**

- Crossing Island: Using crossing islands indicate that pedestrian-vehicle incidents decrease by 46 percent at marked crossings, and by 39 percent at unmarked crossings. The factors contributing to pedestrian safety include reduced conflicts, reduced vehicle speeds approaching the island, greater attention to the existence of a pedestrian crossing, opportunities for additional signs in the middle of the road, and reduced exposure time for pedestrians.
- Chocker or curb extension*:* Curb extensions improve pedestrians safeties because they increase visibility, reduce speed of turning vehicles, encourage pedestrians to cross at designated locations, shorten the crossing distance, and prevent vehicles from parking close to intersections
- Traffic lane narrowing and reduction (road diet): Narrowing lanes or reducing the number of lanes on a multilane roadway can improve safety and comfort for bicyclist and pedestrians.

4. **To Warn Drivers About Approaching To Crosswalk Especially On Streets With High AADT And Streets Having Large Distance From Upstream And Downstream Signalized Intersections**

- Enhanced signage for pedestrian crossing at and in advance of crosswalk: The visibility of the crosswalk to drivers can be further enhanced through the use of high-visibility crosswalk striping, flashing beacons, and/or signage. Raised crosswalks may also be used to force motorists to slow down.
- Traffic sign: Traffic signs including yield and stop signs in major streets at uncontrolled intersections reduce the likelihood of incidents.

- Speed hump/table: Speed humps are vertical traffic control measure which are usually three to four inches high at their center. Such vertical measures tend to have the most predictable speed reduction impacts. Speed tables can also enhance the pedestrian environment at pedestrian crossings.
- Pedestrian signal: Using advance yield markings at uncontrolled intersections can be particularly useful when combined with signs and beacons, such as the Pedestrian Hybrid Beacon or rectangular rapid flash beacon (RRFB). Traffic signals such as countdown pedestrian signals and upgrading pedestrian signal timing to meet the new 3.5ft/s walking speed required in the FHWA's Manual on Uniform Traffic Control Devices.

5. Warn Driver To Slow Down When A Bus Stops At Nearside Of An Intersection

Pedestrians crossing an intersection in front of a near-side bus stop are not as visible to drivers approaching the intersection from behind the bus. They may also risk being hit by the bus itself. The sight lines between pedestrians and approaching vehicles are blocked by the stopped bus. There is also increased potential for conflict between pedestrians crossing in front of a bus as pedestrians may not be clearly visible to a bus driver pulling out of the stop. Therefore, there are some strategies to improve pedestrian safety if a nearside bus stop exists.

- Bus bulb out: Bus bulb outs can also have positive traffic calming impacts by narrowing the roadway, particularly at intersections, it can be designed with smaller curb radii that force right-turning vehicles to reduce speed. Bulb outs also make pedestrians who are about to enter the crosswalk more visible to approaching traffic by putting them out beyond objects such as parked cars or street trees, which may obstruct driver visibility.

- Advance stop lines/ Yield marking***:*** An advance stop or yield line placed 20 to 50 feet ahead of the crosswalk can highly reduce the probability of a multiple-threat crash at un-signalized crossings.

6. Reduce Driver Speed In Commercial Areas

- Landscaping: Landscaping can calm traffic by creating a visual narrowing of the roadway. It can also improve the aesthetic of a commercial district or residential neighborhood.

Figure (14) is an example of a protected intersection by applying the appropriate crossing, traffic calming and landscaping elements.

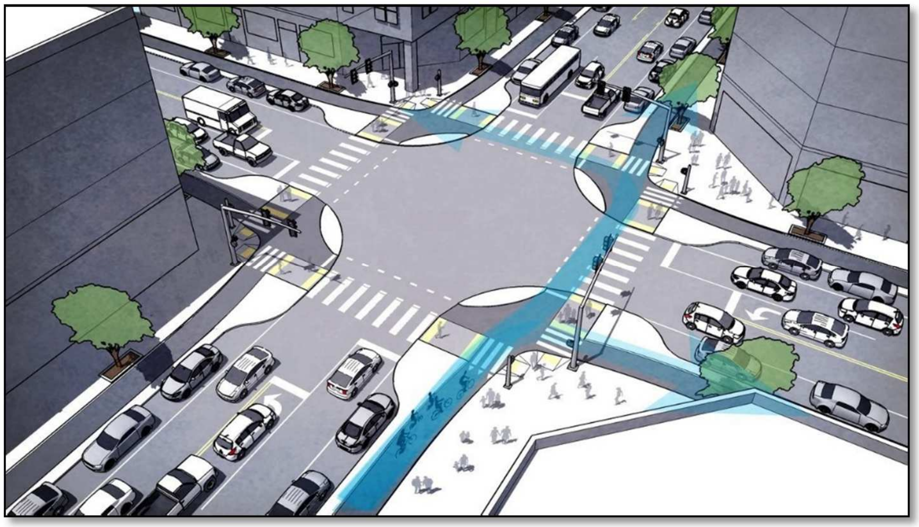


Figure 14: A protected intersection *(Falbo, 2014)*

Education and Enforcement

In addition to improving the road planning and design, behavior change should also be a goal of many organizations. Law enforcement agencies, school officials, or injury prevention group may also seek to improve safety behaviors, to help reduce the role that behaviors play in contributing to crashes. Law enforcement, education and encouragement programs are the key elements of the agencies effort to change the drivers' behaviors.

Roadway safety is a shared responsibility for pedestrians and drivers; so, they both should comply with the rules of the road. Law enforcement agencies are responsible for setting policies, raising awareness about safety issues; influencing behaviors and social norms; and reinforcing and supporting educational and engineering programs and strategies. The strategies should always answer and address a few items including:

- What communities can do to enforce laws?
- What police can do to enforce laws?
- Reviewing and modifying pedestrian laws
- Working with law enforcement officers
- Developing procedures to handle violators
- Implementing enforcement campaigns
- Aiming enforcement at motorists
- Media's role in enforcement (PBIC, 1999).

State and local agencies should provide a starting point for understanding the role of law enforcement through a pre-designed high visibility enforcement program.

As part of the focus on enhancing traffic safety and reducing fatal crashes at the assigned locations, High Visibility Enforcement pilot program is also recommended. HVE combines highly visible and proactive law-enforcement strategies to target the violated drivers not yielding to the pedestrian right of way at crosswalks. It offers law enforcement agencies a proven alternative for preventing many of the unsafe driving practices that passenger and drivers engage in on roads. By targeting passenger and drivers, they raise everyone's awareness of the joint responsibility that we all have to drive carefully and share the road safely.

Similar to Van Houten et al study, a program of high visibility enforcement of pedestrian yield right-of-way can be conducted in four waves in February, May, July and November supported by radio ads, media, public outreach to schools and communities, street signage, and feedback signs. The Pedestrian Safety Program can be coordinated between the police department and the University of Wisconsin-Milwaukee. During the implication of the programs in the four waves, officers would report the citations and warnings for failure to yield right-of-way to pedestrians. Officers should issue only one warning except to violators, along with flyers that explained the law and announce future enforcement efforts. The "Pedestrian Law Enforcement Operation" sandwich boards can be used upstream and downstream of each intersection to increase passing motorists' awareness of the program at the time of the enforcement.

The police department can prepare and run radio ads and prepare flyers that explained the Milwaukee's law, proper yielding behavior of drivers, proper crossing behaviors of pedestrians and ask drivers to be follow the rule for the safety of themselves and pedestrians. The University of Wisconsin-Milwaukee can run information in the school newspaper and on the university's website. The university's website displays the feedback signs and the yielding percentage of the past week and the record to date along high traffic roads.

Encouragement

Encouragement activities play an important role in moving the program forward because they build interest and enthusiasm which require time and resources. Encouragement is one of the complementary strategies that safe routes to school programs use to increase the number of children who walk and bicycle to school safely (Insight, 2015). In particular, encouragement and education strategies are closely intertwined. They are working together to promote walking and bicycling by rewarding participation and educating children and adults about safety and the benefits of bicycling and walking. Special events, mileage clubs, ongoing activities all provide ways for people to discover, know more and do a lot of fun.

Evaluation

We can combine engineering, encouragement, enforcement and education strategies to address certain challenges such as pedestrian fatalities issues at uncontrolled intersections. It's used to determine if the aims of the strategies are being met and ensures that safety resources are used to meet a sustainable environment. Benefits of evaluation include (Insight, 2015):

- Setting reasonable expectations about what your program can do
- Determines if the safety program is creating the desired results
- Identifies changes that will improve your program

7-4- Limitation

A few challenges and limitations exist for this research as discussed in following.

This study is focused exclusively on uncontrolled pedestrian crossings of arterial and collector roadways that have speed limits of 25 to 30 mph. Therefore, this research was done on a specific and limited set of locations.

Despite my expectation, a few independent variables got opposite sign in relation to the driver yielding behavior. As an example, it was expected that by increase of the distance from lake, the driver yielding decision decreases. However, the result showed the opposite relationship. The reason could be due to some proxy for neighborhood socioeconomic characteristics or neighborhood social norms that can be explored more in the future research. The specific variables at the census tract or block group level from the American Community Survey may be used for the purpose of this work in the future.

It is worthwhile noting that pedestrian crossing volume is a potentially important variable which I did not consider in this study. The reason that I did not consider pedestrian volume in this study is because some intersections were located in the quite residential areas, where a few pedestrians were crossing the intersection; therefore, some extra tests were done by my team to collect sufficient data for those intersections. Future studies could capture this by doing longer counts at more times of day. Pedestrian volume variable will also help justify the relationship between the existences of commercial area surrounding the uncontrolled intersection with driver yielding decision.

Due to lack of time for this research, some pedestrian safety treatments were only recommended. These strategies have a possibility to be investigated more and be implementable in near future.

7-5- Future Work

It appears that vehicles make a decision whether or not to yield for a pedestrian based on some factors. Sometimes, if a pedestrian is not assertive and stands in a driver's visibility area then the vehicle reaches a decision to stop or not by weighing their own benefit costs (Harrell, W A, 1993). The costs of a vehicle to stop or not can only be subject to speculation but would include such considerations as extra gas consumption, a delay to reach the destination, risk of getting hit from rear- end, being pushed to not to yield because of following cars having high speed, risk of hitting a pedestrian and injuries,..etc. Potential benefits of stopping for a pedestrian can be avoiding a ticket for failing to yield to a pedestrian, or helping a pedestrian cross the street. So the impact of the various pedestrian features can be examined for driver yielding behaviors and also for outlying the benefit-cost analysis. The future work of this research is to identify new contributing factors on driver's yielding behaviors.

In this research, I showed that among all behavioral characteristics of pedestrians, assertiveness is a highly correlated factor with the driver yielding behaviors. Since, no study has been done in this area, the measure of pedestrian and driver assertiveness as well as their interaction at uncontrolled intersections are the potential future work for this research. Specific methods will be identified and used to evaluate the level of assertiveness of pedestrians and drivers at uncontrolled intersections.

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APPENDICES

Appendix A:

Sheet 1: Intersection Characteristics

- Time: List the time of day when data collection starts and ends. All observations should be made during daylight hours.
- Traffic volume: Record the annualized average daily traffic volume (AADT) for the main roadway. See https://trust.dot.state.wi.us/roadrunner/ for data.
- Two-way street: Record whether or not the street is one-way or two-way. This particular study considers only two way roads.
- Marked or un-marked Crosswalk: Record whether the crosswalk is marked or unmarked. A marked crosswalk is designated by visible lines (either paint or thermoplastic). Unmarked crosswalks are the extension of a sidewalk through the intersection but are not designated by visible lines.
- Crosswalk crossing distance (feet): Record the crosswalk crossing distance. This is defined as the shortest distance from the curb on one side of the street to the curb on the other side of the street within the crosswalk. Depending on the number and width of travel lanes, crosswalk width might be longer or shorter.
- Crosswalk sign at the intersection (Type): Record all types of crosswalk signs at the intersection. These signs may include the standard crosswalk sign (yellow diamond warning sign at crosswalk), in-street "State Law: yield to pedestrians" signs on the roadway centerline, or pedestrian crosswalk overhead signs.

- Crosswalk sign in advance of the intersection (Y/N): Record whether or not there is an advance warning sign for the crosswalk. This type of sign may simply be a yellow warning sign with a pedestrian figure or may say “Pedestrian Crosswalk Ahead.”
- Bump out (Y/N): Record whether or not there is a bump out (curb extension) on the side of the intersection where pedestrians will be entering the crosswalk.
- Number of travel lanes being crossed: Record the number of travel lanes being crossed at the study crosswalk. Travel lanes include all general purpose travel lanes as well as left- and right-turn lanes. Bicycle lanes should not be treated as travel lanes. Parking lanes should not be treated as travel lanes (unless there is a peak hour parking restriction and there is moving traffic in the parking lane at the time of study).
- On-street parking (Y/N): Record whether or not there is on-street parking on the side of the street adjacent to the direction of vehicle approaching the crosswalk. Note that there might not be on street parking at certain time of a day. If cars park too close to the intersection, they may block drivers’ views of pedestrians entering the crosswalk.
- Distance from the last car parked from the intersection (feet): Record the distance from the edge of the intersection to the closest car parked on the street in advance of the crossing (in the direction from where the study vehicles are coming from). Based on Wisconsin law, the minimum distance from the last car parked from the intersection should be 15 feet.
- Nearside bus stop near the intersection (Y/N): Record whether or not the intersection has a bus stop on the near side (in the direction of the approaching study vehicles). Busses stopped on the near side of an intersection may block drivers’ views of pedestrians crossing.

- Farside bus stop near the intersection (Y/N): Record whether or not the intersection has a bus stop on the far side (in the direction of the approaching study vehicles).
- Right-turn lane in the direction of the traffic at the intersection (Y/N): Record whether or not there is a designated right-turn lane in the direction of the approaching study vehicles.
- Left-turn lane in the intersection of traffic at the intersection (Y/N): Record whether or not there is a designated left-turn lane in the direction of the approaching study vehicles.
- Curb extension in the direction of the pedestrian crossing (Y/N): Record whether or not there is a curb extension on the side of the roadway where the study pedestrians are entering the crosswalk.
- Median in the direction of the pedestrian crossing (Y/N): Record whether or not there is a median in the specific crosswalk being studied.
- Speed limit in the direction of the traffic being studied (miles per hour): Record the speed limit in the direction of approaching study vehicles. All case studies should have similar speed limit. This measurement item is important, since based on the drivers' speed, they can find out the suitable distance for yielding to pedestrians.
- School zone or specific land use: Use the space provided to record the presence of any school, business or specific land use near the intersection.
- Signal difference: The maximum and minimum distance from each un-signalized intersection to the next signalized intersection on a major street are measured in Google Map. The difference between maximum and minimum distances are named signal difference.

- Distance from lake: The linear distance from a benchmark (Atwater Park) locates in upper east side of the city to each un-signalized intersection location. The distances are measured in Google Map.

Note: Data collectors should always take a picture of the crosswalk to help illustrate these characteristics when they first arrive at the intersection.

General Information for Sheets 2 and 3

General information should be provided at the top of Sheets 2 and 3. This includes the name of observer, intersection location, travel characteristics, and environmental characteristics.

- Name of observer: ………………………..
- Intersection location: Major roadway …….. Minor roadway……….
- Crosswalk leg (e.g., North, South, East, West)
- Vehicle travel direction (e.g., Southbound/Northbound)
- Posted speed limit in direction of travel (mph)
- Pedestrian travel direction (e.g., Eastbound/Westbound)
- Location of observer at intersection (Observers can stand in any safe place at intersections where can have a good view to pedestrians crossing and drivers yielding)
- Time period of data collection: Start time …………… End time …………
- Day of week: ……………………
- Date (e.g., 6/27/16): ……………..
- Weather (e.g., sunny, partly, cloudy, rainy, snowy): …………………………
- Temperature (F): ………………….

To collect the data for drivers' characteristics, 2 observers are needed at the same time. One observer for recording the physical characteristics of drivers and another observer for recording the data related to cars yield. Unless otherwise sheet 2 and sheet 3 should be filled out in two different days.

Sheet 2: Pedestrian Behavior and Demographic Characteristics

- Pedestrian direction: Record the direction that the pedestrian is crossing the street (e.g., northbound/southbound). This direction should be perpendicular to the driver's direction of travel (e.g., eastbound/westbound).
- Crosswalk location: Record the location of the crosswalk in which the pedestrian is crossing (e.g., east or west; north or south). Do not record pedestrians who start crossing outside of the crosswalk, but you may record pedestrians if they go outside of the crosswalk lines near the end of their crossing.
- Time: Record the time that the pedestrian enters the crosswalk to the closest ten seconds (e.g., 4:32:10 pm). Note that the time stamp allows the pedestrian characteristics to be matched with the driver characteristics.
- Yielding opportunity (Y/N): Record whether or not there is a car approaching with an opportunity to yield to the pedestrian. If there is, record "Yes". If there is not, record "No". In both cases, record all other relevant data fields. An approaching driver is defined as having an opportunity to yield to the pedestrian at the crosswalk if he or she is a minimum distance away from the crosswalk when the pedestrian arrives at the curb. This definition is slightly different than state law, which requires drivers to yield the right

of way to a pedestrian once he or she has put at least one foot in the crosswalk. The method described by Van Houten et al. (2013) is used to calculate safe stopping distance. Based on a driver reaction time of 2.5 seconds, the posted speed limit in feet per second, and a conservative deceleration rate of 11.2 feet per second, the safe stopping distance for vehicles traveling at 30 mph on a flat grade is 196 feet.

- Gender (Female/Male): Estimate the gender of the pedestrian. People of different genders might be yielded to at different rates.
- Race (Black/White/Latino/Asian/Other): Estimate the race of the pedestrian. People with different racial appearances might be yielded to at different rates.
- Age: Estimate the general age category of the driver to the closest five years or decade (<20, 20s, 30s, 40s, 50s, 60s, 70s, 80s, 90s).
- Physical disability (wheelchair/walker/other): Record if the pedestrian has a physical disability.
- Standing location (On the Curb/In the Street/On Median or Centerline): Record whether the pedestrian is standing on the curb, in the street (has at least one foot in the crosswalk), or on the median or centerline of the street. By standing on the street, pedestrians may make themselves more visible and may help oblige drivers to yield.
- Assertive stance (Y/N): Pedestrian assertiveness should be recorded as Yes when one or more of three characteristics is observed: 1) the pedestrian actively leans toward the opposite side of the roadway when in the crosswalk or 2) the pedestrian directs his or her eyes toward approaching drivers for more than 3 seconds, or 3) the pedestrian points his or her arms or fingers toward the crosswalk.

- Group size (number of pedestrians waiting to cross at the same time): Record the group size. This is defined as the total number of pedestrians waiting to cross at one time, as long as at least one person in the group is intending to enter the crosswalk. If additional pedestrians arrive after the initial pedestrian or group sets foot into the crosswalk, make a note of this on the data collection sheet. Drivers may be more likely to yield for a group of people waiting to cross rather than for a single pedestrian.
- Waiting time to cross (less than 10 sec/ more than 10 sec): Record whether the pedestrian needed to wait less than 10 seconds or more than 10 seconds before they were able to cross the street. This may depend on whether or not drivers yield as well as traffic volumes.
- Number of cars that drove through crosswalk without yielding (Total): Record the total number of vehicles that passed through the crosswalk without yielding before the pedestrian crossed.
- Driver yielded (Y/N): Record whether or not a driver yielded to the pedestrian when he or she crossed. It is possible that the pedestrian simply crossed when there was a gap in traffic. In that case, mark No.

Sheet 3: Driver Yielding Behavior and Demographic Characteristics

- Driver direction: Record the driver's direction of travel (e.g., eastbound/westbound). This direction should be perpendicular to the direction that the pedestrian is crossing the street (e.g., northbound/southbound).
- Time: Record the time that the driver passes the point on the roadway where he or she has sufficient distance to stop for a pedestrian in the crosswalk (whether a pedestrian is

present or not) to the closest ten seconds (e.g., 4:32:10 pm). Note that the time stamp allows the driver characteristics to be matched with the pedestrian characteristics.

- Yielded to the pedestrian (Y/N): If a driver has the opportunity to yield but the driver does not yield, then the observer should record this item as “No”. If a driver stops to yield or slows visibly to allow the pedestrian sufficient time to cross the street, this item should be recorded as Yes. See yielding definition in the Sheet 2 description for more details about safe stopping distance.
- Number of pedestrians at curb or crosswalk waiting to cross: Record the number of pedestrians waiting together (regardless of whether they appear to know each other or not). Babies being carried by their parents count as separate individuals. Drivers might not yield for one pedestrian waiting to cross, but they compel to yield for a group of people willing to cross.
- Gender (Female/ Male): Estimate the gender of the driver. There may be differences in driver yielding between male and female drivers.
- Race (Black/White/Latino/Asian/other): Estimate the race of the driver. There may be differences in driver yielding by race, ethnicity, or culture.
- Age: Estimate the general age category of the driver to the closest five years or decade (20 ft/did not stop (slowed/rolled)). If the driver did not yield, do not record a measurement in this field.

University of Wisconsin-Milwaukee Driver Yielding Field Study
Sheet 2: Pedestrian Behavior and Demographic Characteristics

Name of observer: ....
Intersection location: Major Roadway .... Minor Roadways ....
Crosswalk leg (e.g., North, South, East, West): .... Vehicle travel direction (e.g., Southbound/Northbounad): ....
Posted speed limit in direction of travel: .... Pedestrian travel direction (e.g., Eastbound/Westbound): ....
Location of observer at intersection (e.g., Southeast/Southwest): ....
Time period of data collection: Start time .... End time ....
Day of week: .... Date: ....
Weather (e.g., sunny, partly cloudy, cloudy, rainy, snowy): .... Tempreture (F): ....

	Pedestrian Characteristics																								
	Ped direction	Crosswalk location	Time	Yielding opportunity	Gender		Race					Age	Physical disability			Standing location			Assertive?		Group	Waiting time to cross		# of cars	Driver
	(NB/SB/EB/WB)	(N/S/E/W)	Hr:Min:Sec	Yes/No	Female	Male	Black	White	Latino	Asian	Other	(Est.)	Weelchair	Walker	Other	On curb	In street	Median	Yes	No	Size	<10 sec	>10 sec	not yielding	Yielded (Y/N)
1																									
2																									
3																									
4																									
5																									
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28																									
29																									
30																									

University of Wisconsin-Milwaukee Driver Yielding Field Study
Sheet 3: Driver Yielding and Demographic Characteristics

Name of observer: ....
Intersection location: Major Roadway .... Minor Roadways ....
Crosswalk leg (e.g., North, South, East, West): .... Vehicle travel direction (e.g., Southbound/Northbounad): ....
Posted speed limit in direction of travel: .... Pedestrian travel direction (e.g., Eastbound/Westbound): ....
Location of observer at intersection (e.g., Southeast/Southwest): ....
Time period of data collection: Start time .... End time ....
Day of week: .... Date: ....
Weather (e.g., sunny, partly cloudy, cloudy, rainy, snowy): .... Tempreture (F): ....

								Driver Characteristics									
	Direction	Time (when ped arrives)	Yielded	#Peds waiting to	Gender	Race					Age	Where the car yielded					
	(NB/SB/EB/WB)	Hr:Min:Sec	Yes/No	cross	F/M	Black	White	Latino	Asian	Other	(Est.)	In XW	Within 5ft	5-10 ft	10-15 ft	>15ft	No stop (slowed/rolled)
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29																	
30																	

University of Wisconsin-Milwaukee Driver Yielding Field Study
Sheet 4: Overall Driver Demographic Characteristics

Name of observer: ....
Intersection location: Major Roadway .... Minor Roadways ....
Crosswalk leg (e.g., North, South, East, West): .... Vehicle travel direction (e.g., Southbound/Northbounad): ....
Posted speed limit in direction of travel: .... Pedestrian travel direction (e.g., Eastbound/Westbound): ....
Location of observer at intersection (e.g., Southeast/Southwest): ....
Time period of data collection: Start time .... End time ....
Day of week: .... Date: ....
Weather (e.g., sunny, partly cloudy, cloudy, rainy, snowy): .... Tempreture (F): ....

Driver Characteristics										
	Direction	Time (when ped arrives)	Gender	Race					Age	Speed
	NB/SB/EB/WB	Hr:Min:Sec	F/M	Black	White	Latino	Asian	Other	(Est.)	(Radar)
1										
2										
3										
4										
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Appendix B

Table Below shows the physical characteristics of each study and control intersection based on their ID. "1" means yes and "0" means no.

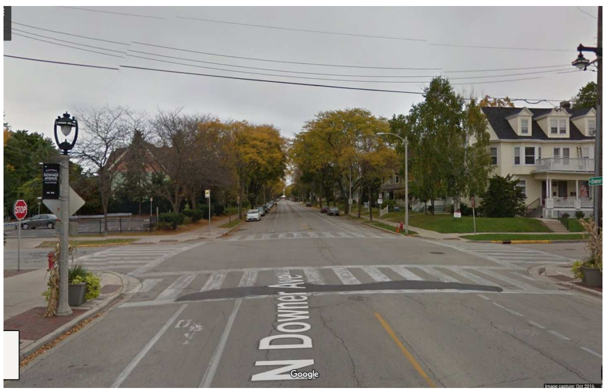
Location specific characteristics of the study locations based on their IDs

ID	Crosswalk marked _1 (Y/N)	Crosswalk marked _2 (Y/N)	Crosswalk crossing distance (feet)	Crosswalk sign at the intersection (Y/N)	Distance from the last car parked from the intersection	Nearside bus stop near the intersection (Y/N)	Right-turn lane at the intersection (Y/N)	Speed limit (miles per hour)	School zone or specific land use*
1	Y	Y	50	Y	30	Y	Y	30	1
2	Y	Y	51	Y	100	N	Y	30	2
3	Y	Y	35	Y	18	N	N	25	1
4	N	N	48	N	80	Y	Y	30	1
5	Y	N	50	N	25	N	N	30	1
6	N	N	35	N	90	N	N	30	3
7	Y	N	45	Y	300	N	N	30	3
8	Y	Y	50	N	500	Y	N	30	1
9	Y	Y	42	N	30	N	N	25	1
10	N	N	44	N	20	N	Y	30	1
11	Y	Y	52	N	200	Y	Y	30	1
12	Y	Y	44	N	30	N	N	30	1
13	Y	Y	51	Y	400	Y	N	30	1
14	Y	N	46	N	200	N	N	30	3
15	N	N	44	N	25	N	Y	30	3
16	Y	Y	42	N	25	N	N	25	1
17	N	N	48	N	200	Y	Y	30	3
18	Y	N	50	Y	400	N	Y	30	3
19	Y	Y	48	N	120	N	N	30	2
20	Y	Y	52	N	200	Y	Y	20	2

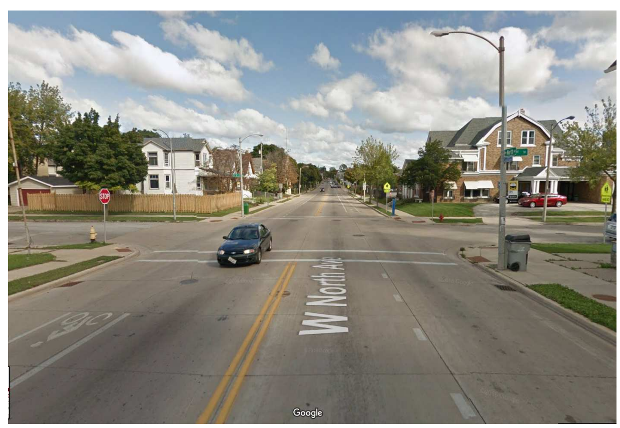
*Land use 1 = commercial, land use 2= school, land use 3= residential

Appendix C

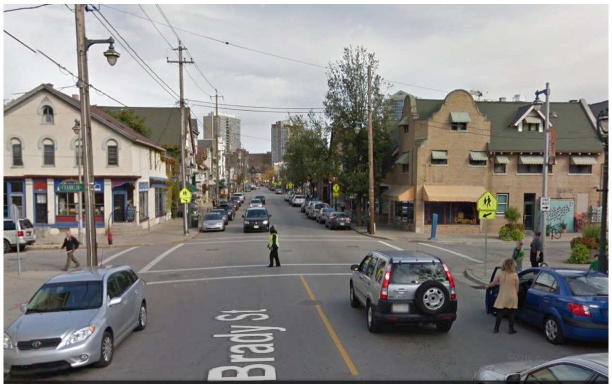
The pictures below indicate the current condition of study intersections vs. control intersections respectively from left to right. All pictures were taken from Google street view of Oct-2016.



E Downer Ave- Park Pl St. *E Downer Ave- Linnwood Ave*



E North Ave- Palmer St *W North Ave- 1st St*

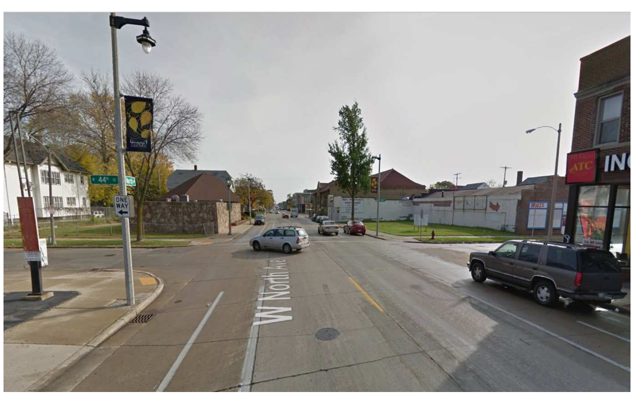


Brady St- Franklin St

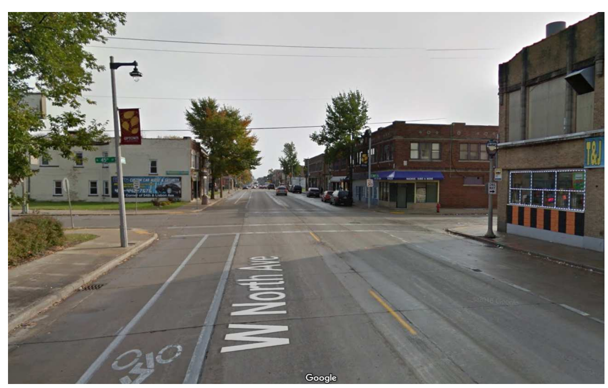
W Historical Mitchell St – 8^{th} St

W Center St- N 5th St

W Center St- *N 9^{th} St*



W North *Ave- N 44^{th} St*

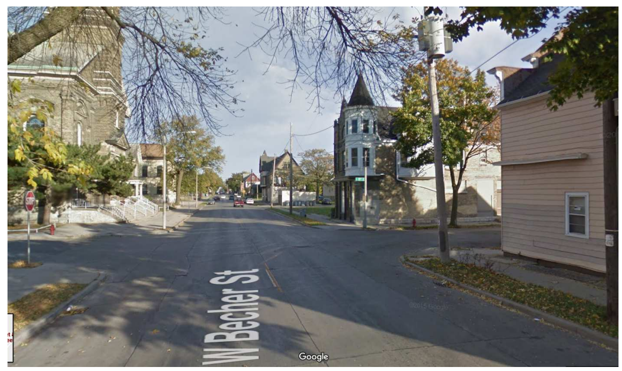


W North Ave- N 45^{th} St

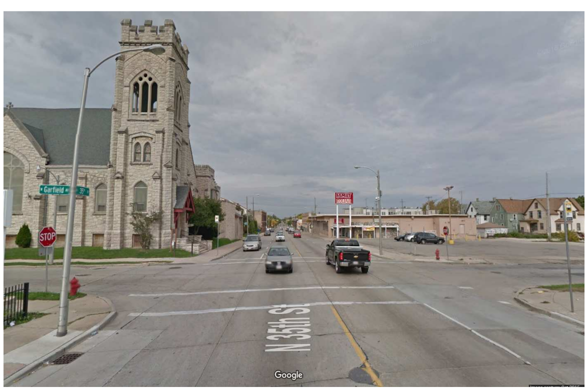
N 20th St- W Melvina St

20th St-W *Meinecke Ave*

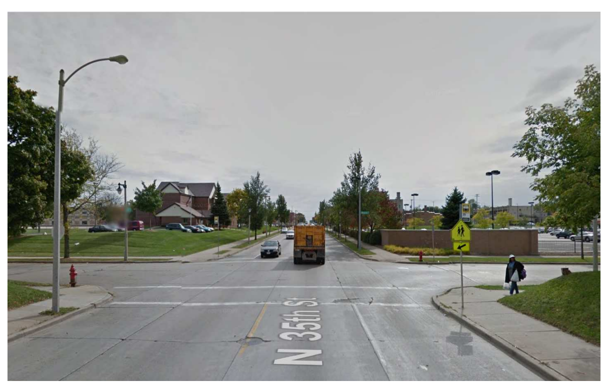
W Becher St- N 7th St



W Becher St- *S 15th St*

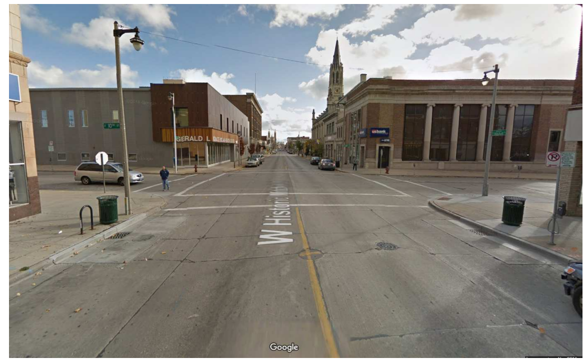


35th St-Garfield Ave

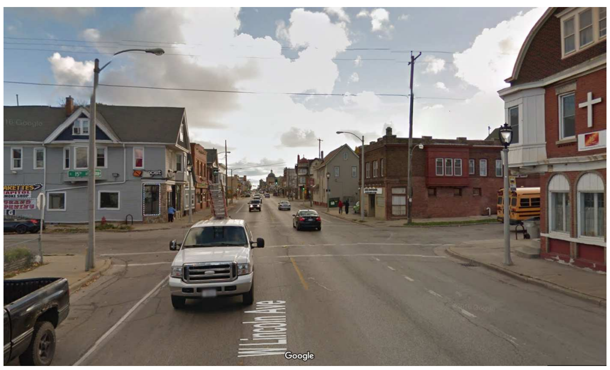


N 35th St-W Meinecke Ave

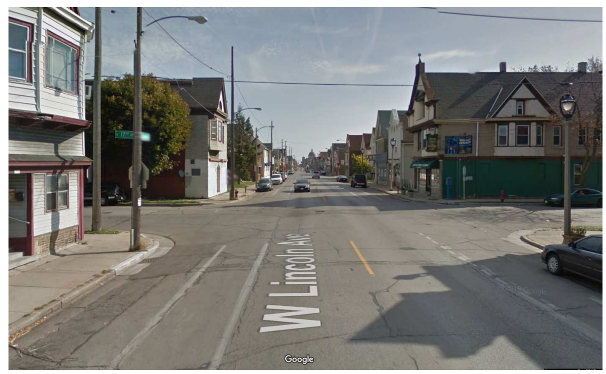
Historic W Mitchell- 12th St



W Historic Mitchell- 10th St



Lincoln Ave- 15th St Pl



Lincoln Ave- 17th St