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Analysis of Pedestrian and Bicycle Crashes in Michigan

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ANALYSIS OF PEDESTRIAN AND BICYCLE CRASHES IN MICHIGAN

by

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Vulnerable road users such as pedestrian and bicyclists are more likely to sustain a severe injury when they are involved in a crash with motor vehicles. Identifying the causes of crashes involving pedestrians and bicyclists is essential to reducing the number and the severity of such crashes. This study identified the causes and risk behaviors associated with pedestrian and bicycle crashes in Michigan by reviewing selected individual crash report (i.e., UD-10). Crash reports for all pedestrian and bicycle fatal crashes (K) and a sample of incapacitating injury crashes (A) from 2010 to 2014 were reviewed and typed individually using the Pedestrian and Bicycle Crash Analysis Tool (PBCAT). The results of analysis revealed the risk behaviors and causes of pedestrian and bicycle crashes in Michigan. Six risk behavior groups and causes for pedestrian crashes included: failing to yield/disregard traffic control by pedestrian or driver, pedestrian in roadway, pedestrian near vehicle, pedestrian walking along the roadway, loss of control, and other or unknown. Similarly, five risk behavior groups and causes for bicycle crashes were identified, including: failing to yield/disregard traffic control by cyclist or driver, overtaking, loss of control/turning error, cyclist rode wrong way, and other or unknown. Additionally, the study investigated the roadway characteristics and environmental characteristics associated with the most prevalent causes and risk behaviors. In conclusion, the study recommended a list of engineering, enforcement, and education and outreach countermeasures for each risk behavior group. The results of this study will assist the practitioners in identifying the causes of pedestrian and bicycle crashes and selecting the appropriate countermeasures in order to reduce the number and severity of those crashes in Michigan.

DEDICATION

To my late father who taught me how to face obstacles

with persistence and strength,

To the kindest woman in the world, my mother,

To the most patient woman in the world, my aunt

To my caring and supportive brothers and sisters

I dedicate this work for you all with respect and love!

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Ahmed Abbas Ghubin Al-zubaidi

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CHAPTER 1

INTRODUCTION

In recent years, an increased focus has been placed on alternative modes of transportation, including bicycling, walking, and jogging. Promotion of these modes has likely resulted in the increase of the number of people choosing these modes. The increase in pedestrian and bicycle traffic has increased the risk of pedestrians and bicyclists being involved in an accident. A pedestrian or bicyclist involved in a collision with a vehicle has an increased risk of injury or death. Statistics have shown that one pedestrian is injured every 4 hours and 28 minutes while one cyclist injury occurs every 6 hours and 21 minutes due to traffic crashes in the state of Michigan (Office of Highway Safety Planning, 2014). Due to this crash rate and the increased injury risk for pedestrians or bicyclists involved in crashes, it is important to identify the primary causes of these crashes in order to implement countermeasures with the great potential to reduce the number and severity of such collisions. Most importantly understanding the behavioral characteristics of pedestrians and bicyclists that contribute to crash occurrence is essential to design outreach and education as well as enforcement programs as countermeasures. This thesis investigates the causes of pedestrian and bicycle crashes in Michigan and recommends appropriate countermeasures.

Research problem and motivation

Walking and cycling are very important transportation modes these days. According to the United States (U.S.) National Household Travel Survey (NHTS), there were 127 million walking trips and 9 million bike trips every day in the Unites States in 2009. In addition, there was an increase of 2.4% in walking and cycling modes from 2001 to 2009. Work trip purpose accounted for 25% of walking trips and 5.8% of bike trips across the nation in 2009 (Santos et al., 2011). However, one of the most important aspects for consideration when promoting those alternative transportation modes is safety. In terms of pedestrian crashes, crash data in Michigan from 2010 to 2014 showed that there was 11,249 total pedestrian crashes and 700 pedestrian fatal crashes. The highest number of pedestrian crashes occurred during 2012 and 2014 while the highest number of fatalities occurred in 2013 followed by 2014. Figure (1) shows the distribution of total pedestrian crashes and fatal crashes by year from 2010 to 2014.

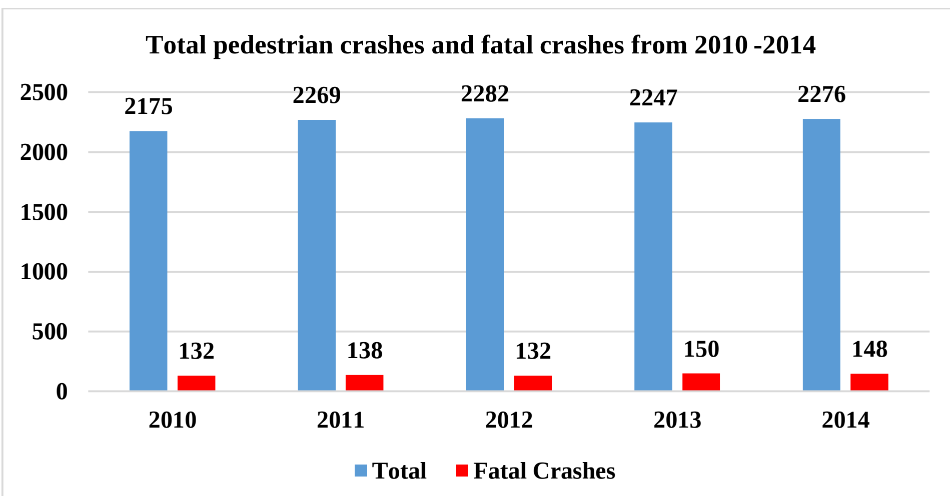


Figure 1: Distribution of Michigan's total and fatal pedestrian crashes by year

Furthermore, there was a total of 9,416 bicycle crashes (all severities) and 125 fatalities from 2010 to 2014. The highest number of bicycle crashes occurred in 2012 followed by 2010. Also, the highest number of bicyclist fatalities occurred in 2010 followed by 2013. Figure (2) shows the distribution of total (all severities) and fatal crashes involving bicyclists by year from 2010 to 2014.

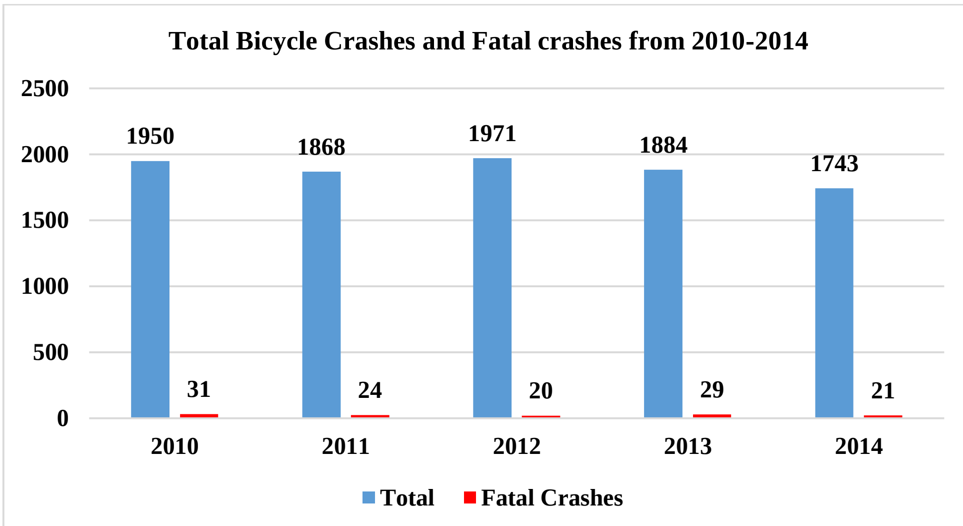


Figure 2: Distribution of total (all severities) and fatal crashes involving bicyclists by year

In order to identify and implement appropriate countermeasure to curb these crashes, the root causes of pedestrian and bicyclist crashes must be known. Also, it is equally important to understand the behavioral characteristics of pedestrians and bicyclists that contribute to the occurrence of these crashes. Knowing these causes will assist in the selection of appropriate engineering countermeasures as well as devising outreach, educational, and enforcement programs.

Objective

The primary purpose of this thesis is to perform analysis of pedestrian-vehicle crashes and bicycle-vehicle crashes in the state of Michigan using the most recent crash data from 2010 to 2014 to identify pedestrian and bicycle crash causes and risk behaviors, including roadway characteristics and environmental characteristics that were associated with those causes. A secondary objective of the study was to survey pedestrian and bicycle stakeholders on the effectiveness and the implementation of pedestrian and bicycle countermeasures in Michigan. In culmination, the study was aimed at identifying potential countermeasures that will help practitioners in selecting appropriate countermeasures to reduce the number and severity of pedestrian and bicycle crashes.

Scope of the study and thesis format

The main focus of this thesis is to identify the causes and risk behaviors of pedestrian and bicycle crashes in Michigan using the 2010-2014 crash data collected by the Office of Highway Safety Planning (OHSP) in the state of Michigan. Crash typing was mainly on fatal and sample incapacitating injury crashes. The content of this thesis will be presented in seven chapters: Introduction (Chapter 1), Review of Literature (Chapter 2), Data collection and Descriptive Statistics (Chapter 3), Countermeasures survey (Chapter 4), Analysis and Results of Pedestrian and Bicycle Crashes (Chapter 5), Countermeasures for Pedestrian and Bicycle Involved Crashes (Chapter 6), and Conclusion and Recommendations (Chapter 7).

CHAPTER 2

REVIEW OF LITERATURE

Causes of pedestrians and bicycles crashes

A study was conducted on the causes of pedestrian crashes in Florida by reviewing the details of each individual crash report. The data that was used in this study consisted of 353 pedestrian fatal crashes from 1998 to 2000 (Spainhour et al., 2006). The results of this study showed that pedestrian behavior such as crossing the roadway without using a crosswalk, pedestrian darting in the roadway, sitting on the roadway, failure to yield to vehicles, and pedestrian walking along the roadway without using sidewalk even when available was a major factor of 76% of fatal pedestrian crashes. Alcohol consumption by drivers and pedestrians was found to be a major contributing factor in 45% of pedestrian fatal crashes. In addition, lack of lighting was found to be a major contributing factor of 60% of pedestrian fatal crashes in this study. The results showed that 53% of fatal pedestrian crashes occurred when the pedestrians tried to cross at non-crosswalk locations. Furthermore, pedestrian walking along the roadway in the absence of sidewalk accounted for 57% of pedestrian fatal crashes. Also, 15% of pedestrian fatal crashes occurred on limited access facilities such as interstate, toll road, and other limited access facilities. Finally, 50% of those crashes occurred when the pedestrian exited from a disabled vehicle (Spainhour et al., 2006).

The New York City department of transportation published a document that identify several factors that cause pedestrian crashes. Driver inattention was found to cause 36% of crashes involving pedestrian with fatal or severe injury (KSI). Failing to yield by the driver when he was trying to turn right or left caused 27% of pedestrian KSI crashes. Pedestrian crossing with

the right-of-way at signalized intersection contributed to 27% of pedestrian KSI crashes. In addition, pedestrian failing to yield at signalized intersection caused 20% of pedestrian KSI crashes. Regions with higher population of African American and Hispanic represents a higher percentage of pedestrian KSI crashes. Finally, pedestrians who did not finish high school had higher pedestrian crash rate compared to those who finished high school (Viola and Shin, 2010).

Research conducted by the U.S Department of Transportation on pedestrian crash characteristics and the effects of different roadway features and traffic control devices on pedestrian safety revealed that there is no difference in crashes between marked and unmarked crosswalks at un-signalized intersections on two lane road. Roads with average daily traffic more than 12000 veh/day with more than two lanes and marked crosswalk experienced a higher percentage of pedestrian crashes while the same road with unmarked crosswalks had a lower percentage of pedestrian crashes. In addition, at signalized intersection the pedestrian count-down signal with the standard signal timing was not very effective in reducing pedestrian crash rate. Furthermore, pedestrian count-down signal with exclusive pedestrian interval was effective in reducing pedestrian crashes (Campbell et al., 2004).

In 2012, a study by Zegeer, and Bushell documented the causes of pedestrian crashes and the countermeasures that were used in Europe to enhance safety of pedestrians. The authors mentioned, age and gender, alcohol or drug use, pedestrian volume and behavior, and pedestrian with disabilities as pedestrian crash factors. In the U.S.A., children under 15 years old represented 23% of fatal pedestrian crashes during 1997 and 2006, while people over 70 years old represented about 9% during 2007 only. In the Netherlands 50% of fatal pedestrian crashes was for people who were over 65 years old (Zegeer and Bushell, 2012). In India and England

similar trend have been observed. Males represented 70% of fatal pedestrian crashes in the U.S. There is no clear evidence about cause of this trend, but this trend might be due to males having a greater tendency than females to walk through dangerous places. In addition, Zegeer, and Bushell mentioned other factors such as driving speed, driver characteristics, ADT, lighting conditions, geometry of intersection and roadway, weather, day time or night time, pedestrian signal, transit zones, midblock crossing, race, and area type.

Another study by Bertulis and Dulaski conducted in order to find the effect of vehicle speed on changing the drivers' yielding behavior for pedestrians showed results that if the speed increased, the yielding rate will be reduced. For instance, when the speed is 38 mph the yielding rate decrease to 9%, whereas when the speed is 20 mph the yielding rate is 75% (Bertulis, & Dulaski, 2013).

A study on bicycle crashes was conducted in Orlando, Florida. The study reported that bicyclist failed to yield to the red light at signalized intersection and uncontrolled intersection, presence of alcohol, absence of bicyclist reflective vest or warning lights during the night time, bicyclist merge or turn in the path of motorists and using the opposite direction of traffic for cycling are the causes of bicyclist crashes. In addition, these causes accounted for 64.1% of bicycle crashes in Orlando, Florida (Metroplan Orlandos, 2004).

In 2007, a study in North Carolina conducted by Council and Carter compared pedestrian and bicycle crashes between rural areas and urban areas. The study showed that crashes in rural areas is different from urban areas because the rural roadways have different roadway features from urban roadways such as higher speed limit, lack of sidewalks, and unpaved shoulders. In addition the study showed the fatal crash rate is higher in rural areas than urban areas (Council and Carter, 2007).

Countermeasures for pedestrians and bicycles crashes

In 2006, the city of Burlington, Vermont started a long-term pedestrian safety program in order to promote safety between citizens. The safety program included: education program, enforcement program, and implementation of engineering countermeasures. Engineering countermeasures included countermeasures such as: enhance pedestrian access to public transit and development of transportation modes. Enforcement program included countermeasures such as: incorporation with mayor and police department in order to promote a livable community by providing educational materials to pedestrian, cyclists, and motorists who violate the traffic laws. In addition, an enforcement program was applied to cyclists and pedestrians. Education countermeasures included: radio and TV announcements that promote safety, presentation slides about safety in cinemas, and press releases and seminars that focus on promoting safety of pedestrians and bicycles. In addition, coupons for safety clothes and products about safety were distributed during the education program. The outcome of these programs results in a campaign that is held each year (Pedestrian and Bicycle Information Center).

A study conducted by Turner, Fitzpatrick, Brewer, and Park on the effectiveness of some engineering countermeasures that can be utilize to enhance the safety of pedestrians while they are crossing unsignalized intersections with a marked crosswalk on arterials showed that a 94% yielding rate of motorist was achieved when there was a red signal or mounted beacon. A 65% yielding rate of motorist was achieved where there was pedestrian crossing mounted flags and an 87% yielding rate was achieved when warning lights for pedestrian crossing are placed on the pavement of crosswalk. In addition, a 17% yielding rate of motorist in case when there were streets with high visibility signs and marking and speed limit of 35 mph. Finally, a 61% yielding rate was found for motorist when the speed limit was 25 mph (Turner et al., 2006).

In 2010, a study was conducted by Viola, Roe, and Shin and the New York City Department of transportation on pedestrian safety. The document identified countermeasures to reduce pedestrian and bicycle crashes. These countermeasures are engineering, education, and enforcement. Regarding the engineering countermeasures the authors mentioned the following countermeasures: signals for pedestrian, slow speed zones near schools, and prevent curb parking in order to provide sufficient visibility for pedestrians and drivers. In addition, programs such as Safe Routes to School, Safe Streets for Seniors, and speed humps are currently implemented in New York City. In 2007, the New York Department of Transportation implemented safety improvements such as roadway signs, speed humps, and bike lanes in 123 school zones. In 2008, the NYDOT implemented the Safe Streets for Seniors program in five areas with a majority of senior pedestrians. The authors reported that other programs would be implemented such as school programs for students, Safe Routes to School, workshops for parents, and introducing education safety programs with different foreign languages in order to promote pedestrian safety in New York City. Regarding the engineering countermeasures, the authors stated that NYDOT would install new pedestrian count-down signals, new reduced speed zones and prevent on-street parking in specific location in order to enhance the visibility of pedestrian. Regarding the enforcement countermeasures NYDOT would increase the use of speed cameras and red light cameras, provide large vehicles with crossover mirrors, and enforce strong penalties for the drivers who don’t have driver license or it’s not updated (Viola, Roe, & Shin, 2010). A study on four signalized intersections was conducted in order to check the safety impacts for different types of pedestrian signals. The types that have been used are programmed in different walking modes. Two intersection had recall mode and rest in walk mode while the other two intersections had no recall mode or rest in walk mode. The results revealed that signalized intersections with

recall mode and rest in walk mode had higher yielding rates for pedestrian and cyclists (Mirabella, & Zhang, 2014).

In 2014, a study in Montgomery County, Maryland was conducted on pedestrian safety. The purpose of this study was to enhance safety of pedestrians by implementing three types of countermeasures included: engineering, education and enforcement. Engineering countermeasures including: traffic calming techniques such as road diet, curb extension, pedestrian refuge islands, speed humps, chokers and chicanes, and improved road signs and marking. An education program was implemented on a neighborhood that had a foreign population who don't know English well, so the program used curb marking in Spanish and English in order to teach this portion of community (Dunckel et al., 2014). Enforcement countermeasure focused on citing pedestrians and drivers who failed to yield and citation for all midblock crossing. In addition, the authors stated that 2000 citations were issued by police for pedestrians and drivers who violated the safety laws for crossing. Enforcement included 374 driver citation issued by using pedestrian decoys, and 839 citations were issued in school zones (Dunckel et al., 2014). The results of this study showed a reduction of 7% in pedestrian crash rate in 2012 and 21% reduction in crash severity for incapacitating and fatal crashes. Furthermore, 50% reduction in pedestrian crash rate for areas without high crash rate and at least 5 mph reduction in driving speed due to the implementation of traffic calming techniques was shown. Finally, a reduction in crash rate from 1.45 to 0.21 per year was found due to the implementation of Safe Route to School program in school zones (Dunckel et al., 2014).

In 2004, a study was conducted by Metroplan Orlandos on the effectiveness of bicyclist countermeasures. Regarding the effectiveness of engineering countermeasures, cycling in the direction of traffic can reduce bicycle crashes by about 43% while there is no evidence that

cycling with motorist on the same roadway reduce the crash rate. In addition, the study showed that lane positioning reduce crashes by about 12% and using warning lights when the lighting condition is low reduce crashes by about 28%. Regarding the effectiveness of motorist countermeasures, the study mentioned appropriate and safe maneuvers reduce crashes by 7-8%, driving consciously reduce crashes by 3-19 %, and motorists yielding at intersection when they were making left or right turns reduce crashes by 19% and 5% respectively. Regarding the effectiveness of engineering countermeasure, the study indicated that the presence of separated bike lanes from the roadway reduce crashes by 7% while the presence of bike lanes beside the roadway reduce crashes by 6%. In addition, Metroplan Orlandos study showed that paved shoulders reduce crashes by 6% and the lighting of roadway reduce crashes by 9%. Regarding the effectiveness of enforcement countermeasures, enforcement of the presence of alcohol and/or drugs in the driver's body reduce crashes by 3%-19%. In addition, the study showed that enforcement for the drivers who failed to yield while they were turning right or left at intersections reduces the crashes by 5% and 19% respectively (Metroplan Orlandos, 2004).

A study on "An Overview of Automated Enforcement Systems and Their Potential for Improving Pedestrian and Bicyclist Safety" conducted by Poole discusses the automated enforcement systems such as red-light cameras (RLC) and automated speed enforcement cameras (ASE) and their role in reducing the crash rate for motorists, bicyclists, and pedestrians. The author stated most of studies showed that implementation of red-light cameras (RLC) and automated speed enforcement cameras (ASE) resulted in reducing the injury crash rates significantly. Red-light cameras (RLC) studies showed using this type of enforcement resulted in reduction in crash severity and right-angle crashes and reducing the violation of drivers for red light ,but there was an increase in rear-end crashes. Automated speed enforcement cameras

(ASE) studies showed that using this type of enforcement decreased the crash rates, injury crashes. In addition, the author mentioned automated speed enforcement cameras are effective in reducing the speed of motorists. Automated enforcement systems implementation have raised a controversy with the public. The author mentioned, the implementation of automated enforcement systems could overcome these issues with the help of engineering, education and campaigns countermeasures (Poole, 2012).

A study in North Carolina conducted by Council and Carter in 2007. The authors identified different types of pedestrian and bicycle crashes and their locations in rural areas. In addition, the document showed the crash types of pedestrian and bicycle crashes and recommended countermeasures for each type of these crashes based on PEDSAFE and BIKESAFE. Regarding the engineering countermeasures for pedestrian crashes in rural areas, the authors mentioned many countermeasures such as installing paved shoulders, installing sidewalks, enhancing the lighting of the roadway and warning signs, and providing surveillance of vehicle speed, motorists assistance programs, pedestrian count-down signal, traffic calming, prevent or restrict on street parking, providing overpasses and underpasses, and enhancing school zones. Regarding the education countermeasures, the study mentioned education programs and campaigns for pedestrians and drivers. Regarding to the enforcement countermeasures the study mentioned enforcement of law for intoxicated drivers. Furthermore, the study mentioned different countermeasures for bicycle crashes including: roadway narrowing in order to provide a bike lane, increasing the number of warning signs, installing paved shoulders, installing paved medians and refuge islands, pavement marking for bicycles, preventing on street parking, traffic calming, installing a bicycle path separately from the roadway, roadway maintenance, enhancing school zones, and education programs for cyclists. (Council, & Carter, 2007).

The last section of the literature review documents some of the studies that provide the effectiveness of engineering, enforcement, and education countermeasures for pedestrian and bicycle crashes. Crash Modification Factor (CMF) Clearinghouse website was used to identify and document the effectiveness of pedestrian and bicycle countermeasures (CMF Clearinghouse, 2013). Table (1) shows the engineering countermeasures that had been implemented to enhance pedestrian and bicycle safety. Table (2) shows the enforcement and education countermeasures that had been implemented to enhance pedestrian and bicycle safety. This section of the literature review was used along with section 2 for the development of survey questionnaires that are discussed in the next chapter of this research. Finally, Tables (1) and (2) provide information about the crash reduction factor (CRF), type of area, crash type, location, and the reference.

Table 1: Effectiveness of engineering countermeasures

Engineering Countermeasures	Description (Location/crash type/effectiveness)	Crash type	Reference
Raised island with left turn lane	Roadway urban and suburban/Increasing in crash rate by 48%	Vehicle/bicycle	Schepers et al., 2011
Raised island with a separate space for cyclists	urban and suburban areas/ Increasing in crash rate by 43%	Vehicle/bicycle	Schepers et al., 2011
Raised island with additional lanes and raised island	Roadway/urban and suburban/ Increasing in crash rate by 10%	Vehicle/bicycle	Schepers et al., 2011
Installation of a speed hump or other speed reducing measure for through motorized vehicles on the main road	Roadway/urban and suburban/Increasing in crash rate by 28%	Vehicle/bicycle	Schepers et al., 2011
Presence of speed restriction devices (bike crashes)	Urban signalized intersections/ reduction in crash rate by 71.92%	Vehicle/bicycle	Oh et al., 2008
Provide bike lanes	Reduction in crash rate by 35%/ for fatal serious, and minor injury crashes)	Vehicle/bicycle	Rodegerdts et al., 2004
Replacement of traditional intersection with roundabout with a grade separated cycle path	Intersection/Urban/ reduction in crash rate by 44% (for all types of injury severity)	Vehicle/bicycle	Daniels et al. (2009), 2009

Table 1 - Continued

Engineering Countermeasures	Description (Location/crash type/effectiveness)	Crash type	Reference
Replacement of traditional intersection with roundabout with a grade separated cycle path	Intersection/Urban/ increasing in crash rate by 31% (for fatal and serious injury crashes)	Vehicle/bicycle	Daniels et al. (2009), 2009
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane) - 9 or more intersections, target crashes	reduction in crash rate by 45%/crash type (all)/ area type (all)	all	Lyles et al., 2012
Road diet (Convert 4-lane undivided road to 2-lanes plus turning lane) - commercial areas	Increasing in crash rate by 5%/ crash type (all)/ area type (all)	all	Lyles et al., 2012
Convert to roundabout	Rural/ increasing in crash rate by 1%	Vehicle/bicycle	Daniels et al., 2008
Install cycle tracks, bike lanes, or on-street cycling	Urban area/ (1 to 3 lanes) / reduction in crash rate by 85%	Vehicle/bicycle	Nosal and Miranda-Moreno, 2012
Install cycle tracks, bike lanes, or on-street cycling	Urban area/ intersection related /(1 to 2lanes) / reduction in crash rate by 88%	Vehicle/bicycle	Nosal and Miranda-Moreno, 2012
Install cycle tracks, bike lanes, or on-street cycling	Urban area/(1 to 3 lanes) / reduction in crash rate by 94%/different location	Vehicle/bicycle	Nosal and Miranda-Moreno, 2012
Installation of bicycle lanes at 4-leg signalized intersections	Urban & suburban/ increasing in crash rate by 37%/crash severity (all)	Vehicle/bicycle	Turner et al., 2011
Installation of bicycle lanes at 4-leg signalized intersections	Urban & suburban/ reduction in crash rate by 58%/crash severity (all)/ different location	Vehicle/bicycle	Turner et al., 2011
Install lighting	Roadway all/night time/Rural area/ /reduction in crash rate by 70%	Vehicle/pedestri an	Wanvik, 2009
Install intersection lighting	3,4 leg-intersection/area type (all)/crash severity (all)/reduction in crashes by 11.9%	Night-time	Donnell, Porter, Shankar, 2010
Provide intersection illumination	Intersection/ night time/ reduction in crash rate by 42%	Night-time & Vehicle/pedestri an	Elvik, R. and Vaa, T., 2004
Provide intersection illumination	Intersection/ reduction in crash rate by 59%	Vehicle/pedestri an	Elvik, R. and Vaa, T., 2004
Provide intersection illumination	Intersection/reduction in crash rate by 82%/fatal crashes only	Vehicle/pedestri an	Elvik, R. and Vaa, T., 2004
Provide intersection illumination	Intersection/reduction in crash rate by 43.8%	Vehicle/pedestri an	Ye et al., 2008
Increase all red clearance interval	3,4 leg-intersection/urban area/ reduction in crashes by 20.2%/ crash severity (all)	All	Srinivasan, et al., 2011

Table 1 - Continued

Engineering Countermeasures	Description (Location/crash type/effectiveness)	Crash type	Reference
Modify signal phasing (implement a leading pedestrian interval)	3,4 leg-intersection/urban area/ reduction in crashes by 37% / crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Fayish and Gross, 2009
Install high-visibility crosswalk	3,4 leg-intersection/urban area/ reduction in crashes by 40% / crash severity (all)	Vehicle/pedestrian	Li Chen, Cynthia Chen, and Reid Ewing, 2012
Install raised pedestrian crosswalks	Urban and suburban/reduction in crash rate by 46%/ Serious injury, Minor injury	Vehicle/pedestrian	Elvik, R. and Vaa, T., 2004
Installation of a High intensity Activated crosswalk (HAWK) pedestrian-activated beacon at an intersection	3,4 leg-intersection/Urban and suburban/reduction in crash rate by 69% /Crash severity (all)	Vehicle/pedestrian	Fitzpatrick, K., and Park, E.S., 2010
Raised median with marked crosswalk	Principal Arterial/ urban and suburban/ reduction in crash rate by 46%	Vehicle/pedestrian	Zegeer et al., 2002
Raised median with unmarked crosswalk	Principal Arterial/ urban and suburban/ reduction in crash rate by 39%	Vehicle/pedestrian	Zegeer et al., 2002
Crosswalk on one minor approach	4-leg intersection unsignalized/(Area type all)/ reduction in crash rate by 65%	Vehicle/pedestrian	Haleem and Abdel-Aty, 2010

Table 2: Effectiveness of enforcement and education countermeasures

Enforcement and education Countermeasures	Description (Location/crash type/effectiveness)	Crash type	Reference
Implement automated speed enforcement cameras	Principle arterial other/ urban area/reduction in crash rate by 88%/Crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Shin et al., 2009
Implement automated speed enforcement cameras	Principle arterial other/ urban area/ reduction in crash rate by 90%/ PDO crashes	Vehicle/bicycle & Vehicle/pedestrian	Shin et al., 2009
Implement automated speed enforcement cameras	Principle arterial other/ urban area/ reduction in crash rate by 86%/ Serious injury & minor injury	Vehicle/bicycle & Vehicle/pedestrian	Shin et al., 2009
Install red-light cameras	Roadway type and area type (all)/ signalized intersection/ reduction in crash rate by 14%/crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011

Table 2 - Continued

Enforcement and education Countermeasures	Description (Location/crash type/effectiveness)	Crash type	Reference
Install red-light cameras	Principle arterial other/ all area types/signalized intersection/reduction in crash rate by 19%/ crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011
Install red-light cameras	Roadway type and area type (all)/ signalized intersection/ increasing in crash rate by 25%/ crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011
Install red-light cameras	Roadway type and area type (all)/ signalized intersection/ reduction in crash rate by 33%/ crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011
Install red-light cameras	Principle arterial other/ and area type all /signalized intersection/ increasing in crash rate by 63%/ crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011
Install red-light cameras	Principle arterial other/ and area type all /signalized intersection/ increasing in crash rate by 67%/ crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Walden and Bochner, 2011
Implement Safe Routes to School Program	Reduction in crash rate by 16.1%/ Minor injury	Vehicle/bicycle & Vehicle/pedestrian	Guiterrez et al., 2008
Implement Safe Routes to School Program	reduction in crash rate by 13% /Crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Guiterrez et al., 2008
Implement Safe Routes to School Program	reduction in crash rate by 11.6% / Crash severity (all)	Vehicle/bicycle	Guiterrez et al., 2008
Implement Safe Routes to School Program	reduction in crash rate by 13.9% / Crash severity (all)	Vehicle/pedestrian	Guiterrez et al., 2008
Implement Safe Routes to School Program	Increasing in crash rate by 28% / Fatal & serious injury	Vehicle/bicycle & Vehicle/pedestrian	Guiterrez et al., 2008
Implement to Safe Routes to School Program (Age 5-12)	reduction in crash rate by 27.6% / Crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Guiterrez et al., 2008
Implement Safe Routes to School Program (Age 13-17)	increasing in crash rate by 5% / Crash severity (all)	Vehicle/bicycle & Vehicle/pedestrian	Guiterrez et al., 2008

CHAPTER 3

DATA COLLECTION AND DESCRIPTIVE STATISTICS

Data collection

Pedestrian and bicycle crash data was obtained from the Office of Highway Safety Planning (OHSP) in the state of Michigan. Five years of non-motorized crash data from 2010 to 2014 was used for this study. Non-motorized crash data from OHSP contains detailed information about the crash, such as date, location, injury severity, environmental characteristics, roadway characteristics, vehicle characteristics, and so on. In this chapter, descriptive statistics for the five year pedestrian and bicycle crash data and cross tabulation of injury severity with environmental, characteristics, and other variables are presented in detail. In addition, the data was analyzed using Geographic Information System (GIS) in order to identify the areas with high numbers of pedestrian and bicycle crashes. Finally, descriptive statistics and cross-tabulation is essential to gaining a better understanding of the trend of pedestrian and bicycle crashes and identifying the crash causes that are discuss in Chapter (5).

Descriptive statistics for pedestrian crashes

Figure (3) shows the distribution of total pedestrian crashes and fatality percentages by year. The highest percentage of pedestrian fatalities occurred in 2013. Additionally, 2014 had the second highest pedestrian fatalities. Furthermore, 2010 had the lowest number of total pedestrian crashes. Finally, 2012 had the highest number of total pedestrian crashes and the lowest percentage of pedestrian fatalities.

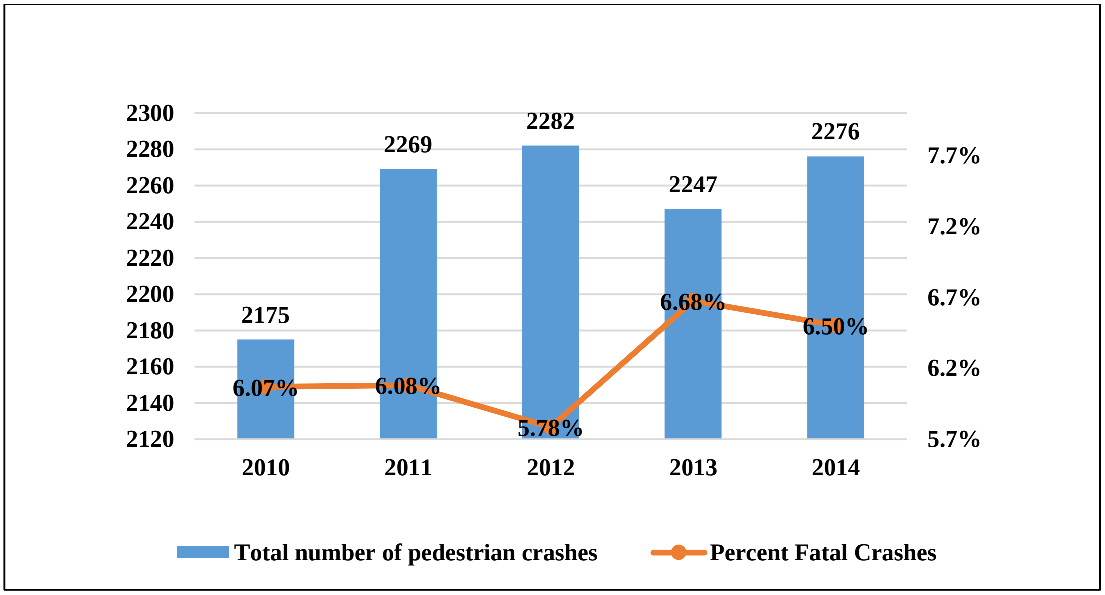


Figure 3: Distribution of total pedestrian crashes and fatality percentages by year

Figure (4) shows the distribution of pedestrian crashes by injury severity by year. 2010 and 2011 had the highest percentages of incapacitating injury crashes. However, 2013 and 2014 had the highest percentages of fatal crashes. In addition, there was a very minor difference in pedestrian fatal crashes from 2010 to 2012. Finally, non-incapacitating injury and possible injury crashes accounted for the majority of crashes during the five year period (2010-2014).

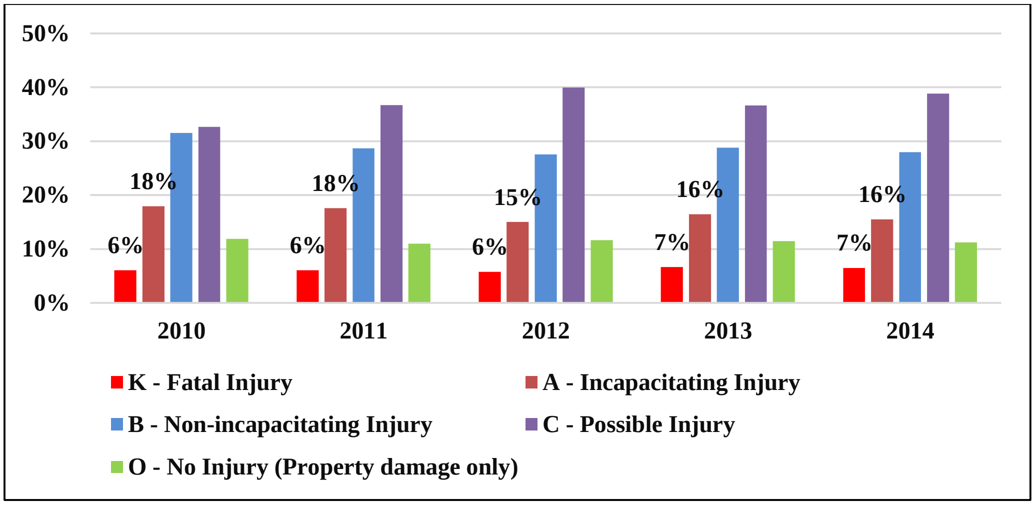


Figure 4: Distribution of pedestrian crashes by injury severity by year

Figure (5) shows the distribution of total pedestrian crashes by gender for five years (2010-2014). The graph shows that the majority of pedestrian crashes involved males. In addition, crashes involving male pedestrians tend to be more severe than crashes involving female pedestrian. This observation can be explained by the fact that males are more likely to walk during or in dangerous situations than females and this fact is supported by the findings from the literature review.

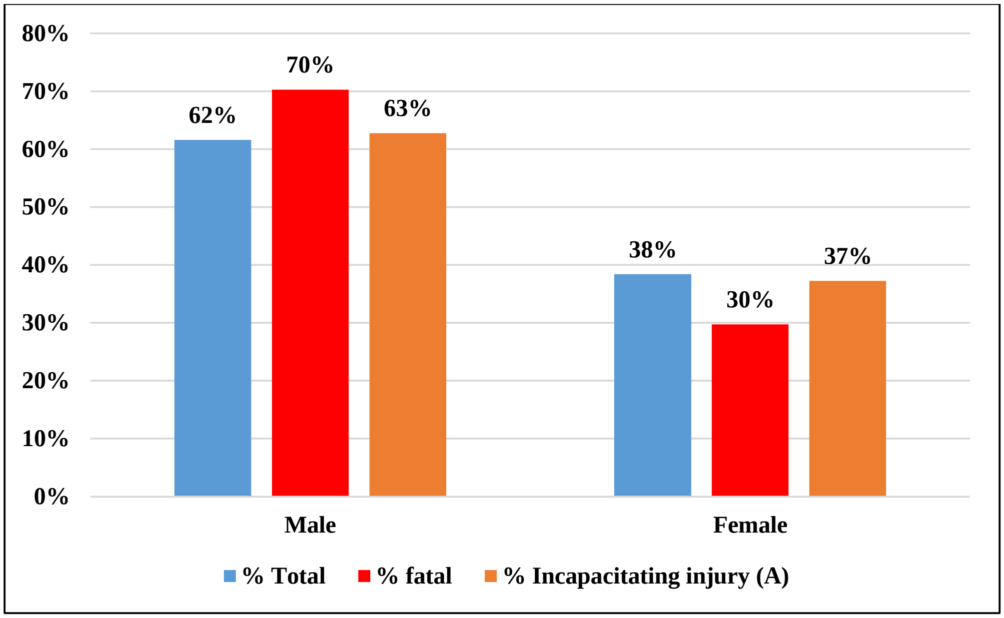


Figure 5: Distribution of total pedestrian crashes by gender (2010-2014)

Figure (6) shows the distribution of pedestrian crashes by pedestrian's age for five years (2010-2014). The figure shows that the 45-64 age range had the highest proportion of fatalities and incapacitating injury crashes, followed by the 25-44 age range and the 65+ age range. In addition, the 25-24 age range had the highest percentage of total crashes compared to the other age groups.

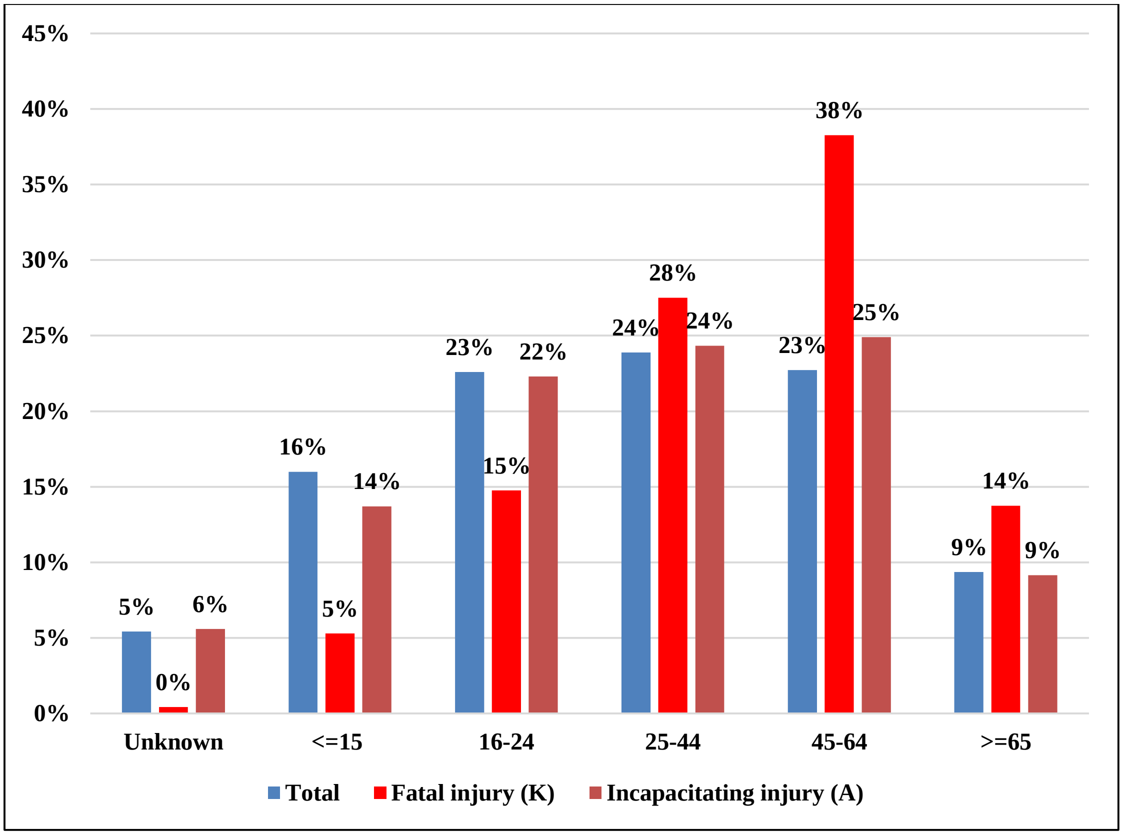


Figure 6: Distribution of pedestrian crashes by pedestrian's age 2010-2014)

Figure (7) presents the distribution of pedestrian crashes by alcohol involvement by severity for five years (2010-2014). The figure shows that fatal crashes and incapacitating injury crashes had a high proportion of alcohol involvement compared to other injuries. This observation was supported by the fact that crashes involving alcohol tend to be more severe.

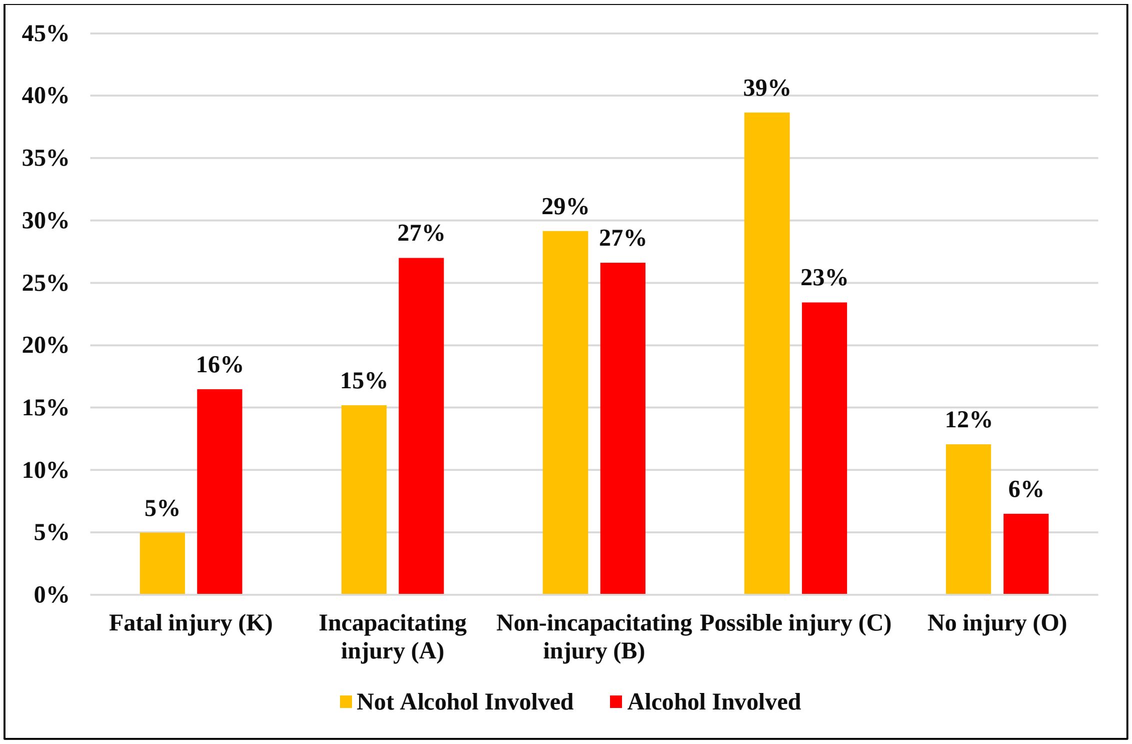


Figure 7: Distribution of total pedestrian crashes by alcohol involvement by severity (2010-2014)

Figure (8) shows the distribution of pedestrian crashes by the day of week for five years (2010-2104). The graph shows that pedestrian crashes were distributed approximately evenly through the weekdays (e.g., Monday through Friday). Furthermore, Friday and Saturday had the lowest percentage of pedestrian crashes. This trend can be explained by the fact that most people's activities take place during the weekdays, while less activities take place during the weekend. Figure (9) shows the proportion of pedestrian crashes by injury severity by day of the week for five years (2010-2014). The figure shows that Sunday and Saturday had the highest percentages of fatal and incapacitating injury crashes compared to the weekdays (e.g., Monday through Friday). Furthermore, the distribution of injury severity was similar during the weekdays.

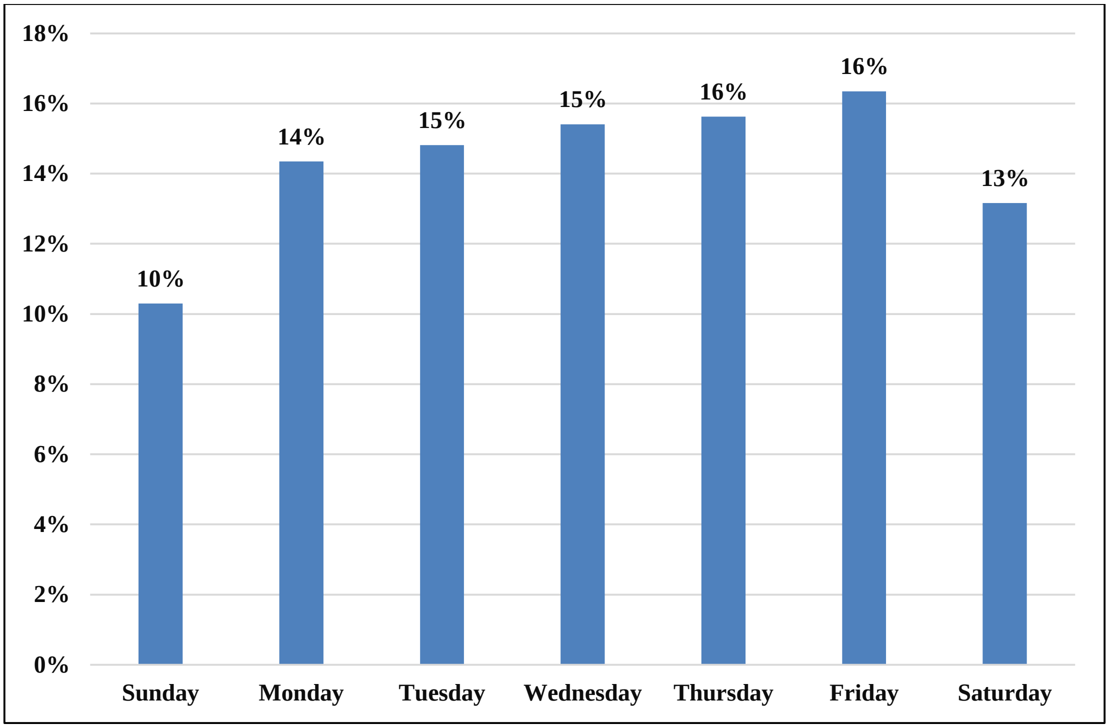


Figure 8: Distribution of total pedestrian crashes by the day of week (2010-2014)

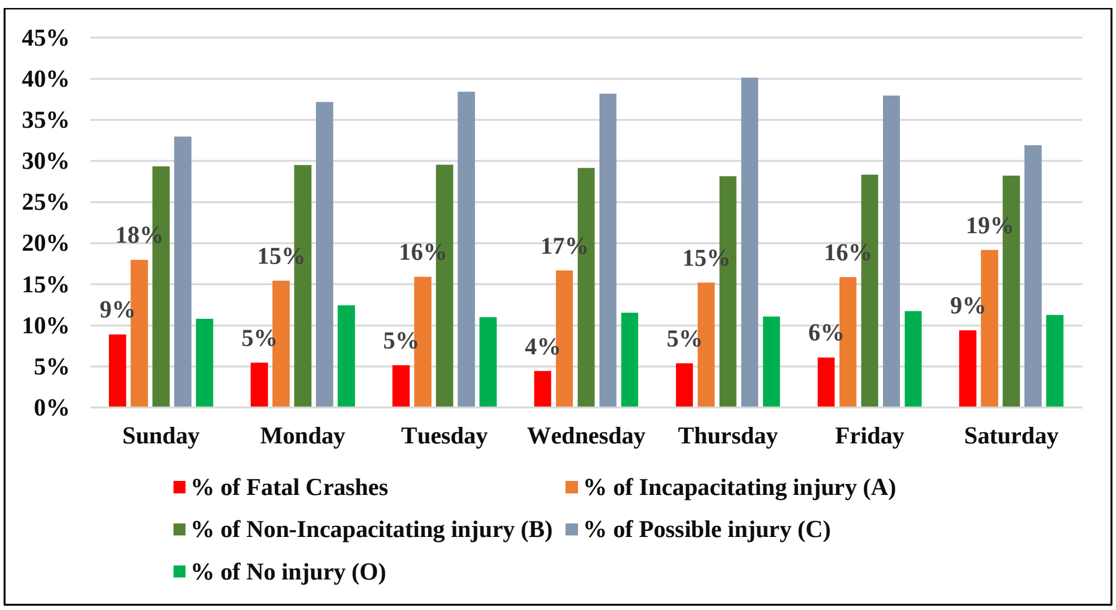


Figure 9: Distribution of total pedestrian crashes by severity by day of the week (2010-2014)

Figure (10) shows the distribution of total pedestrian crashes by MDOT crash location for five years (2010-2014). In terms of MDOT area type, the majority of pedestrian crashes occurred at intersections and mid-blocks (70% and 27% of pedestrian crashes respectively). A small portion of pedestrian crashes occurred at interchanges. Figure (11) shows the distribution of pedestrian crashes by injury severity by MDOT crash location for five years (2010-2014). It should be noted that this study used classification provided by MDOT. When broken down by injury severity, interchange and mid-block crash locations had more severe crashes than intersection crash locations. This trend can be explained by the fact that the speed of the vehicle is higher on interchanges and mid-block crash locations. Furthermore, when the crash occurred on the major road which doesn't has a traffic control device but the minor road has a traffic control device, the MODT area type for that crash will be classified as intersection. This information was proved by investigating the crash location by using the crash coordinates and the Google Earth Pro.

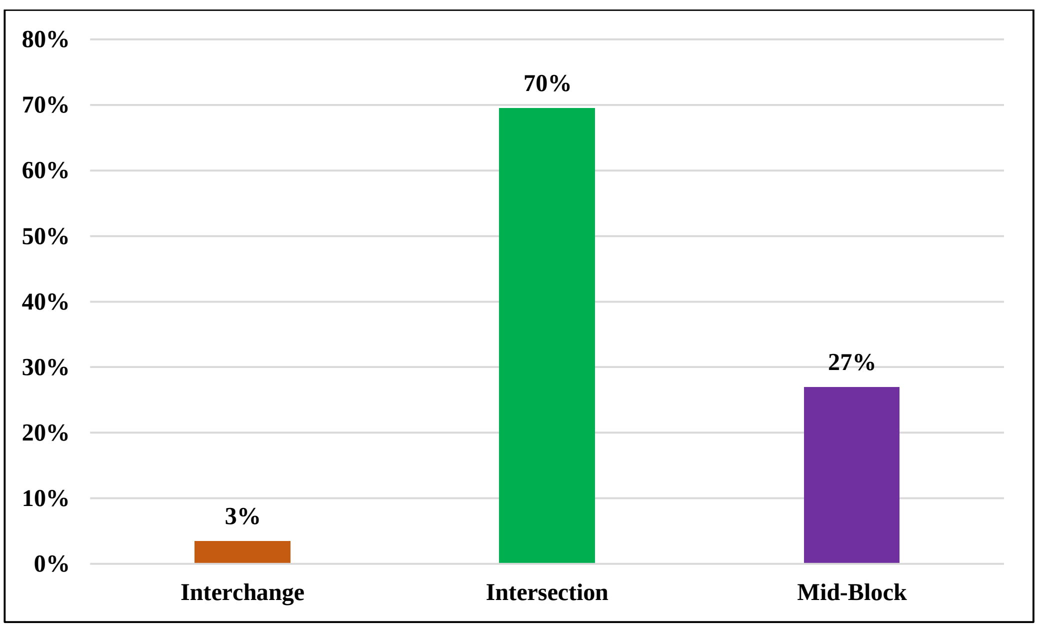


Figure 10: Distribution of total pedestrian crashes by MDOT crash location (2010-2014)

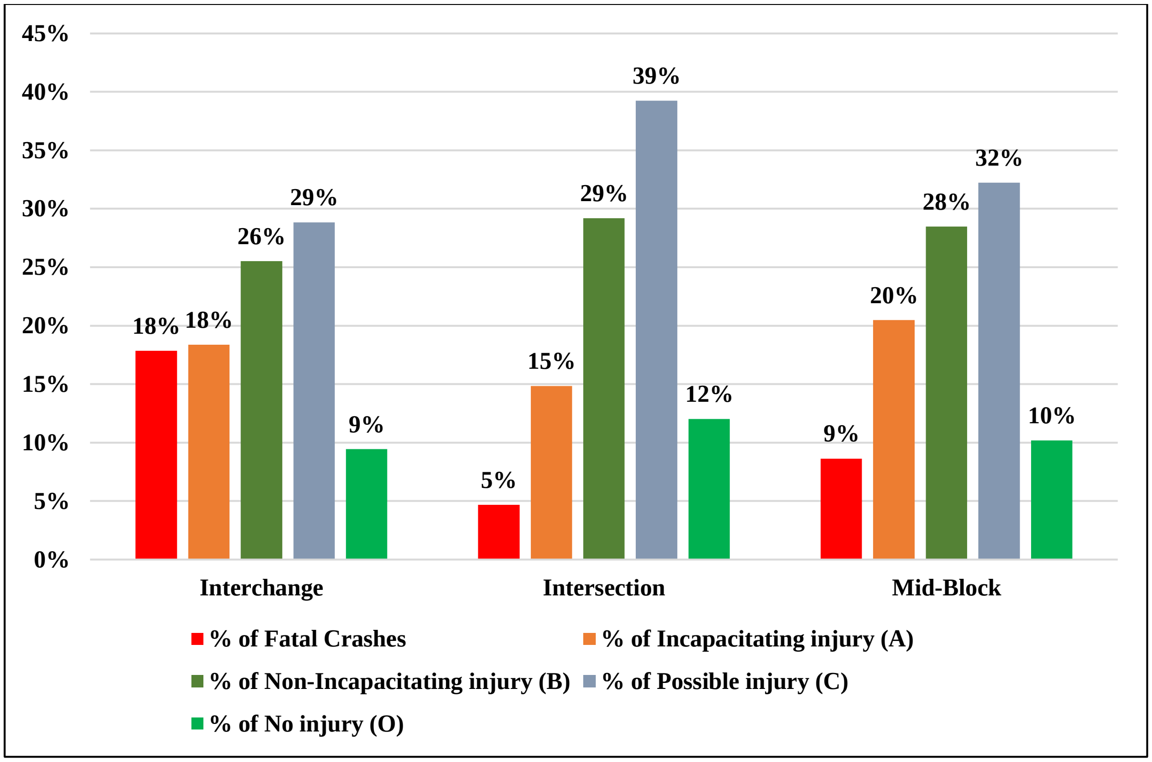


Figure 11: Distribution of total pedestrian crashes by severity by MDOT crash location 2010-2014)

Figure (12) presents the distribution of pedestrian crashes by injury severity by traffic control device for five years (2010-2014). When broken down by injury severity, the majority of severe crashes and fatalities occurred where there was no traffic control device, followed by a yield sign. This observation can be explained by the fact that the absence of traffic control devices may increase the likelihood of injury severity.

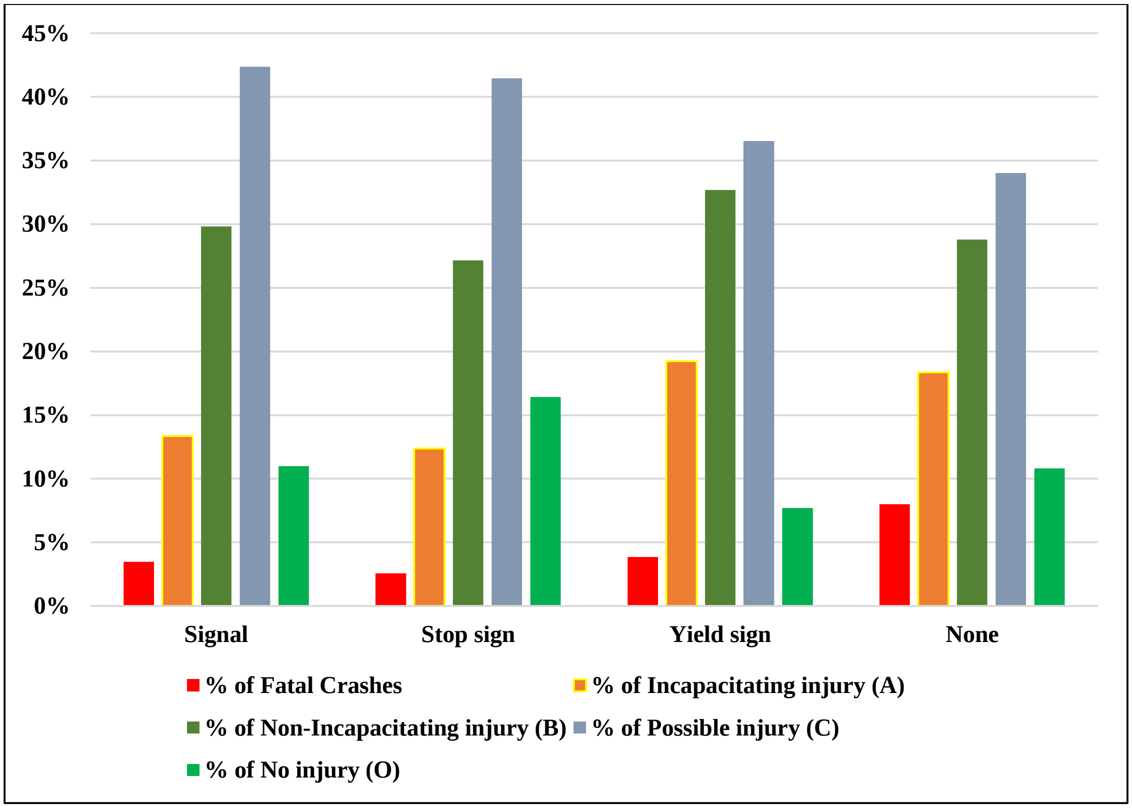


Figure 12: Distribution of total pedestrian crashes by severity by traffic control device (2010-2014)

Figure (13) shows the distribution of total pedestrian crashes by number of lanes for five years (2010-2014). In terms of number of lanes, the majority of pedestrian crashes occurred in roads with two lanes (48%) followed by roads with four or more number of lanes (36%). In addition, roads with one lane (e.g., one-way roads) had the lowest percentage of pedestrian crashes. Figure (14) shows the distribution of pedestrian crashes by injury severity by number of lanes for five years (2010-2014). When broken down by crash severity, crashes experienced in roadways with four or more number of lanes tend to be more severe (i.e., incapacitating or fatal). This observation can be explained by the fact that wider roadways increase the exposure of pedestrians to the vehicles because the crossing distance is longer.

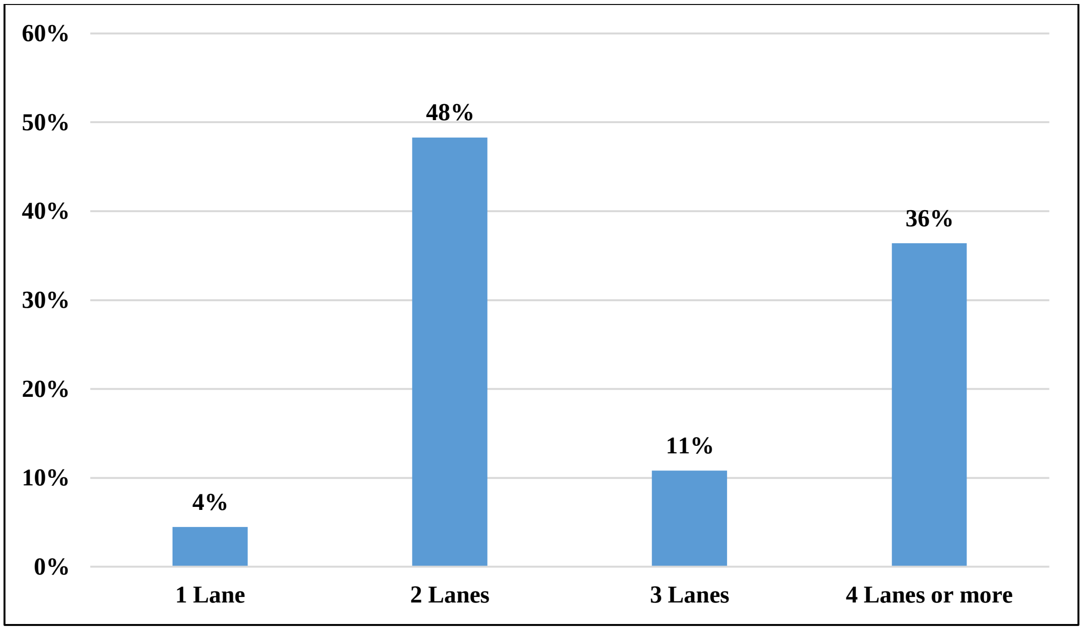


Figure 13: Distribution of total pedestrian crashes by number of lanes (2010-2014)

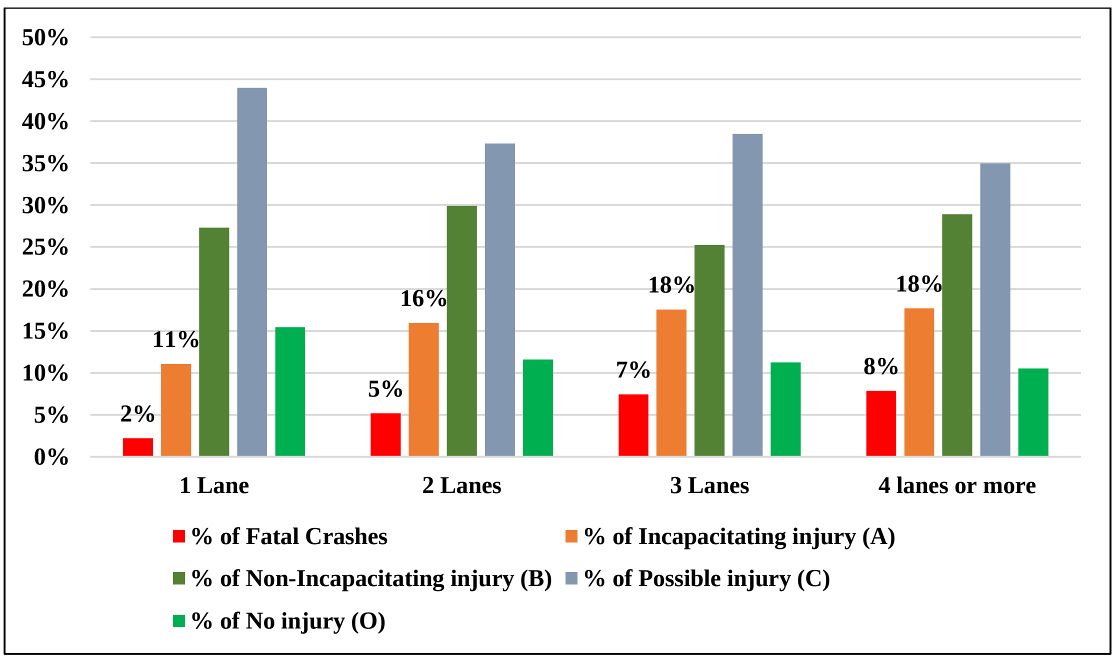


Figure 14: Distribution of total pedestrian crashes by severity by number of lanes (2010-2014)

Figure (15) presents the distribution of total pedestrian crashes by speed limit for five years (2010-2014). The majority of pedestrian crashes occurred in roads with a speed limit of 25 mph or less, followed by roads with a speed limit from 25 to 35 mph. Figure (16) shows the distribution of pedestrian crashes by injury severity by speed limit for five years (2010-2014). When broken down by injury severity, crashes experienced on roadways with a 45 mph speed limit and higher tend to be more severe. This observation can be explained by the fact that a higher speed limit might increase the likelihood of severe injury.

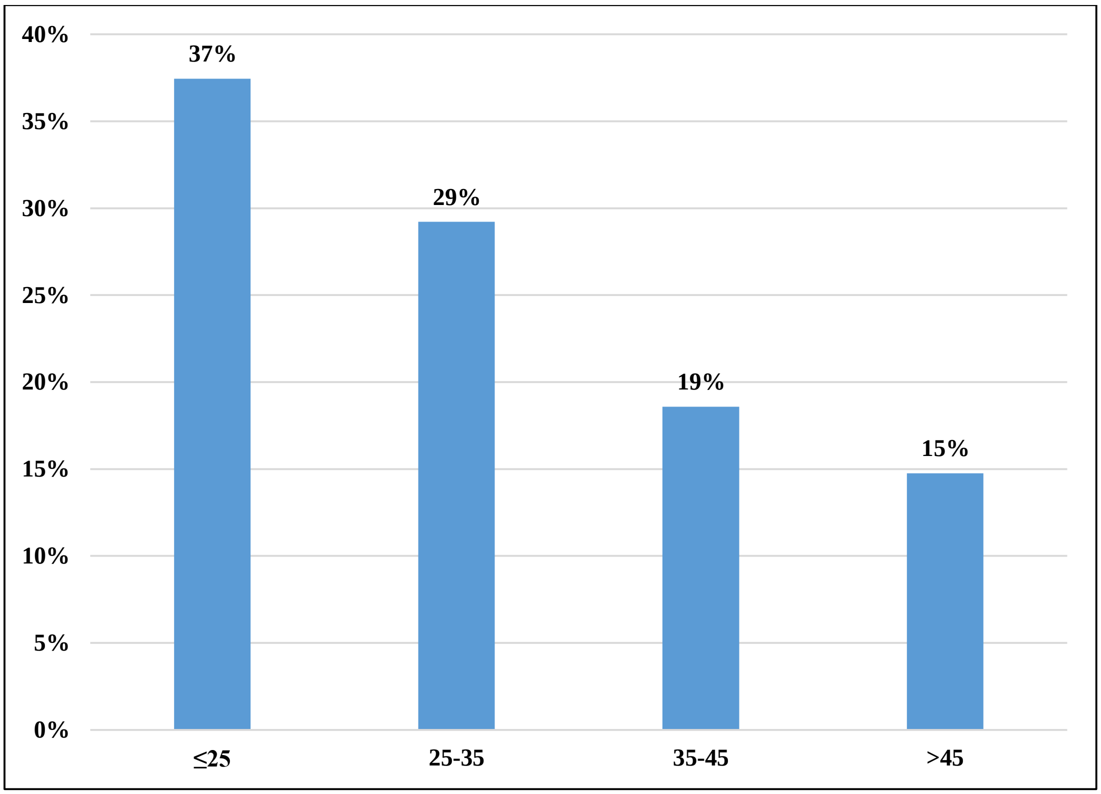


Figure 15: Distribution of total pedestrian crashes by speed limit (2010-2014)

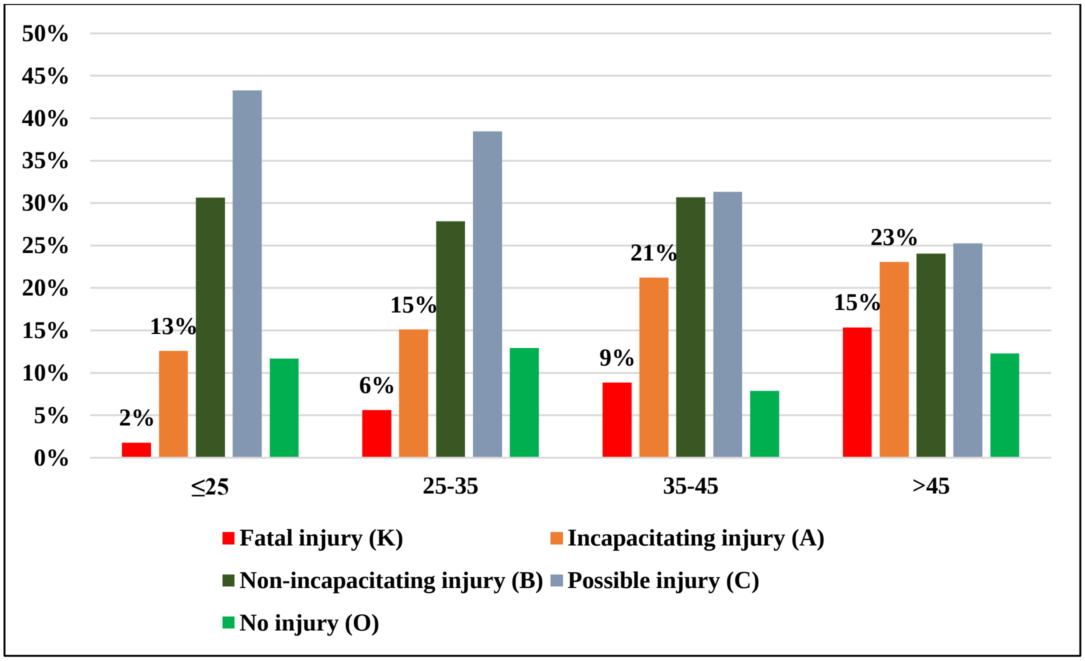


Figure 16: Distribution of total pedestrian crashes by severity by speed limit (2010-2014)

Figure (17) shows the distribution of total pedestrian crashes by highway class for five years (2010-2014). In terms of traffic highway class, the majority of pedestrian crashes occurred within the road, city street or unknown highway category (70% of pedestrian crashes), while 19% of pedestrian crashes occurred at the M Route highway class. In addition, 3% of pedestrian crashes occurred on interstates. Figure (18) shows the distribution of pedestrian crashes by injury severity by highway class for five years (2010-2014). When broken down by injury severity, crashes experienced on interstates and M routes tend to be more severe (i.e., incapacitating or fatal) than those at lower highway classes, because those roads have higher speed limits.

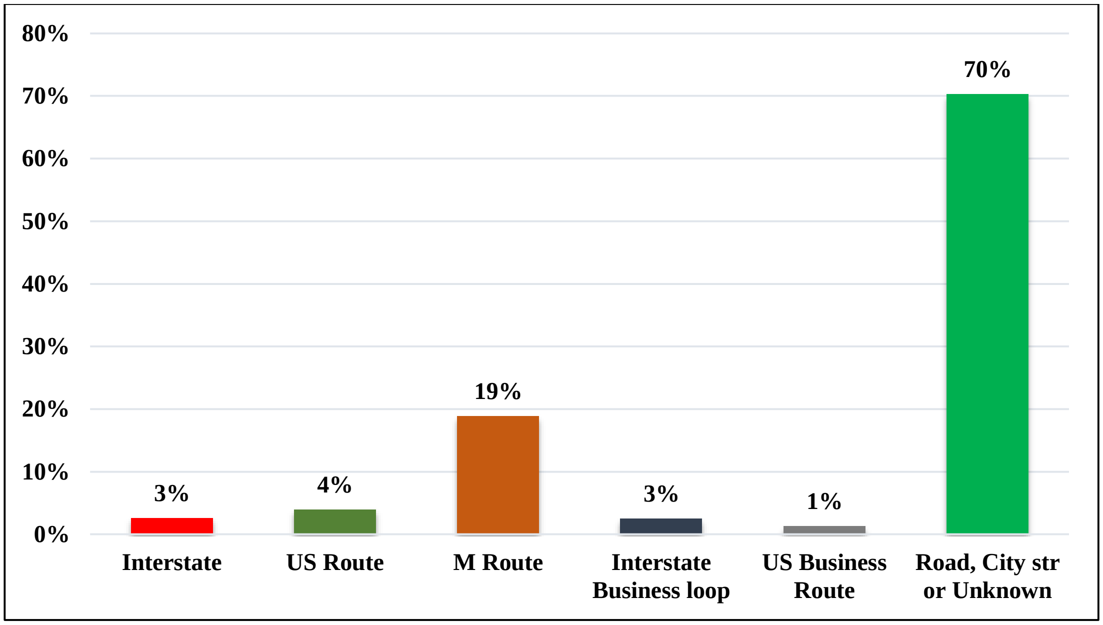


Figure 17: Distribution of total pedestrian crashes by highway class (2010-2014)

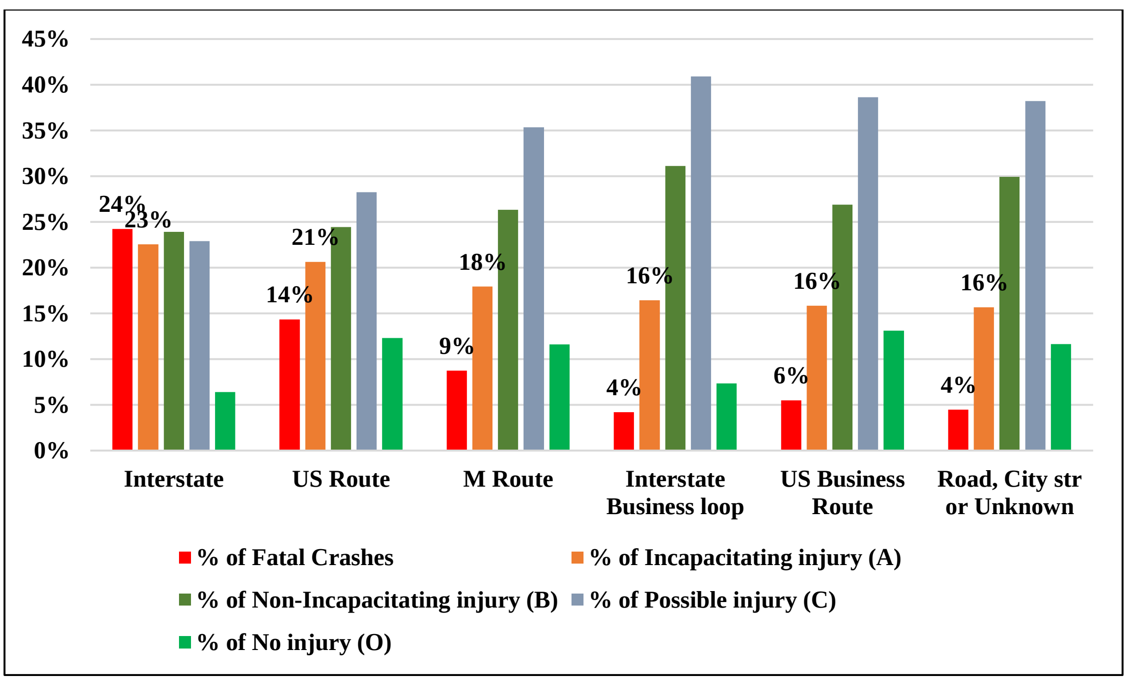


Figure 18: Distribution of total pedestrian crashes by severity by highway class (2010-2014)

Figure (19) presents the distribution of total pedestrian crashes by lighting condition for five years (2010-2014). In terms of lighting condition, the majority of pedestrian crashes occurred during the daylight. This observation can be explained by the fact that most people's activities take place during the daylight. Figure (20) shows the distribution of pedestrian crashes by injury severity by lighting condition for five years (2010-2014). When broken down by injury severity, dark-lighted and dark-unlighted lighting conditions tend to be more severe in terms of fatalities and incapacitating injury crashes than other lighting conditions. This observation suggests that lack of lighting might affect the visibility of the motorists, or pedestrians cannot be detected easily during the night time.

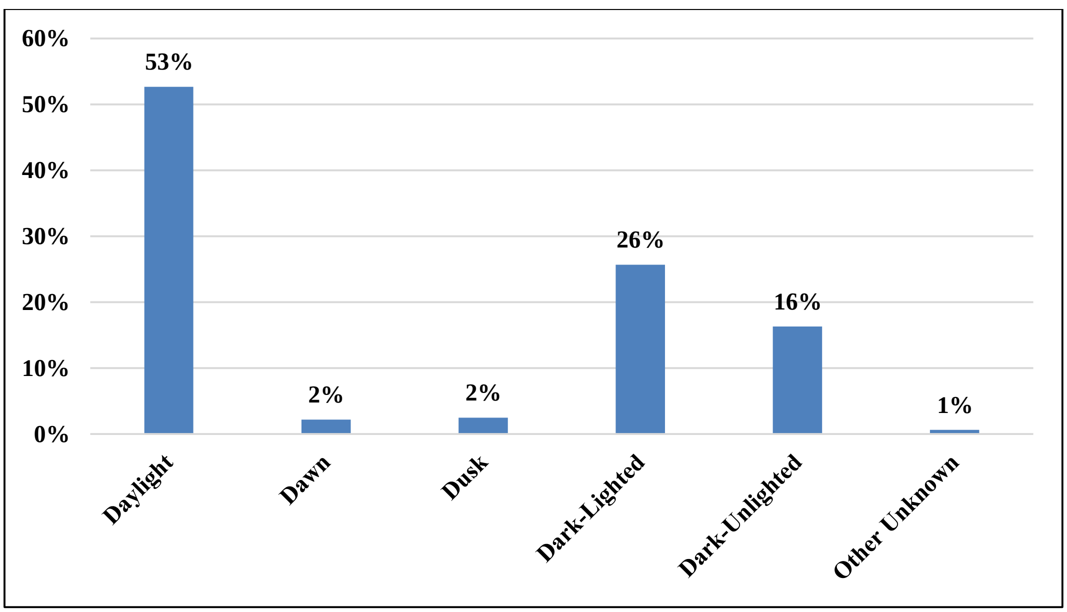


Figure 19: Distribution of total pedestrian crashes by lighting condition (2010-2014)

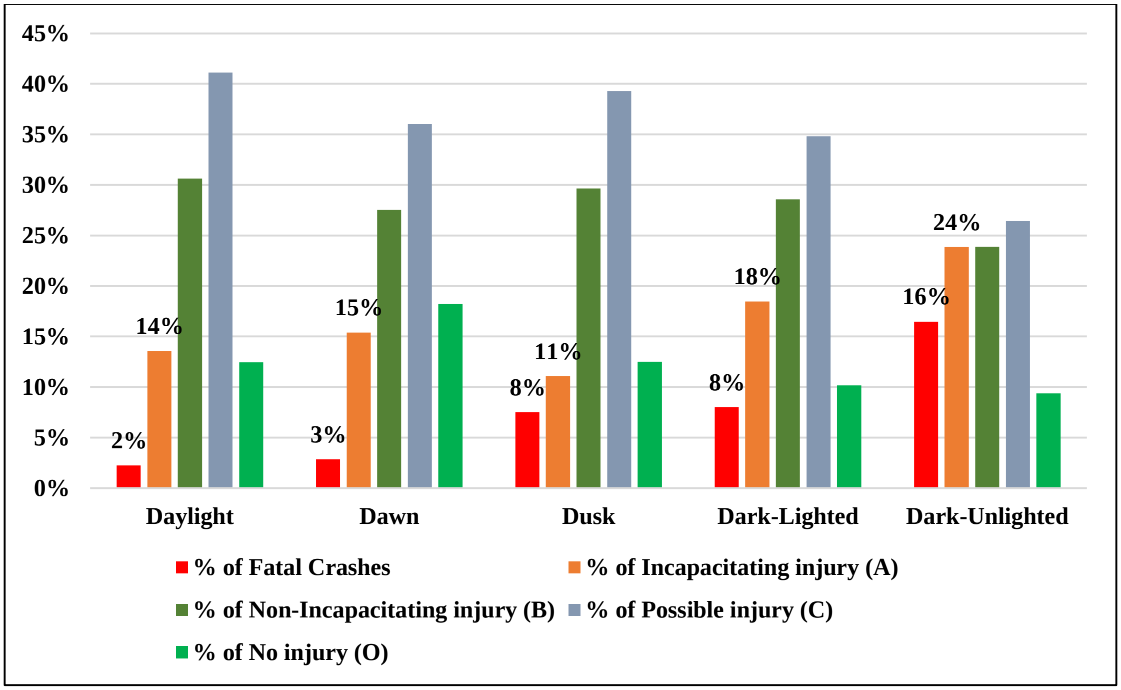


Figure 20: Distribution of total pedestrian crashes by severity by lighting condition (2010-2014)

Figure (21) shows the distribution of total pedestrian crashes by weather condition for five years (2010-2014). In terms of weather condition, the majority of pedestrian crashes occurred in clear weather conditions, followed by cloudy and rain weather conditions. This observation leads to the conclusion that inclement weather conditions had a very minor effect on the likelihood of pedestrian crashes. In addition, most pedestrians choose to walk when the weather condition is either clear or cloudy, as it is unpleasant to walk in weather conditions involving precipitation. Figure (22) shows the distribution of pedestrian crashes by injury severity by weather condition for five years (2010-2014). When broken down by crash severity, foggy or smoky and windy weather conditions had the highest proportion of severe crashes (i.e., incapacitating or fatal). In addition, crashes occurred during sleet/hail weather conditions tended to be more severe than crashes that occurred during clear or cloudy weather conditions.

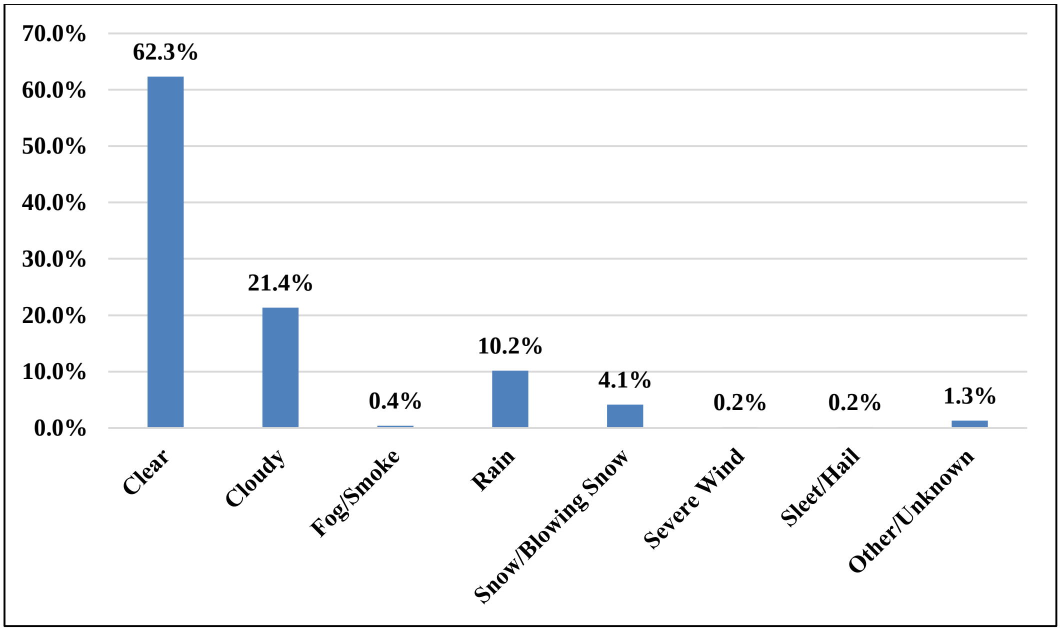


Figure 21: Distribution of total pedestrian crashes by weather condition (2010-2014)

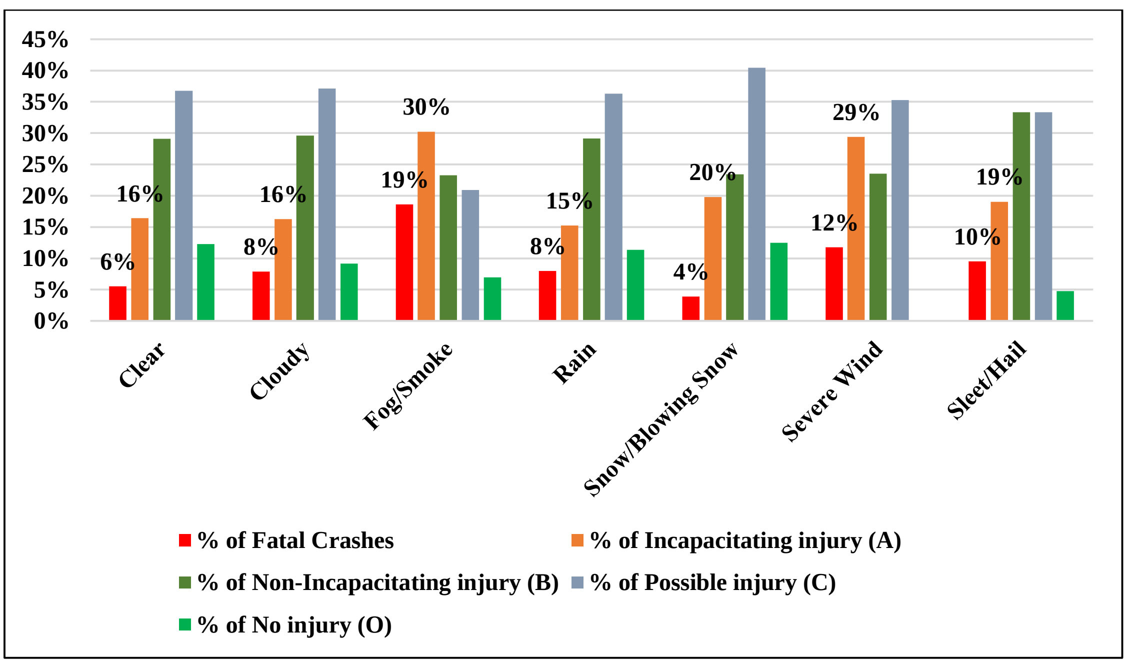


Figure 22: Distribution of pedestrian crashes by severity by weather condition (2010-2014)

Finally, Arc GIS 10.1 software package was used to create ratio maps by dividing the total number of pedestrian crashes in 1 km by 1 km grid by the total number of crashes on that grid in order to get a better representation for hot areas. Figure (23) illustrates the ratio map for all pedestrian crashes from 2010 to 2014. As the figure shows, a higher ratio of pedestrian crashes is concentrated around urban areas.

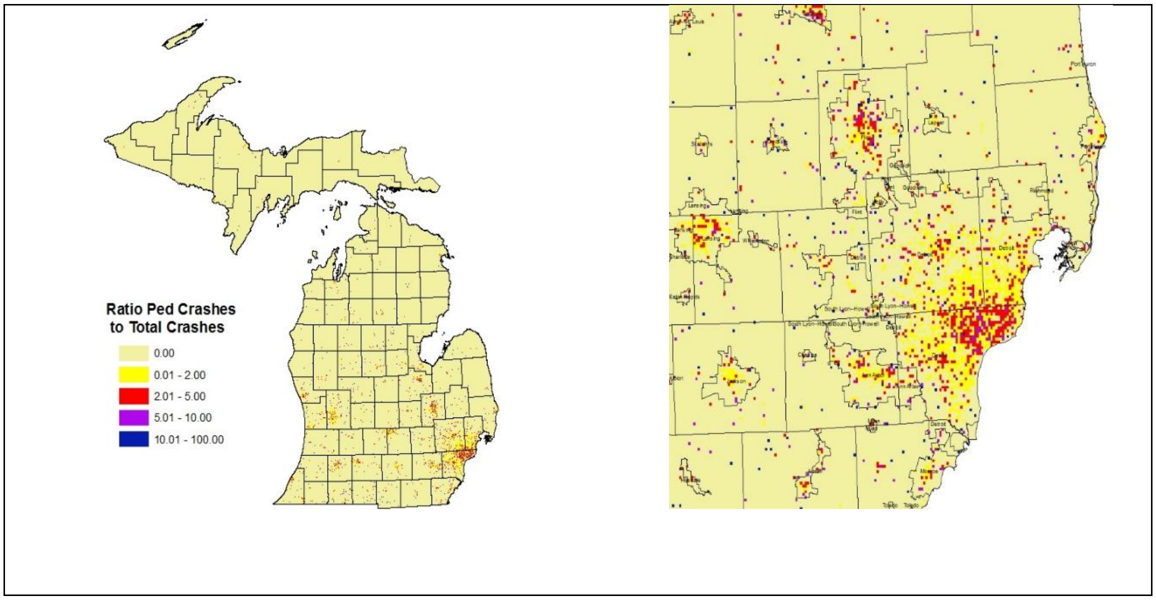


Figure 23: Ratio map for pedestrian crashes

Descriptive statistics for bicycle crashes

Figure (24) presents the distribution of total bicycle crashes and percentage of fatalities by year. The year 2012 had the highest number of total bicycle crashes and the lowest percentage of bicycle fatalities. In addition, 2010 had the second highest total bicycle crashes and the highest percentage of bicycle fatalities during the five years.

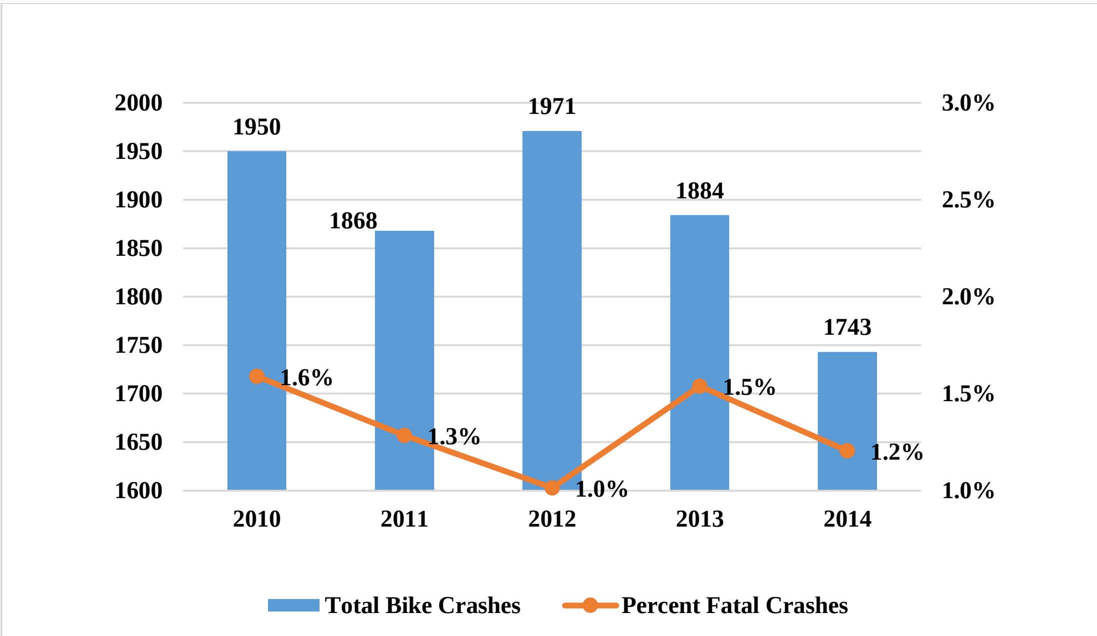


Figure 24: Distribution of bicycle crashes and percentage of fatalities by year

Figure (25) shows the distribution of bicycle crashes by injury severity by year. Both 2012 and 2013 had the highest percentages of incapacitating injury crashes. However, 2010 and 2013 had the highest percentages of bicycle fatal crashes. In addition, 2011 and 2012 had the lowest percentages of bicycle fatal crashes during the five years.

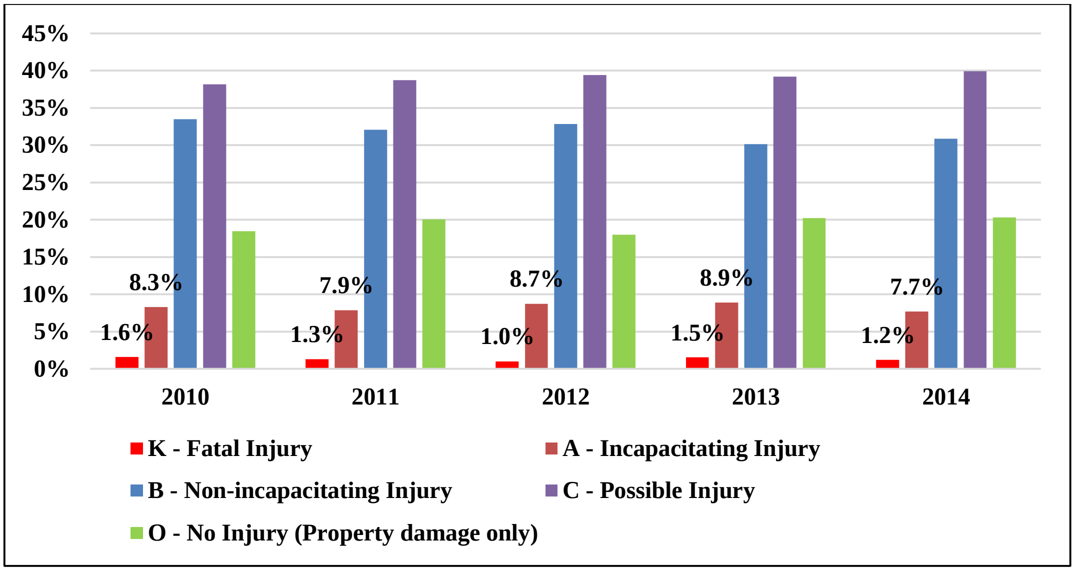


Figure 25: Distribution of bicycle crashes by severity by year

Figure (26) presents the distribution of total bicycle crashes by injury severity by gender for five years (2010-2014). The graph shows that the majority of bicycle crashes involved male bicyclists. In addition, crashes involving male bicyclists tended to be more severe than crashes involving female bicyclists in terms of fatal and incapacitating injury crashes. This observation can be explained by the fact that males are more likely to cycling during or in dangerous situations than females.

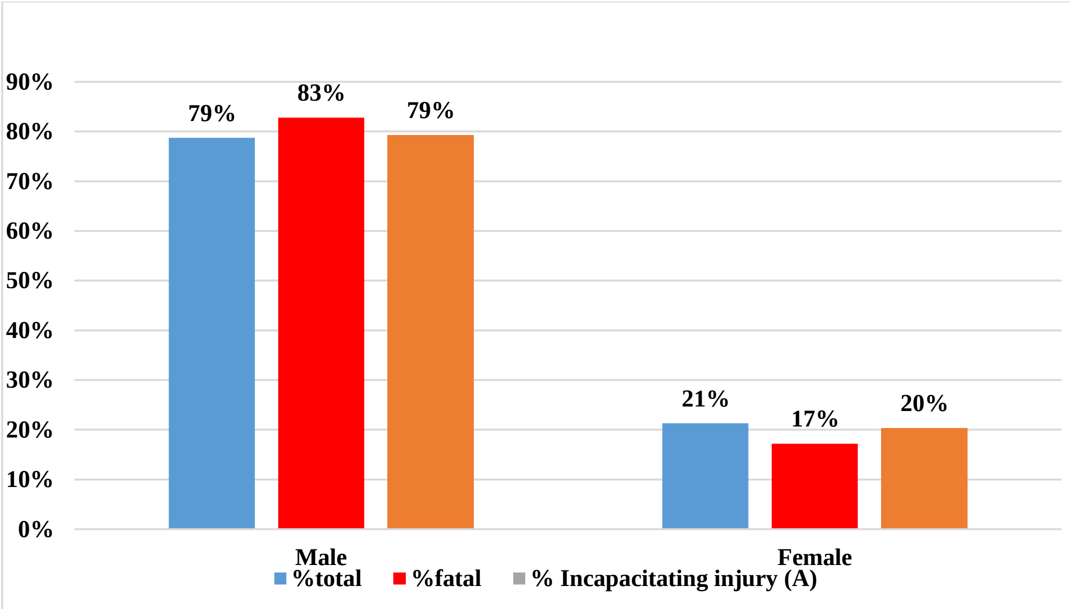


Figure 26: Distribution of total bicycle crashes by severity by gender (2010-2014)

Figure (28) shows the distribution of total bicycle crashes by injury severity by bicyclist's age for five years (2010-2014). The graph shows that the 45-64 age range had a higher proportion of fatal and incapacitating injury crashes than total crashes. This observation can be explained by the fact that increases in the cyclist's age might increase the likelihood of injury severity due to the physical structure of older people. In addition, the 16-24 age range had the highest percentage of total crashes compared to other age groups.

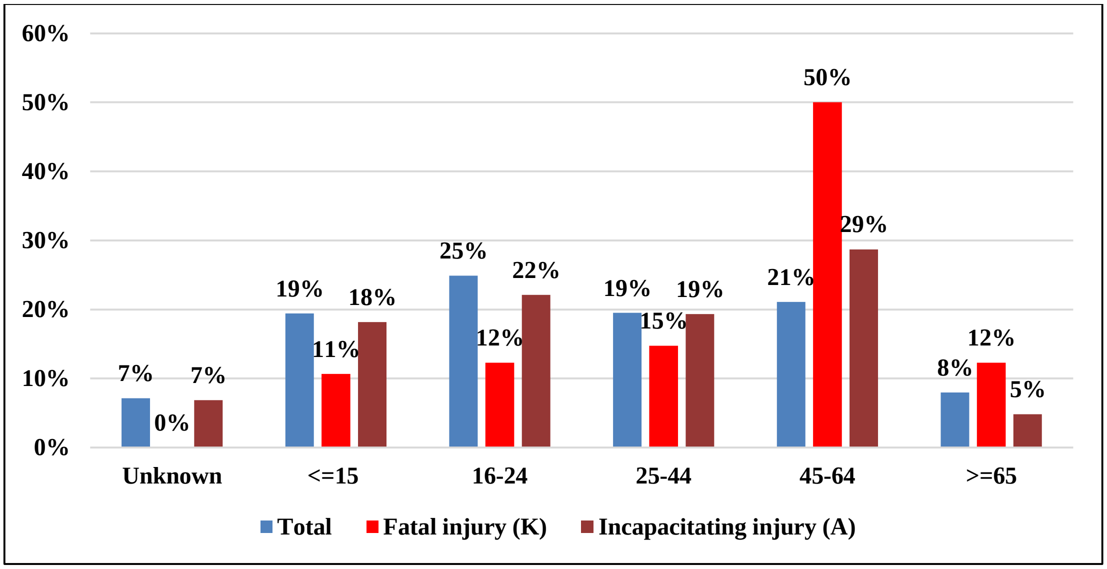


Figure 27: Distribution of total bicycle crashes by bicyclist's age for five years (2010-2014)

Figure (28) presents the distribution of total bicycle crashes by alcohol involvement by severity for five years (2010-2014). The figure shows that fatal crashes and incapacitating injury crashes had a high proportion of alcohol involvement compared to other injuries. This observation can be supported by the fact that crashes involving alcohol tend to be more severe.

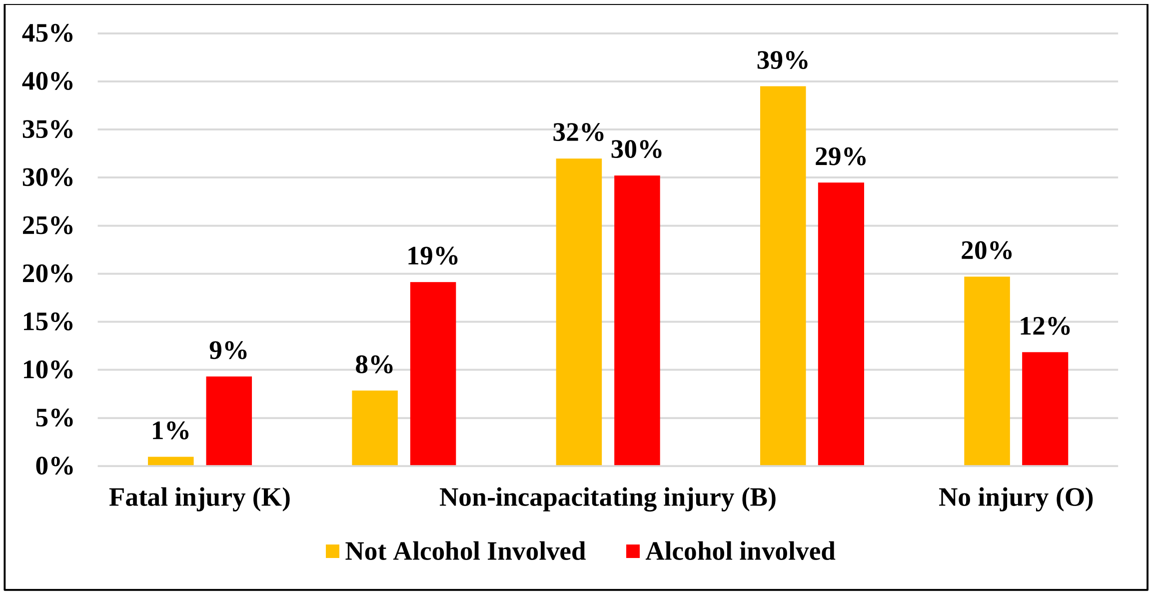


Figure 28: Distribution of total bicycle crashes by alcohol involvement by severity (2010-2014)

Figure (29) shows the proportion of total bicycle crashes by day of the week for five years (2010-2104). The graph shows that bicycle crashes distributed approximately evenly through the weekdays (e.g., Monday through Friday). Furthermore, Friday and Saturday had the lowest percentage of bicycle crashes. This trend can be explained by the fact that most of cycling activities took place during the weekdays while less activities took place during the weekend. Figure (30) shows the distribution of total bicycle crashes by injury severity by day of the week for five years (2010-2014). The figure shows that bicycle crashes occurred during Sunday, Saturday, and Monday tend to be more severe in terms of fatal and incapacitating injury crashes compared to the other days.

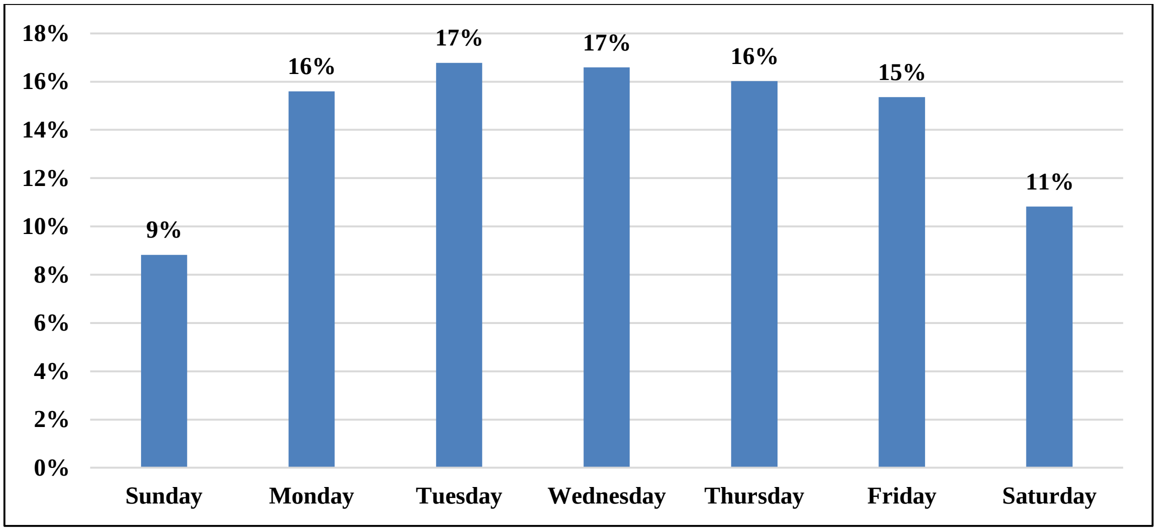


Figure 29: Distribution of total bicycle crashes by day of the week for five years (2010-2104)

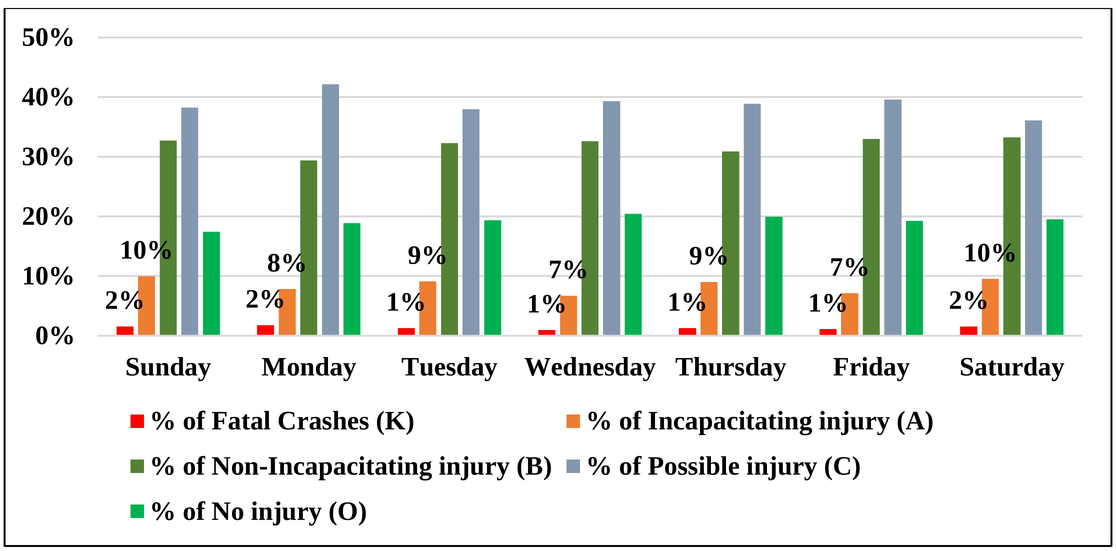


Figure 30: Distribution of total bicycle crashes by severity by day of the week (2010-2014)

Figure (31) presents the distribution of total bicycle crashes by MDOT crash location for five years (2010-2014). In terms of MDOT area type, the majority of bicycle crashes occurred at intersections and mid-blocks (78% and 19% of total bicycle crashes respectively). A small portion of total bicycle crashes occurred at interchanges. Figure (32) shows the distribution of

bicycle crashes by injury severity by MDOT crash location for five years (2010-2014). When broken down by injury severity, interchange and mid-block crash locations had more severe crashes in terms of fatal crashes than intersections. This trend can be explained by the fact that the speed of vehicles is higher on interchanges and mid-blocks and can affect the crash severity. Finally, intersections and mid-blocks had the highest percentage of incapacitating injury crashes compared to interchanges.

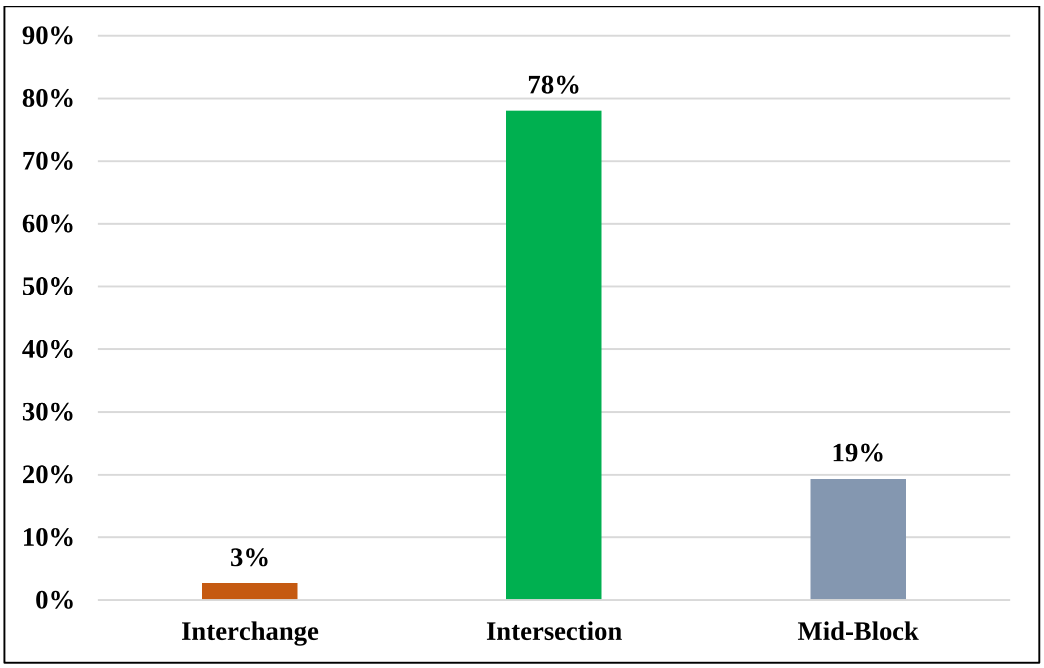


Figure 31: Distribution of total bicycle crashes by MDOT crash location (2010-2014)

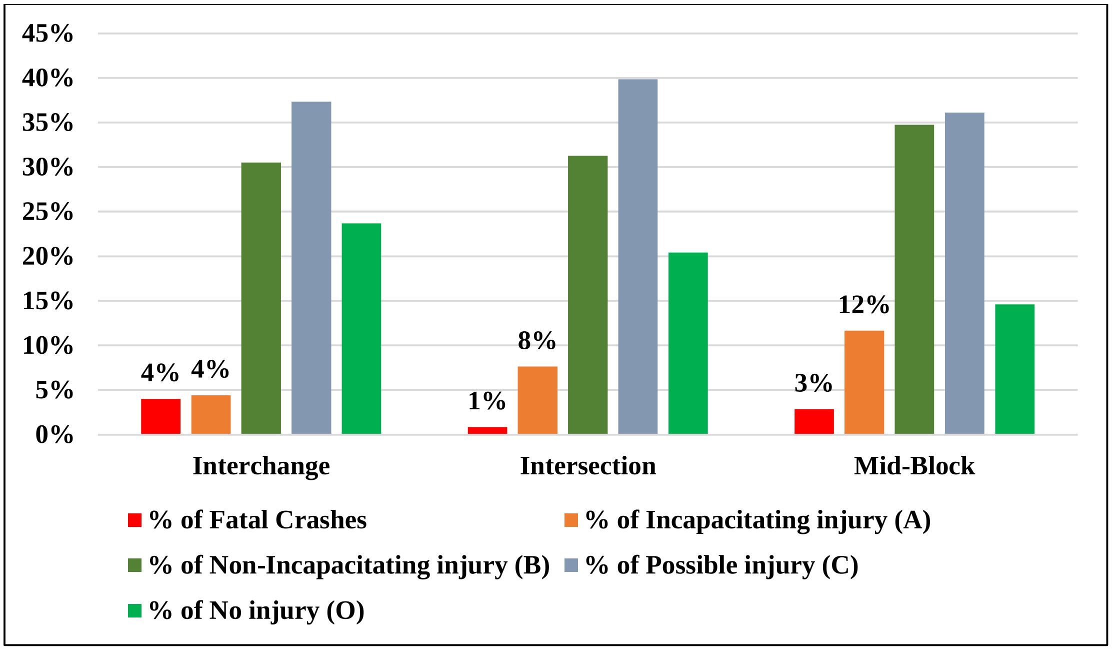


Figure 32: Distribution of bicycle crashes by severity by MDOT crash location 2010-2014)

Figure (33) shows the distribution of total bicycle crashes by traffic control device for five years (2010-2014). In terms of traffic control device, the majority of bicycle crashes occurred where there was no traffic control device present at the location of the crash. Furthermore, 31% of bicycle crashes occurred at signalized intersections and 26% of crashes occurred at sign-controlled intersections. Figure (34) shows the distribution of bicycle crashes by injury severity by traffic control device for five years (2010-2014). When broken down by injury severity, the majority of severe crashes and fatalities occurred where there was no traffic control device. This observation suggests that the absence of traffic control devices may increase the likelihood of injury severity of bicycle crashes.

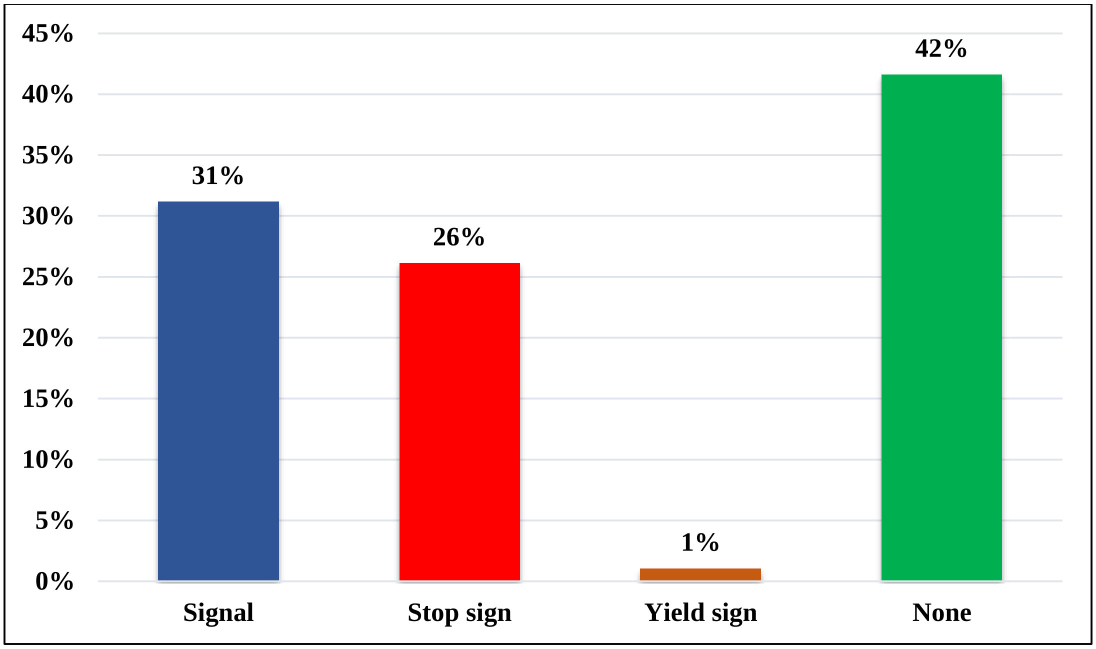


Figure 33: Distribution of total bicycle crashes by traffic control device (2010-2014)

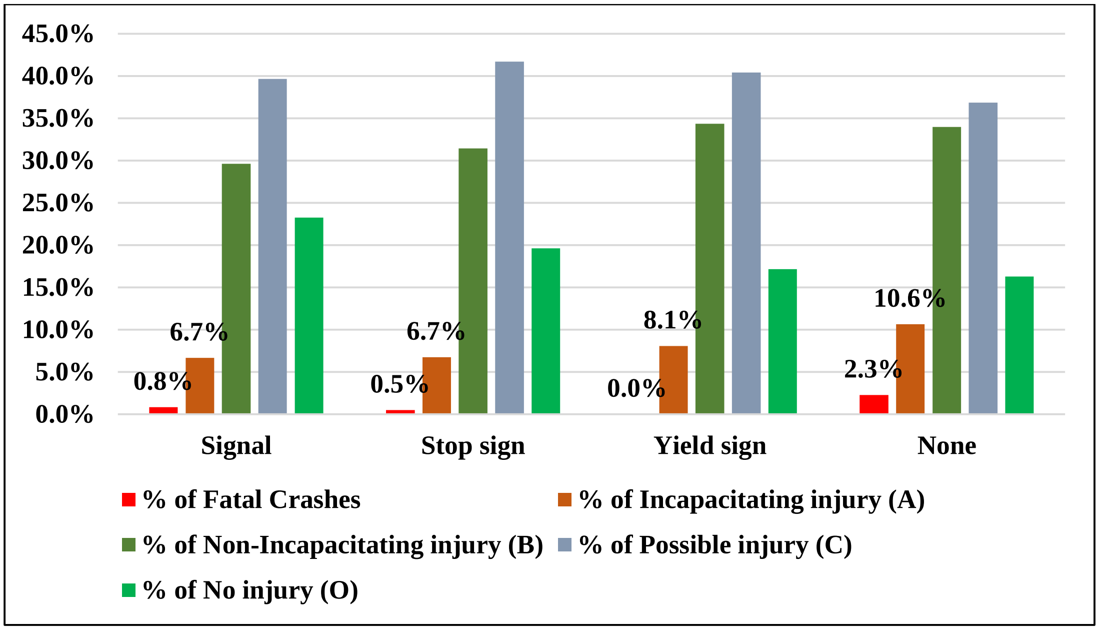


Figure 34: Distribution of total bicycle crashes by severity by traffic control device (2010-2014)

Figure (35) presents the distribution of total bicycle crashes by highway class for five years (2010-2014). In terms of traffic highway class, the majority of pedestrian crashes occurred within the road, city street or unknown highway category (72% of bicycle crashes). The figure shows that 19% of bicycle crashes occurred at the M Route highway class. In addition, 1% of bicycle crashes occurred on interstates. Figure (36) shows the distribution of bicycle crashes by injury severity by highway class for five years (2010-2014). When broken down by injury severity, crashes experienced on interstates, US routes, and M routes tend to be more severe (i.e., incapacitating or fatal) than those at lower highway classes. This observation can be explained by the fact that those highway classes had higher speed limits compared to the other highway classes and might increase the likelihood of injury severity.

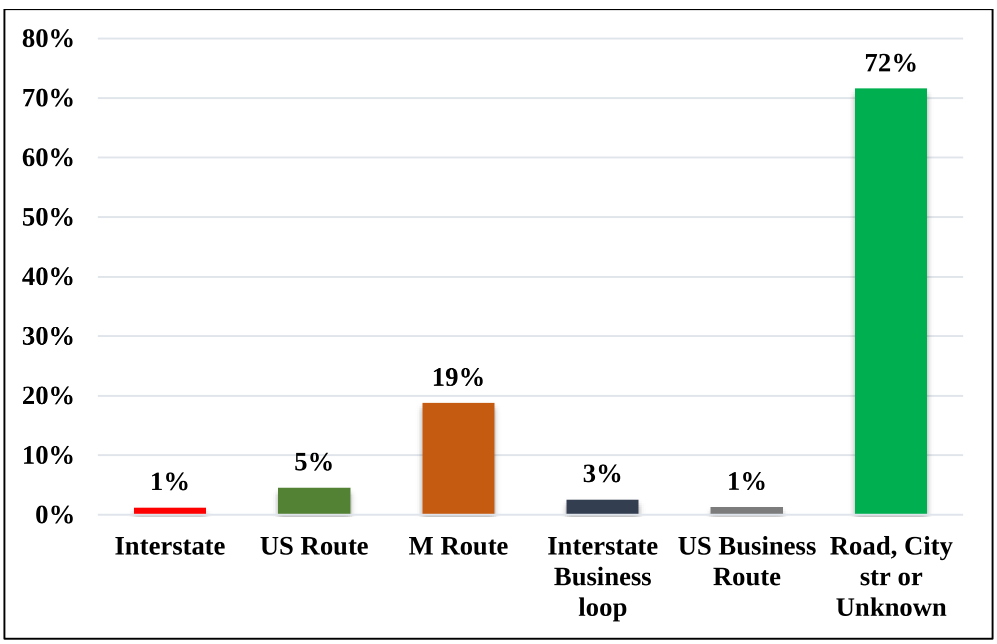


Figure 35: Distribution of total bicycle crashes by highway class (2010-2014)

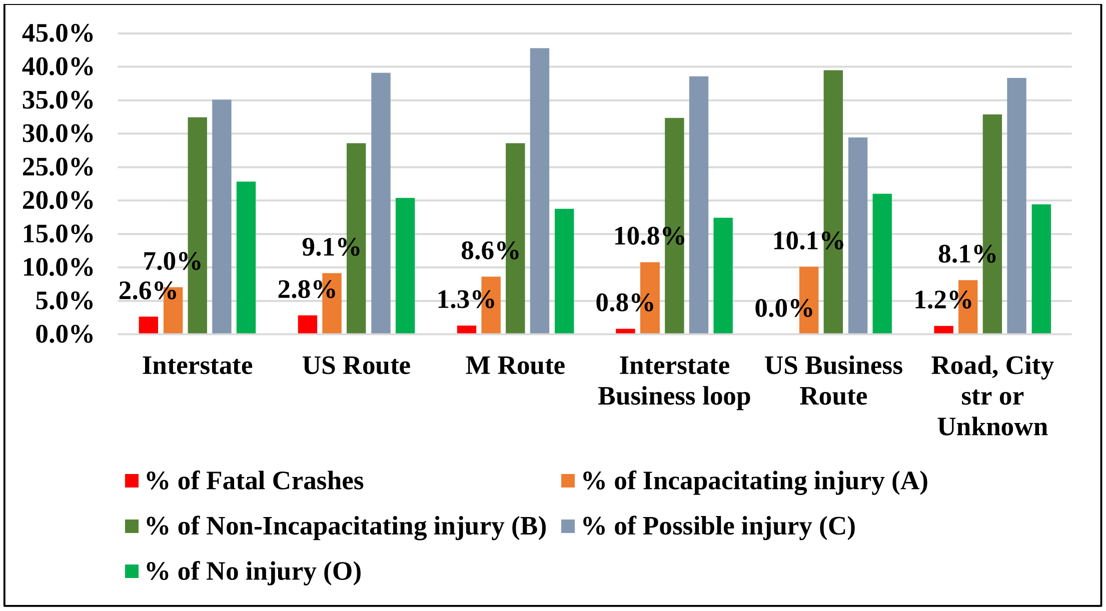


Figure 36: Distribution of total bicycle crashes by severity by highway class (2010-2014)

Figure (37) shows the distribution of total bicycle crashes by number of lanes for five years (2010-2014). In terms of number of lanes, the majority of bicycle crashes occurred in roads with two lanes (53%) followed by roads with four or more lanes (30%). In addition, roads with one lane (e.g., one-way roads) had the lowest percentage of bicycle crashes. Figure (38) shows the distribution of bicycle crashes by injury severity by number of lanes for five years (2010-2014). When broken down by crash severity, crashes experienced in roadways with one lane tend to be more severe (i.e., incapacitating or fatal). This observation suggests that insufficient space for cycling in narrow roadways might increase the likelihood of injury severity.

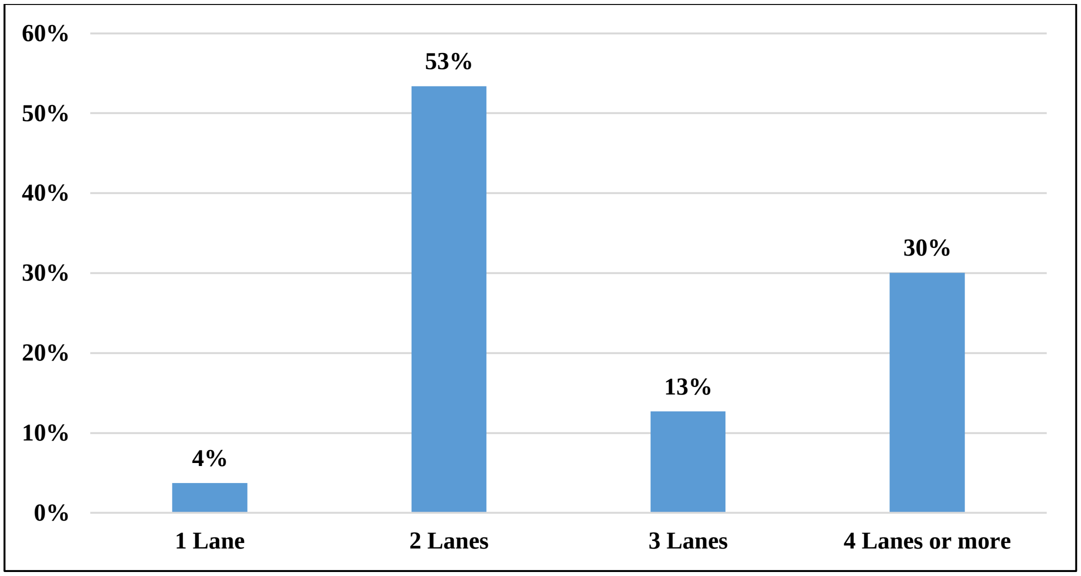


Figure 37: Distribution of total bicycle crashes by number of lanes (2010-2014)

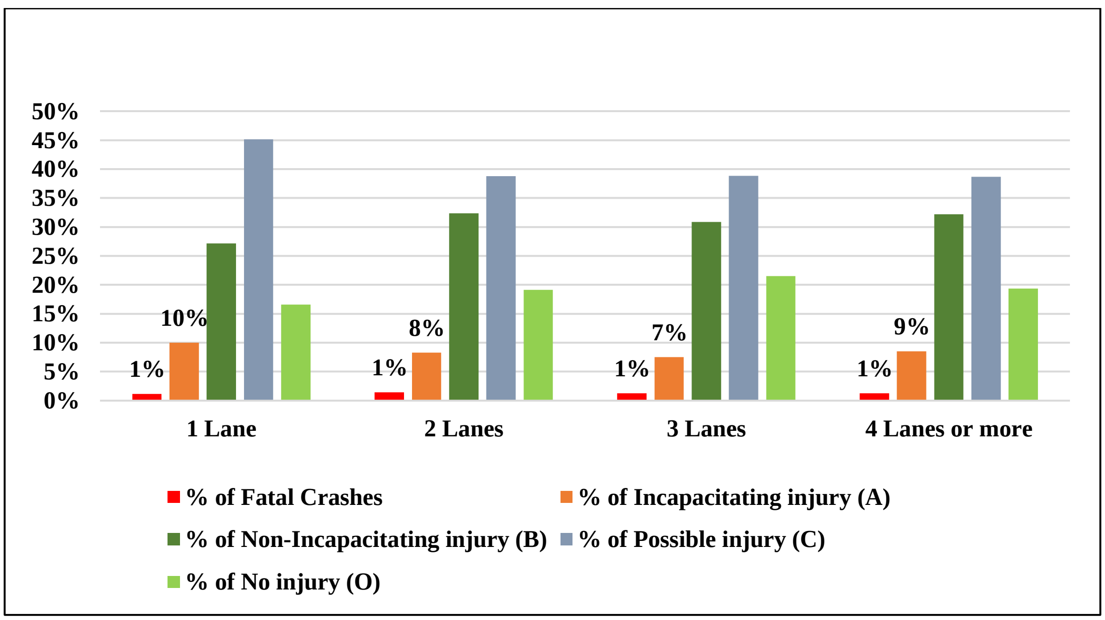


Figure 38: Distribution of total bicycle crashes by severity by number of lanes (2010-2014)

Figure (39) presents the distribution of total bicycle crashes by speed limit for five years (2010-2014). In terms of speed limit, the majority of bicycle crashes occurred in roads with a speed limit of 25 mph or less followed by roads with a speed limit from 25 to 35 mph. In addition. Figure (40) shows the proportion of bicycle crashes by injury severity by speed limit for five years (2010-2014). When broken down by crash severity, the majority of crashes experienced on roadways with a 45 mph speed limit and higher tended to be more severe (i.e., incapacitating or fatal). This observation can be explained by the fact that higher speeds most likely will cause severe injury.

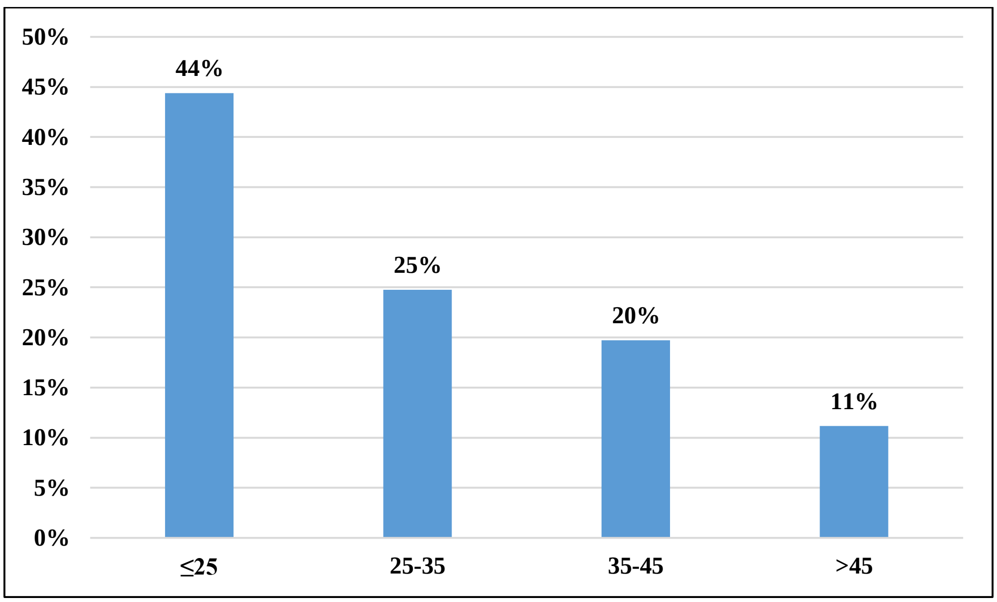


Figure 39: Distribution of total bicycle crashes by speed limit (2010-2014)

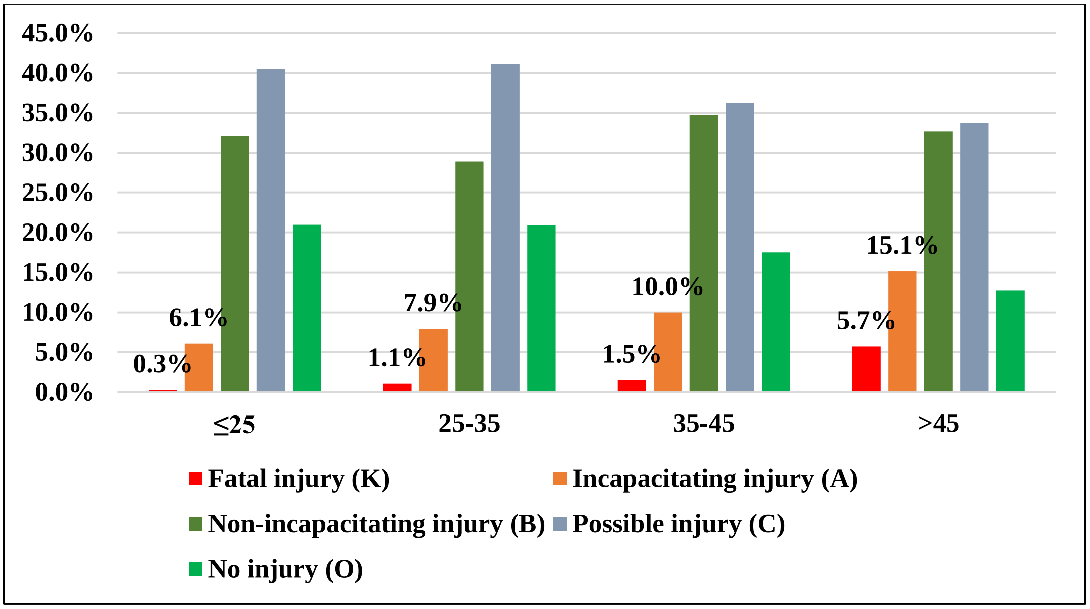


Figure 40: Distribution of total bicycle crashes by severity by speed limit (2010-2014)

Figure (41) shows the distribution of total bicycle crashes by lighting condition for five years (2010-2014). In terms of lighting condition, the majority of bicycle crashes occurred during the daylight. This observation can be explained by the fact that most cycling activities took place during the daylight. Figure (42) shows the distribution of bicycle crashes by injury severity by lighting condition for five years (2010-2014). When broken down by injury severity, dark-lighted and dark-unlighted lighting conditions tended to be more severe in terms of fatalities and incapacitating injury crashes than other lighting conditions. This observation can be explained by the fact that lack of lighting might affect the visibility of the motorist, or the cyclist cannot be detected easily during the night time.

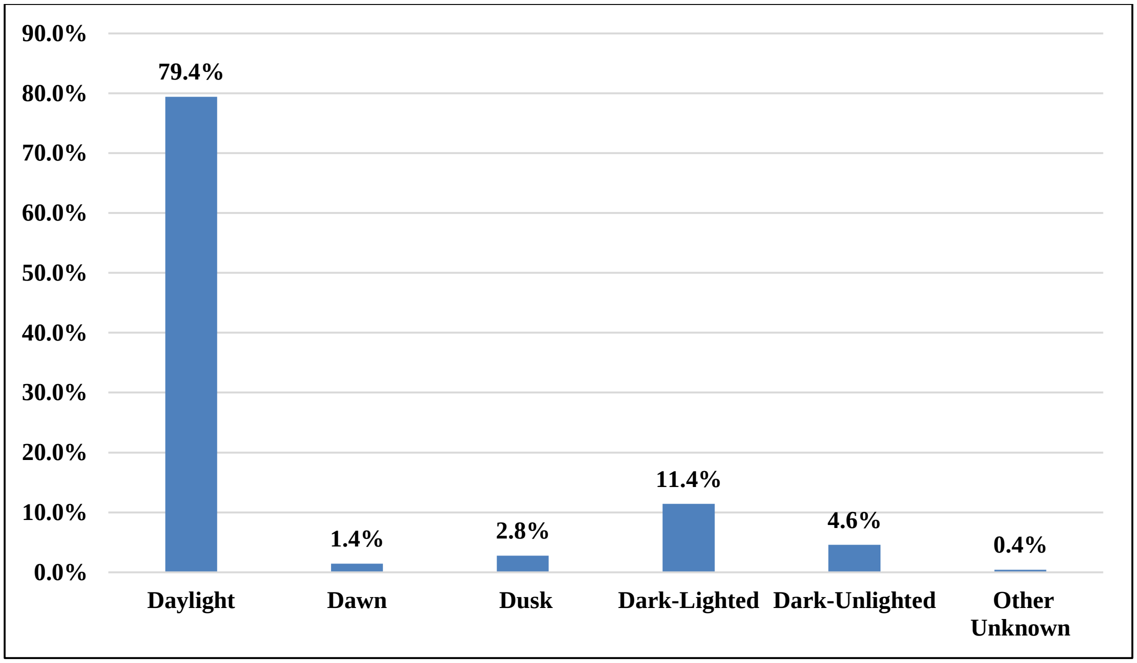


Figure 41: Distribution of total bicycle crashes by lighting condition (2010-2014)

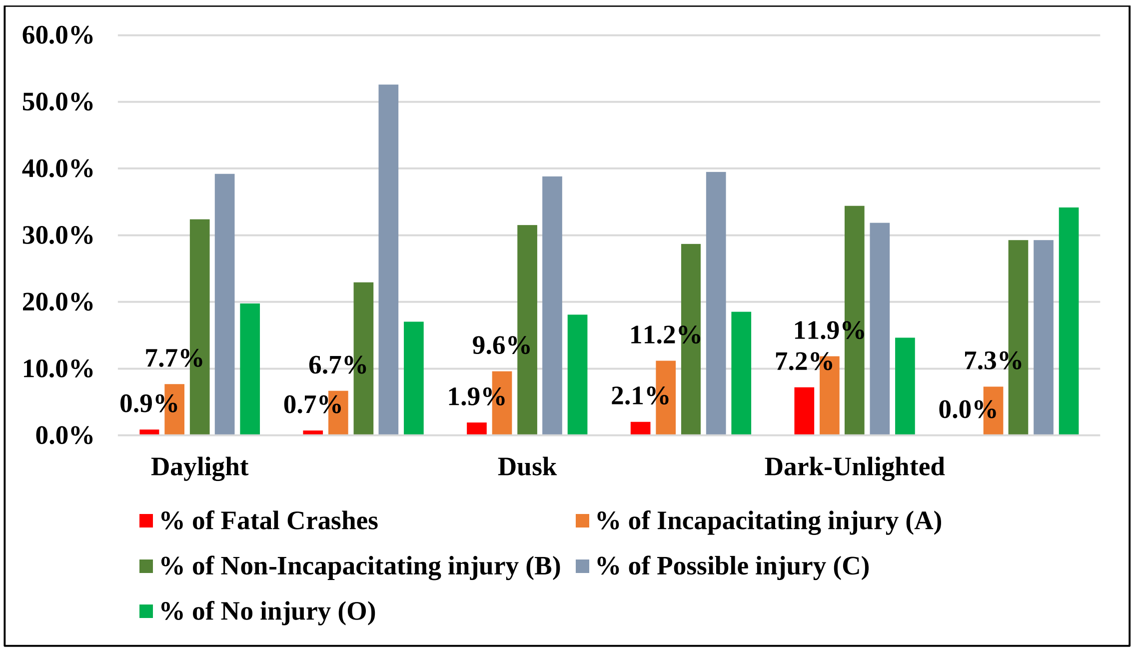


Figure 42: Distribution of total bicycle crashes by severity by lighting condition (2010-2014)

Figure (43) presents the distribution of total bicycle crashes by weather condition for five years (2010-2014). In terms of weather condition, the majority of bicycle crashes occurred in clear weather conditions, followed by cloudy and rain weather conditions. Figure (44) shows the distribution of bicycle crashes by injury severity by weather condition for five years (2010-2014). When broken down by crash severity, crashes occurred during foggy or smoky, rainy, and snowy weather conditions tended to be more severe (i.e., incapacitating or fatal) than crashes that occurred in other weather conditions. This observation suggests that inclement weather conditions may increase the likelihood of injury severity.

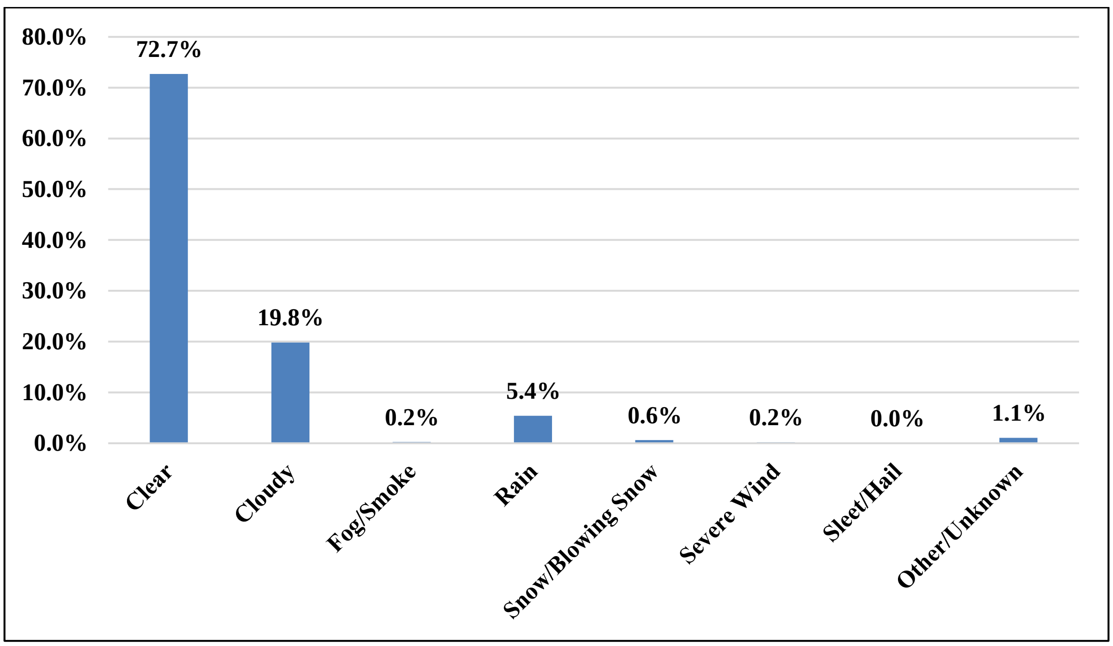


Figure 43: Distribution of total bicycle crashes by weather condition (2010-2014)

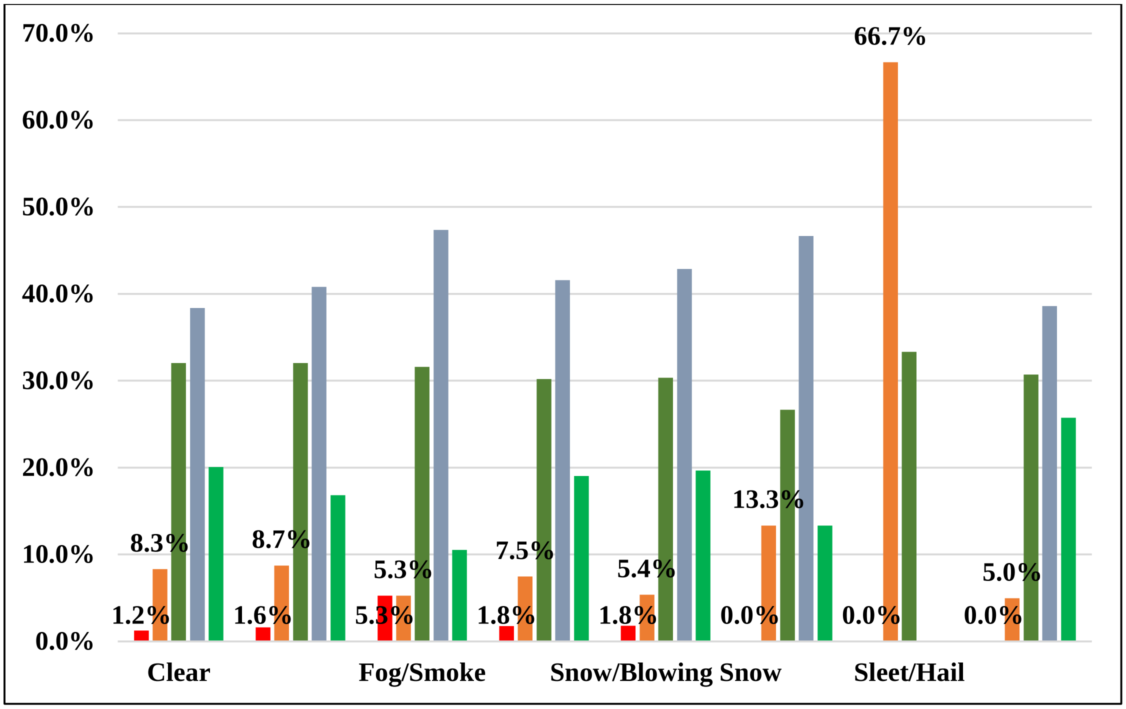


Figure 44: Distribution of bicycle crashes by severity by weather condition (2010-2014)

In addition, a ratio map was created by dividing the total number of bicycle crashes in 1 km by 1 km grid by the total number of crashes on that grid in order to get a better representation for hot areas. Figure (45) illustrates the ratio map for all bicycle crashes from 2010 to 2014. The graph shows a higher ratio of bicycle crashes concentrated around urban areas.

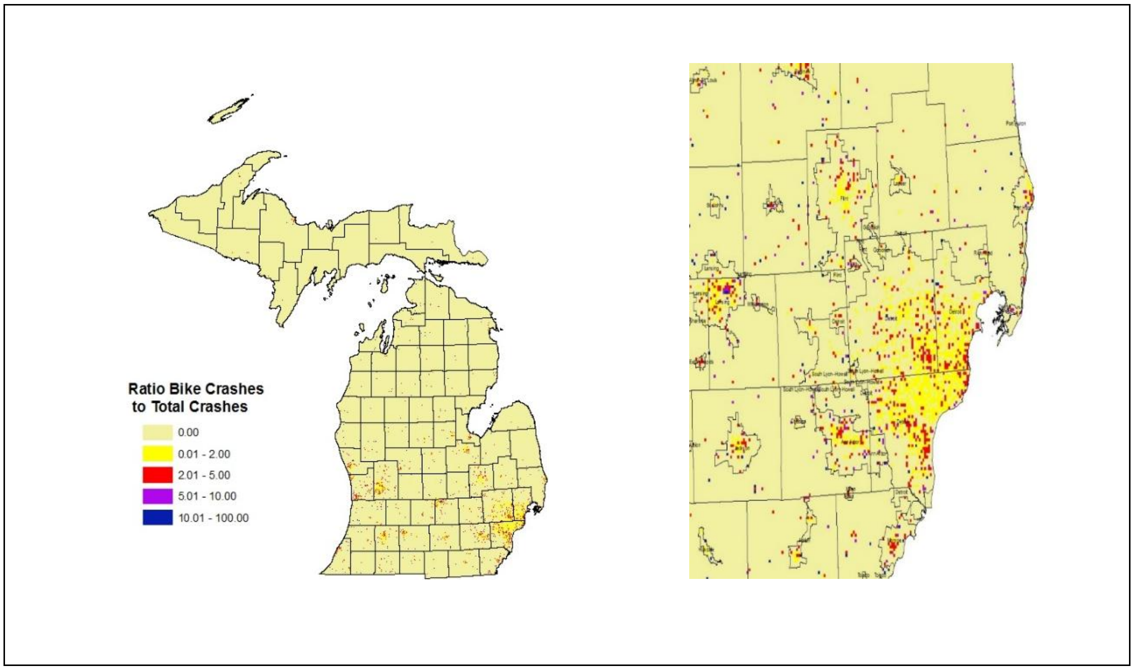


Figure 45: Ratio map for bicycle crashes

CHAPTER 4

COUNTERMEASURES SURVEY

Survey objective and formation

In this study, a survey on pedestrian and bicycle countermeasures was conducted in order to get information about the implementation and the effectiveness of current engineering, enforcement, and education countermeasures in the state of Michigan. Participants were asked about the effectiveness and the implementation of a specific countermeasure. The list of countermeasures that had been used in this survey was developed based on the literature review and PEDSAFE/BIKESAFE website (Harkey and Zegeer, 2004; Hunter and Thomas, 2006). The countermeasures were categorized into groups' including: infrastructure engineering countermeasures, traffic control engineering countermeasures, traffic signs and marking engineering countermeasures, facility engineering enhancements, enforcement countermeasures, and education and outreach countermeasures. The survey targeted three groups of participants: engineers/planners/designers, law enforcement officers, and advocacy groups. Additionally, the survey had two parts: the first part was about the pedestrian countermeasures and the second part was about bicycle countermeasures. An online survey tool was utilized to design this survey and the survey was distributed via email to the participants.

Figure (46) shows a sample of the survey question for the pedestrian countermeasures part. Figure (47) shows a sample of the survey question for the bicycle countermeasures part. In those two questions, the participants was asked about a specific countermeasure that had been implemented in their jurisdiction and rate it based on their experience and a scale of 1, "not

effective”, through 4, “very effective”. The participants had the ability to add their comments in a separate text box on each question. Furthermore, wording of questions was different for each group based on their experience and specialties. For instance, engineers were asked about if the engineering countermeasures had been implemented or not while law enforcement officers and advocacy group members were asked if they had seen the engineering countermeasure implemented in their jurisdiction. Appendix (A) shows the complete survey questions.

Has your jurisdiction implemented the following *traffic control engineering countermeasures* to improve pedestrian safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Traffic signals						
Pedestrian Signals						
Right-Turn-on-Red restrictions						
Advanced stop lines at traffic signals						
Left turn phasing						
Left turn prohibition						
Leading Pedestrian Interval						
Pedestrian push buttons						
Pedestrian Hybrid Beacon (PHB)						
Rectangular Rapid Flashing Beacon (RRFB)						

Other traffic control countermeasures (please describe including effectiveness)

Figure 46: Sample of the survey questions for the pedestrian countermeasures part

Has your jurisdiction implemented the following *traffic control engineering countermeasures* to improve bicyclist's safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Traffic signals						
Optimizing signal timing for bicyclists						
Bicycle signal activated by cyclists						
Right-Turn-on-Red Restrictions						
Advanced stop lines at traffic signals						
Bicycle signal heads						
Left turn phasing to promote safety of bicyclists						
Left turn prohibition to promote safety of bicyclists						

Other traffic control countermeasures (please describe including effectiveness)

Figure 47: Sample of the survey questions for the bicycle countermeasures part

Survey participants

Out of the 166 participants, 22% were engineers/planners/designers, 38% were law enforcement officers, 33% were advocacy groups, and 8% were other (e.g., road superintendent, city manager). Figure (48) shows the participants based on the area type of their jurisdiction. . Analysis of the data shows that 47% of responses were from suburban areas and 27% of the responses were from rural areas. Finally, 22% of responses were from urban areas and 3% from metropolitan areas. The effectiveness of each countermeasures category is shown in this chapter. Appendix B presents the percentage of implementation of countermeasures based on survey participants prospective.

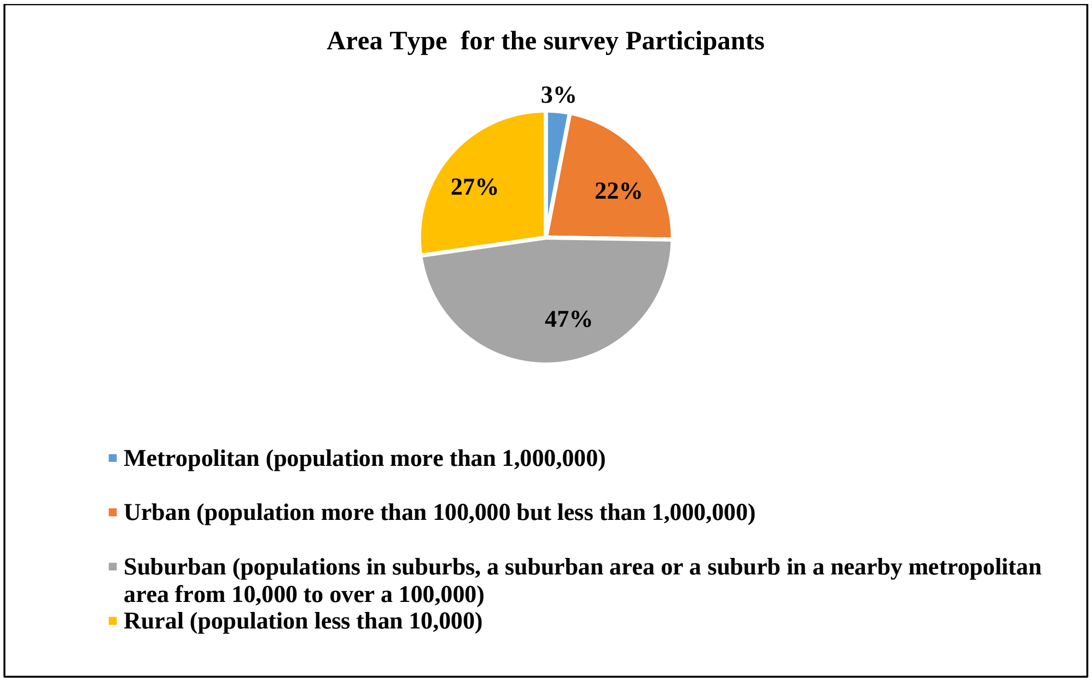


Figure 48: Area type for the survey Participants

Pedestrian countermeasures survey results

In terms of pedestrian countermeasures, participants were asked to rate the pedestrian safety in their jurisdictions based on a scale of -1 and 3, where -1 is not safe, 0 is Neutral, 1 is somewhat safe, 2 is safe, and 3 is very safe. Figure (49) shows the rating of pedestrian safety based on survey participants' responses. Regarding the pedestrian safety, engineers' responses rated pedestrian safety in their jurisdictions with an average rating of 1.24. Law enforcement officers rated pedestrian safety with an average rating of 1.36. Finally, advocacy groups rated pedestrian safety with an average rating of 0.7.

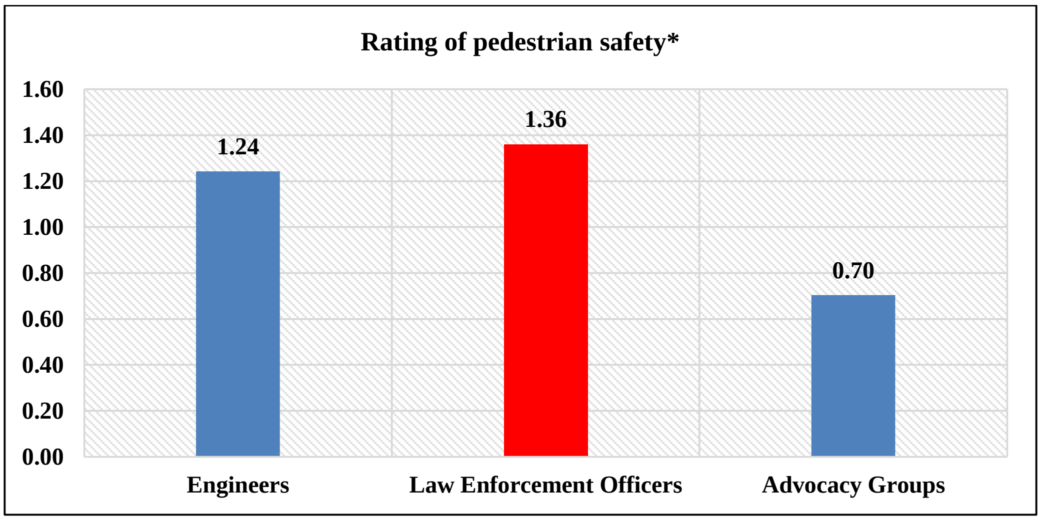


Figure 49: Rating of pedestrian safety

Table (3) presents the level of effectiveness of infrastructure engineering countermeasures for pedestrians. When considering infrastructure engineering countermeasures, engineers considered installation of sidewalks to be effective, with an average rating of 3.5. Law enforcement officers considered pedestrian overpass/underpass to be effective with an average

rating of 3.7, while advocacy groups considered installing raised pedestrian crossing and curb extension to be effective with an average rating of 3.3.

Table 3: Effectiveness of infrastructure engineering countermeasures for pedestrian

	Level of Effectiveness*		
Infrastructure Engineering Countermeasures	**Engineers**	**Law Enforcement Officers**	**Advocacy Groups**
Sidewalk	3.5	3.0	3.1
Crossing island	2.9	2.8	2.6
Road diet	3.1	2.2	3.2
Conversion of intersection to roundabout	3.1	2.8	2.9
Pedestrian overpass/underpass	3.3	3.7	3.2
Raised median	2.9	3.0	2.3
Raised median with crosswalk	3.0	3.1	2.9
Raised pedestrian crossing	2.3	3.4	3.3
Installing paved shoulder	2.8	2.9	3.1
Curb extension or ramp	2.8	3.2	3.3
Fence along the median to prevent midblock pedestrian crossing	3.3	3.0	2.8
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, serpentine design)	2.6	2.6	2.6

*** Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”**

Table (4) presents the level of effectiveness of traffic control engineering countermeasures for pedestrians. When considering traffic control engineering countermeasures, engineers considered the installation of traffic signals and pedestrian signals to be effective with an average rating of 3.2. Law enforcement officers considered the using of a rectangular rapid flashing beacon (RRFB) to be effective with an average rating of 3.3. In addition, advocacy groups considered the installation of pedestrian signals to be effective with an average rating of 3.2.

Table 4: Effectiveness of traffic control engineering countermeasures for pedestrian

Traffic Control Engineering Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Traffic signals	3.2	3.2	3.0
Pedestrian Signals	3.2	3.2	3.2
Right-Turn-on-Red restrictions	2.3	2.7	2.5
Advanced stop lines at traffic signals	2.8	2.6	1.6
Left turn phasing	2.8	3.1	2.1
Left turn prohibition	2.5	2.7	1.8
Leading Pedestrian Interval	2.7	3.2	2.3
Pedestrian push buttons	3	2.7	3.0
Pedestrian Hybrid Beacon (PHB)	2.3	3.0	3.0
Rectangular Rapid Flashing Beacon (RRFB)	2.3	3.3	3.0

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (5) presents the level of effectiveness of traffic signs and marking engineering countermeasures for pedestrians. In terms of traffic signs and marking engineering countermeasures, engineers and advocacy groups considered using high visibility crosswalks to be effective with an average rating of 3.1. In addition, law enforcement officers considered using marked crosswalks to be effective with an average rating of 2.9.

Table 5: Effectiveness of traffic signs and marking engineering countermeasures for pedestrian

Traffic Signs and Marking Engineering Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Marked crosswalk	3.0	2.9	2.9
Unmarked crosswalk	1.8	1.2	1.7
High visibility crosswalk (high visibility pavement markings, marking Pattern, signs)	3.1	2.8	3.1
Intersection illumination	3.0	2.8	3.0
Intersection markings	3.0	2.8	2.8
On-street parking restriction	2.8	2.7	2.2
Pedestrian warning signs	2.4	2.3	2.4
Pedestrian crossing mounted flags with high visibility colors	2.4	2.5	2.7

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (6) shows the level of effectiveness of facility engineering enhancements for pedestrians. In regard to facility engineering enhancements, engineers considered the installation of lighting in roadways and transit stop enhancements to be effective with an average rating of 3.1. Law enforcement officers considered street furniture and enhancement of driveways to be effective with an average rating of 3.1. Finally, advocacy groups considered tunnel and underpass access for pedestrians to be effective with an average rating of 3.6.

Table 6: Effectiveness of facility engineering enhancements for pedestrian

	Level of Effectiveness*		
Facility Engineering Enhancements	**Engineers**	**Law Enforcement Officers**	**Advocacy Groups**
Lighting	3.1	2.8	3.2
Street furniture (e.g., street trees, bus shelter, bench, trash/recycling receptacle)	2.4	3.1	2.5
Driveway enhancement (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	2.7	3.1	2.8
Transit stop enhancement (concrete pad, concrete curb, metal bench, chair, trash can, shelter)	3.1	2.9	2.7
Snow removal on sidewalks	3.0	3.0	2.9
Bridge and overpass access	2.8	3.0	2.9
Tunnel and underpass access	3.2	3.0	3.6

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (7) shows the level of effectiveness of enforcement countermeasures for pedestrians. In terms of enforcement countermeasures, engineers considered enforcement of alcohol and/or drug use laws for motorists to be effective with an average rating of 2.8. In addition, law enforcement officers and advocacy groups had the same opinion as the engineers, which was enforcement of alcohol and/or drug use law for motorists was effective in enhancing pedestrian safety.

Table 7: Effectiveness of enforcement countermeasures for pedestrian

Enforcement Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Enforcement of pedestrians failure to yield	2.3	2.4	1.0
Enforcement of motorists failure to yield	2.7	2.5	2.5
Enforcement of alcohol and/or drug use law (pedestrian)	2.8	2.6	2.0
Enforcement of alcohol and/or drug use law (motorist)	3.0	3.3	2.7
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	2.8	2.9	2.6

* Level of effectiveness (1 "not effective", 2 "somewhat effective", 3 "effective", 4 "very effective"

Table (8) shows the level of effectiveness of education and outreach countermeasures for pedestrians**.** In regard to education and outreach countermeasures, engineers considered road safety training or safety classes in schools to be effective with an average rating of 2.8. In addition, law enforcement officers considered the Safe Routes to School program to be effective with an average rating of 2.7. Finally, advocacy groups considered the Safe Streets for Seniors program to be effective with an average rating of 3.5 followed by workshops for parents, with an average rate of 3.

Table 8: Effectiveness of education and outreach countermeasures for pedestrian

Education and Outreach Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Safe Routes to School Program	2.6	2.7	3.0
Education programs for motorists	2.1	2.3	2.0
Education programs for pedestrians	2.4	2.2	2.3
Safe Streets for Seniors	2.7	2.5	3.5
Workshops for parents	2.4	2.2	3.0
Road safety training or safety classes in schools	2.8	2.6	3.0
Maps for pedestrian routes	2.5	2.0	2.9
Introducing education safety programs for pedestrians with language background other than English	2.3	2.5	1.8
Media campaigns for pedestrian safety	2.3	2.1	2.8

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

In addition, the average for the level of effectiveness and implementation for each category was calculated in order to get a full picture about the effectiveness and implementation of each category of countermeasures. Table (9) shows the average level of effectiveness for each category for pedestrian countermeasures**.** Response data shows that engineers considered infrastructure engineering countermeasures effective with an average rating of 2.97 followed by facility engineering enhancements with an average rating of 2.91. In addition, law enforcement officers considered infrastructure engineering and facility engineering enhancement countermeasures to be the most effective countermeasures with an average rating of 2.99 and 2.98 respectively. Advocacy groups also considered infrastructure engineering and facility engineering enhancement countermeasures to be the most effective countermeasures with an average rating of 2.95 and 2.93 respectively.

Based on responses data, education and outreach countermeasures had been rated less effective than other categories of countermeasures. This rating may be based on the fact that all

individuals surveyed responded with education and outreach countermeasures to be least implemented. The lack of implementation impacted the overall effectiveness rating. Finally, traffic control countermeasures scored low for engineers and advocacy group members with a level of effectiveness of 2.69 and 2.54 for engineers and group members respectively.

Table 9: Average effectiveness of pedestrian countermeasures

	Average Level of Effectiveness		
Countermeasures	**Engineers**	**Law Enforcement Officers**	**Advocacy Groups**
Infrastructure Engineering Countermeasures	2.97	2.98	2.93
Traffic Control Engineering Countermeasures	2.69	2.96	2.54
Traffic Signs and Marking Engineering Countermeasures	2.71	2.51	2.59
Facility Engineering Enhancements	2.91	2.99	2.95
Enforcement Countermeasures	2.82	2.83	2.54
Education and Outreach Countermeasures	2.48	2.40	2.68

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (10) shows the average percentage of implementation for pedestrian countermeasures. Based on response data, engineers’ responses show that infrastructure engineering countermeasures are the most implemented category with 65% of engineers’ responses. Traffic control engineering countermeasures received a response of 52% implementation based on the engineers surveyed. In addition, 65% of law enforcement officers responded that traffic signs and marking engineering countermeasures have been seen within their jurisdiction along with a 62% implementation rate for enforcement countermeasures. Finally, 69% of advocacy group members responded that infrastructure engineering

countermeasures are the most seen, followed by a response of 68% of advocacy group members observing that traffic signs and marking countermeasures have been seen. Based on the response data for all individuals surveyed, the results point to increasing the emphasis on the implementation of enforcement and education and outreach countermeasures for pedestrians in Michigan in order to promote pedestrian safety. Response data shows that enforcement and education and outreach countermeasures implementation or observation was ranked the lowest in terms of the percentage of the responses.

Table 10: Average percentage of implementation for pedestrian countermeasures

Countermeasures	Average % of Implemented "Engineers"	Average % of Seen "Law Enforcement Officers"	Average % of Seen "Advocacy Groups"
Infrastructure Engineering Countermeasures	45%	40%	56%
Traffic Control Engineering Countermeasures	52%	57%	54%
Traffic Signs and Marking Engineering Countermeasures	65%	65%	68%
Facility Engineering Enhancements	49%	50%	69%
Enforcement Countermeasures	41%	62%	42%
Education and Outreach Countermeasures	39%	36%	37%

Bicycle countermeasures survey results

When considering bicycle countermeasures, participants were asked to rate the bicyclist safety in their jurisdictions based on a scale of -1 and 3, where -1 is not safe, 0 is Neutral, 1 is somewhat safe, 2 is safe, and 3 is very safe. Figure (50) shows the rating of bicyclist safety based on survey participants’ responses. Regarding bicyclist safety, engineers’ responses rated the bicyclist safety in their jurisdiction with an average rating of 0.906. In addition, law enforcement

officers rated bicyclist safety with an average rating of 1.1. Finally, advocacy groups rated bicyclist safety with an average rating of 0.4.

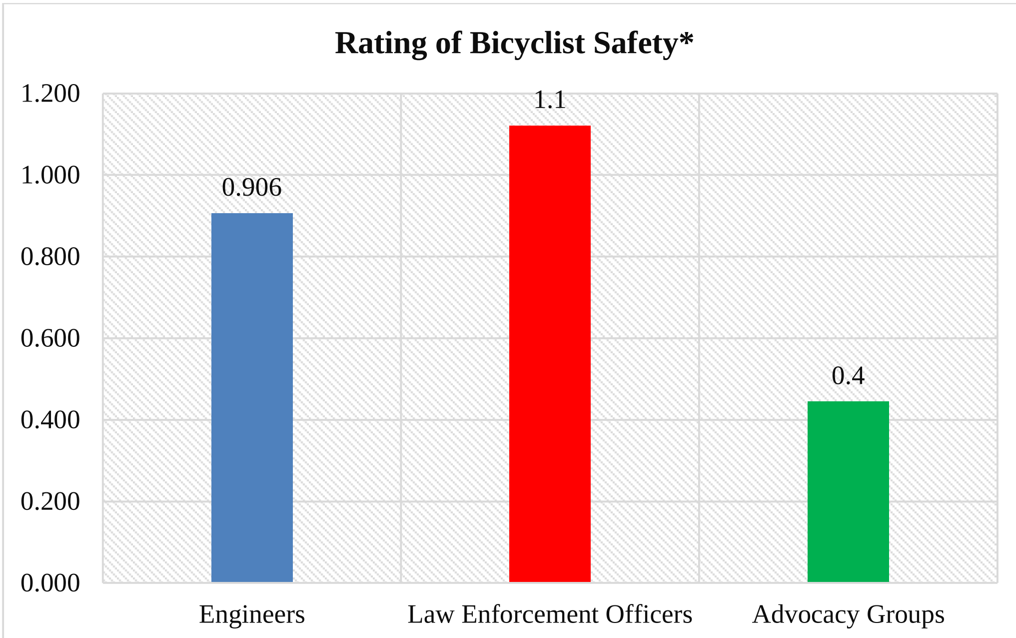


Figure 50: Rating of bicyclist safety

Table (11) presents the level of effectiveness of infrastructure engineering countermeasures for bicycle crashes. When considering infrastructure engineering countermeasures for bicycles, engineers considered installation of grade separated cycle path and bicycle trails to be effective with an average rating of 3.5. Law enforcement officers considered construction of bridge or tunnel access to be effective with an average rating of 3.5, while advocacy groups considered installing grade separated cycle paths to be effective with an average rating of 3.7.

Table 11: Effectiveness of infrastructure engineering countermeasures for bicycles

Infrastructure Engineering Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Dedicated bicycle lane	3.0	2.7	3.2
Shared bicycle lane	2.6	2.5	2.5
Grade separated cycle path	3.5	3.1	3.5
Bridge or tunnel access	3.5	3.5	3.4
Road diet	2.8	1.6	2.9
Refuge island	2.9	2.6	2.7
Raised median	2.6	2.8	2.4
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, mini-circles, visual narrowing)	2.7	2.6	2.6
Installation of paved shoulder	3.0	2.7	3.0
Wide curb lane	2.8	2.9	2.8
Bicycle Trails	3.5	3.4	3.7

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (12) shows the level of effectiveness of traffic control engineering countermeasures for bicycles. In regard to traffic control engineering countermeasures, engineers considered installation of bicycle signal heads to be effective with an average rating of 3.3 followed by traffic signals with an average rate of 3.1. In addition, law enforcement officers considered optimization of signal timing for cyclists and traffic signals to be effective with an average rating of 3. Advocacy groups considered installing bicycle signals activated by cyclists to be effective, with an average rating of 3.6, followed by the prohibition of left turns with an average rate of 4.

Table 12: Effectiveness of traffic control engineering countermeasures for bicycles

Traffic Control Engineering Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Traffic signals	3.1	3.0	2.9
Optimizing signal timing for bicyclists	3.0	3.0	3.2
Bicycle signal activated by cyclists	3.0	3.2	3.6
Right-Turn-on-Red Restrictions	2.0	2.8	2.6
Advanced stop lines at traffic signals	2.7	2.8	2.8
Bicycle signal heads	3.3	2.0	3.3
Left turn phasing to promote safety of bicyclists	2.8	2.4	2.5
Left turn prohibition to promote safety of bicyclists	3.0	2.7	4.0

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (13) shows the level of effectiveness of facility and bicycle engineering enhancements for bicycles. In regard to facility and bicycle engineering enhancements, engineers considered enhancing school zones to be effective with an average rating of 3. Law enforcement officers considered bicyclists use of warning lights to be effective with an average rating of 3. Finally, advocacy groups considered bicyclists use of warning lights to be effective with an average rating of 3.6.

Table 13: Effectiveness of facility and bicycle engineering enhancements for bicycles

Facility and Bicycle Engineering Enhancements	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
School zone enhancement (warning signs, crossing guards, high visibility crosswalks, and speed humps)	3.0	2.9	3.0
Prevention or restriction of on-street parking	2.6	2.8	2.3
Lighting	2.8	2.7	2.8
Enhancement of sight distance at driveways (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	2.8	2.7	2.7
Roadway maintenance (street sweeping, landscaping, pavement maintenance)	2.8	2.7	2.7
Bicyclists use of warning lights (white headlight, red-rear reflector, and backlight)	2.8	3.0	3.1
Signage improvements for bicyclists	2.7	2.8	2.9
Signage improvements for motorists	2.8	2.7	2.7
Pavement marking improvements to increase awareness	2.8	2.6	2.8

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective

Table (14) presents the level of effectiveness of enforcement countermeasures for bicycles. In regard to enforcement countermeasures, engineers considered enforcement of laws for the cyclists who didn’t use warning signs at night time to be effective with an average rating of 3.5. In addition, law enforcement officers and advocacy groups considered enforcement of laws for the motorists for using alcohol and/or drug while driving to be effective with an average rate of 3.2 and 2.6 respectively.

Table 14: Effectiveness of enforcement countermeasures for bicycles

Enforcement Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Enforcement of laws on bicyclists failure to yield	2.4	2.1	1.8
Enforcement of laws on motorists failure to yield	2.7	2.6	2.6
Enforcement of laws on bicycle warning lights use at night time	3.5	2.4	2.5
Enforcement of law on alcohol and/or drug use while riding (bicyclists)	3.0	2.1	1.8
Enforcement of law on alcohol and/or drug use while operating (motorist)	3.1	3.2	2.6
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	2.9	2.9	2.6

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (15) shows the level of effectiveness of education and outreach countermeasures for bicycles. In terms of education and outreach countermeasures, engineers considered road safety training or safety classes in schools to be effective with an average rating of 2.8. In addition, law enforcement officers considered the Safe Routes to School program and road safety training or safety classes in schools to be effective with an average rating of 2.8. Finally, advocacy groups considered the Bicycle Ambassadors Program and Safe Routes to the School program to be effective with an average rating of 3.

Table 15: Effectiveness of education and outreach countermeasures for bicycles

Education and Outreach Countermeasures	Level of Effectiveness*		
	Engineers	Law Enforcement Officers	Advocacy Groups
Safe Routes to School Program	2.5	2.8	3.0
Bicycle Ambassadors Program	2.6	2.5	3.0
Education programs for motorists	2.4	2.3	2.3
Education programs for bicyclists	2.7	2.4	2.6
Workshops for parents	2.7	2.0	2.8
Road safety training or safety classes in schools	2.8	2.8	2.8
Introducing education safety programs for pedestrians with language background other than English	2.5	1.0	2.6
Media campaigns on cyclists safety	2.4	2.1	2.3
Safety messages and free classes for how to bike safely.	2.6	2.1	2.8
Posters promoting the safety of cycling	2.1	2.0	2.4
Maps for cyclists routes	2.6	2.4	2.8

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (16) presents the average level of effectiveness for each category for bicycles countermeasures. Response data shows that engineers considered infrastructure engineering countermeasures effective with an average rating of 2.99 followed by enforcement countermeasures with an average rate of 2.90. In addition, law enforcement officers considered infrastructure engineering and facility and bicycle engineering enhancements to be the most effective countermeasures, with an average rating 2.77. Finally, advocacy groups also considered traffic control engineering and infrastructure engineering countermeasures to be the most effective countermeasures, with an average rating 3.11 and 2.97 respectively. Based on response data, education and outreach countermeasures were rated less effective than other categories of countermeasures. This rating may be based on the fact that all individuals surveyed responded with education and outreach countermeasures to be least implemented as shown in Table (17). The lack of implementation impacted the overall effectiveness rating.

Table 16: Average effectiveness of bicycles countermeasures

Countermeasures	Average Level of Effectiveness		
	Engineers	Law Enforcement Officers	Advocacy Groups
Infrastructure Engineering Countermeasures	2.99	2.77	2.97
Traffic Control Engineering Countermeasures	2.87	2.72	3.11
Facility and Bicycle Engineering Enhancements	2.78	2.77	2.78
Enforcement Countermeasures	2.90	2.59	2.44
Education and Outreach Countermeasures	2.54	2.22	2.68

* Level of effectiveness (1 “not effective”, 2 “somewhat effective”, 3 “effective”, 4 “very effective”

Table (17) shows the average percentage of implementation for bicycles countermeasures. Based on response data, engineers’ responses show that facility and bicycle engineering enhancements are the most implemented category of countermeasures with 66% of engineers responding that those countermeasures have been implemented. Infrastructure engineering countermeasures received a response of 50% implementation based on the engineers surveyed. In addition, 63% of law enforcement officers responded that facility and bicycle engineering enhancements have been seen within their jurisdiction along with a 55% implementation rate for enforcement countermeasures. Finally, 67% of advocacy group members responded that facility and bicycle engineering enhancements are the most seen, followed by a response of 60% of advocacy group members observing that infrastructure engineering countermeasures have been seen. Based on the response data for all individuals surveyed, the results point to increase the emphasis on the implementation of traffic control engineering countermeasures, enforcement, education, and outreach countermeasures for bicycles in the state of Michigan in order to promote bicyclists safety, because the implementation or observation for those countermeasures was very low based on survey participants prospective.

Table 17: Average percentage of implementation for bicycles countermeasures

Countermeasures	Average % of Implemented "Engineers"	Average % of Seen "Law Enforcement Officers"	Average % of Seen "Advocacy Groups"
Infrastructure Engineering Countermeasures	50%	42%	60%
Traffic Control Engineering Countermeasures	23%	26%	33%
Facility and Bicycle Engineering Enhancements	66%	63%	67%
Enforcement Countermeasures	38%	55%	40%
Education and Outreach Countermeasures	41%	27%	41%

Analysis of survey results

A t-test was conducted for the survey responses in order to indicate when there was a difference between the responses of different groups of participants. The most frequent significant differences occurred in the areas of enforcement and education countermeasures. Table (18) shows the results of t-test for pedestrian countermeasures. At a 95% confidence level, both engineers and law enforcement officers didn’t answer similarly to advocacy group members in terms of enforcement countermeasures. At a 90% confidence level, both engineers and law enforcement officers didn’t respond similarly to advocacy group members in terms of education and outreach countermeasures. The differences observed for various countermeasures can be explained by the fact that different groups of participants involve individuals with different professions.

Table 18: T-test results for pedestrian countermeasures

Countermeasures	T-value Engineers & Law Enforcement Officers	T-value Engineers & Advocacy Groups	T-value Law Enforcement Officers & Advocacy Groups
Infrastructure Engineering Countermeasures	-0.0571	0.191	0.2759
Traffic Control Engineering Countermeasures	-2.0248**	0.8251	2.7391**
Traffic Signs and Marking Engineering Countermeasures	2.6112**	0.9775	-0.9661
Facility Engineering Enhancements	-0.6178	-0.4648	0.2754
Enforcement Countermeasures	-0.2063	2.5942**	2.4867**
Education and Outreach Countermeasures	1.4396	-1.7903*	-1.8560*

* Significant at 90% confidence level
** Significant at 95% confidence level

Table (19) shows the results of the t-test for bicycles countermeasures. Again, the most frequent significant differences occurred in the areas of enforcement and education countermeasures. At a 95% confidence level, engineers responded differently than law enforcement officers, engineers responded differently than advocacy group members, and law enforcement officers responded differently than advocacy group members in terms of education and outreach countermeasures. At a 95% confidence level, both engineers and law enforcement officers didn’t answer similarly to advocacy group members in terms of enforcement countermeasures. Finally, engineers responded differently than law enforcement officers in terms of enforcement countermeasures at 90% confidence level. Again, the differences observed for various countermeasures can be explained by the fact that different groups of participants involve individuals with different professions.

Table 19: T-test results for bicycles countermeasures part

Countermeasures	T-value		
	Engineers & Law Enforcement Officers	Engineers & Advocacy Groups	Law Enforcement Officers & Advocacy Groups
Infrastructure Engineering Countermeasures	2.0278**	0.4303	-1.5549
Traffic Control Engineering Countermeasures	0.5898	-1.5811	-1.7695*
Facility and Bicycle Engineering Enhancements	0.4500	0.1890	-0.1644
Enforcement Countermeasures	1.8792*	3.6247**	2.2831**
Education and Outreach Countermeasures	2.2416**	-2.1926**	-3.2841**

* Significant at 90% confidence level
** Significant at 95% confidence level

CHAPTER 5

ANALYSIS AND RESULTS OF PEDESTRIAN AND BICYCLE CRASHES

This chapter discusses the analysis and the results of pedestrian and bicycle crashes in the state of Michigan. In addition to the information in the electronic database about, the analysis went further into reviewing each crash report individually by reviewing the whole crash report (UD-10), including the narrative of the police officer, the crash diagram, and other information that were available in the crash report. Reviewing the crash reports individually was helpful for gaining a better understanding about the circumstances of the crash and the cause of the crash. Crash reports were obtained from the Office of Highway Safety Planning (OHSP)'s "Michigan Traffic Crash Facts (MTCF) website. In terms of pedestrian crashes, all fatal crash reports for five years (2010-2014) and a sample of incapacitating injury crashes and property damage-only crashes for five years (2010-2014) were reviewed. In regard to bicycle crashes, all fatal crash reports for five years (2010-2014) and a sample of incapacitating injury crashes and property damage-only crashes for five years (2010-2014) were reviewed. Finally, this chapter discusses the methodology and reveals the causes of pedestrian and bicycle crashes in the state of Michigan based on the analysis of crash data for five years (2010-2014).

Methodology

Identifying crash types and crash groups for pedestrian and bicycle crashes is the major goal of this study, because crash types and crash groups represent the causes of those crashes. The Pedestrian and Bicycle Crash Analysis Tool (PBCAT) was developed by the North Carolina Highway Safety Research Center (NCHSRC) and the Federal Highway Administration (FHWA). PBCAT provides help in assigning each pedestrian-vehicle crash and bicycle-vehicle crash to a unique crash type and crash group. However, details of the crash should be known in order to accomplish the crash typing process. UD-10 reports had detailed information about the crash including location, weather condition, roadway condition, other information, and the narrative. The most essential part for the crash typing is the narrative portion of the crash report. The narrative of the crash report explain the circumstances of the crash and hazardous actions of involved parties prior to the crash. Nevertheless, not all crash reports had details about the circumstances and the actions of involved parties, because it is difficult for law enforcement officers in some situations to know the hazardous actions prior to the crash. In addition, hit-and-run crashes are most likely to have no information about hazardous actions of the involved parties prior to the crash. The crash report procedure starts with choosing whether it's pedestrian-vehicle or bicycle-vehicle crash. The next step is entering the unique crash ID from the UD-10 report for a specific crash, and after that reviewing the crash report and specifying the location of the crash (e.g., intersection or intersection related, midblock, and non-roadway). Figure (51) illustrates the interface of PBCAT while specifying the location of the crash. The next step is continuing through options and characteristics that had been embedded in the PBCAT in order to assign a crash type for that specific crash, based on the information that will be selected from the interface of PBCAT.

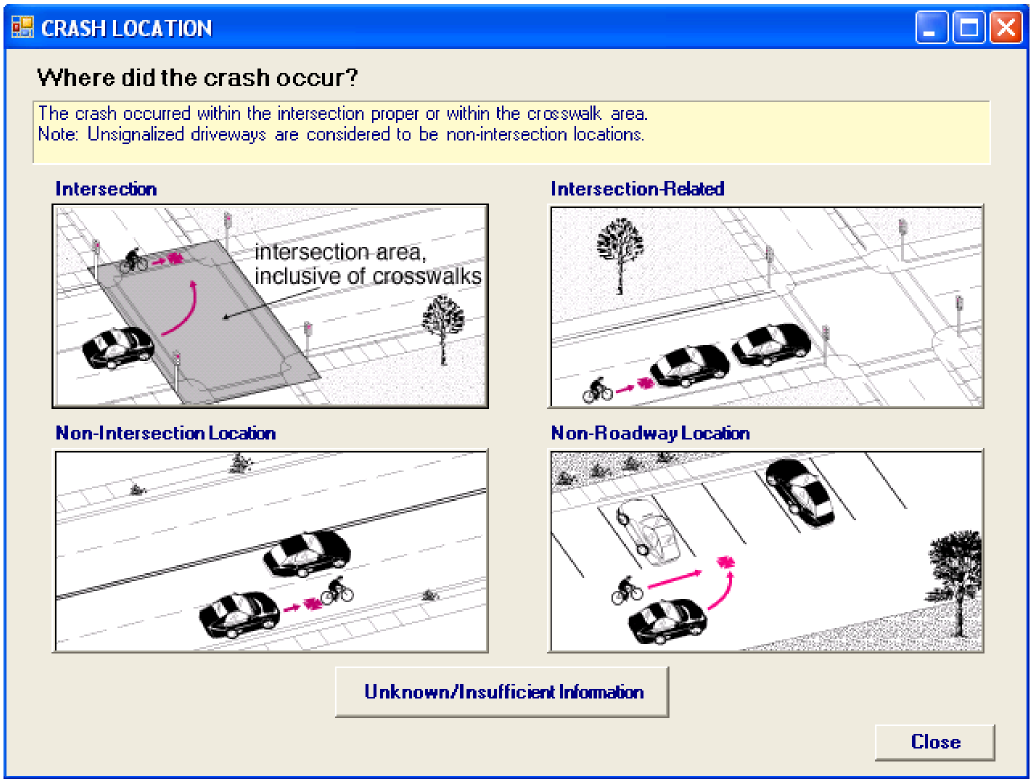


Figure 51: PBCAT interface while specifying the location of the crash

For example, Figure (52) shows a brief example of a pedestrian failing to yield crash type, and from reading the narrative it was found that the pedestrian was trying to cross the roadways in a non-crosswalk area and failed to yield for the northbound traffic. So the screen shoot on the left (PBACT interface) shows the possible pedestrian actions at the time of the crash, which is in this example crossing the roadway (from the narrative). After selecting this option, another menu will pop up (screen shot on the right). The screen shot on the right shows the possible circumstances of the crash in which is pedestrian failing to yield in this case (from the narrative). PBCAT has so many crash types, and because of that, the PBCAT provides another feature which is the crash group, which consists of several crash types in order to

facilitate the analysis of the results. The crash typing will continue following the same procedure for the other crashes and a database is created for all the crashes. Finally, identifying crash types and crash groups for pedestrian and bicycle crashes is helpful in knowing the causes of crashes and selecting an appropriate countermeasures.

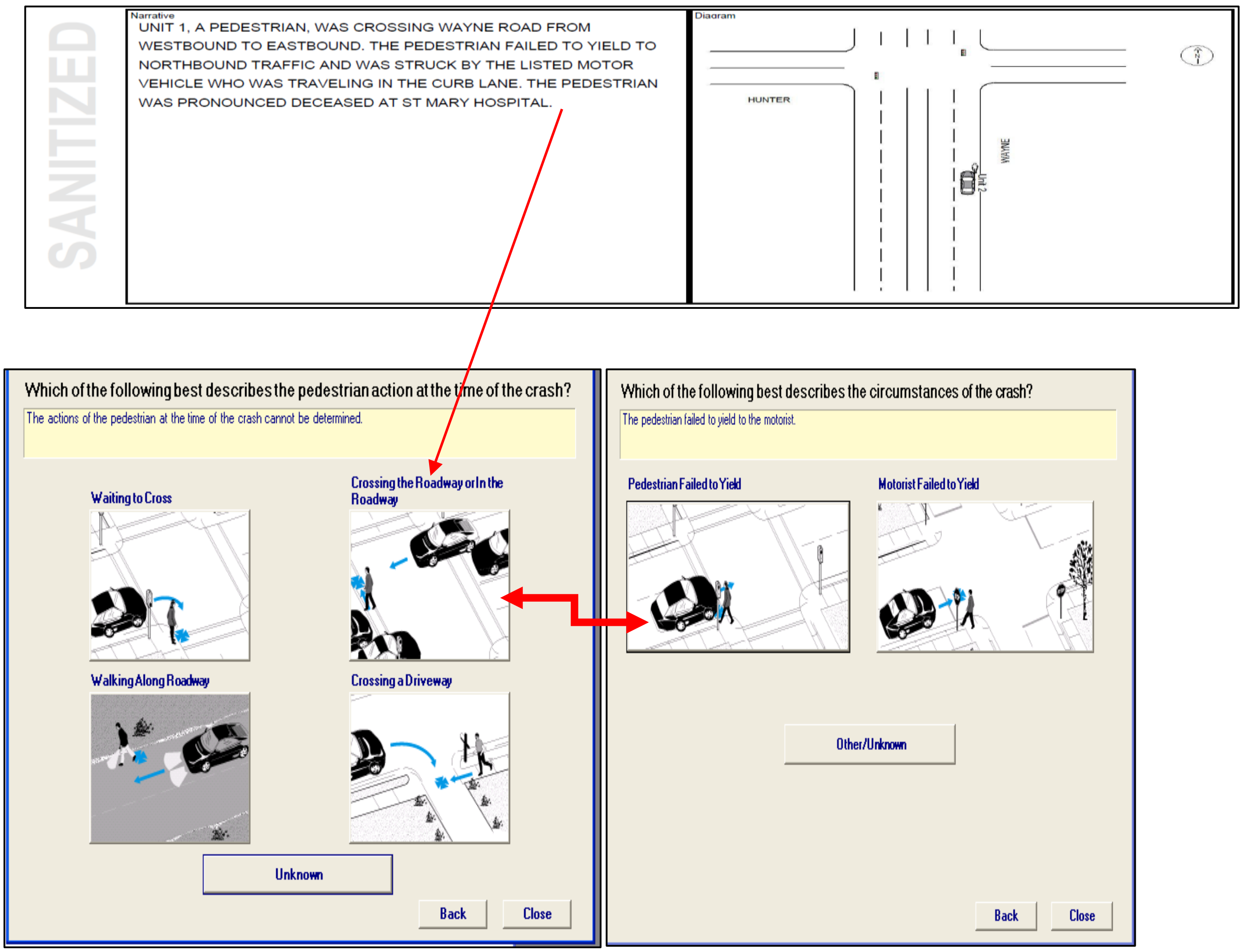


Figure 52: Brief example of pedestrian failing to yield crash type using PBCAT

Causes of pedestrian crashes

The methodology section discussed the process of obtaining the crash types and crash groups for pedestrian crashes using Pedestrian and Bicycle Crash Analysis Tool (PBCAT). All UD-10 reports for pedestrian fatal crashes for five years (2010-2014) have been reviewed and analyzed (e.g., 675 UD-10 reports). By reviewing the details of each single crash using PBCAT software, the crash groups and the crash types for pedestrian fatal crashes were identified. Furthermore, a sample size of 100 UD-10 reports for each year for type (A) crashes (e.g., incapacitating injury crashes) was reviewed and analyzed (e.g., 500 UD-10 reports for the five years). The 100 UD reports sample size was chosen based on a random sampling method from the 7 districts in the State of Michigan. This sample size represents an average percentage of 26% from the total number of pedestrian incapacitating injury crashes. A sample of 10% for each year from 2010 to 2014 of property damage-only crashes was reviewed in order to capture a full picture about the causes of pedestrian crashes across all injury severities. Finally, crash types that had been identified in this section reveal the pedestrian crash causes in the state of Michigan.

In addition, each crash group obtained from the PBCAT had a list of crash types that falls under it. The results of analysis of all pedestrian fatal crashes (K) and a sample of incapacitating injury crashes for five years (2010-2014) are shown in Table (20). It’s clear from the table that the highest percentage of pedestrian crashes fall into the crossing roadway-vehicle not turning crash group, followed by the unusual circumstances crash group, and followed by the pedestrian in roadway crash group. The majority of pedestrian crashes (e.g., 70% of all K crashes and sample of A crashes) fall into the three groups aforementioned. In addition, 5.3% of crashes were typed as other/unknown-insufficient information, this crash group can be explained by the graph in Figure (53). The graph shows that the majority of crashes that falls under this group were hit-

and-run crashes. So, there was insufficient information in the crash reports to determine the cause of the crash. The crash groups are shaded in grey color with bold text.

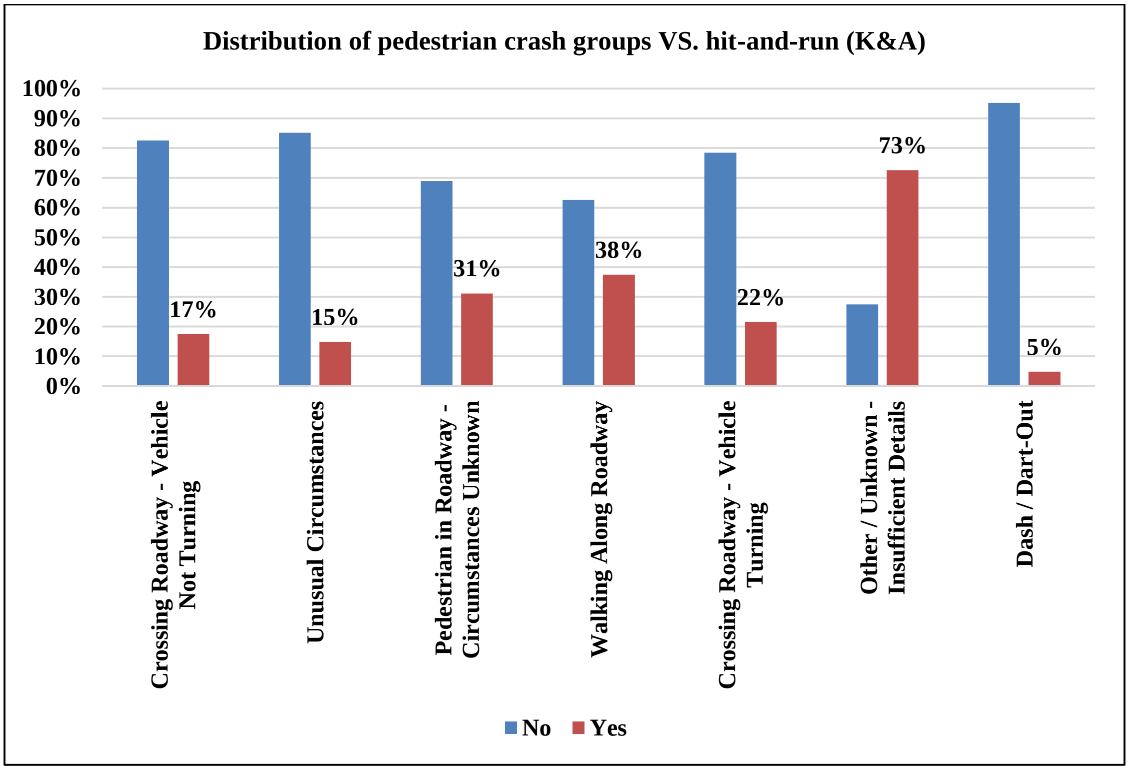


Figure 53: Distribution of pedestrian crash groups VS. hit-and-run for K&A crashes

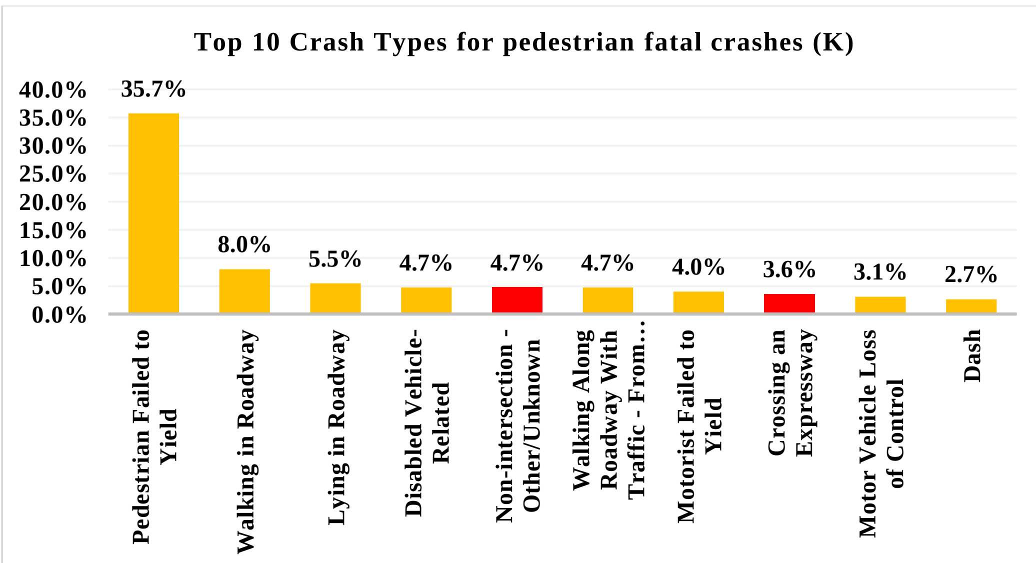
Table 20: Crash groups and crash types for pedestrian crashes

Crash Groups and Crash Types	Percentage
Crossing Roadway - Vehicle Not Turning	**42.5%**
Motorist Failed to Yield	**6.2%**
Pedestrian Failed to Yield	**36.3%**
Unusual Circumstances	**15.6%**
Disabled Vehicle-Related	**4.0%**
Dispute-Related	**0.5%**
Driverless Vehicle	**0.7%**
Emergency Vehicle-Related	**0.1%**
Motor Vehicle Loss of Control	**3.4%**
Other Unusual Circumstances	**0.7%**
Pedestrian Loss of Control	**2.1%**
Pedestrian on Vehicle	**1.1%**
Play Vehicle-Related	**0.1%**
Vehicle - Vehicle / Object	**2.9%**
Pedestrian in Roadway - Circumstances Unknown	**11.7%**
Lying in Roadway	**3.4%**
Standing in Roadway	**1.6%**
Walking in Roadway	**6.7%**
Walking Along Roadway	**6.1%**
Walking Along Roadway - Direction / Position Unknown	**0.9%**
Walking Along Roadway Against Traffic - From Front	**1.0%**
Walking Along Roadway With Traffic - From Behind	**4.2%**
Crossing Roadway - Vehicle Turning	**5.6%**
Motorist Left Turn - Parallel Paths	**4.3%**
Motorist Left Turn - Perpendicular Paths	**0.3%**
Motorist Right Turn - Parallel Paths	**0.4%**
Motorist Right Turn - Perpendicular Paths	**0.2%**
Motorist Right Turn on Red - Parallel Paths	**0.2%**
Motorist Right Turn on Red – Perpendicular Paths	**0.2%**
Motorist Turn / Merge - Other / Unknown	**0.2%**
Other / Unknown - Insufficient Details	**5.3%**
Intersection - Other / Unknown	**1.7%**
Non-intersection - Other/Unknown	**3.1%**
Other - Unknown Location	**0.5%**

Table 20—Continued

Crash Groups and Crash Types	Percentage
Dash / Dart-Out	**3.5%**
Dart-Out	**0.6%**
Dash	**2.9%**
Crossing Expressway	**2.3%**
Crossing an Expressway	**2.3%**
Working or Playing in Roadway	**2.0%**
Playing in Roadway	**0.9%**
Working in Roadway	**1.0%**
Unique Midblock	**1.8%**
Entering / Exiting Parked Vehicle	**1.1%**
Ice Cream / Vendor Truck-Related	**0.1%**
Mailbox-Related	**0.6%**
Backing Vehicle	**1.4%**
Backing Vehicle - Driveway	**0.3%**
Backing Vehicle - Driveway / Sidewalk Intersection	**0.3%**
Backing Vehicle - Parking Lot	**0.1%**
Backing Vehicle - Roadway	**0.6%**
Multiple Threat / Trapped	**1.4%**
Multiple Threat	**1.2%**
Trapped	**0.2%**
Bus-Related	**0.3%**
Commercial Bus-Related	**0.3%**
School Bus-Related	**0.1%**
Crossing Driveway or Alley	**0.3%**
Motorist Entering Driveway or Alley	**0.2%**
Motorist Exiting Driveway or Alley	**0.2%**
Off Roadway	**0.2%**
Off Roadway - Other / Unknown	**0.1%**
Off Roadway - Parking Lot	**0.1%**
No group	**0.1%**
Waiting to Cross - Vehicle Not Turning	**0.1%**
Grand Total	**100.0%**

Figure (54) compares the distribution of the top 10 crash types for pedestrian fatal crashes (K) and incapacitating injury crashes (A). There is a very small difference in terms of crashes types between the fatal crashes and incapacitating injury crashes, and those differences are highlighted in red. Both figures show that pedestrian failing to yield was the top one for fatal and incapacitating injury crashes. In addition, pedestrian failing to yield accounted for the majority of the crashes.



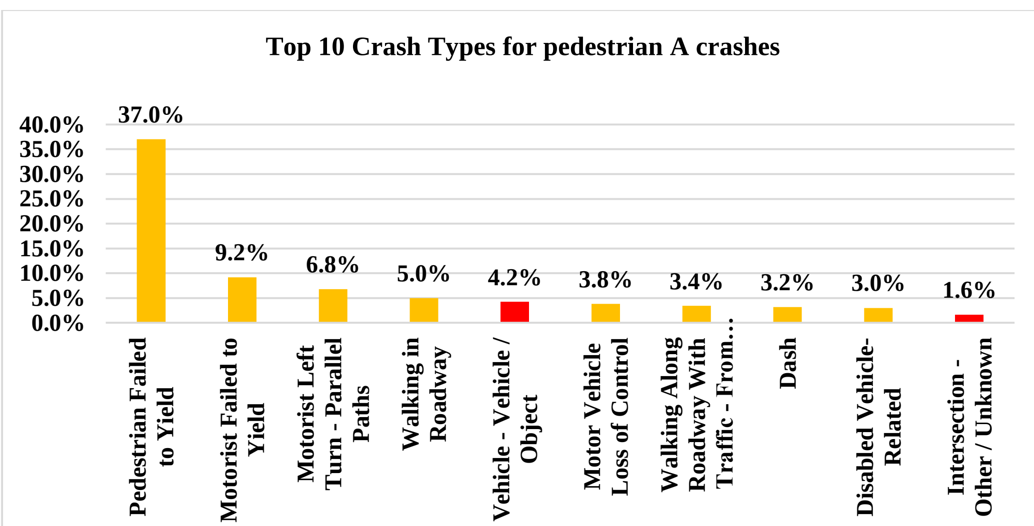


Figure 54: Distribution of tope 10 crash types for K and A crashes

Figure (55) shows the distribution of the top 10 crash types of pedestrian fatal crashes (K) and incapacitating injury crashes (K) combined. The top 10 crash types for both K&A crashes combined accounted for approximately 78% of the total crash types. In terms of property damage-only crashes (PDO), the crash typing was done for a sample of 10% for each year from 2010 to 2014 for pedestrian PDO crashes. The results showed differences in the ranking of crash types between K&A crash types and PDO crash types. In addition, a Chi square test was conducted in order to compare the distribution of crash types for property damage-only crashes (PDO) and the crash types for fatal (K) and incapacitating injury (A) crashes from a statistical prospective. The null hypothesis is that there is no difference in the distribution of PDO crashes and K&A crashes. The p-value for the Chi square test was 0.046 at a 95% confidence level, which means that we fail to accept the null hypothesis that there is no difference between the two distributions. However, when comparing the distribution of top 10 crash types for K&A crashes in Figure (55) and the distribution of top 10 crash types for PDO crashes in Figure (56), the majority of crashes that had been analyzed are failing to yield by pedestrian for both PDO crashes and K&A crashes. Figure (56) shows the distribution of crash types for pedestrian PDO crashes.

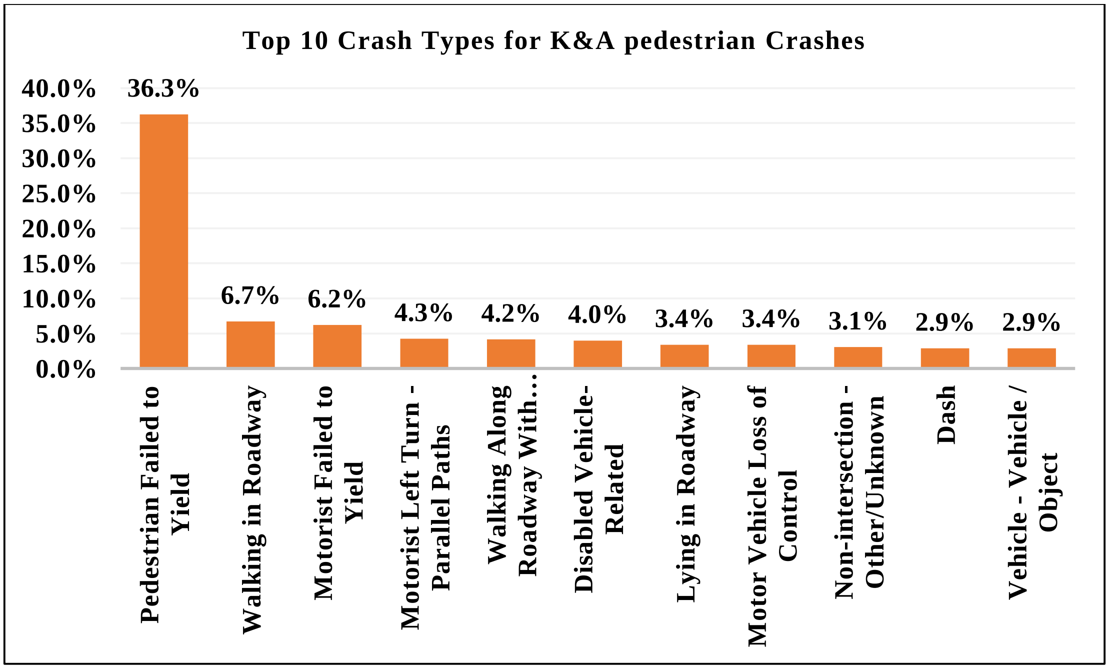


Figure 55: Distribution of tope 10 crash types for K and A crashes combined

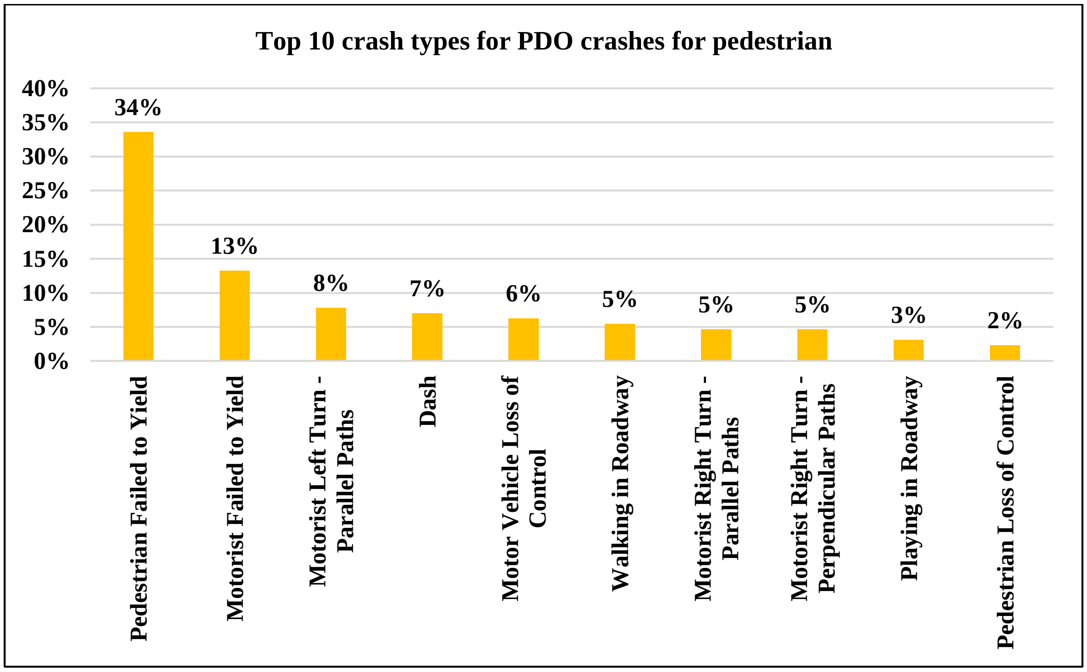


Figure 56: Distribution of tope 10 crash types for PDO crashes

Based on the results that were obtained from the PBACT, many crash types were identified. These crash types represent the causes of pedestrian crashes in the state of Michigan. In addition, the definition of those causes are as follows:

- Pedestrian failing yield: Pedestrian crossing the roadway without the right-of-way at intersections, midblock locations, and interchanges. This cause accounted for 36.3% of crash causes.
- Pedestrian walking in roadway: Pedestrian walking in the roadway and specifically inside the travel lane. This cause accounted for 6.7% of crash causes.
- Motorist failed to yield: Driver failing to yield for pedestrian when the pedestrian had the right-of-way at intersections, midblock locations, and interchanges. This cause accounted for 6.2% of crash causes.
- Motorist left turn-parallel paths: The driver was turning left and pedestrian was crossing the roadway and the driver was at fault. This cause accounted for 4.3% of crash causes.
- Pedestrian walking along the roadway with traffic from behind: The pedestrian was walking along the roadway outside the fog line (not inside the travel lane) with the direction of traffic and got hit from behind. This cause accounted for 4.2% of crash causes.

- Disabled vehicle-related: Pedestrian got hit nearby disabled vehicle inside the roadway (inside the travel lane) or outside the roadway (shoulder). This cause accounted for 4% of crash causes.

- Pedestrian lying in roadway: The pedestrian was lying in roadway prior to the crash because he was injured, intoxicated, or intentionally lying in roadway. This cause accounted for 3.4% of crash causes.

- Motor vehicle loss of control: Driver of the vehicle lost control due to mechanical failure, surface conditions, driver error, or impairment. This cause accounted for 3.4% of crash causes.
- Non-intersection-other/unknown: Crashes occurred at non intersections and the majority of those crashes were hit-and-run. There was insufficient information about those crashes from the crash report in order to identify the cause of the crash. This cause accounted for 3.1% of crash causes.
- Dash: The pedestrian ran into the roadway and was struck by vehicle whose view of pedestrian was unobstructed (pedestrian at fault). This cause accounted for 2.9% of crash causes.
- Vehicle-vehicle/object: The pedestrian was struck as a result of a prior vehicle-into-vehicle or vehicle-into-object crash. This cause accounted for 2.9% of crash causes.
- Crossing an expressway: The pedestrian was crossing the freeway without the right-of-way. This cause accounted for 2.3% of crash causes
- Pedestrian loss of control: The pedestrian stumbled, fell, or rolled into the path of the vehicle due to surface conditions, impairment, or other mishap. This cause accounted for 2.1% of crash causes.
- Intersection-other/unknown: crashes occurred at intersections and the majority of those crashes were hit-and-run. There was insufficient information about those crashes from the

crash reports in order to identify the cause of the crash. This cause accounted for 1.7% of crash causes.

- Standing in roadway: The pedestrian was standing inside the travel lane then was struck by the vehicle. This cause accounted for 1.6% of crash causes.
- Multiple threat: The pedestrian entered the travel lane in front of stopped or slowing vehicles and was struck by a vehicle. This cause accounted for 1.2% of crash causes.
- Entering/existing parked vehicle: The pedestrian was trying to exist or enter from a parked vehicle then was struck by another vehicle. This cause accounted for 1.1% of crash causes.

Further analysis was done by connecting the most frequent crash groups for pedestrians (e.g., 7 crash groups) with the electronic database. This analysis is helpful to understanding the other contributing factors that might be associated with those crashes. The analysis was based on connecting the most frequent crash groups with the alcohol involvement, drug involvement, weather condition, roadway condition, lighting condition, MDOT location of the crash, traffic control device, and highway class.

Figure (57) shows the distribution of the most frequent pedestrian crash groups by alcohol involvement. The graph shows that pedestrians in roadway and pedestrian walking along roadway crash groups had the highest percentage of alcohol involvement compared to other crash groups. This observation points to the possibility that alcohol involvement might be one of the contributing factors.

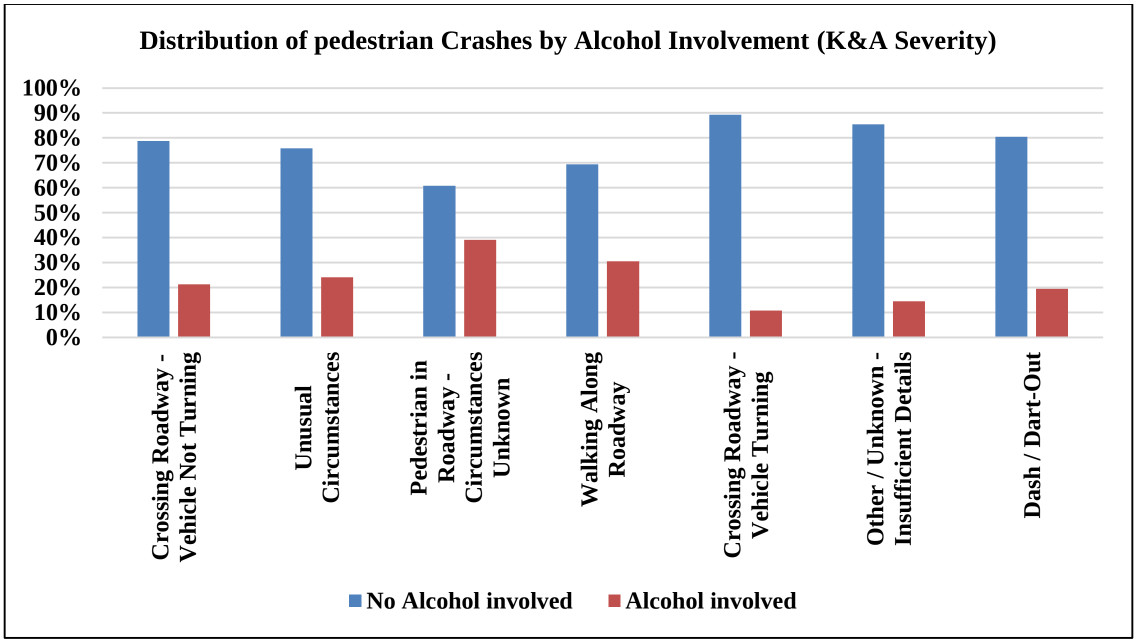


Figure 57: Distribution of most frequent pedestrian crash groups by alcohol involvement

Figure (58) shows the distribution of the most frequent pedestrian crash groups by drug involvement. The graph shows that unusual circumstances and pedestrian walking along roadway crash groups had the highest percentage of drug involvement compared to other crash groups. This observation points to the possibility that drug involvement might be one of the contributing factors.

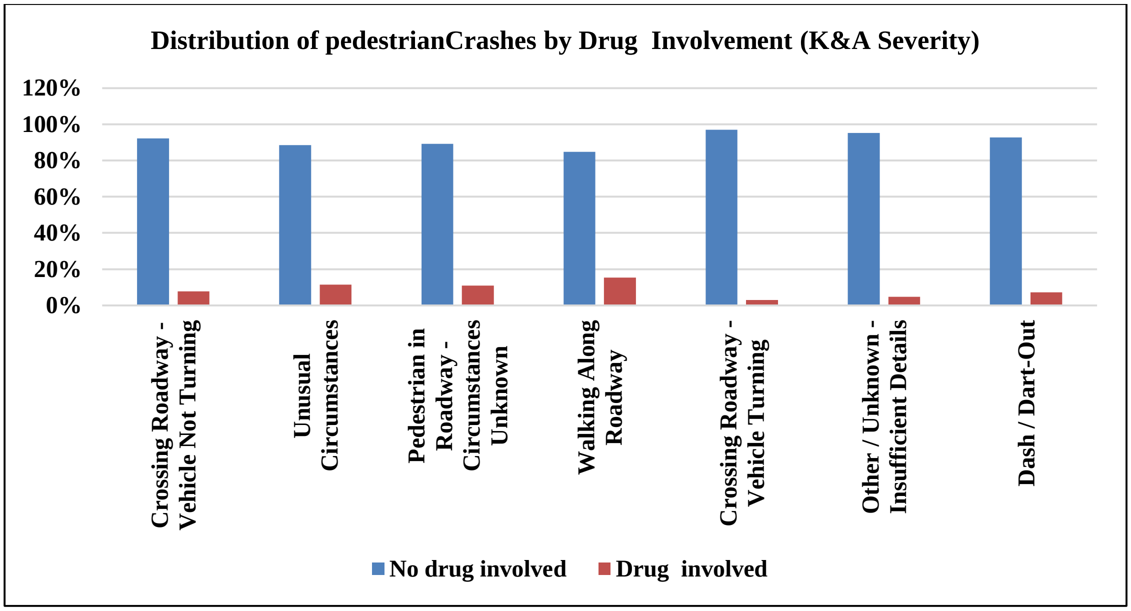


Figure 58: Distribution of most frequent pedestrian crash groups by drug involvement

Figure (59) shows the distribution of most frequent pedestrian crash groups by weather condition. The graph shows that the majority of crashes occurred during clear weather conditions, followed by cloudy and rain weather conditions. This observation points to the possibility that most of pedestrians try to avoid walking in inclement weather.

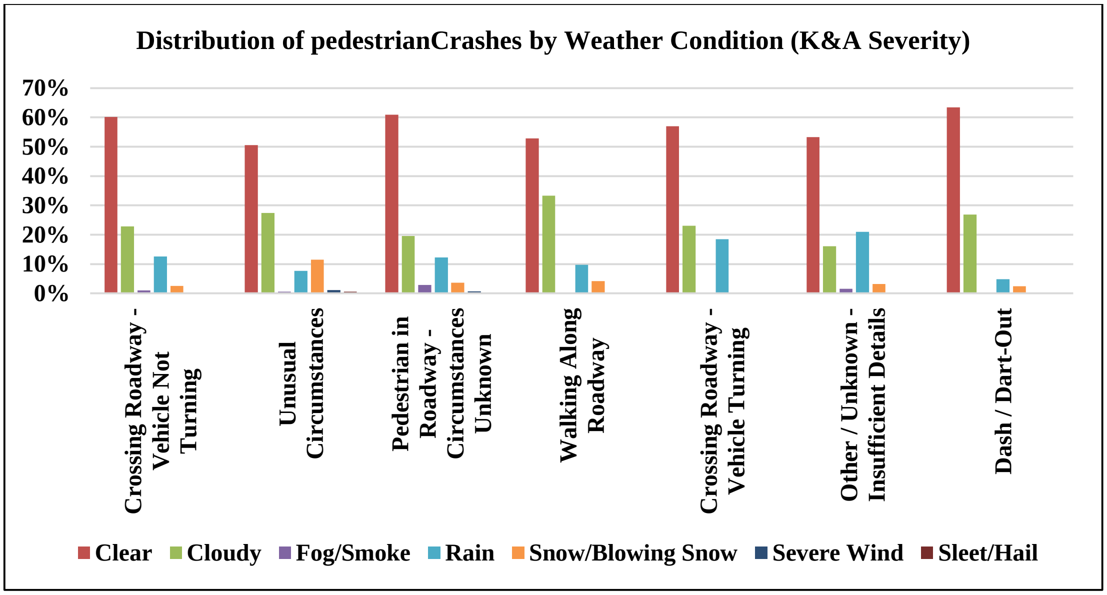
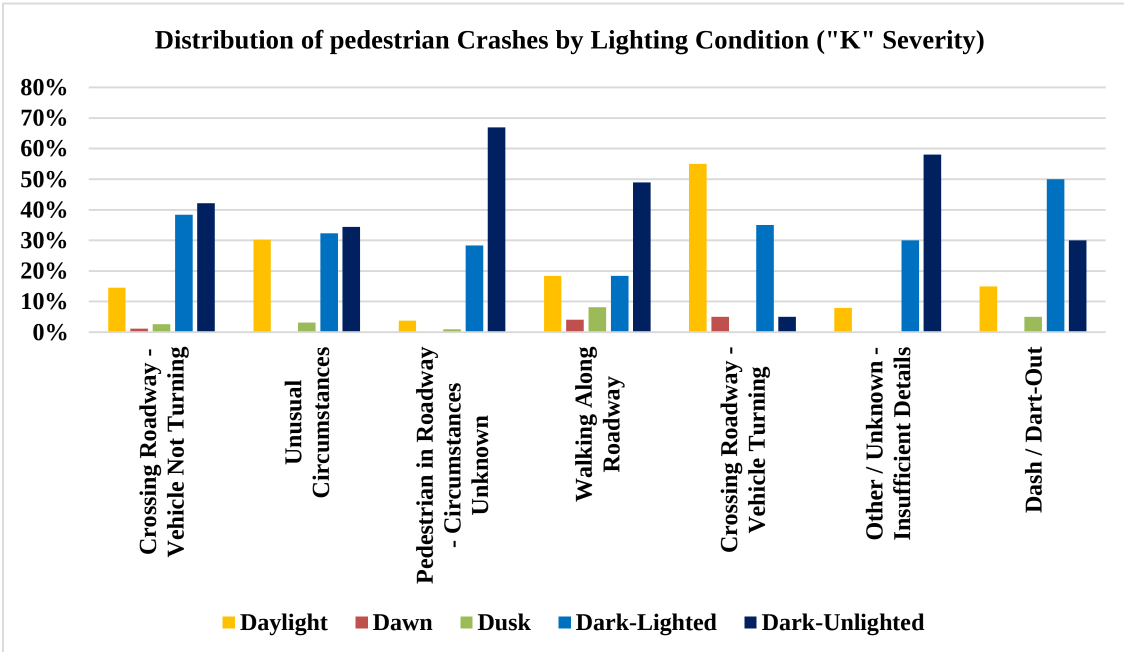


Figure 59: Distribution of most frequent pedestrian crash groups by weather condition

Figure (60) presents the distribution of most frequent pedestrian crash groups by lighting conditions for fatal crashes (K) and incapacitating injury crashes (A). The graph shows that lighting condition had an effect on injury severity and this was supported by the cross tabulation in the data section. In addition, the graphs shows that most of crashes occurred during dark-lighted and dark-unlighted lighting conditions.



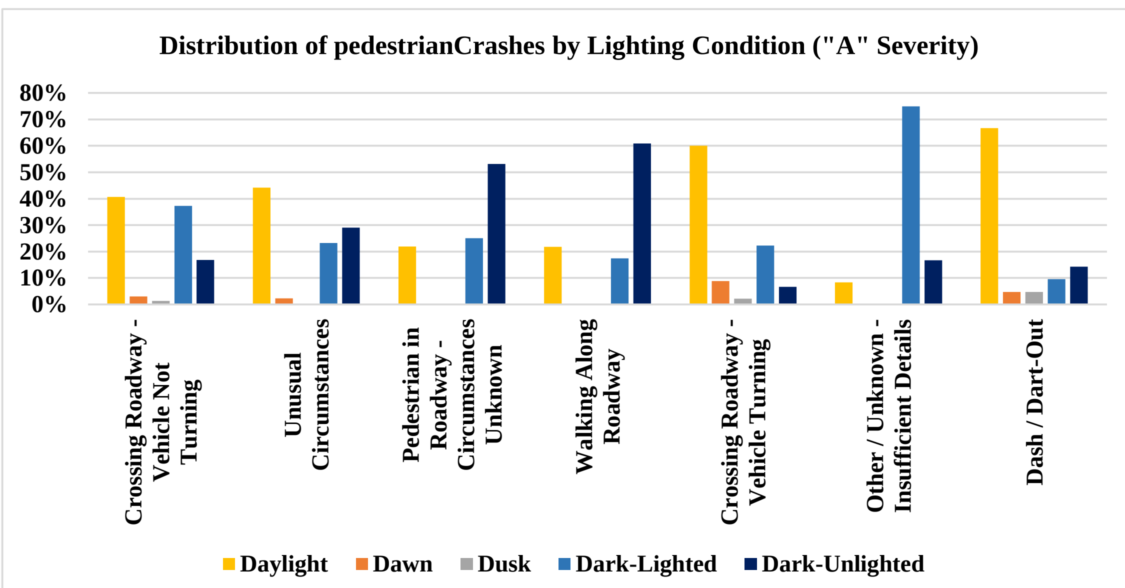


Figure 60: Distribution of most frequent pedestrian crash groups by lighting conditions for A&K crashes

Figure (61) shows the distribution of most frequent pedestrian crash groups by road condition. The graph shows that the majority of crashes occurred when the roads were dry followed by wet and icy road conditions. This observation can be supported by the fact that most pedestrians try to avoid walking during inclement roadway conditions.

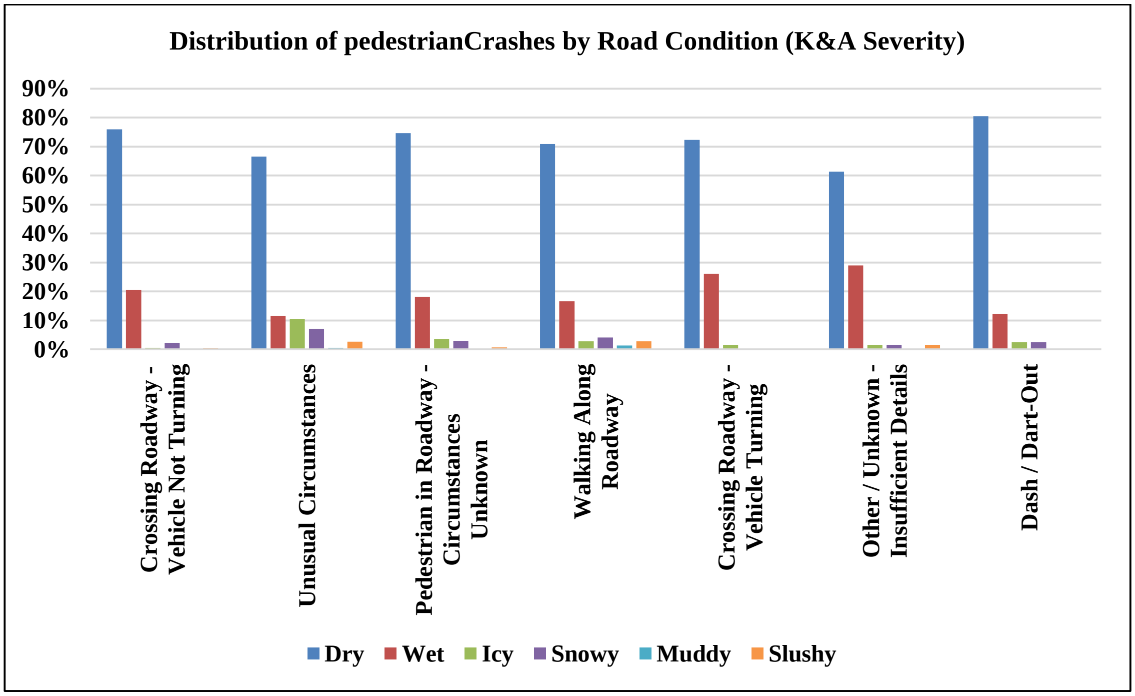


Figure 61: Distribution of most frequent pedestrian crash groups by road condition

Figure (62) presents the distribution of most frequent pedestrian crash groups by traffic control device. The graph shows that the majority of crashes occurred when there was no traffic control device present at the location of the crash followed by traffic signal. Furthermore, it's important to mention that intersection with no traffic control device doesn't always means uncontrolled intersection. In many cases, the major road had no traffic control device while the minor road had a traffic control device. Figure (63) illustrates an example of this case. In this

figure the crash occurred on the major road and the minor road had stop sign. So, the crash will be coded as intersection crash with no traffic control device because the crash occurred on the major road.

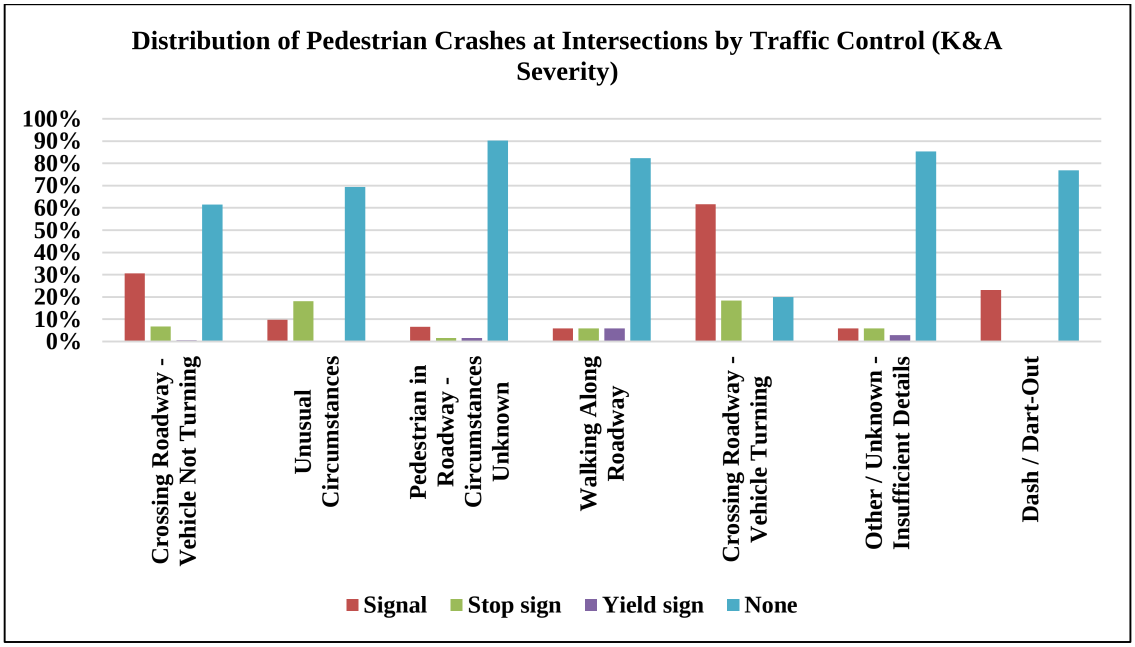


Figure 62: Distribution of most frequent pedestrian crash groups by traffic control device

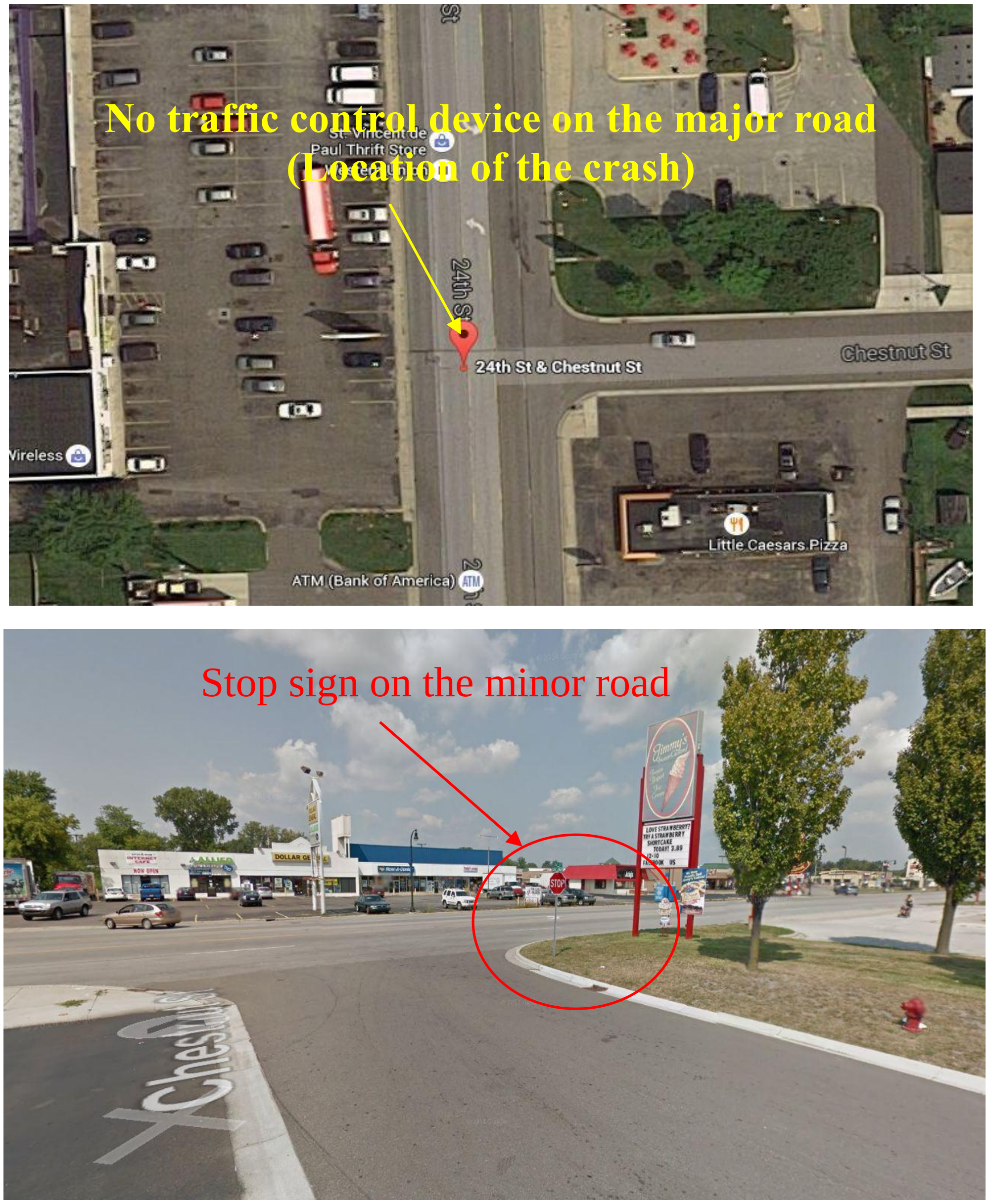


Figure 63: Example of intersection with no traffic control device on the major road (Google Earth Pro, 2015)

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Figure (64) shows the distribution of most frequent pedestrian crash groups by MDOT crash location. The graph shows that the majority of crashes occurred at intersections followed by midblock locations.

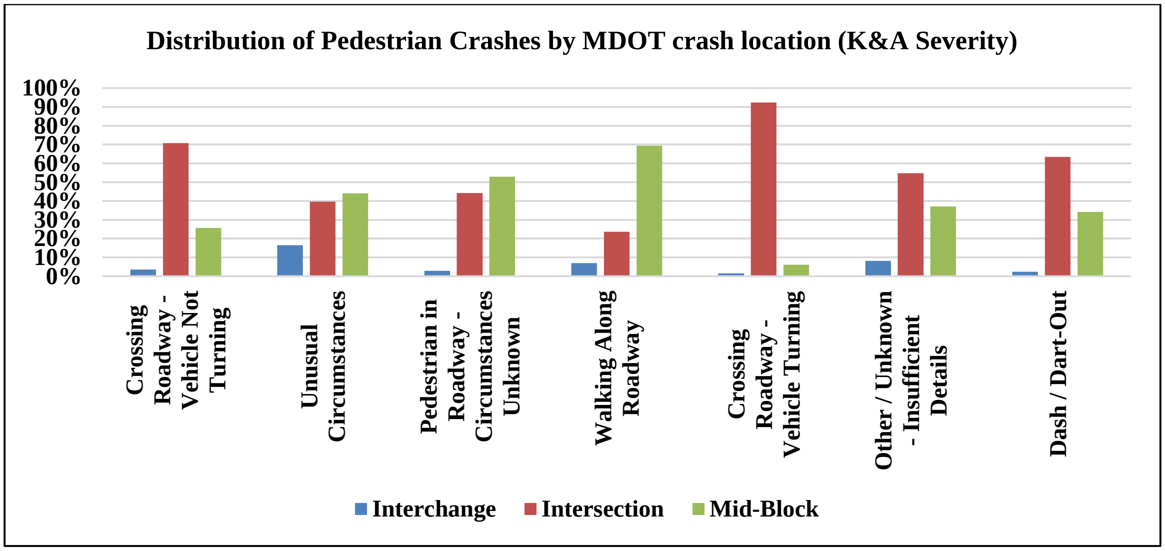


Figure 64: Distribution of most frequent pedestrian crash groups by MDOT crash location

Figure (65) shows the distribution of the most frequent pedestrian crash groups by highway class. The graph shows that the majority of crashes occurred at a roadway, city street, or unknown highway class, followed by M route highway class.

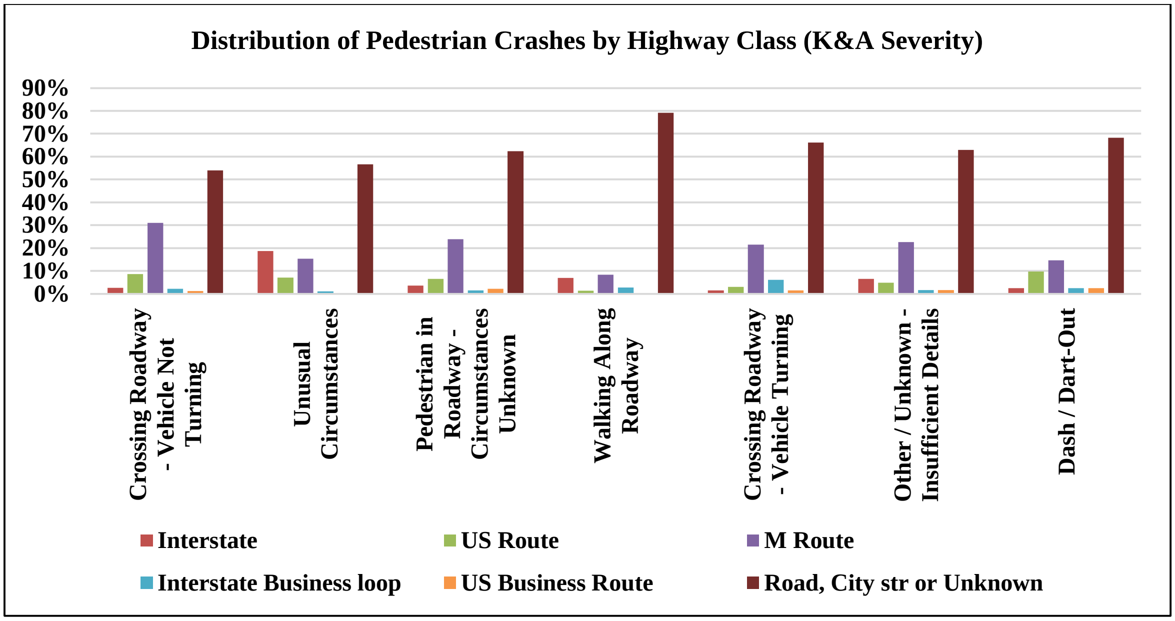


Figure 65: Distribution of most frequent pedestrian crash groups by highway class

Categorization of crash types based on pedestrian/driver risk behavior

Since there were many crash types (causes) that had been identified previously in this chapter, groups of pedestrian/driver risk behavior were created by assigning each crash cause to a certain risk behavior. This categorization helps to get a better understanding about pedestrian crash causes in the state of Michigan. In addition, this categorization facilitates the process of selecting appropriate countermeasures to reduce pedestrian crashes by narrowing down those crash causes to a few groups of pedestrian/driver risk behavior. Table (21) shows the distribution of crash causes by risk behavior groups. The table shows that there were six risk behavior groups generated and each of those groups was the main cause of the crash. Finally, failure to yield or disregard traffic control risk behavior group was the major crash cause of pedestrian crashes based on the crashes that had been analyzed from 2010 to 2014.

Table 21: Crash causes by risk behavior groups for pedestrian

Risk Behavior Groups	Frequency
Failure to Yield/disregard traffic control	57.53%
Pedestrian Failed to Yield	36.3%
Motorist Failed to Yield	6.2%
Motorist Left Turn - Parallel Paths	4.3%
Dash	2.9%
Crossing an Expressway	2.3%
Multiple Threat	1.2%
Dart-Out	0.6%
Mailbox-Related	0.6%
Backing Vehicle - Roadway	0.6%
Motorist Right Turn - Parallel Paths	0.4%
Backing Vehicle - Driveway	0.3%
Backing Vehicle - Driveway / Sidewalk Intersection	0.3%
Motorist Left Turn - Perpendicular Paths	0.3%
Motorist Right Turn - Perpendicular Paths	0.2%
Motorist Right Turn on Red - Parallel Paths	0.2%
Motorist Right Turn on Red – Perpendicular Paths	0.2%
Motorist Turn / Merge - Other / Unknown	0.2%
Motorist Entering Driveway or Alley	0.2%
Motorist Exiting Driveway or Alley	0.2%
Trapped	0.2%
Backing Vehicle - Parking Lot	0.1%
Pedestrian Near Vehicle	10.21%
Disabled Vehicle-Related	4.00%
Vehicle - Vehicle / Object	2.89%
Pedestrian on Vehicle	1.11%
Entering / Exiting Parked Vehicle	1.11%
Driverless Vehicle	0.68%
Commercial Bus-Related	0.26%
Ice Cream / Vendor Truck-Related	0.09%
School Bus-Related	0.09%
Pedestrian in Roadway	13.79%
Walking in Roadway	6.72%
Lying in Roadway	3.40%
Standing in Roadway	1.62%
Working in Roadway	1.02%
Playing in Roadway	0.94%
Play Vehicle-Related	0.09%

Table 21 - Continued

Risk Behavior Groups	Frequency
Loss of Control	5.62%
Motor Vehicle Loss of Control	3.4%
Pedestrian Loss of Control	2.1%
Off Roadway - Other / Unknown	0.1%
Pedestrian Walking Along Roadway	6.13%
Walking Along Roadway With Traffic - From Behind	4.17%
Walking Along Roadway Against Traffic - From Front	1.02%
Walking Along Roadway - Direction / Position Unknown	0.94%
Other/Unknown	6.72%
Non-intersection - Other/Unknown	3.1%
Intersection - Other / Unknown	1.7%
Other Unusual Circumstances	0.7%
Dispute-Related	0.5%
Other - Unknown Location	0.5%
Off Roadway - Parking Lot	0.1%
Waiting to Cross - Vehicle Not Turning	0.1%
Emergency Vehicle-Related	0.1%

Analysis of failure to yield/disregard traffic control risk behavior

Further analysis was performed in order to understand and describe the failure to yield/disregard traffic control risk behavior groups. The analysis was done by investigating the roadway characteristics that were associated with this group. The data that was used for this analysis was all pedestrian fatal crashes (K) and a sample of incapacitating injury crashes (A) from 2010 to 2014, which was the same set of data that had been used in crash typing. Figure (66) presents the distribution of pedestrian crashes at midblock locations or intersections with area type. The figure shows that 75% of pedestrian crashes at intersections occurred in small urban areas, and were considered failure to yield/disregard traffic control. In addition, 54% of pedestrian crashes at mid-blocks occurred in large urbanized area type and were categorized as failure to yield/disregard traffic control.

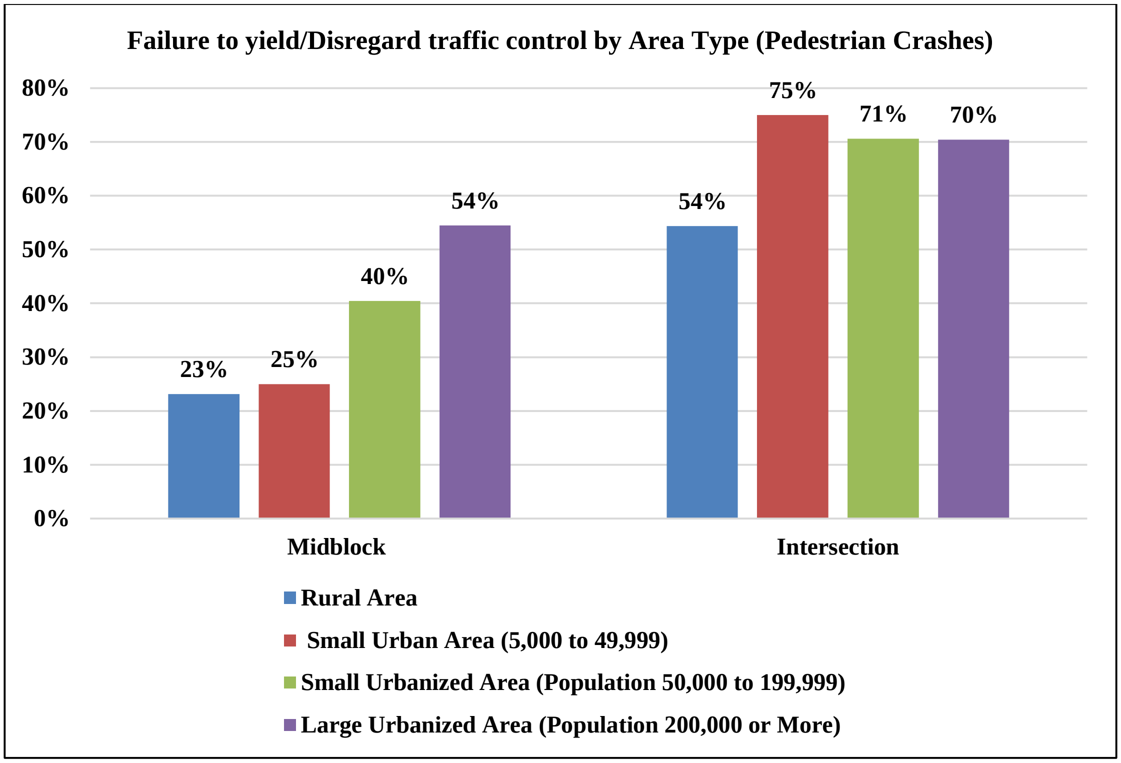


Figure 66: Proportion of pedestrian crashes at midblock locations or intersections with area type

Figure (67) shows the distribution of pedestrian crashes at midblock locations or intersections with the speed limit. The figure shows that 75% of pedestrian crashes at intersections occurring when the speed limit was 35 to 45 mph fall were categorized as to yield/disregard traffic control. In addition, 67% of pedestrian crashes at mid-blocks occurring when the speed limit was 25 mph fall under failure to yield/disregard traffic control group.

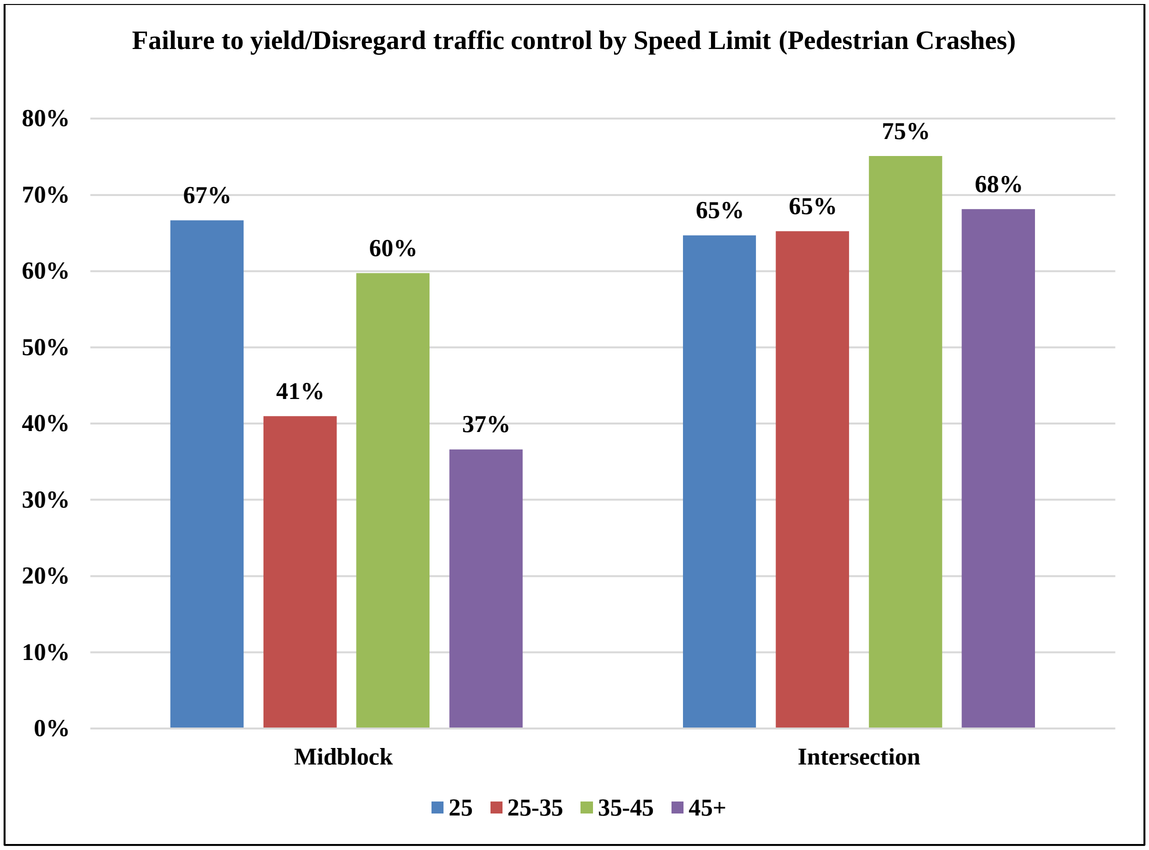


Figure 67: Proportion of pedestrian crashes at midblock locations or intersections with the speed limit

Figure (68) shows the distribution of pedestrian crashes at midblock locations or intersections with number of lanes. The figure shows that 75% of pedestrian crashes at intersections occurring on intersections with 4 or more lanes were considered failure to yield/disregard traffic control. In addition, 62% of pedestrian crashes at mid-blocks occurred in roadways with 4 or more lanes fall under failure to yield/disregard traffic control group.

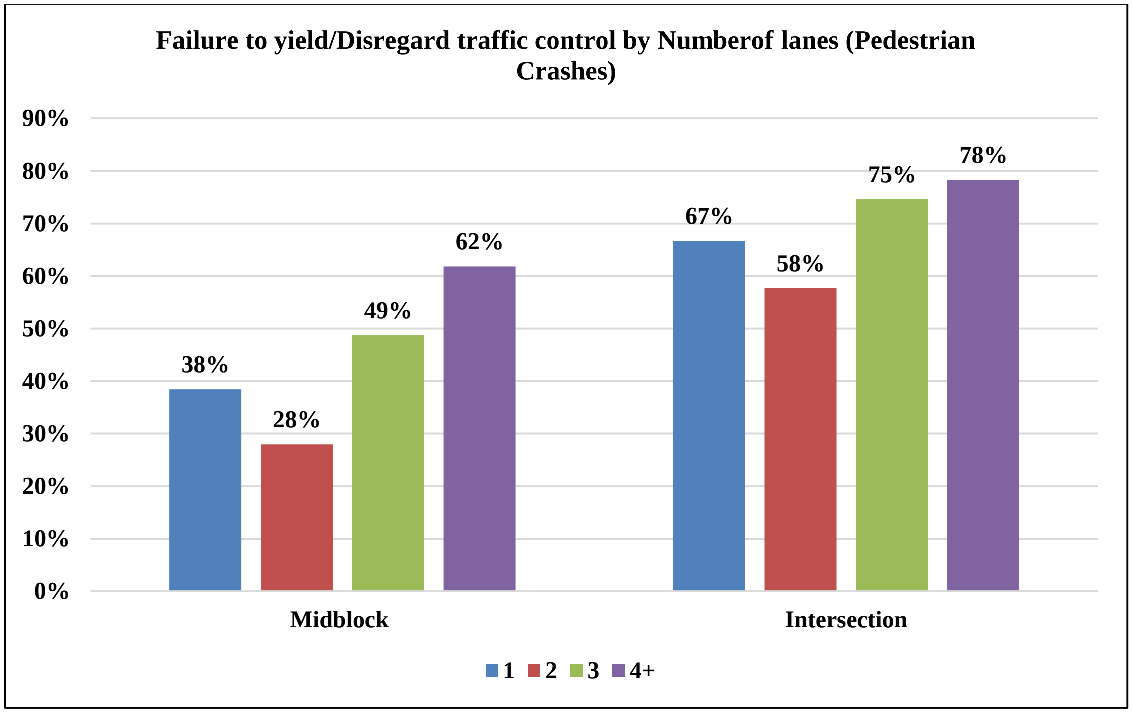


Figure 68: Proportion of pedestrian crashes at midblock locations or intersections with number of lanes

Figure (69) shows the distribution of pedestrian crashes at midblock locations with type of median. The figure shows that 59% of pedestrian crashes at mid-blocks occurring on divided roadways without barrier were categorized as failure to yield/disregard traffic control. In addition, 38% of pedestrian crashes at mid-blocks occurring on divided roadways with barrier fall under failure to yield/disregard traffic control group. This observation can be explained by the fact that divided roadways with physical barriers might help in reducing pedestrian failure to yield behavior at mid-block locations.

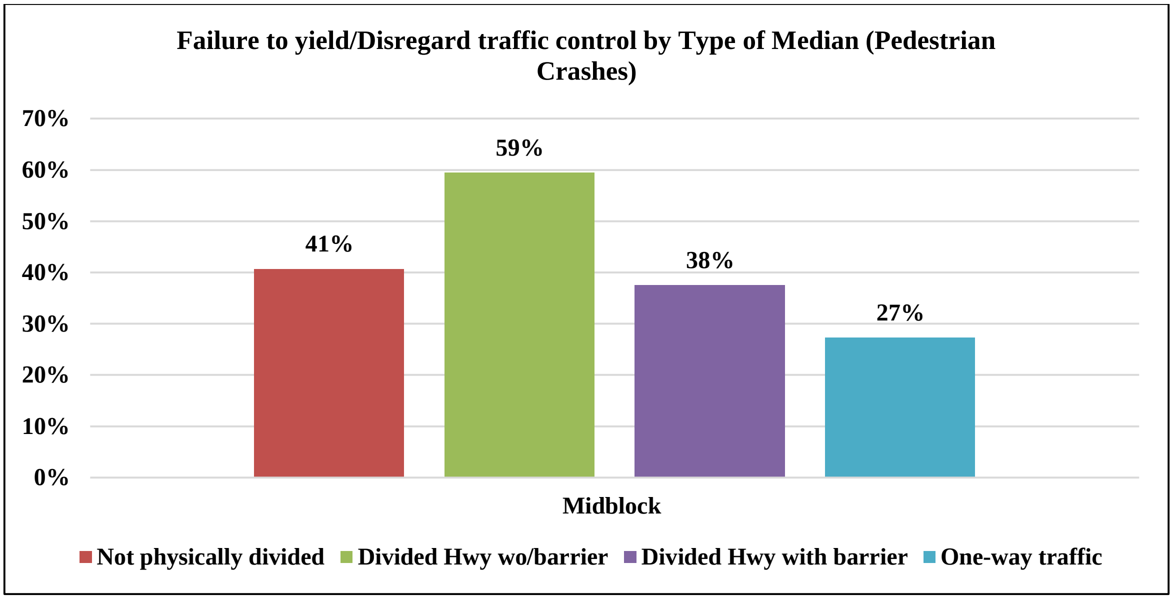


Figure 69: Proportion of pedestrian crashes at midblock locations by median type

Figure (70) presents the distribution of pedestrian crashes at midblock locations or intersections with roadway lighting. The figure shows that 60% of pedestrian crashes at intersections occurring on dark-unlighted intersections were considered failure to yield/disregard traffic control. In addition, 32% of pedestrian crashes at mid-blocks occurring on dark-lighted roadways fall under failure to yield/disregard traffic control group. This observation suggest that lack of roadway lighting might be one of the contributing factors for this risk behavior group.

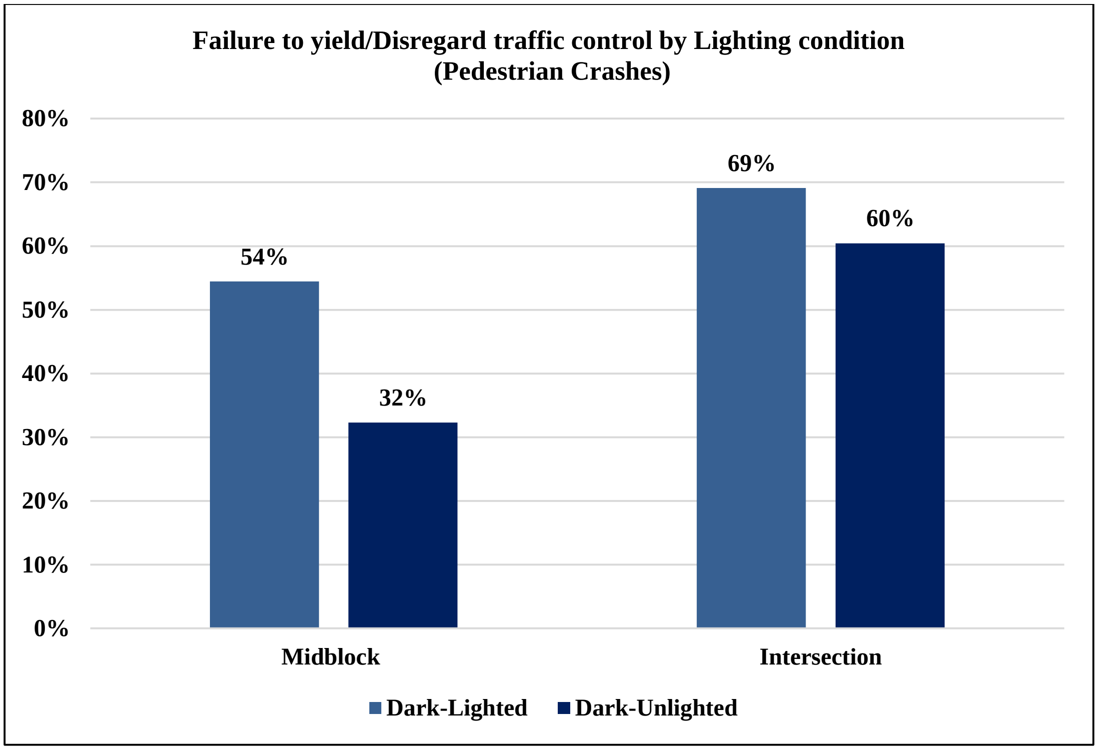


Figure 70: Proportion of pedestrian crashes at midblock or intersections by lighting condition

Figure (71) presents the distribution of pedestrian crashes at intersections with traffic control device. The figure shows that 91% of pedestrian crashes occurring at signalized intersections were considered failure to yield/disregard traffic control. In addition, 67% of pedestrian crashes occurring at sign-controlled intersections were categorized as failure to yield/disregard traffic control. Finally, 62% of pedestrian crashes at uncontrolled intersections fall under failure to yield/disregard traffic control group.

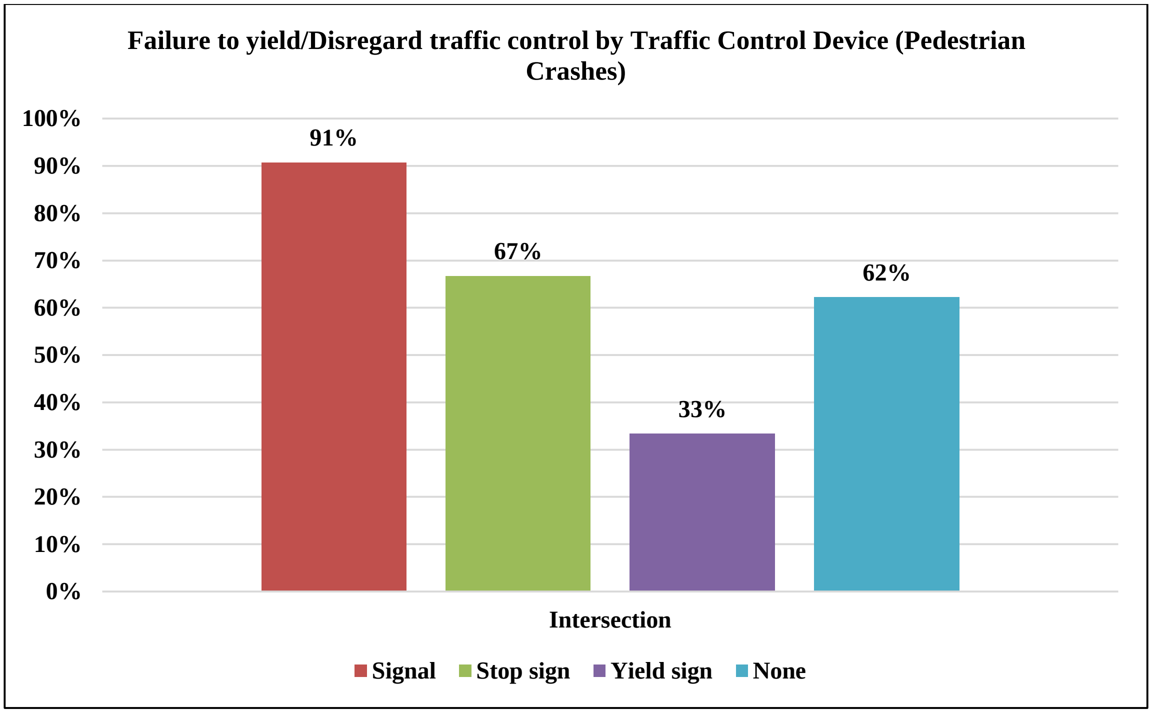
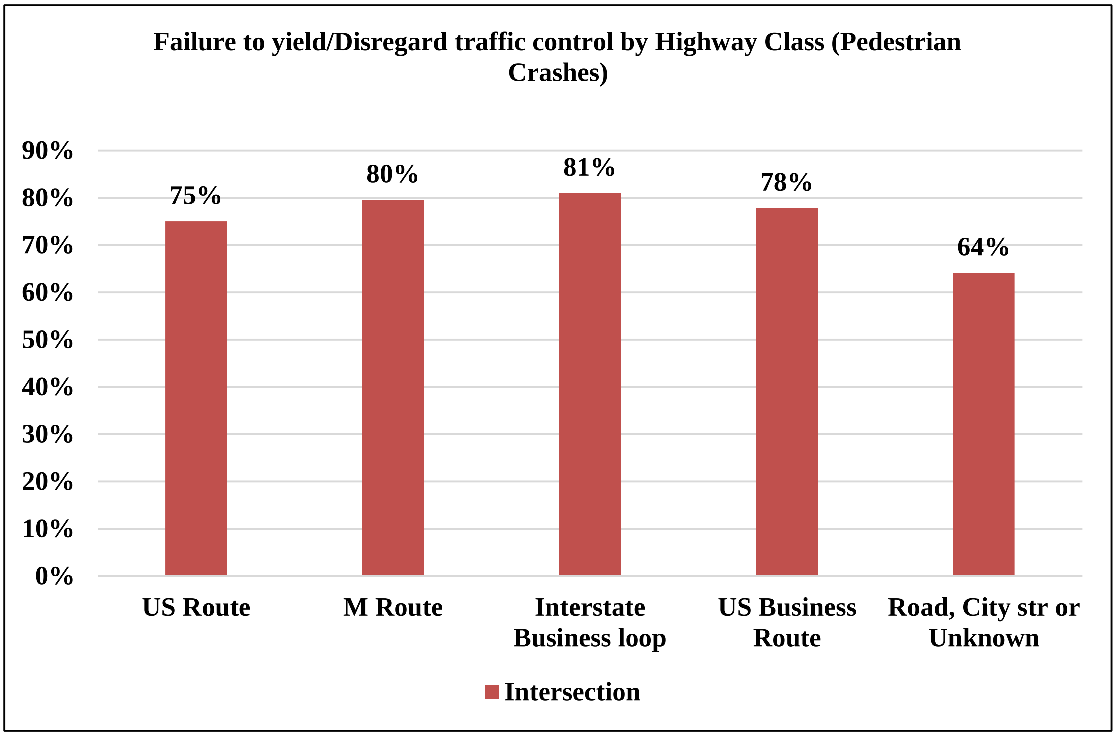


Figure 71: Proportion of pedestrian crashes at intersections by traffic control device

Figure (72) presents the distribution of pedestrian crashes at intersections and midblock locations with highway class. The figure shows that 81% of pedestrian crashes at intersections occurring on interstate business loop highway class fall under failure to yield/disregard traffic control. In addition, 80% of pedestrian crashes at intersections occurring on M route highway class were considered failure to yield/disregard traffic control. In terms of midblock crash location, the figure shows that 53% of pedestrian crashes at midblock locations occurring on US route highway class were considered failure to yield/disregard traffic control. In addition, 50% of pedestrian crashes at midblock locations occurring on US business route highway class fall under failure to yield/disregard traffic control group



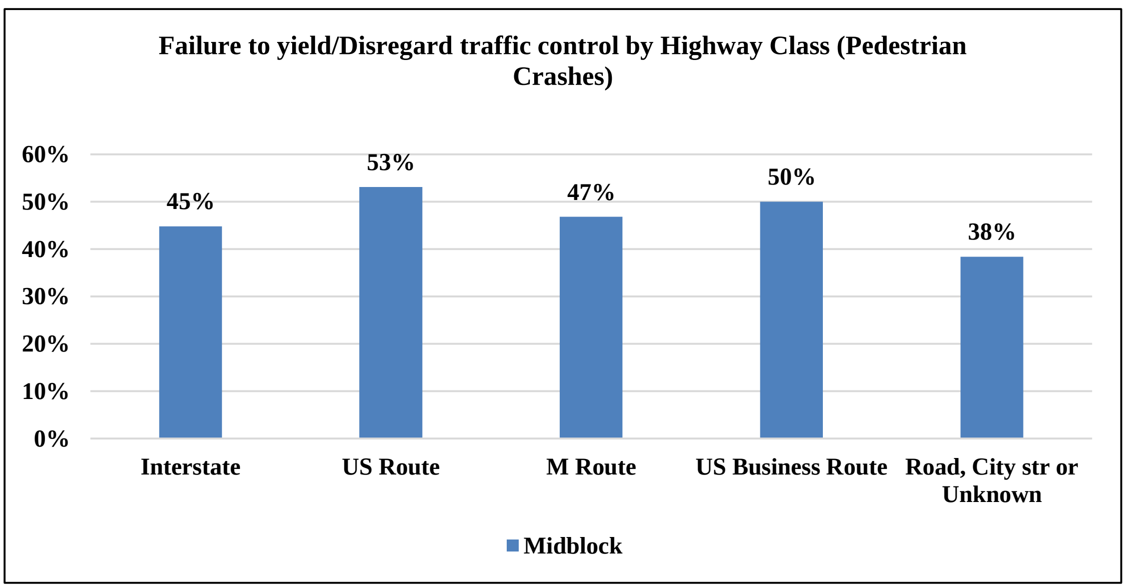


Figure 72: Proportion of pedestrian crashes at midblock or intersections by highway class

In addition, the electronic database of the crashes had a lack of information about the roadway characteristics such as presence of crosswalk, type of the crosswalk, signage, and presence of pedestrian signal. So, the analysis goes further by investigating the presence of aforementioned roadway characteristics for failure to yield/disregard traffic control risk behavior group at intersections. A sample from 2010 to 2011was used to investigate the presence of those roadway features. Additionally, crash reports (sample from 2010 to 2011) and Google Earth Pro were used for this analysis. Figure (73) shows the distribution of failure to yield/disregard traffic control crashes and the presence of a crosswalk. The figure shows that 45% of crashes occurred at marked crosswalks and 40% of crashes occurred when there was no crosswalk at the location of the crash. Furthermore, 13% of crashes occurred at unmarked crosswalk. One example of the analysis process is shown in Figures (74). The narrative of the crash report shows clearly the pedestrian was trying to cross the major road. By combing the information from the narrative and satellite images from Google earth Pro, it was found that the major road doesn’t have a crosswalk while the minor road has an unmarked crosswalk.

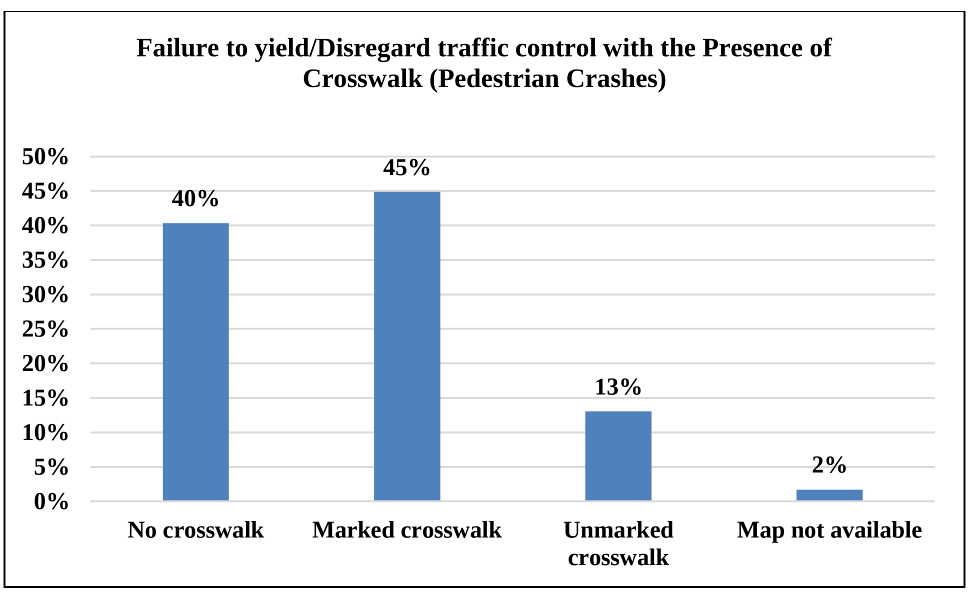
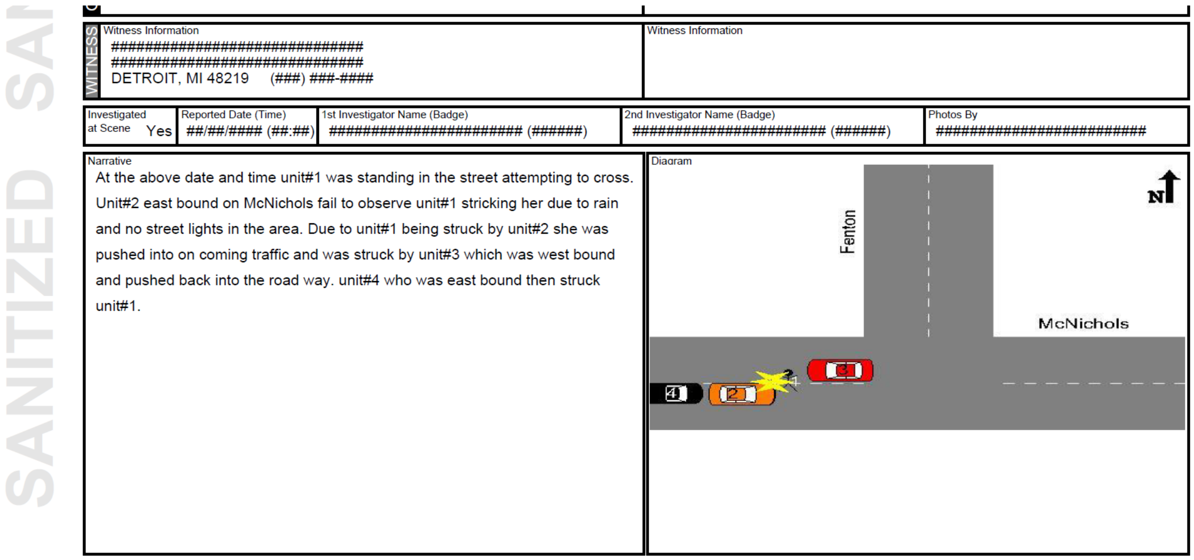


Figure 73: Distribution of failure to yield/disregard traffic control crashes and the presence of crosswalk



WITNESS	
Witness Information ############################## ############################## DETROIT, MI 48219 (###) ###-####	Witness Information

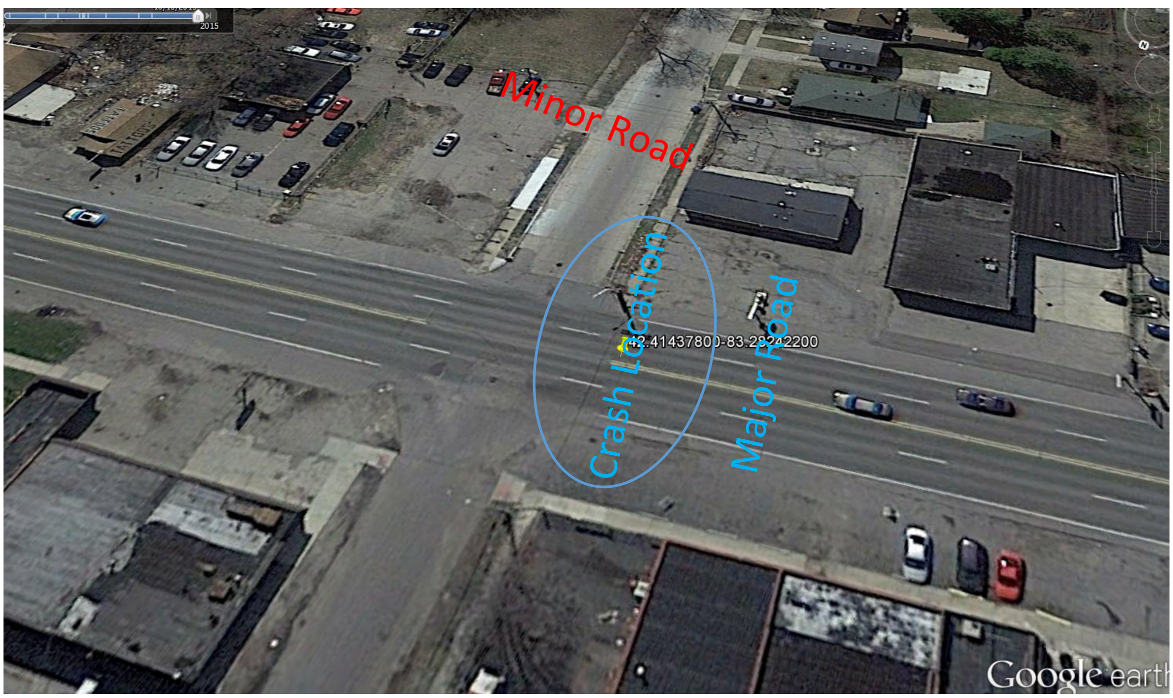
Investigated at Scene	Reported Date (Time)	1st Investigator Name (Badge)	2nd Investigator Name (Badge)	Photos By
Yes	##/##/#### (##:##)	###################### (######)	###################### (######)	#########################

Narrative

At the above date and time unit#1 was standing in the street attempting to cross. Unit#2 east bound on McNichols fail to observe unit#1 stricking her due to rain and no street lights in the area. Due to unit#1 being struck by unit#2 she was pushed into on coming traffic and was struck by unit#3 which was west bound and pushed back into the road way. unit#4 who was east bound then struck unit#1.

Diagram

(Narrative portion of a crash report)



(Satellite image for the crash location)

Figure 74: Narrative portion of a crash report and the satellite image from Google Earth Pro for the crash location (Google Earth Pro, 2015)

Figure (75) shows the distribution of failure to yield/disregard traffic control crashes at intersections and the presence of a pedestrian signal. The figure shows that 61% of crashes occurred when there was no pedestrian signal at the location of the crash. However, 38% of crashes occurred when there was a pedestrian signal at the location of the crash.

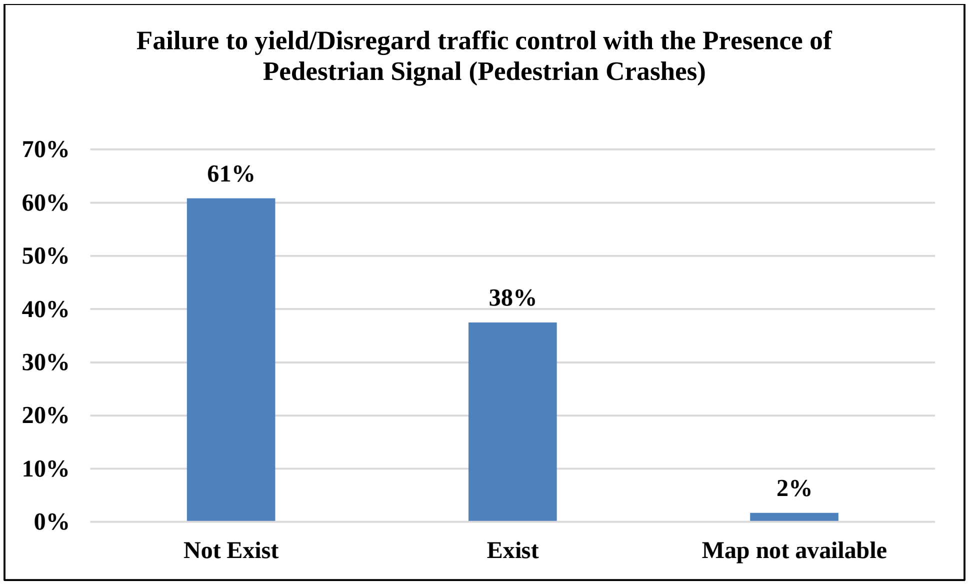


Figure 75: Distribution of failure to yield/disregard traffic control crashes and the presence of pedestrian signal

Figure (76) shows the distribution of failure to yield/disregard traffic control crashes at intersections and the presence of signage (e.g., “School Zone”, “Pedestrian Crossing Sign”). The figure shows that 89% of crashes occurred when there wasn’t any type of signage present. This observation may suggest that lack of signage may have an effect on failure to yield/disregard traffic control crashes.

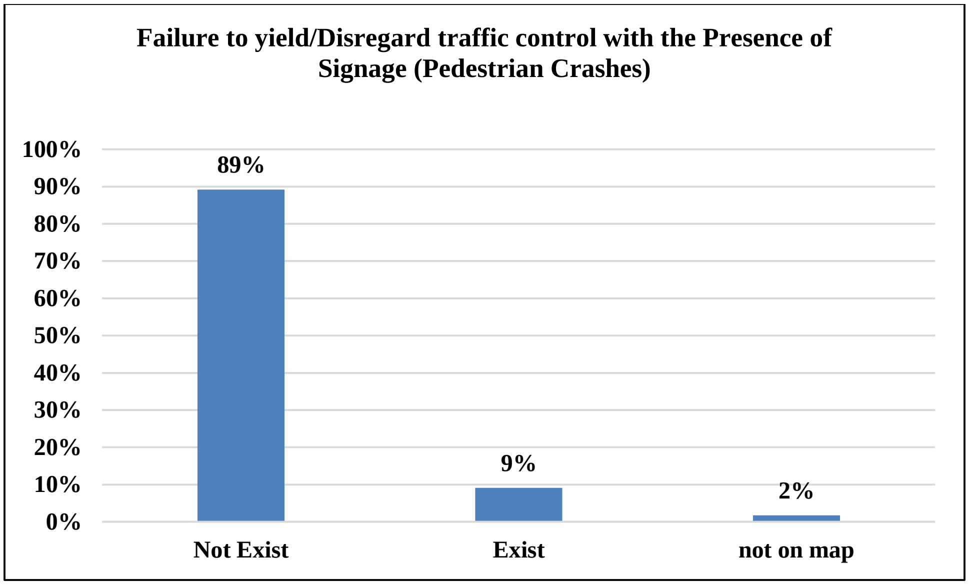


Figure 76: Distribution of failure to yield/disregard traffic control crashes at intersections and the presence of signage

Causes of bicycle crashes

The methodology section discussed the procedure of obtaining the crash types and crash groups for bicycle crashes using the Pedestrian and Bicycle Crash Analysis Tool (PBCAT). All UD-10 reports for bicycle fatal crashes for five years (2010-2014) have been reviewed and analyzed (e.g., 123 UD-10 reports). By reviewing the details of each single crash using PBCAT software, the crash groups and the crash types for bicycle fatal crashes were identified. Furthermore, a sample size of 50 UD-10 reports for each year for type (A) crashes (e.g., incapacitating injury crashes) was reviewed and analyzed (e.g., 250 UD-10 reports for the five years). The 50 UD reports sample size was chosen based on a random sampling method from the 7 districts in the State of Michigan. This sample size represents an average percentage of 32% from the total number of bicycle incapacitating injury crashes from 2010 to 2014. A sample of 25 for each year from 2010 to 2014 of property damage-only crashes was reviewed in order to

capture a full picture about the causes of bicycle crashes across all injury severities. Finally, crash groups that had been identified in this section disclose the bicycle crash causes in the state of Michigan.

The results of analysis of bicycle fatal crashes (K) and a sample of incapacitating injury crashes for five years (2010-2014) are shown in Table (22). It's clear from the table that the highest percentage of bicycle crashes analyzed falls under motorist overtaking bicyclist crash group, followed by bicyclist failed to yield at signalized intersection and sign-controlled intersection.

Table 22: Distribution of crash groups (causes) for bicycle crashes

Crash Groups	Frequency
Motorist Overtaking Bicyclist	26.5%
Bicyclist Failed to Yield - Signalized Intersection	12.1%
Bicyclist Failed to Yield - Sign-Controlled Intersection	12.1%
Bicyclist Failed to Yield - Midblock	7.0%
Loss of Control / Turning Error	5.6%
Head-On	5.1%
Motorist Left Turn / Merge	5.1%
Crossing Paths - Other Circumstances	4.6%
Bicyclist Left Turn / Merge	3.8%
Motorist Failed to Yield - Sign-Controlled Intersection	3.2%
Motorist Right Turn / Merge	3.2%
Motorist Failed to Yield - Signalized Intersection	2.4%
Motorist Failed to Yield - Midblock	2.1%
Other/Unknown - Insufficient Details	2.1%
Parallel Paths - Other Circumstances	1.3%
Bicyclist Right Turn / Merge	1.1%
Bicyclist Overtaking Motorist	0.8%
Other / Unusual Circumstances	0.8%
Backing Vehicle	0.5%
Non-Roadway	0.5%
Total	**100.0%**

Figure (77) shows the distribution of the top 10 crash groups of bicycle fatal crashes (K) and incapacitating injury crashes (K) combined. The top 10 crash groups for both K&A crashes combined accounted for 88% of the total crash groups that had been analyzed. When considering property damage-only crashes (PDO), the crash typing was done for a sample of 25 crashes for each year from 2010 to 2014 for bicycle PDO crashes. The results shows that the trend still the same and there is no big difference in crash groups between K&A crash types and PDO crash types. Figure (78) shows the distribution of crash types for pedestrian PDO crashes. Furthermore, A Chi square test was conducted in order to compare the distribution of crash groups for property damage-only crashes (PDO) and the crash groups for fatal (K) and incapacitating injury (A) crashes from statistical prospective. The null hypothesis is that there is no difference in the distribution of PDO crashes and K&A crashes. The p-value for the Chi square test was 0.497 at 95% confidence level which means that we accept the null hypothesis that there is no difference between the two distributions. In conclusion, the crash groups that had been identified for bicycle fatal crashes (K) and incapacitating injury crashes (A) are applicable across all the five injury severities.

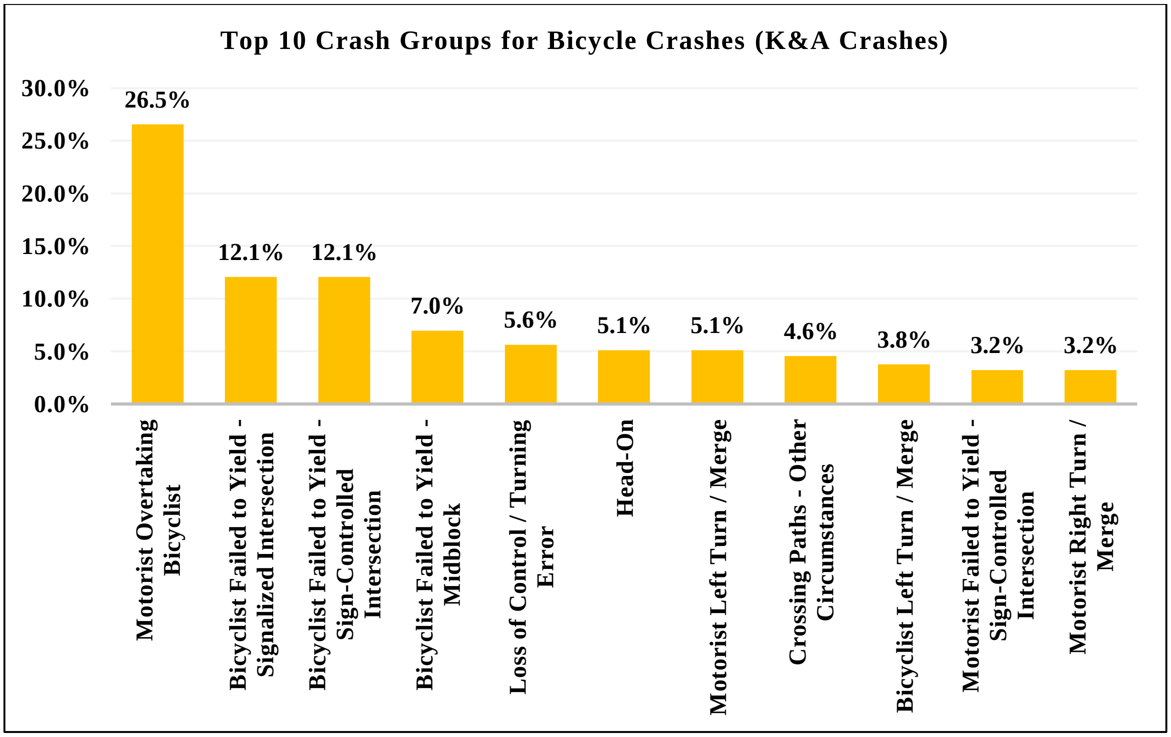


Figure 77: Top 10 crash group for bicycle crashes K&A combined

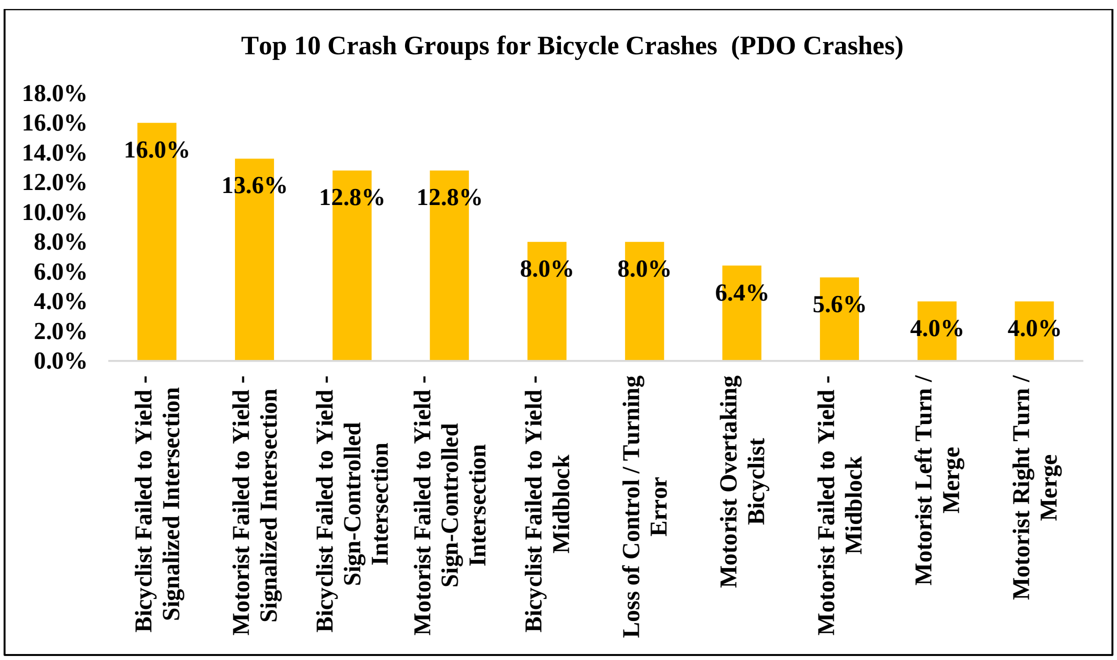
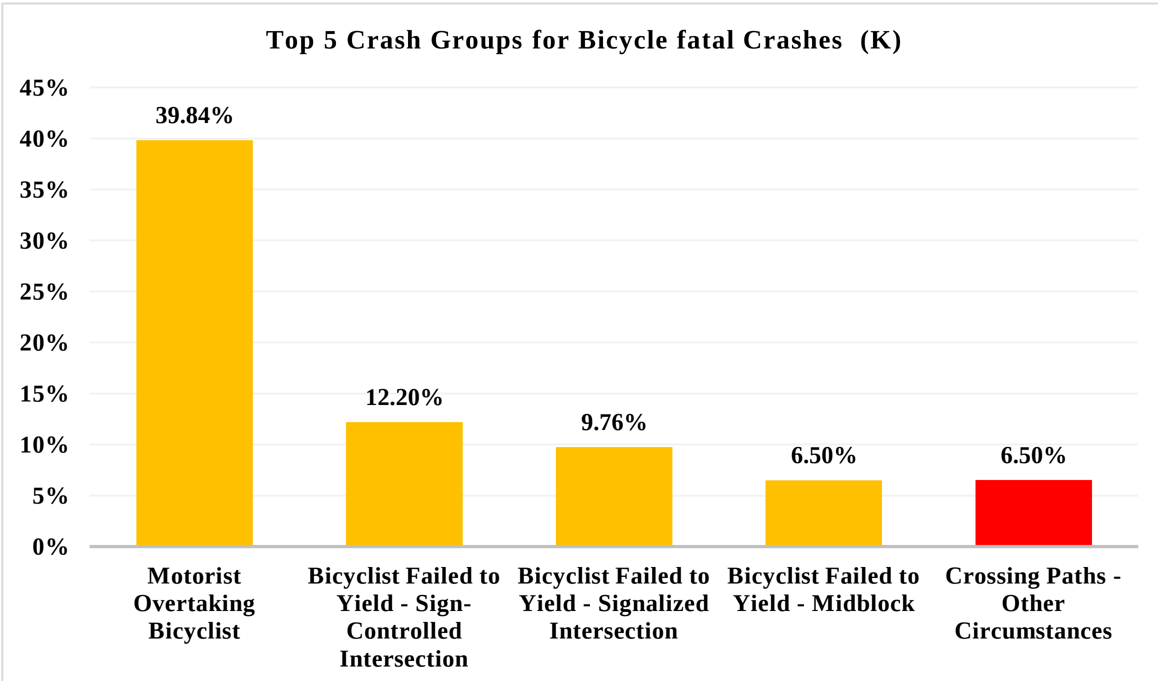


Figure 78: Top 10 crash group for bicycle crashes PDO crashes

Figure (79) illustrates the distribution of the top 10 crash groups for bicycle fatal crashes (K) and incapacitating injury crashes (A). There is a slight difference in terms of crash groups between the fatal crashes and incapacitating injury crashes and those differences are highlighted in red. Both figures show that motorist overtaking bicyclist was the top one for fatal and incapacitating injury crashes. In addition, the order of crash groups has changed between fatal crashes and incapacitating injury crashes, in particular bicyclist failed to yield at signalized intersections and failed to yield at sign control intersections.



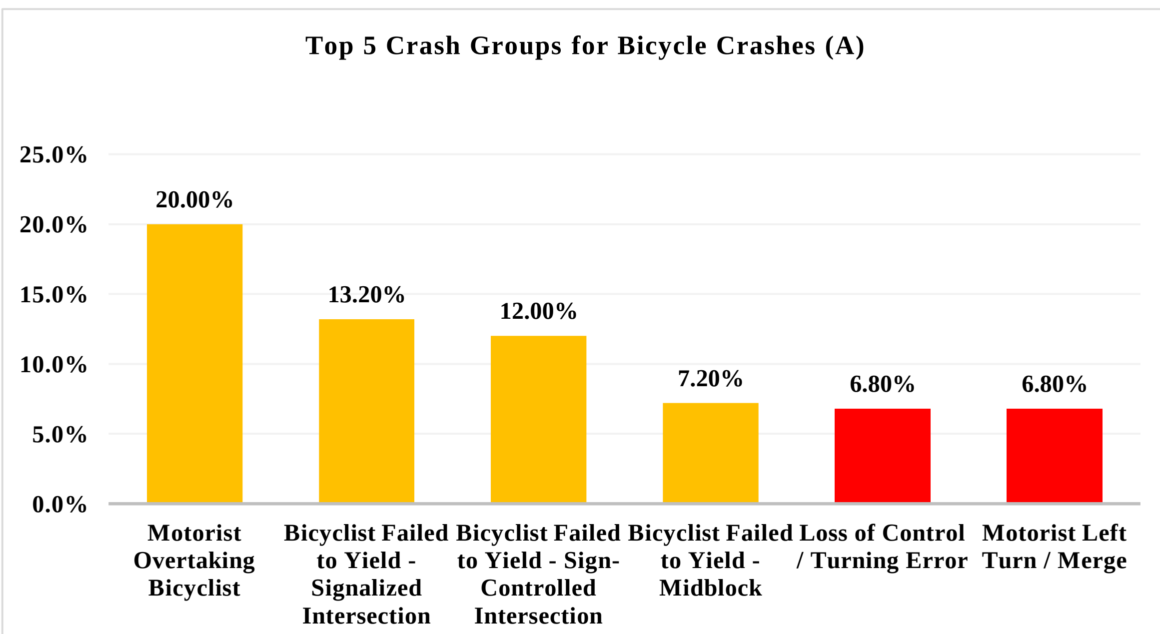


Figure 79: Distribution of top 10 crash groups for bicycle K and A crashes

Based on the results that were obtained from the PBACT, many crash groups were identified. These crash groups represent the causes of bicycle crashes in the state of Michigan. In addition, the definition of those causes are as follows:

- Motorist overtaking bicyclist: Three possible scenarios for that cause: motorist misjudged the space and struck the bicyclist, bicyclist swerved into the path of vehicle, the motorist failed to detect the bicyclist due to lack lighting, roadway curvature. This cause accounted for 26.5% of bicycle crash causes.
- Bicyclist failed to yield – signalized intersection: Cyclist failed to yield the right-of-way at signalized intersection and struck by a vehicle. This cause accounted for 12% of bicycle crash causes.
- Bicyclist failed to yield – sign-controlled intersection: Cyclist failed to yield the right-of-way at sign-controlled intersection and struck by a vehicle. This cause accounted for 12.1% of bicycle crash causes.
- Bicyclist failed to yield –midblock: Cyclist failed to yield the right-of-way at midblock locations and struck by a vehicle. This cause accounted for 7% of bicycle crash causes.

- Loss of control/turning error: Either the cyclist or the driver lost control due to mechanical failure, surface condition, impairment, oversteering, improper braking, and speeding. Cyclist or driver turning error while turning left, right, and other turning maneuvers. This cause accounted for 5.6% of bicycle crash causes.
- Head-on: The cyclist was cycling wrong way and collided with the vehicle head on. This cause accounted for 5.1% of bicycle crash causes.

- Motorist left turn/merge: The motorist struck the bicyclist while he was turning/merging left in the same direction or in the opposite direction (motorist at fault). This cause accounted for 5.1% of bicycle crash causes.
- Crossing paths-other circumstances: The cyclist and the driver were at crossing location and the crash occurred. The fault was unknown. This cause accounted for 4.6% of bicycle crash causes.
- Bicyclist left turn/merge: The cyclist struck by the vehicle while he was turning/merging left in the same direction or in the opposite direction (cyclist at fault). This cause accounted for 3.8% of bicycle crash causes.
- Motorist failed to yield-sign-controlled intersection: The motorist failed to yield the right-of-way at sign-controlled intersection and struck the bicyclist. This cause accounted for 3.2% of bicycle crash causes.
- Motorist right turn/merge: The motorist struck the bicyclist while he was turning/merging right in the same direction or in the opposite direction (motorist at fault). This cause accounted for 3.2% of bicycle crash causes.

Further analysis was done by connecting the most frequent crash groups for bicycles (e.g., 7 crash groups) with the electronic database. This analysis is helpful to understand the other contributing factors that might be associated with those causes. The analysis was based on connecting the most frequent crash groups with the alcohol involvement, drug involvement, weather condition, roadway condition, lighting condition, MDOT location of the crash, traffic control device, and highway class.

Figure (80) shows the distribution of most frequent bicycles crash groups by alcohol involvement. The graph shows that motorist overtaking taking bicyclist and loss of control/turning error crash groups had the highest percentage of alcohol involvement compared to other crash groups. This observation suggests that alcohol involvement as a contributing factor for bicycle crashes falls under loss of control/turning error crash group. Furthermore, the proportion of alcohol involvement was approximately similar for the rest of groups.

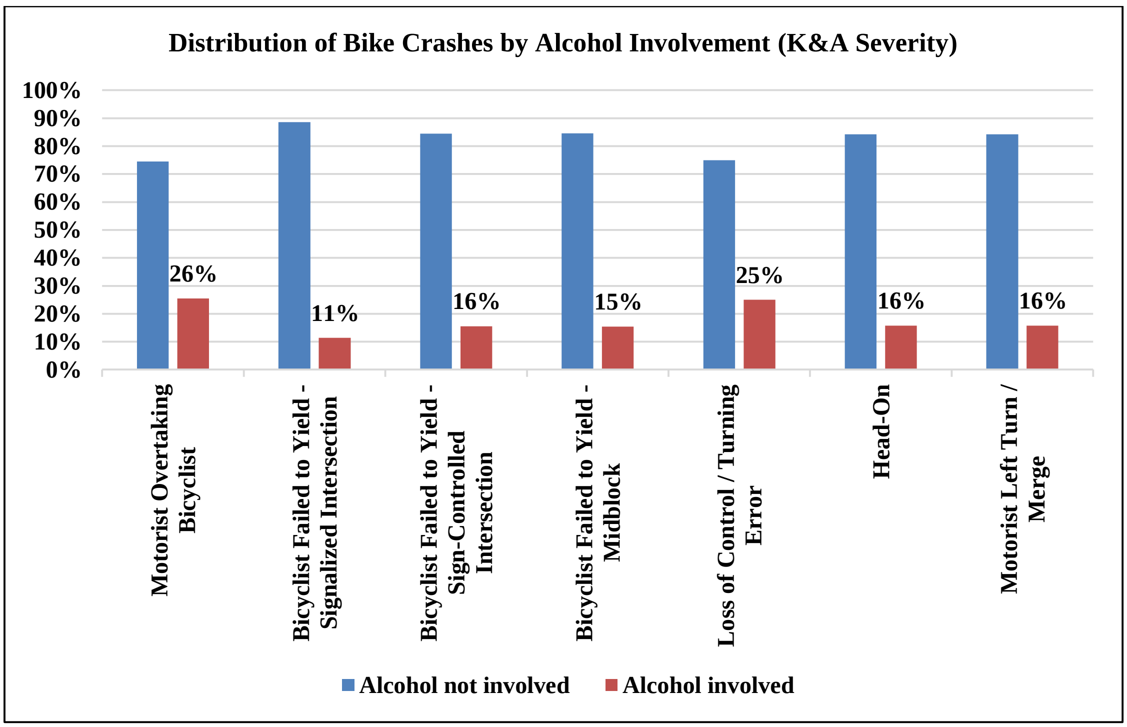


Figure 80: Proportion of most frequent bicycle crash groups by alcohol involvement

Figure (81) illustrates the distribution of most frequent bicycles crash groups by drug involvement. The graph shows that motorist overtaking taking bicyclist had the highest percentage of drug involvement compared to other crash groups. This observation points to the possibility that drug involvement might be one of the contributing factors.

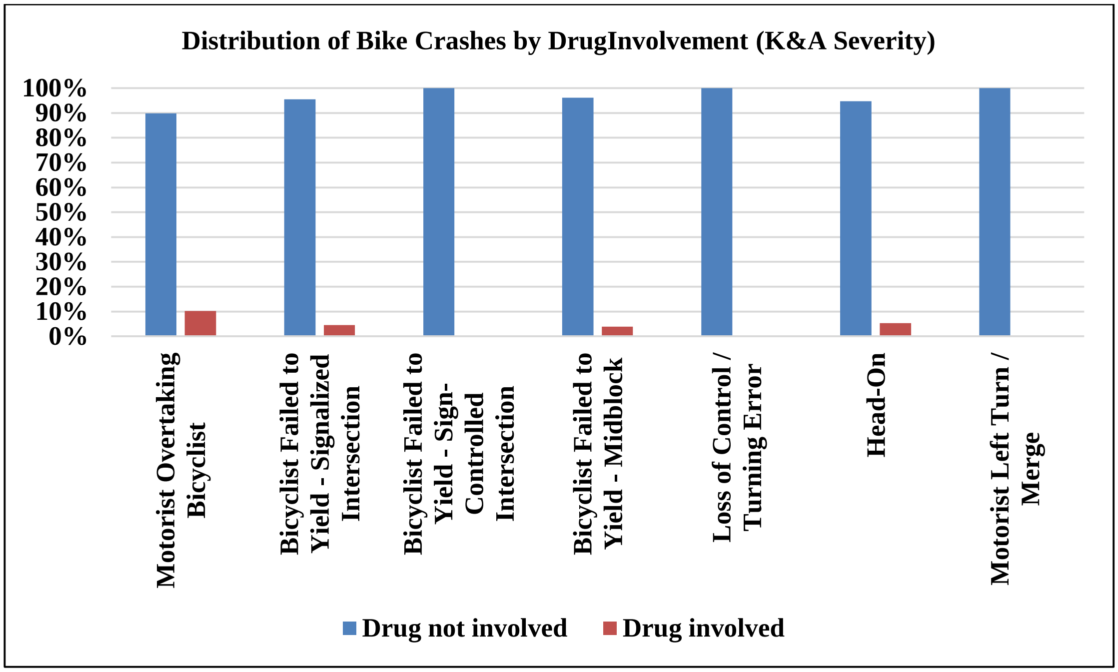


Figure 81: Proportion of most frequent bicycle crash groups by drug involvement

Figure (82) presents the distribution of most frequent bicycles crash groups by weather condition. The graph shows that the majority of crashes occurred during clear weather condition followed by cloudy and rain weather conditions. This observation can be explained by the fact that most cyclists try to avoid cycling in inclement weather.

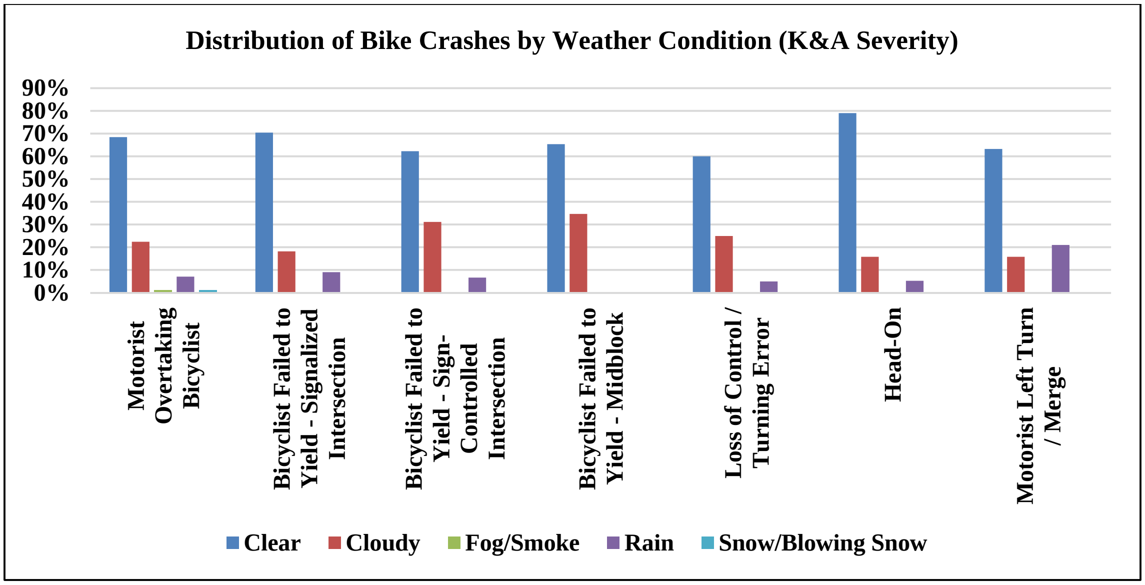


Figure 82: Proportion of most frequent bicycle crash groups by weather condition

Figure (83) illustrates the distribution of most frequent bicycles crash groups by road condition. The graph shows that the majority of crashes occurred when the roads were dry followed by wet and icy road conditions. This observation can be supported by the fact that most cyclists trying to avoid cycling during inclement roadway conditions.

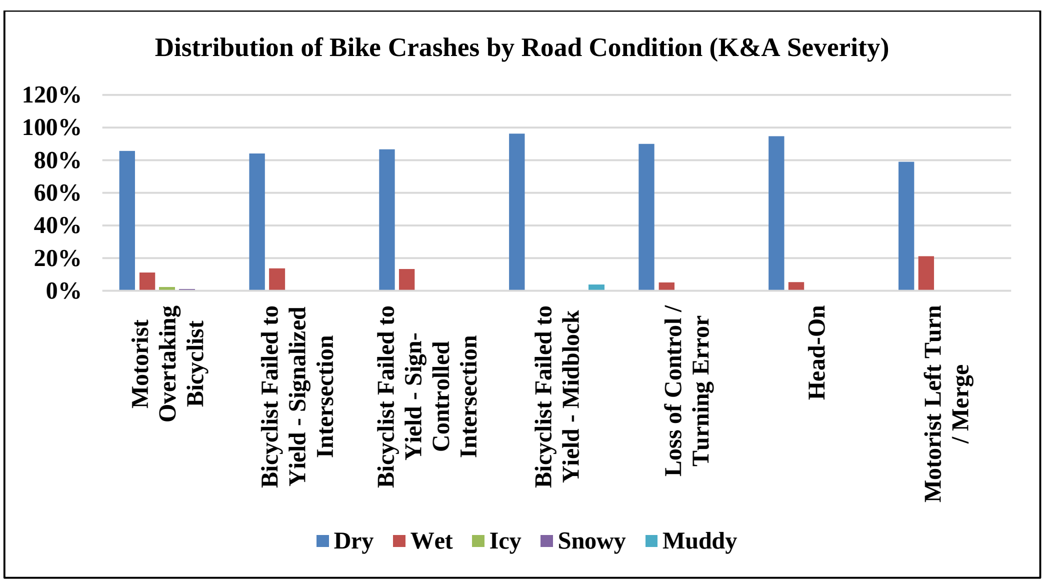
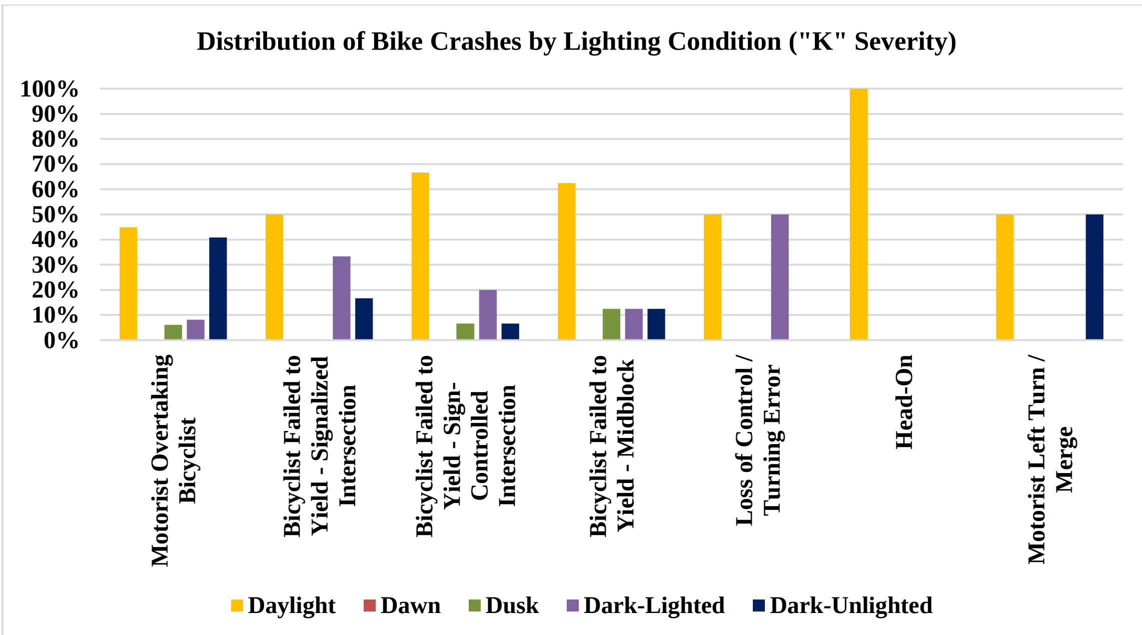


Figure 83: Proportion of most frequent bicycle crash groups by road condition

Figure (84) compare the most frequent bicycles crash groups by lighting conditions for fatal crashes and incapacitating injury crashes respectively. The graphs shows that lighting condition had an effect on injury severity and this observation was supported by the cross tabulation in the data section.



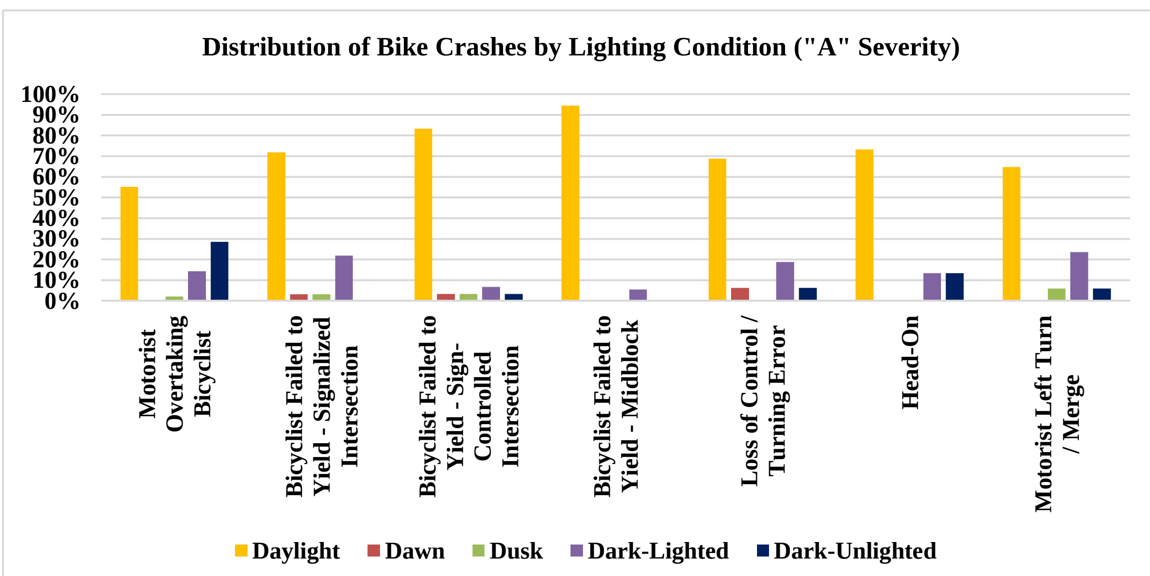


Figure 84: Comparison of distribution of K and A crashes by lighting condition

Figure (85) presents the distribution of most frequent bicycles crash groups by MDOT crash location. The graph shows that the majority of crashes occurred at intersections and midblock locations. In addition, most of crashes that falls under motorist overtaking bicyclist crash group occurred on midblock locations.

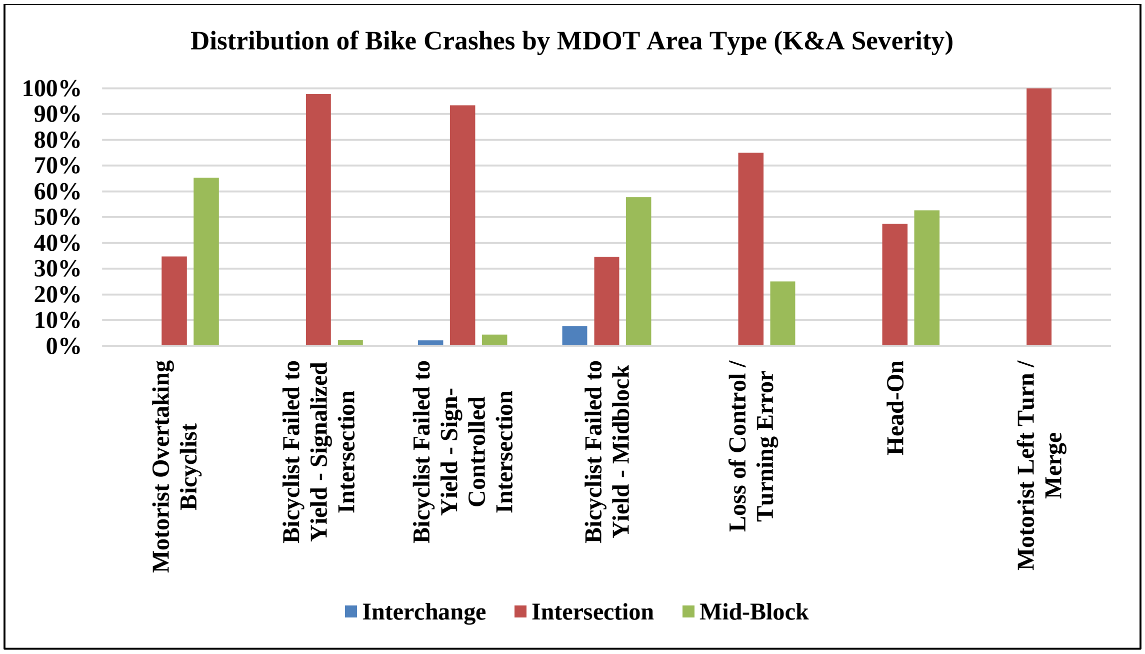


Figure 85: Proportion of most frequent bicycle crash groups by MDOT area type

Figure (86) illustrates the distribution of most frequent bicycles crash groups at intersections by traffic control device. The graph shows that the majority of crashes occurred when there was no traffic control device present at the intersection. It is important to mention that “none” doesn’t always mean uncontrolled intersection. In many cases, the major road (e.g., when the crash occurred) was uncontrolled and the minor road had a stop sign or yield sign.

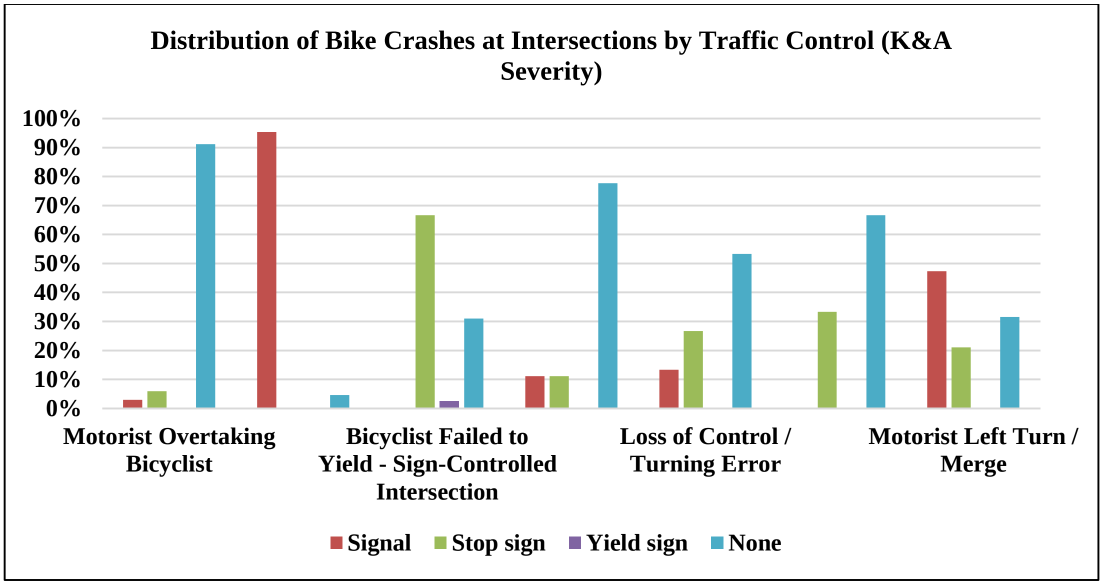


Figure 86: Proportion of most frequent bicycle crash groups by traffic control device

Figure (87) presents the distribution of most frequent bicycles crash groups by highway class. The graph shows that the majority of crashes occurred at roadway/city street or unknown highway class followed by M route highway class.

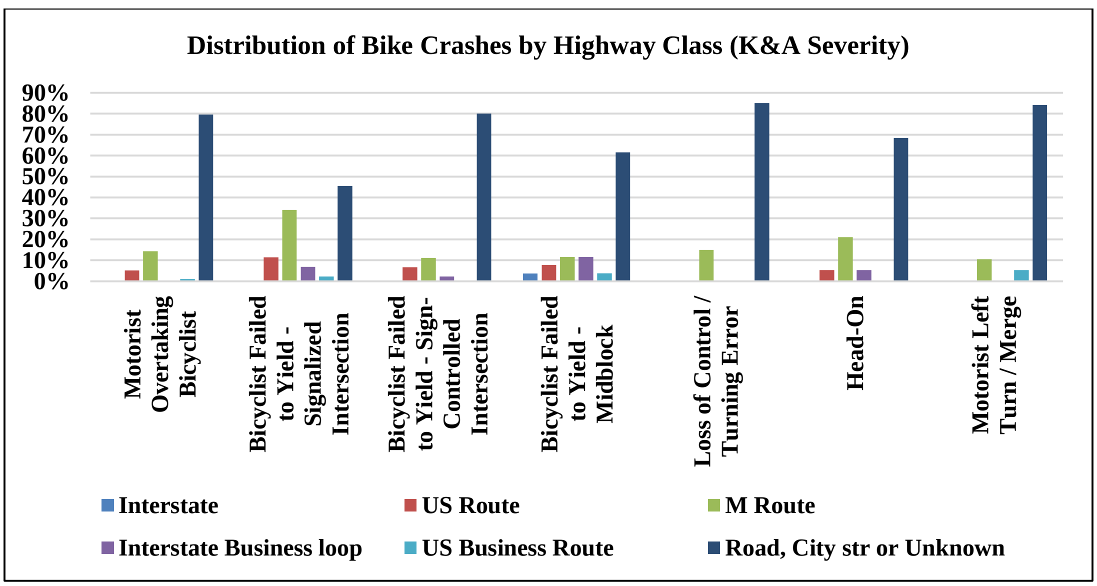


Figure 87: Proportion of most frequent bicycle crash groups by Highway class

Figure (88) illustrates the distribution of most frequent bicycles crash groups by type of median. The graph shows that the majority of crashes occurred on undivided roadways. This observation was supported by the fact that the majority of crashes occurred at roadway/city street what they are undivided roadways.

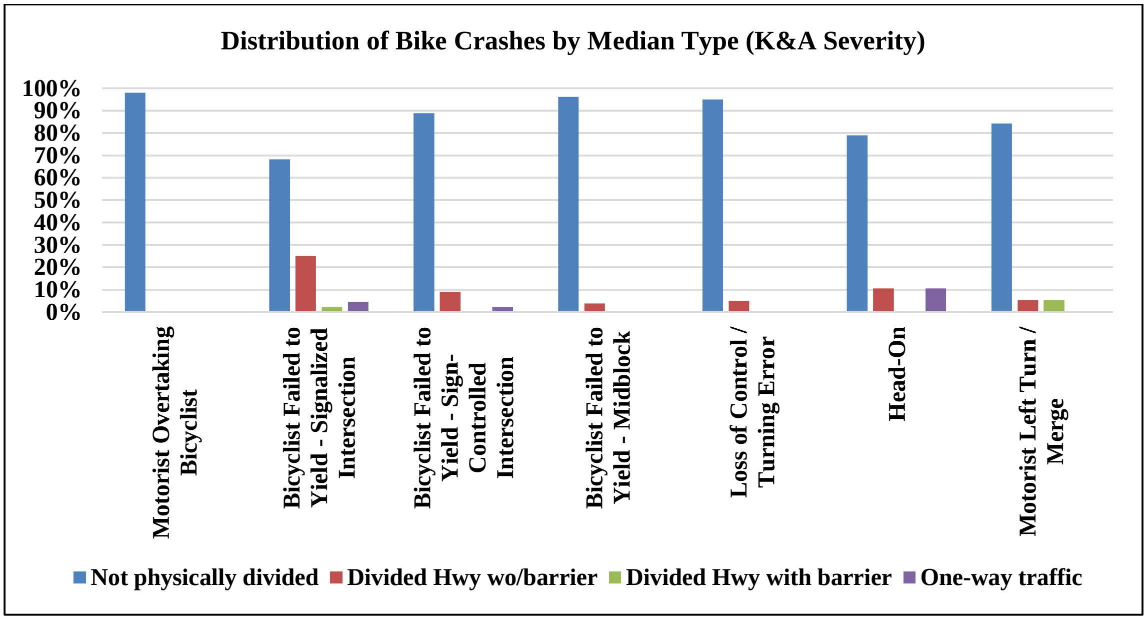


Figure 88: Proportion of most frequent bicycles crash groups by median type

Categorization of crash groups based on bicyclist /driver risk behavior

Since there were many crash types/groups (causes) that had been identified previously in this chapter, groups of bicyclist/driver risk behavior were created by assigning each crash cause to a certain risk behavior. This categorization helps to get a better understanding about bicycle crash causes in the state of Michigan. In addition, this categorization facilitates the process of selecting appropriate countermeasures to reduce bicycle crashes.

Table (23) shows the distribution of crash causes by risk behavior groups. The table shows that there were five risk behavior groups had been generated and each of those groups was the main cause of the crash. Finally, failure to yield or disregard traffic control risk behavior group was the major crash cause of bicycle crashes based on the crashes that had been analyzed from 2010 to 2014.

Table 23: Distribution of crash causes by risk behavior groups for bicycle crashes

Risk Behavior Groups	Frequency
Failing to Yield/disregard traffic control	**57.6%**
Bicyclist Failed to Yield - Signalized Intersection	12.1%
Bicyclist Failed to Yield - Sign-Controlled Intersection	12.1%
Bicyclist Failed to Yield - Midblock	7.0%
Motorist Left Turn / Merge	5.1%
Bicyclist Left Turn / Merge	3.8%
Motorist Failed to Yield - Sign-Controlled Intersection	3.2%
Motorist Right Turn / Merge	3.2%
Motorist Failed to Yield - Signalized Intersection	2.4%
Motorist Failed to Yield - Midblock	2.1%
Crossing Paths - Other Circumstances	4.6%
Bicyclist Ride Out - Parallel Path	0.5%
Backing Vehicle	0.5%
Bicyclist Right Turn / Merge	1.1%
Overtaking	**27.3%**
Motorist Overtaking Bicyclist	26.5%
Bicyclist Overtaking Motorist	0.8%
Loss of Control/Turning Error	**5.6%**
Loss of Control / Turning Error	5.6%
Cyclist Rode Wrong Way	**5.1%**
Head-on	5.1%
Other/Unknown	**4.3%**
Other/Unknown - Insufficient Details	2.1%
Parallel Paths - Other / Unknown	0.8%
Non-Roadway	0.5%
Other / Unusual Circumstances	0.8%

Analysis of failure to yield/disregard traffic control risk behavior

Further analysis was performed in order to understand and describe the failure to yield/disregard traffic control risk behavior group at intersections. The analysis was done by connecting the roadway characteristics that were not available in the electronic database with failing to yield/disregard traffic control risk behavior. The data that was used for this analysis was all bicycle fatal crashes (K) and a sample of incapacitating injury crashes (A) from 2010 to 2014, which was the same set of data that had been used in crash typing. In addition, the data that had been used for this type of analysis consists of two sets of data. The first set of data was obtained from an electronic database and the second from field data collection using Google Earth Pro.

Figure (89) shows the distribution of bicycle crashes at midblock locations or intersections by area type. The figure shows that 74% of bicycle crashes at intersections occurring at small urban areas and large urbanized areas were considered failure to yield/disregard traffic control. When considering midblock locations, 80% of bicycle crashes at mid-blocks occurring at small urban areas type we categorized as failure to yield/disregard traffic control.

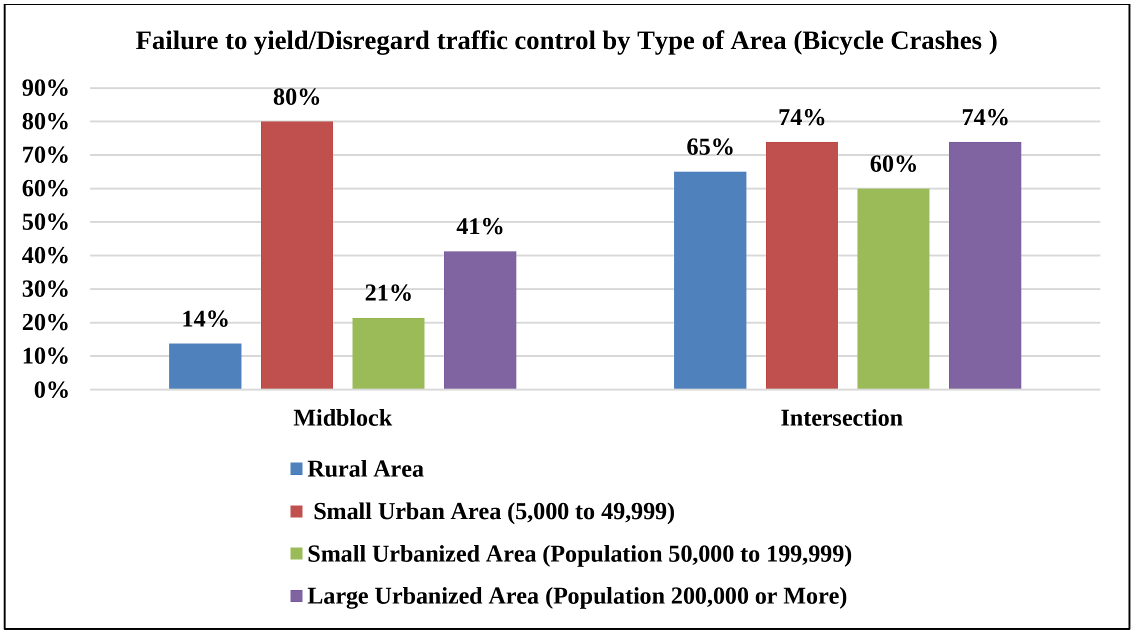


Figure 89: Proportion of bicycle crashes at midblock locations or intersections by area type

Figure (90) shows the distribution of bicycle crashes at intersections with number of lanes. 88% of bicycle crashes at intersections occurring on intersections with 3 lanes were considered failure to yield/disregard traffic control. In addition, 88% of bicycle crashes at intersections occurred in roadways with 4 or more lanes fall under failure to yield/disregard traffic control group.

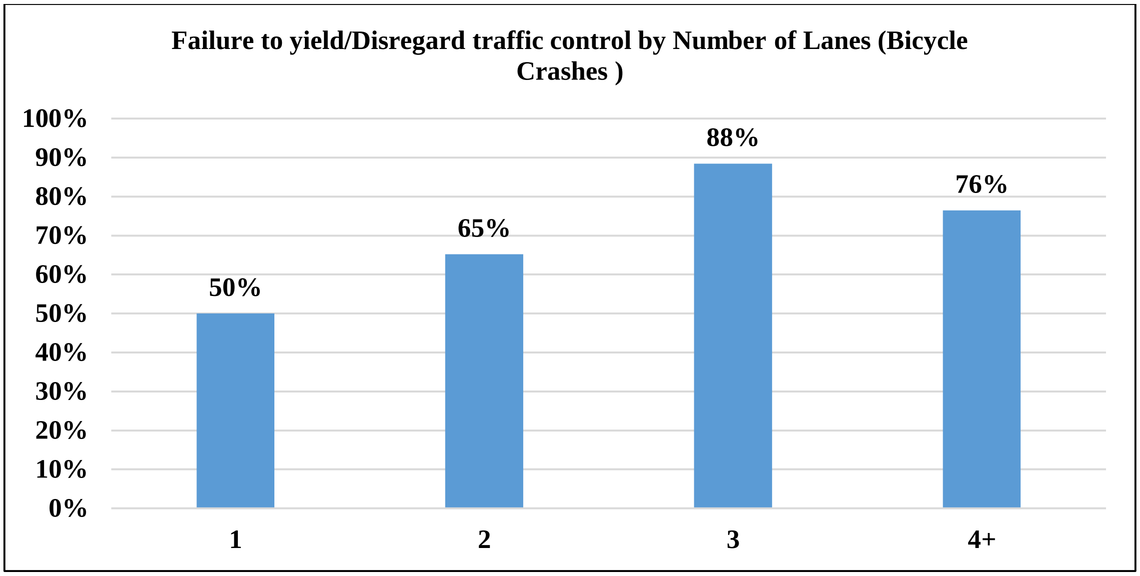


Figure 90: Proportion of bicycle crashes at intersections by number of lanes

Figure (91) illustrates the distribution of bicycle crashes at intersections with the speed limit. The figure shows that 81% of bicycle crashes at intersections occurring when the speed limit was 35 to 45 mph were categorized as to yield/disregard traffic control. In addition, 72% of bicycle crashes at intersections occurring when the speed limit was 0 to 35 mph fall under failure to yield/disregard traffic control group.

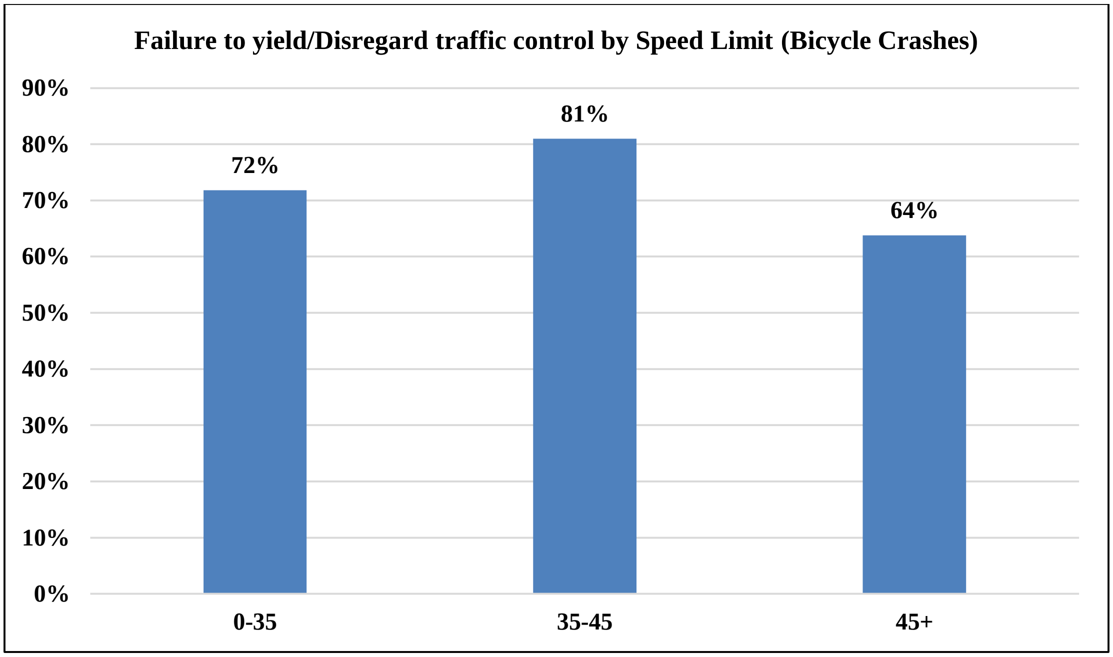


Figure 91: Proportion of bicycle crashes at intersections by speed limit

Figure (92) presents the distribution of bicycle crashes at intersections with traffic control device. The figure shows that 93% of bicycle crashes occurring at signalized intersections were considered failure to yield/disregard traffic control. In addition, 82% of bicycle crashes occurring at sign-controlled intersections were categorized as failure to yield/disregard traffic control. Finally, 50% of bicycle crashes at uncontrolled intersections fall under failure to yield/disregard traffic control group.

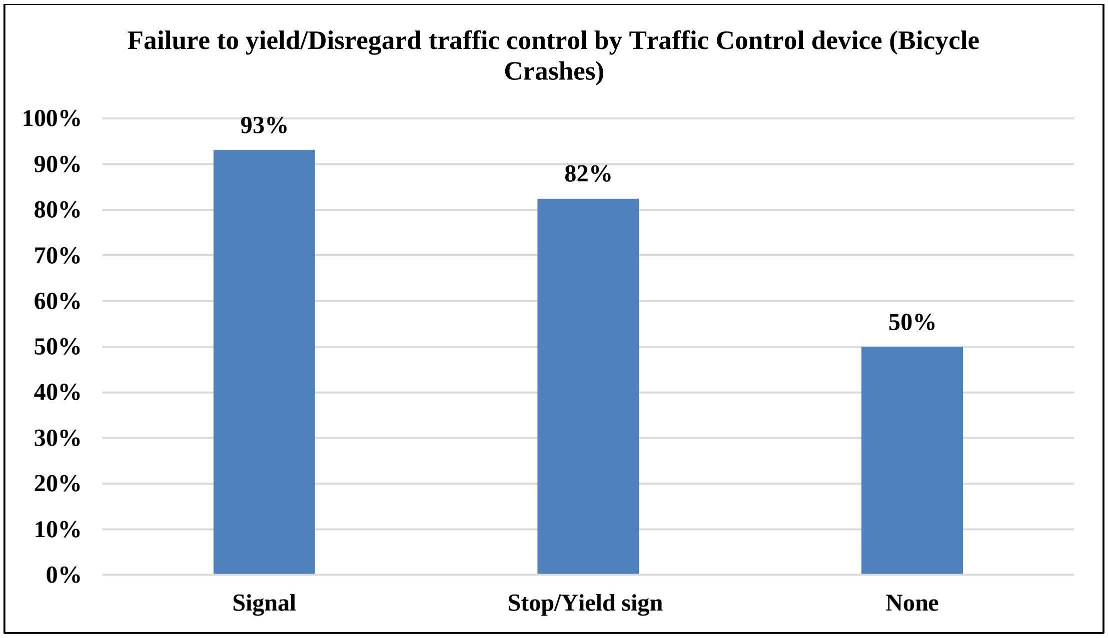


Figure 92: Proportion of bicycle crashes at intersections by traffic control device

Figure (93) shows the distribution of failure to yield/disregard traffic control crashes and the presence of dedicated bike lane. 93% of crashes occurred when there was no dedicated bike lane present at the location of the crash. In addition, only 4% of crashes occurred when there was dedicated bike lane present at the location of the crash. This observation suggests that lack of on-road bicycle infrastructures (e.g., dedicated/shared bike lane) might be one of the contributing factors for increasing the likelihood of failing to yield/disregard traffic control risk behavior. Finally, some crash locations did not have adequate mapping to investigate the availability of bicycle facilities, so these crashes were labeled “map not unavailable.”

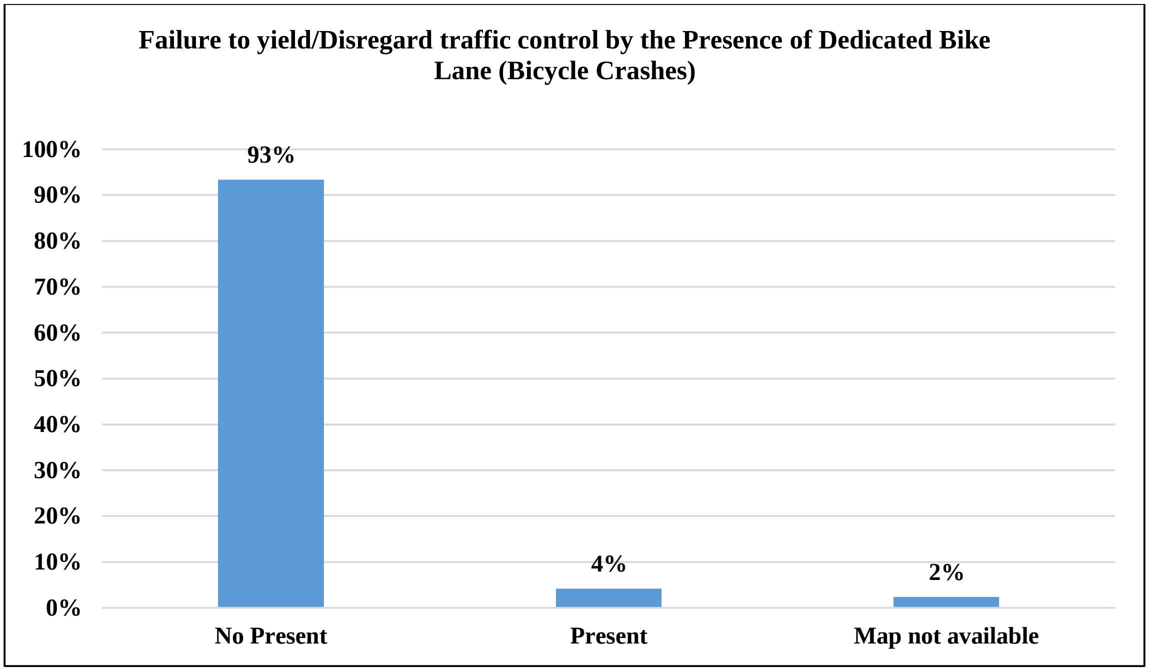


Figure 93: Distribution of failure to yield/disregard traffic control crashes by the presence of dedicated bike lane

Figure (94) shows the distribution of bicycle crashes analyzed by the presence and type of bicycle signage. The figure shows that 86% of bicycle crashes occurring during the absence of signage (e.g., “School Zone”, “Bike Lane/Route” “Pedestrian Warning”). In addition, 8% of bicycle crashes occurred when school zone sign present at the location of the crash. This observation reveals that there is a lack of bicycle signage on roadways because the presence of bicycle signage is correlated with the presence of on-road bicycle infrastructure (e.g., dedicated/shared bike lane). Finally, some crash locations did not have adequate mapping to investigate the availability of bicycle facilities, so these crashes were labeled “map not unavailable.”

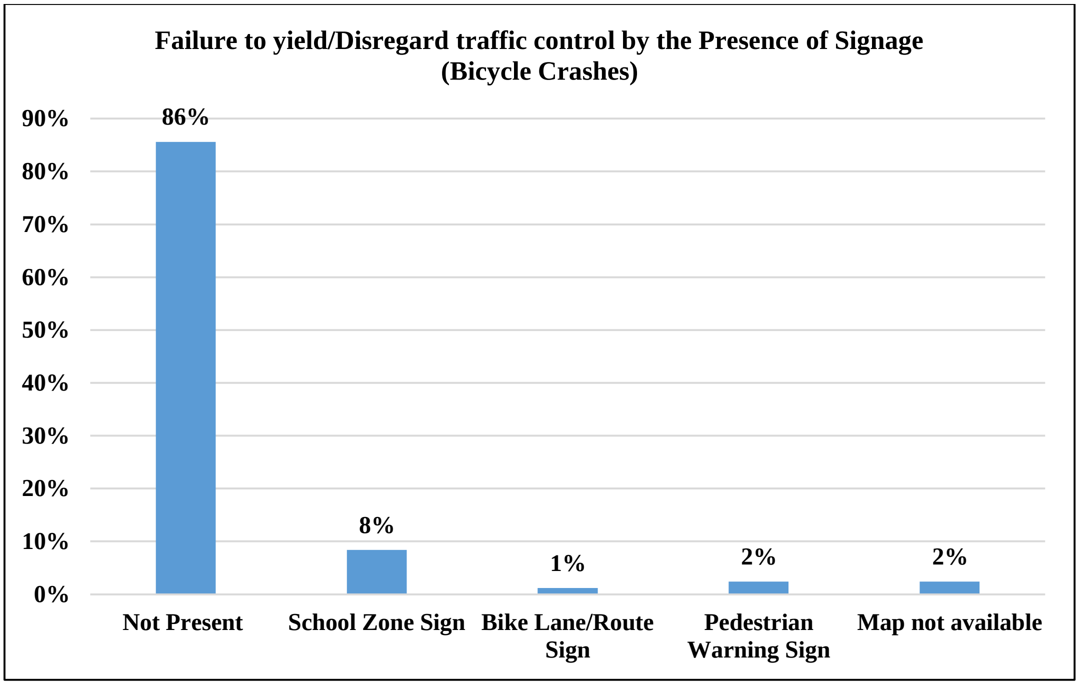


Figure 94: Distribution of failure to yield/disregard traffic control crashes by the presence of signage

Figure (95) presents the distribution of bicycle crashes analyzed by the presence of roadway marking for bicycles. The figure shows that 95% of bicycle crashes occurring during the absence of roadway marking. Additionally, 2% of bicycle crashes occurred when the roadway marking for bicycles was present at the location of the crash. This observation is not surprising because the presence of roadway marking for bicycles is correlated with the presence of on-road bicycle infrastructure (e.g., dedicated/shared bike lane).

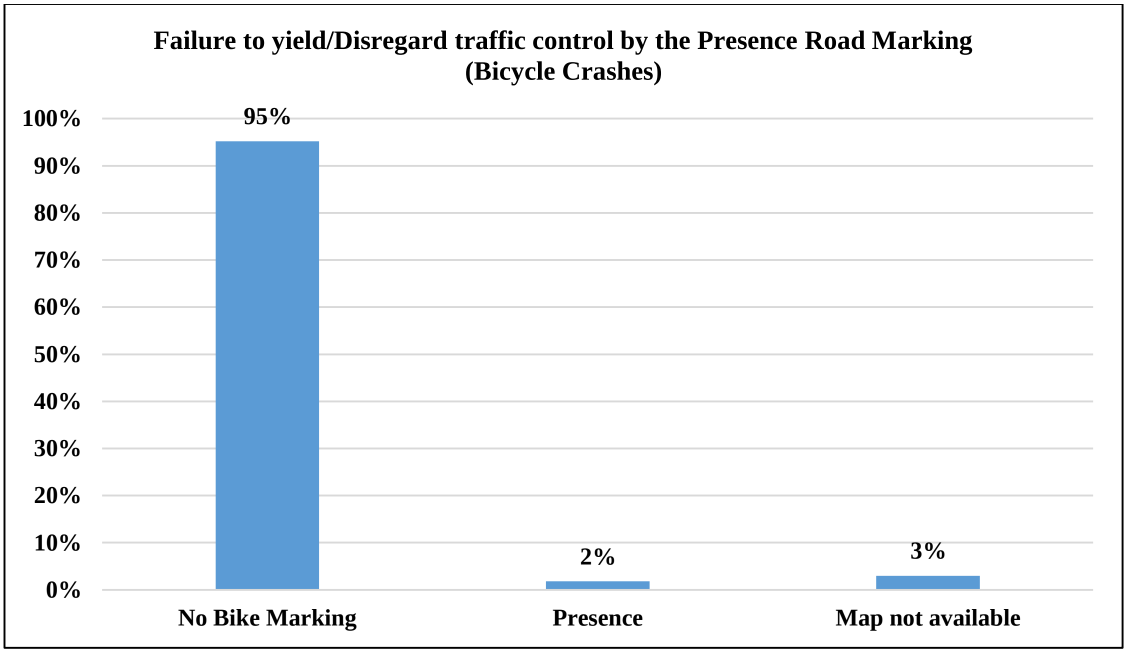


Figure 95: Distribution of failure to yield/disregard traffic control crashes by the presence of road marking

Figure (96) illustrates the distribution of bicycle crashes analyzed by the presence and type of shoulder. It’s clear from the graph that 84% of bicycle crashes occurred on roadways that didn’t have shoulder. In addition, 8% of bicycle crashes occurred on roadways that had a paved shoulder, while, 5% of bicycle crashes occurred on roadways that had an unpaved shoulder.

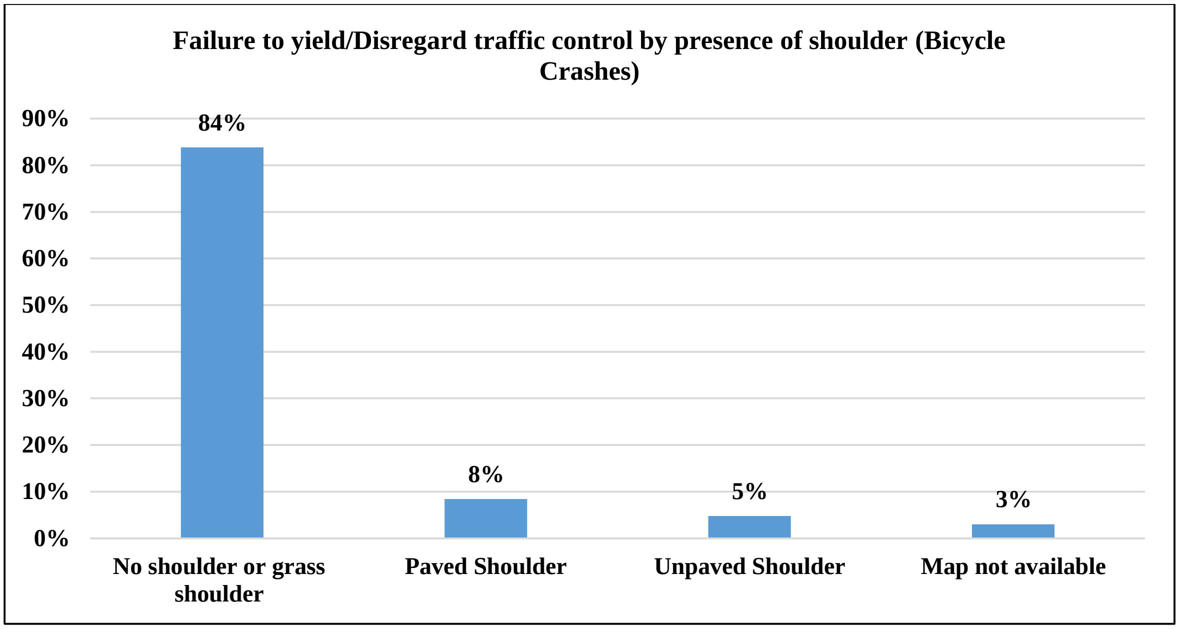


Figure 96: Distribution of failure to yield/disregard traffic control crashes by the presence of shoulder

Figure (97) shows the distribution of bicycle crashes analyzed with cyclist riding position prior to the crash. The graph shows that 41% of bicycle crashes occurred when the cyclist was riding on the sidewalk prior to the crash. An example of analysis procedures are shown in Figure (98). After combing the information from the narrative and the Google Earth Pro images, it was possible to locate the cyclist riding position before the crashes. For this example, the cyclist was found to be riding on the sidewalk prior to the crash. Finally, determining the riding position of the cyclist prior to the crashes is essential, because that can help in sharpening the education message during the selection and the implementation of education countermeasures.

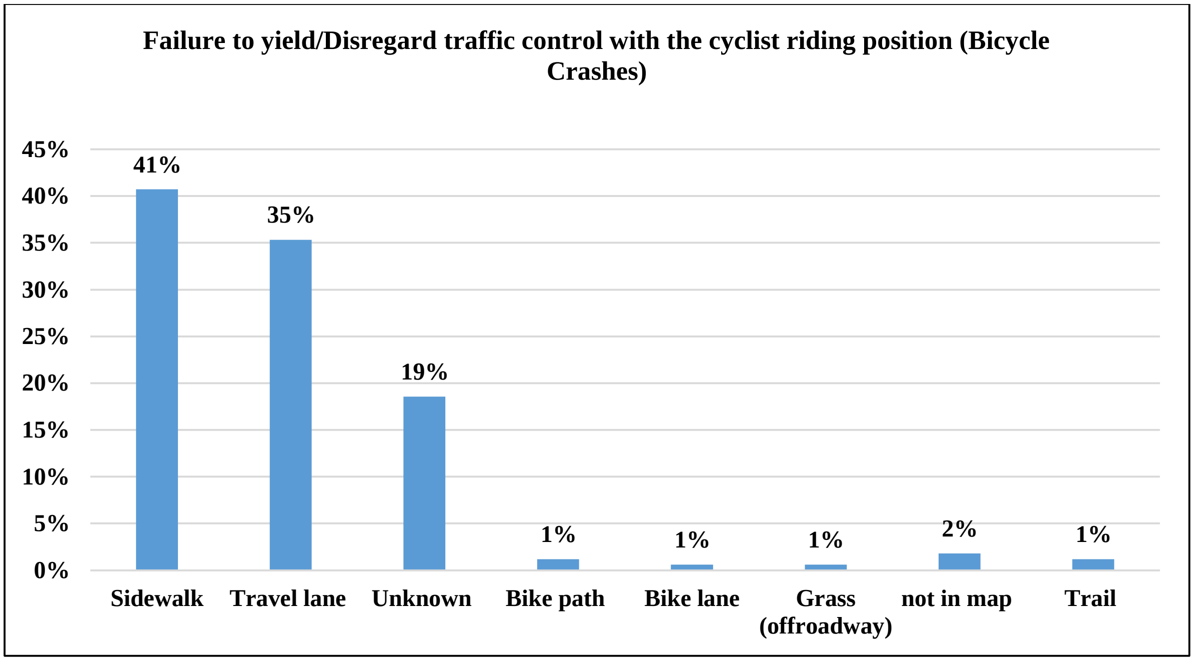
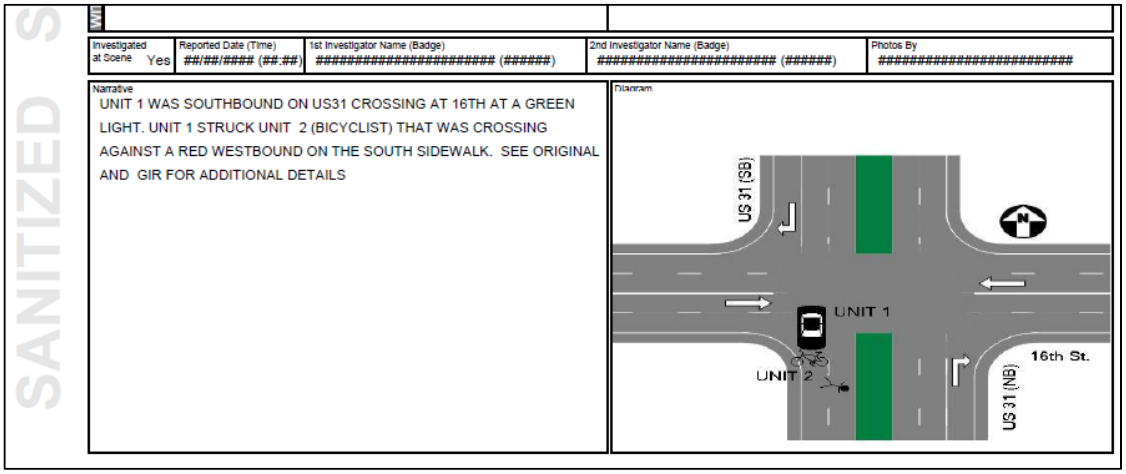


Figure 97: Distribution of failure to yield/disregard traffic control crashes with the cyclist riding position



SANITIZED

Investigated at Scene	Reported Date (Time)	1st Investigator Name (Badge)	2nd Investigator Name (Badge)	Photos By
Yes	##/##/#### (##.##)	######################## (######)	######################## (######)	##########################

Narrative

UNIT 1 WAS SOUTHBOUND ON US31 CROSSING AT 16TH AT A GREEN LIGHT. UNIT 1 STRUCK UNIT 2 (BICYCLIST) THAT WAS CROSSING AGAINST A RED WESTBOUND ON THE SOUTH SIDEWALK. SEE ORIGINAL AND GIR FOR ADDITIONAL DETAILS

Diagram

Figure 98: Example of analysis procedure for cyclist riding position before the crash3 (Google Earth Pro, 2015)

Analysis of overtaking risk behavior

The overtaking risk behavior group accounted for 27.3% of bicycle crashes that had been analyzed, and because of that, it's important to investigate the roadway characteristics that were associated with this risk behavior and get a better understanding about overtaking risk behavior. By using the same procedure that had been used for failing to yield/disregard traffic control risk behavior and with the data set consisting of all bicycle fatal crashes and a sample of incapacitating injury crashes from 2010 to 2014, the analysis was performed.

Figure (99) shows the distribution of bicycle crashes that were categorized as overtaking with the presence of dedicated bike lane. The graph shows that 95% of bicycle crashes occurred during the absence of a dedicated bike lane. Only 5% bicycle crashes occurred when there was a dedicated bike lane at the location of the crash.

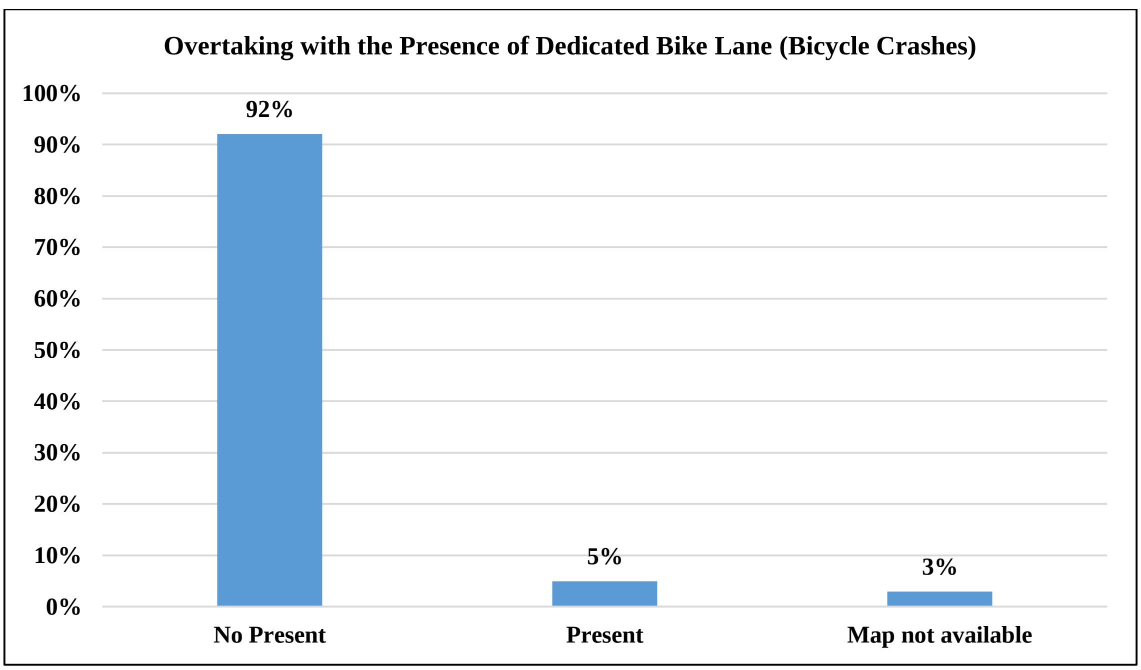


Figure 99: Distribution of overtaking crashes by the presence of dedicated bike lane

Figure (100) illustrates the distribution of bicycle crashes that were considered as overtaking with the presence and type of bicycle signage, where 85% of bicycle crashes occurred during the absence of signage (e.g., “School Zone”, (“Bike Lane/Route” “Pedestrian Warning”). In addition, 7% of bicycle crashes occurred when a school zone sign was present at the location of the crash. Finally, 4% of bicycle crashes occurred when bike signage existed at the location of the crash.

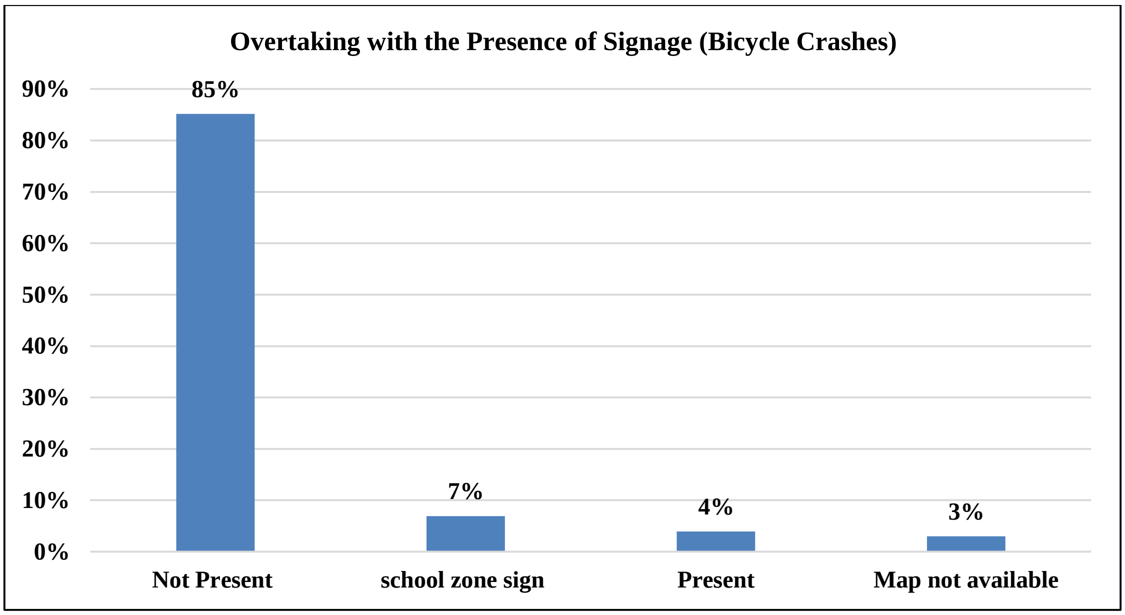


Figure 100: Distribution of overtaking crashes by the presence of signage

Figure (101) shows the proportion of bicycle crashes that were considered as overtaking with the presence of bike marking. The figure shows that 94% of bicycle crashes occurred during the absence of bike marking. Only 3% of bicycle crashes occurred when bike marking was present at the location of the crash.

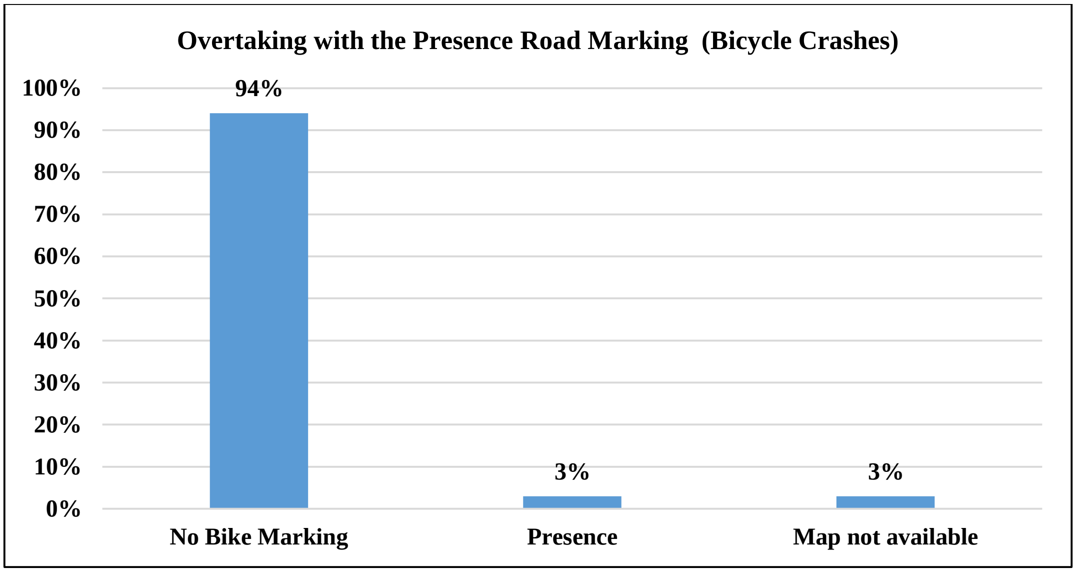


Figure 101: Distribution of overtaking crashes by the presence of road marking

Figure (102) shows the distribution of bicycle crashes that were considered as overtaking with the presence and type of shoulder. The figure shows that 46% of bicycle crashes occurred on roadways with an unpaved shoulder. Additionally, 39% of bicycle crashes occurred when there was no shoulder present at the location of the crash. Finally, 13% of bicycle crashes occurred on roadways with a paved shoulder.

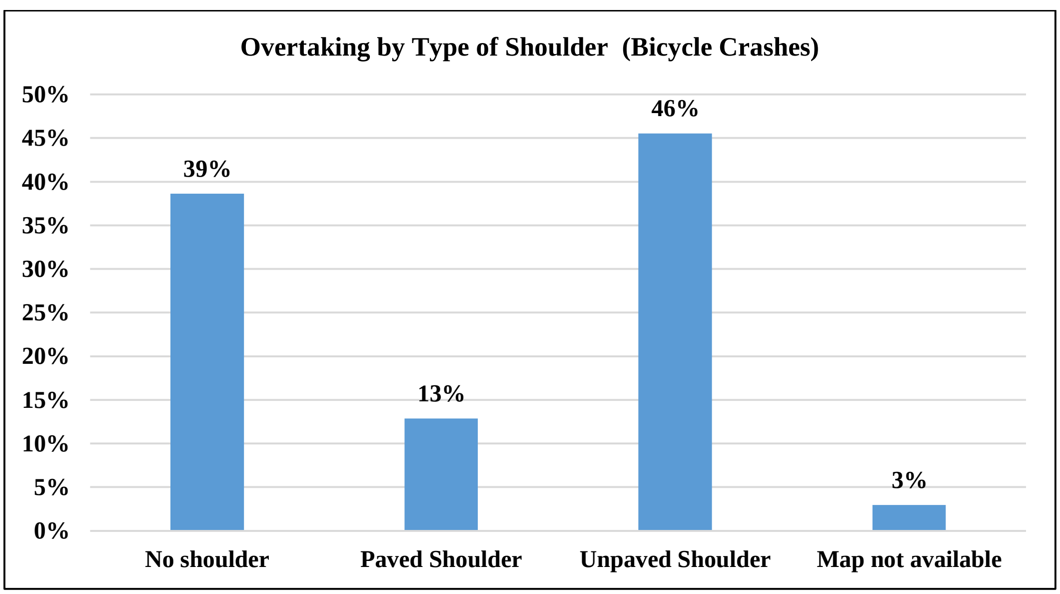


Figure 102: Distribution of overtaking crashes by the presence of shoulder

Figure (103) illustrates the proportion of bicycle crashes that were categorized as overtaking with the cyclist riding position prior to the crash. The graph shows that 54% of bicycle crashes occurred when the cyclist was riding on the travel lane prior to the crash. In addition, 16% of bicycle crashes occurred when the cyclist was riding on the shoulder prior to the crash. This observation shows a different trend from failing to yield/disregard traffic control risk behavior in terms of cyclist riding position prior to the crash. Again, determining the riding position of the cyclist prior to the crash is very important, because that can help in sharpening the education message during the selection and the implantation of education countermeasures.

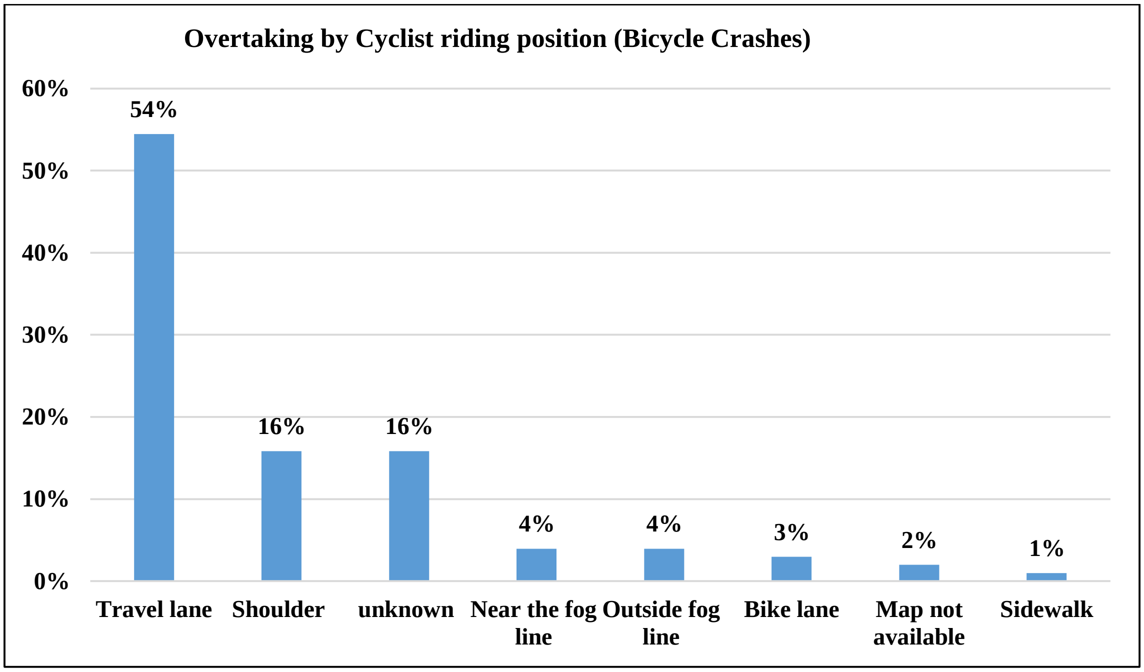


Figure 103: Distribution of overtaking crashes by cyclist riding position

CHAPTER 6

PEDESTRIAN AND BICYCLE COUNTERMEASURES

The causes of pedestrian and bicycle crashes were identified in Chapter 5 by reviewing each individual crash report (e.g., UD-10). Crash types for pedestrian crashes and crash groups for bicycle crashes were narrowed down into risk behavior groups in order to facilitate the process of selecting the appropriate countermeasures. Six risk behavior groups for pedestrian crashes were created to represent the causes of pedestrian crashes in the state of Michigan. Similarly, five risk behavior groups for bicycle crashes were chosen to represent the causes of bicycle crashes in Michigan. Pedestrian and Bicycle Safety Guide and Countermeasure Selection Systems (e.g., PEDSAFE and BIKESAFE) were used to select appropriate countermeasures for pedestrian and bicycle crashes based on the pedestrian and bicycle risk behavior groups and the crash types and crash groups that fall under each risk behavior group. PEDSAFE and BIKESAFE recommend pedestrian and bicycle countermeasures based on the crash types and crash groups. Furthermore, countermeasures for pedestrian and bicycle crashes from the survey chapter and literature review were also considered for preparing a comprehensive list of countermeasures for pedestrian and bicycle crashes separately.

In addition, the available crash modification factors were conducted using the CMF Clearinghouse website and complied with the countermeasures in order to get a better understanding about the effectiveness of a specific countermeasures in the comprehensive list of countermeasures. Additionally, effectiveness of a specific countermeasure from the survey results was combined with the comprehensive list of countermeasures for pedestrian and bicycle crashes separately. Tables (24) and (25) provide a comprehensive list of countermeasures for pedestrian and bicycle crashes respectively. “X” denotes that the countermeasure is applicable

for a specific risk behavior or cause. Furthermore, the effectiveness from the survey results reported is based on a scale of 1 through 4, 1 denotes "not effective", 2 denotes "somewhat effective", 3 denotes "effective", and 4 denotes "very effective".

Table 24: Recommended countermeasures for pedestrian crashes based on risk behavior (cause)

Pedestrian Countermeasures	Fail to yield / Disregard Traffic Control	Pedestrian in Roadway	Pedestrian Near Vehicle	Loss of Control	Pedestrian Walking Along Roadway	CMF		Avg. Perceived Effectiveness
						All Crashes	Pedestrian Crashes	
Infrastructure Engineering Countermeasures								
Curb Extension	X		X	X				3.1
Pedestrian Crossing Island	X		X					2.7
Raised Pedestrian Crossing	X		X			0.64-0.7	0.55	3.0
Overpass/Underpass	X	X		X				3.4
Bike Lane/Shoulder	X	X	X	X	X	0.28-1.42		3.0
Road Diet	X	X			X	0.51-1.07		2.8
Reduce lane width	X	X	X		X	1.01-1.21		2.8
Raised Median	X					0.29-2.28	0.487-1.704	3.0
Temporary Installations for Traffic Calming	X	X	X	X		0.67-0.75		2.6
Choker	X							2.6
Chicane	X	X	X					2.6
Speed Humps	X	X	X			0.5-0.95		2.6
Speed Table (midblock)	X	X	X					2.6
Driveway Link/Serpentine	X	X	X					2.6
Diverter	X	X	X					
Full Street Closure	X	X	X					
Partial Street Closure	X	X	X					
Pedestrian Street	X	X	X					
Shared Street	X	X	X					
Fewer Lanes	X	X	X		X	0.51-1.07		2.8

Table 24 - Continued

Pedestrian Countermeasures	**Fail to yield / Disregard Traffic Control**	**Pedestrian in Roadway**	**Pedestrian Near Vehicle**	**Loss of Control**	**Pedestrian Walking Along Roadway**	**CMF**		**Avg. Perceived Effectiveness**
						All Crashes	**Pedestrian Crashes**	
Intersection Median Barrier	X			X		0-1.91		
Curb Ramp	X		X		X			3.1
Smaller Curb Radius	X			X				
Modify Skewed Intersections	X							
Pedestrian Accommodations at Complex Interchanges	X	X						
Mini-Circle	X	X	X	X				
Sidewalk/Walkway	X	X	X	X	X	1.12		3.2
One-Way Street	X					0.2-0.46		
Right Turn Slip Lane	X							
Modern Roundabout	X					0-2.073	0.27	2.9
Modified T-Intersection	X	X		X				
Puffin Crossing	X					0.74-0.83	0.61-0.78	
Raised median with crosswalk	X			X			0.54-0.61	3.0
Fence along the median to prevent midblock pedestrian crossing	X		X	X		0-1.91		3.0
Traffic Control Engineering Countermeasures								
Traffic Signal	X		X			0.402-1.5	1.12	3.1
Pedestrian Signal	X		X					3.2
Signal Enhancement	X		X				0.49-0.63	
Automated Pedestrian Detection	X							
Leading Pedestrian Interval	X						0.554-0.711	2.7
Left Turn Prohibitions	X					0.28-0.96		2.3
Pedestrian Signal Timing	X							
Right Turn on Red (RTOR) Restriction	X					0.72-0.96		2.5
Left Turn Phasing	X					0.45-0.67		2.6

Table 24 - Continued

Pedestrian Countermeasures	Fail to yield / Disregard Traffic Control	Pedestrian in Roadway	Pedestrian Near Vehicle	Loss of Control	Pedestrian Walking Along Roadway	CMF		Avg. Perceived Effectiveness
						All Crashes	Pedestrian Crashes	
Push Buttons & Signal Timing	X						0.3-0.45	2.9
Traffic Signs and Marking Engineering Countermeasures								
Sign Improvement	X	X	X	X	X			
Speed Monitoring Trailer	X	X	X	X	X			
Advanced Stop Lines	X		X			0.4-0.92		2.2
Pedestrian Hybrid Beacon (HAWK)	X		X			0.71-0.85	0.31	2.8
Rectangular Rapid Flashing Beacon (RRFB)	X		X					3.0
Work Zones - Pedestrian Detours	X	X	X		X			
Pedestrian Safety at Railroad Crossings	X				X			
Marked crosswalk	X							2.9
Unmarked crosswalk								1.5
High visibility crosswalk (high visibility pavement markings, marking Pattern, signs)	X						0.6-0.63	3.0
Intersection illumination	X					0.23-0.69	0.19-0.58	2.9
Intersection markings	X					0.7		2.8
Pedestrian warning signs	X	X	X		X			2.4
Pedestrian crossing mounted flags with high visibility colors	X		X					2.6
Crosswalk barricades (including gateway in-street signs)	X							
Facility Engineering Enhancements								
Street Furniture (e.g., benches, bus shelters, etc.)	X		X		X			2.7
Crosswalk Enhancement	X		X					
Roadway Lighting	X	X	X	X	X	0.23-1.39	0.19-0.58	3.0
Parking Restrictions	X	X	X	X		0.21-1.49		2.9
Transit Stop Treatments	X		X			0.55-1.85		2.8

Table 24 - Continued

Pedestrian Countermeasures	Fail to yield / Disregard Traffic Control	Pedestrian in Roadway	Pedestrian Near Vehicle	Loss of Control	Pedestrian Walking Along Roadway	CMF		Avg. Perceived Effectiveness
						All Crashes	Pedestrian Crashes	
Gateway	X	X	X			0.68-0.98		
School Zone Improvement	X	X	X	X	X		0.63	
Identify Neighborhood	X	X	X	X	X			
Parking Enhancement	X	X	X	X	X			
Driveway Improvements (e.g., narrowing driveways, etc.)	X			X	X			2.9
Access to Transit	X		X		X	0.55-1.85		2.7
Landscape Options (planted area)	X			X		0.82-3.26		2.7
Paving Treatments	X					0.57-1.06		
Snow removal on sidewalks	X	X	X		X			3.0
Enforcement Countermeasures								
Police Enforcement	X	X	X	X	X			2.7
Automated Enforcement Systems	X	X	X	X		0.45-1.15	0.67-1.67	
Enforcement of pedestrians failure to yield	X	X			X			1.8
Enforcement of motorists failure to yield	X		X		X			2.5
Enforcement of alcohol and/or drug use law (pedestrian)	X	X		X	X			2.4
Enforcement of alcohol and/or drug use law (motorist)	X		X	X	X			3.0
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	X		X	X	X			2.8
Education and Outreach Countermeasures								
Pedestrian Education	X	X	X	X	X			2.1
Driver Education	X	X	X	X	X			2.3
Safe Routes to School Program	X	X	X		X		0.724-1.28	2.8
Safe Streets for Seniors	X	X	X		X			2.9
Workshops for parents	X	X	X		X			2.6

Table 24 - Continued

Pedestrian Countermeasures	Fail to yield / Disregard Traffic Control	Pedestrian in Roadway	Pedestrian Near Vehicle	Loss of Control	Pedestrian Walking Along Roadway	CMF		Avg. Perceived Effectiveness
						All Crashes	Pedestrian Crashes	
Road safety training or safety classes in schools	X	X	X	X	X			2.8
Maps for pedestrian routes	X	X			X			2.5
Introducing education safety programs for pedestrians with language background other than English	X	X	X	X	X			2.2
Media campaigns for pedestrian safety	X	X	X	X	X			2.4

Table 25: Recommended countermeasures for bicycle crashes based on risk behavior (cause)

Bicycle Countermeasures	Failing to Yield / Disregard Traffic Control	Overtaking	Loss of Control / Turning Error	Cyclist Rode Wrong Way	CMF		Avg. Perceived Effectiveness
					All Crashes	Bicycle Crashes	
Infrastructure Engineering Countermeasures							
Median/Crossing Island	X	X	X			0.96-1.48	
Reduce Lane Number	X	X	X		0.51-1.07		2.4
Reduce Lane Width	X	X	X		1.01-1.21		2.4
Bike Lanes	X	X	X			0.42-2.03	2.7
Curb Radii Revisions	X	X	X				
Roundabouts	X	X	X		0-2.073	0.56-1.93	
Mini Traffic Circles	X	X	X				
Chicanes	X	X	X				2.6
Speed Tables/Humps/Cushions	X	X	X		0.5-0.95	1.28	2.6
Visual Narrowing	X	X	X				2.6
Traffic Diversion	X	X	X				
Merge and Weave Area Redesign	X	X	X				
Bridge and Overpass Access	X	X					3.5

Table 25 - Continued

Bicycle Countermeasures	Failing to Yield / Disregard Traffic Control	Overtaking	Loss of Control / Turning Error	Cyclist Rode Wrong Way	CMF		Avg. Perceived Effectiveness
					All Crashes	Bicycle Crashes	
Tunnel and Underpass Access	X	X					3.5
Wide Curb Lanes	X	X					2.8
Paved Shoulders	X	X	X		0.28-1.42		2.9
Combination Lanes	X	X	X				
Separate Shared-Use Path	X	X					
Cycle tracks	X	X	X	X		0.37-2.29	3.3
Refuge island	X		X				2.7
Raised median	X		X		0.29-2.28	0.487-1.031	2.6
Bicycle Trails	X	X	X	X			3.6
Traffic Control Engineering Countermeasures							
Turning Restrictions	X	X	X				2.8
Install Signal					0.402-1.5		3.0
Signal Optimize Timing	X	X	X			0.554-0.711	3.1
Rectangular Rapid Flash Beacons (RRFB)	X						
Pedestrian Hybrid Beacon	X				0.712-0.849		
Bicycle signal heads	X	X	X				2.8
Bike-Activated Signal	X	X	X				3.3
Right-Turn-on-Red Restrictions	X		X		0.72-0.96		2.5
Advanced stop lines at traffic signals	X						2.8
Left turn phasing to promote safety of bicyclists	X		X		0.45-0.67		2.5
Left turn prohibition to promote safety of bicyclists	X		X				3.3
Facility and Bicycle Engineering Enhancements							
Lighting Improvements	X	X	X		0.23-1.392	0.4	2.8
Parking Treatments	X	X	X				2.6
Intersection Markings	X	X	X			1.74-2.53	
Sight Distance Improvements	X	X	X				2.7
Path Intersection Treatments	X	X	X				

Table 25 - Continued

Bicycle Countermeasures	Failing to Yield / Disregard Traffic Control	Overtaking	Loss of Control / Turning Error	Cyclist Rode Wrong Way	CMF		Avg. Perceived Effectiveness
					All Crashes	Bicycle Crashes	
Sign Improvements	X	X	X				2.8
Pavement Marking Improvements	X	X	X		0.4-1.1	1.74-2.53	2.7
School Zone Improvements	X						2.9
Aesthetics/Landscaping	X	X			0.82-3.26		2.7
Roadway Surface Improvements	X	X	X				
Repetitive/Short-Term Maintenance	X	X	X				2.7
Major Maintenance	X	X	X		0.73-0.89		2.7
Driveway Improvements	X	X	X				2.7
Streetcar track treatments	X	X	X				
Prevention or restriction of on-street parking	X	X					2.6
Bicyclists use of warning lights (white headlight, red-rear reflector, and backlight)	X	X					3.0
Enforcement Countermeasures							
Law Enforcement	X			X			2.5
Enforcement of laws on bicyclists failure to yield	X			X			2.1
Enforcement of laws on motorists failure to yield	X						2.6
Enforcement of laws on bicycle warning lights use at night time	X	X		X			2.7
Enforcement of law on alcohol and/or drug use while riding (bicyclists)	X	X	X	X			2.2
Enforcement of law on alcohol and/or drug use while operating (motorist)	X	X	X				2.9
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	X	X	X				2.8
Education and Outreach Countermeasures							
Bicyclist education	X	X	X	X			2.5
Motorist education	X	X	X	X			2.3
Hazard Identification Program	X	X	X				
Safe Routes to School Program	X	X	X	X		0.724-1.28	2.8

Table 25 - Continued

Bicycle Countermeasures	Failing to Yield / Disregard Traffic Control	Overtaking	Loss of Control / Turning Error	Cyclist Rode Wrong Way	CMF		Avg. Perceived Effectiveness
					All Crashes	Bicycle Crashes	
Bicycle Ambassadors Program	X	X	X	X			2.7
Workshops for parents	X	X	X	X			2.4
Road safety training or safety classes in schools	X	X	X	X			2.8
Introducing education safety programs for pedestrians with language background other than English	X	X	X	X			2.0
Media campaigns on cyclists safety	X	X	X	X			2.3
Safety messages and free classes for how to bike safely.	X	X	X	X			2.5
Posters promoting the safety of cycling	X	X	X	X			2.2
Maps for cyclists routes	X	X		X			2.6

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

A comprehensive analysis was done on crashes involving pedestrians and bicycles in the state of Michigan, and the causes and risk behaviors for pedestrian and bicycle crashes had been identified. Based on the analysis of crash data for five years (2010-2014), in terms of roadway characteristics, the majority of pedestrian and bicycle crashes occurred at intersections and on city streets or roads with two lanes. Most of the crashes occurred when the speed limit was 25 mph or less and 25 to 35 mph for both pedestrian and bicycle crashes. In addition, crashes occurring at midblock locations and roadways with speed limit 45 mph or higher tend to be more severe for both pedestrian and bicycle crashes.

When considering demographic characteristics, the majority of pedestrian and bicycle crashes involved males, and crashes involving males tended to be more severe than crashes involving females. Pedestrian and bicycle crashes that involved alcohol tended to be more severe. Additionally, pedestrian and bicyclist age group from 16 to 24 years old accounted for the majority of pedestrian and bicycle crashes. Furthermore, pedestrian and bicyclist age group from 45 to 64 had the highest proportion of fatalities and incapacitating injury crashes for both pedestrian and bicycle crashes. In regards to environmental conditions, the majority of pedestrian and bicycle crashes occurred during the daylight and dark-lighted lighting conditions and during clear and cloudy weather conditions.

The results of reviewing crash reports (e.g., UD-10) for all pedestrian and bicycle fatal crashes (K) and a sample of incapacitating injury crashes (A) from 2010 to 2014 identified the causes of pedestrian and bicycle crashes in the state of Michigan. Those causes had been

narrowed down and grouped into risk behavior groups in order to facilitate the process of recommending appropriate countermeasures. As a result, six risk behavior groups and crash causes were identified for pedestrian crashes. Similarly, five risk behavior groups and crash causes were identified for bicycle crashes. The six risk behavior groups and crash causes for pedestrian fatal crashes and incapacitating injury crashes are as follows and ranked by frequency:

1. Failing to yield/disregard traffic control: The pedestrian or motorist failed to yield the right-of-way.
2. Pedestrians in roadway: The pedestrian was walking, lying, standing, working, playing, etc.
3. Pedestrian near vehicle: The pedestrian was standing by vehicle, near disabled vehicle, entering/exiting parked vehicle, bus-related, etc.
4. Pedestrian walking along roadway: The pedestrian was walking along the roadway with or against the direction of traffic and got hit by a vehicle.
5. Loss of control: The pedestrian or the motorist lost control due to due to mechanical failure, surface conditions, driver error, or impairment.
6. Other/unknown: The majority of those crashes are hit-and-run and there was insufficient information in the crash reports to determine the cause of the crash.

Further analysis based on a two-year sample from 2010-2011 on failing to yield/disregard traffic control crashes at intersection indicated that 45% of failing to yield/disregard traffic control crashes occurred on marked crosswalks, followed by 40% when there was no crosswalk. In terms of the presence of a pedestrian signal, 38% of crashes occurred when there was no pedestrian signal at the location of the crash. Furthermore, 38% of crashes occurred when there

was a pedestrian signal at the location of the crash. Lack of pedestrian signage (pedestrian warning signs at crossing locations) was indicated based on the sample that had been analyzed.

For bicycles crash causes, the five risk behavior groups and crash causes are as follows and ranked by frequency:

1. Failing to Yield/disregard traffic control: The cyclist or motorist failed to yield the right-of-way.
2. Overtaking: The majority of this risk behavior and crash cause was when the motorist was overtaking the cyclist and a very small portion of crashes analyzed was bicyclist overtaking motorist.
3. Loss of Control/Turning Error: The cyclist or the driver lost control due to mechanical failure, surface condition, impairment, oversteering, improper braking, and speeding. Cyclist or driver turning error while turning left, right, and other turning maneuvers.
4. Cyclist Rode Wrong Way: The bicyclist was cycling the wrong way and collided head on with the vehicle.
5. Other/Unknown: Insufficient information in the crash reports to determine the cause of the crash.

The results of analysis on failing to yield/disregard traffic risk behavior shows that the majority of those crashes occurred on roadways with no dedicated bike lane, bike signage, shoulder, and bike marking at the location of the crash. In addition, the results indicated that the majority of cyclists were riding on the sidewalk prior to the crash, and this observation can help

in sharpening the education message during the selection and the implementation of education countermeasures. When considering overtaking risk behavior, it was found that the majority of crashes analyzed occurred on roadways with no dedicated bike lane, bike signage, or bike marking at the location of the crash. In addition, the majority of crashes that fall under overtaking risk behavior occurred on roadways with an unpaved shoulder. Additionally, the majority of crashes analyzed occurred when the cyclist was riding on the travel lane prior to the crash. Again this observation is helpful for sharpening the education message during the selection and the implantation of education countermeasures.

Information from the literature review and the results of the survey and analysis of crash data were compiled to produce a comprehensive list of countermeasures for risk behavior groups and causes. Based on the results of crash causes, changes in the behavior of pedestrians, bicyclists, and motorists is needed. This changing the behavior can be made by implementing engineering, enforcement, and education and outreach countermeasures that were identified in Chapter 6. Increasing the emphasis on the implementation of enforcement and education countermeasures for reducing pedestrian and bicycle crashes in the state of Michigan is highly recommended, because based on the risk behaviors and crash causes that had been identified in Chapter five, the problem was behavioral. In addition, the results of the survey for the three groups that had been surveyed shows that there was a lack of implementation in terms of enforcement and education countermeasures in the state of Michigan. However, this study recommends increasing the implementation of enforcement and education countermeasures along with the aid of engineering countermeasures to help in reducing pedestrian and bicycle crashes in Michigan.

Future research can be focused on proving the effectiveness of engineering, enforcement, and education and outreach countermeasures for pedestrian and bicycle crashes only, because it was noticed that there was a lack of information about the effectiveness of the aforementioned countermeasures for the non-motorized crashes on the Crash Modification Clearinghouse (CMF) website. More studies should evaluate the effectiveness of enforcement and education and outreach countermeasures for pedestrian and bicycle crashes. In addition, further studies can be done on developing prediction models for pedestrian and bicycle crashes when the pedestrian and bicycle volumes can be collected. Finally, the main contribution of this this research is proposing a matrix of countermeasures and risk behavior groups and causes for pedestrian and bicycle crashes. Six categories of countermeasures were considered, including: infrastructure engineering countermeasures, traffic control engineering countermeasures, traffic signs and marking engineering countermeasures, facility engineering enhancements, enforcement countermeasures, and education and outreach countermeasures. The two matrices will assist and guide the practitioners in the state of Michigan in identifying the causes of pedestrian and bicycle crashes and selecting the appropriate countermeasures that help mitigate those crashes.

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Appendix A

Survey Questionnaire

Survey Questionnaire

Introduction

The Western Michigan University (WMU) and the Michigan Office of Highway Safety Planning (OHSP) are conducting a study on causes and countermeasures for pedestrian and bicycle crashes in Michigan. To achieve the goals of this study, your input about the existing countermeasures in Michigan is highly valued and necessary. We request that you spend a few minutes to respond to this survey thoughtfully. Your feedback will help to promote the safety of pedestrians and bicyclists in Michigan. Your participation is completely voluntary and your responses will be used on aggregate basis only. Please complete the survey by Friday June 26, 2015If you have questions about the survey, please contact the Project Director, Dr. Valerian Kwigizile through e-mail (valerian.kwigizile@wmich.edu) or telephone (269-276-3218). Thank you for your time and support. Please start the survey now by clicking on the continue button below.

Beginning of Survey

Which of the following identifies you more closely?

1. State Planner/Engineer/designer (e.g., MDOT Employee)
2. City/Township/County Engineer (or Designer)
3. City/Township/County Planner
4. State Law Enforcement Officer
5. County Law Enforcement Officer
6. Local Law Enforcement Officer
7. Bicycle/Pedestrian Advocacy Group Member
8. Other

What is the name of your agency/organization?

What is your zip-code?

What is the name of your county?

What is the area type of your jurisdiction?

1. Metropolitan (population more than 1,000,000)
2. Urban (population more than 100,000 but less than 1,000,000)
3. Suburban (populations in suburbs, a suburban area or a suburb in a nearby metropolitan area from 10,000 to over a 100,000)
4. Rural (population less than 10,000)

How would you rate pedestrian safety in your jurisdiction?

1. Not safe
2. Somewhat safe
3. Neutral
4. Safe
5. Very safe

Has your jurisdiction implemented the following infrastructure engineering countermeasures to improve pedestrian safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Infrastructure engineering countermeasures	Not Implemented	Very Effective	Effective	Somewhat Effective	Not Effective	I don't know
Sidewalk	❑	❑	❑	❑	❑	❑
Crossing island	❑	❑	❑	❑	❑	❑
Road diet	❑	❑	❑	❑	❑	❑
Conversion of intersection to roundabout	❑	❑	❑	❑	❑	❑
Pedestrian overpass/underpass	❑	❑	❑	❑	❑	❑
Raised median	❑	❑	❑	❑	❑	❑
Raised median with crosswalk	❑	❑	❑	❑	❑	❑
Raised pedestrian crossing	❑	❑	❑	❑	❑	❑
Installing paved shoulder	❑	❑	❑	❑	❑	❑
Curb extension or ramp	❑	❑	❑	❑	❑	❑
Fence along the median to prevent midblock pedestrian crossing	❑	❑	❑	❑	❑	❑
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, serpentine design)	❑	❑	❑	❑	❑	❑

Other infrastructure countermeasures (please describe including effectiveness)

Has your jurisdiction implemented the following traffic control engineering countermeasures to improve pedestrian safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Traffic control engineering countermeasures	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Traffic signals	❏	❏	❏	❏	❏	❏
Pedestrian Signals	❏	❏	❏	❏	❏	❏
Right-Turn-on-Red restrictions	❏	❏	❏	❏	❏	❏
Advanced stop lines at traffic signals	❏	❏	❏	❏	❏	❏
Left turn phasing	❏	❏	❏	❏	❏	❏
Left turn prohibition	❏	❏	❏	❏	❏	❏
Leading Pedestrian Interval	❏	❏	❏	❏	❏	❏
Pedestrian push buttons	❏	❏	❏	❏	❏	❏
Pedestrian Hybrid Beacon (PHB)	❏	❏	❏	❏	❏	❏
Rectangular Rapid Flashing Beacon (RRFB)	❏	❏	❏	❏	❏	❏

Other traffic control countermeasures (please describe including effectiveness)

Has your jurisdiction implemented the following traffic signs and marking engineering countermeasures to improve pedestrian safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Traffic signs and marking engineering countermeasures	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Marked crosswalk	❑	❑	❑	❑	❑	❑
Unmarked crosswalk	❑	❑	❑	❑	❑	❑
High visibility crosswalk (high visibility pavement markings, marking Pattern, signs)	❑	❑	❑	❑	❑	❑
Intersection illumination	❑	❑	❑	❑	❑	❑
Intersection markings	❑	❑	❑	❑	❑	❑
On-street parking restriction	❑	❑	❑	❑	❑	❑
Pedestrian warning signs	❑	❑	❑	❑	❑	❑
Pedestrian crossing mounted flags with high visibility colors	❑	❑	❑	❑	❑	❑

Other traffic signs and marking countermeasures (please describe including effectiveness)

Has your jurisdiction implemented the following facility engineering enhancements to improve pedestrian safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Facility engineering enhancements	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Lighting	❑	❑	❑	❑	❑	❑
Street furniture (e.g., street trees, bus shelter, bench, trash/recycling receptacle)	❑	❑	❑	❑	❑	❑
Driveway enhancement (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	❑	❑	❑	❑	❑	❑
Transit stop enhancement (concrete pad, concrete curb, metal bench, chair, trash can, shelter)	❑	❑	❑	❑	❑	❑
Snow removal on sidewalks	❑	❑	❑	❑	❑	❑
Bridge and overpass access	❑	❑	❑	❑	❑	❑
Tunnel and underpass access	❑	❑	❑	❑	❑	❑

Other facility enhancement countermeasures (please describe including effectiveness)

Have you seen (or heard of) the following enforcement countermeasures in use in your area to promote pedestrian safety? If yes, please provide your opinion on the effectiveness of the enforcement on improving safety (if not seen/heard, please indicate so).

Enforcement countermeasures	Not seen/heard	Very effective	Effective	Somewhat effective	Not effective	I don't know
Enforcement of pedestrians failure to yield	❑	❑	❑	❑	❑	❑
Enforcement of motorists failure to yield	❑	❑	❑	❑	❑	❑
Enforcement of alcohol and/or drug use law (pedestrian)	❑	❑	❑	❑	❑	❑
Enforcement of alcohol and/or drug use law (motorist)	❑	❑	❑	❑	❑	❑
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	❑	❑	❑	❑	❑	❑

Other enforcement countermeasures (please describe including effectiveness)

Have you seen (or heard of) the following education and outreach countermeasures in use in your area to promote pedestrian safety? If yes, please provide your opinion on the effectiveness of the programs on improving safety (if not seen/heard, please indicate so).

Education and outreach countermeasures	Not seen/heard	Very effective	Effective	Somewhat effective	Not effective	I don't know
Safe Routes to School Program	❑	❑	❑	❑	❑	❑
Education programs for motorists	❑	❑	❑	❑	❑	❑
Education programs for pedestrians	❑	❑	❑	❑	❑	❑
Safe Streets for Seniors	❑	❑	❑	❑	❑	❑
Workshops for parents	❑	❑	❑	❑	❑	❑
Road safety training or safety classes in schools	❑	❑	❑	❑	❑	❑
Maps for pedestrian routes	❑	❑	❑	❑	❑	❑
Introducing education safety programs for pedestrians with language background other than English	❑	❑	❑	❑	❑	❑
Media campaigns for pedestrian safety	❑	❑	❑	❑	❑	❑

Other education and outreach countermeasures (please describe including effectiveness)

How would you rate bicyclist safety in your jurisdiction?

1. Not safe
2. Somewhat safe
3. Neutral
4. Safe
5. Very safe

Has your jurisdiction implemented the following infrastructure engineering countermeasures to improve bicyclist's safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Engineering countermeasures	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Dedicated bicycle lane	❑	❑	❑	❑	❑	❑
Shared bicycle lane	❑	❑	❑	❑	❑	❑
Grade separated cycle path	❑	❑	❑	❑	❑	❑
Bridge or tunnel access	❑	❑	❑	❑	❑	❑
Road diet	❑	❑	❑	❑	❑	❑
Refuge island	❑	❑	❑	❑	❑	❑
Raised median	❑	❑	❑	❑	❑	❑
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, mini-circles, visual narrowing)	❑	❑	❑	❑	❑	❑
Installation of paved shoulder	❑	❑	❑	❑	❑	❑
Wide curb lane	❑	❑	❑	❑	❑	❑
Bicycle Trails	❑	❑	❑	❑	❑	❑

Other infrastructure countermeasures (please describe including effectiveness)

Has your jurisdiction implemented the following traffic control engineering countermeasures to improve bicyclist's safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Traffic control engineering countermeasures	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
Traffic signals	❑	❑	❑	❑	❑	❑
Optimizing signal timing for bicyclists	❑	❑	❑	❑	❑	❑
Bicycle signal activated by cyclists	❑	❑	❑	❑	❑	❑
Right-Turn-on-Red Restrictions	❑	❑	❑	❑	❑	❑
Advanced stop lines at traffic signals	❑	❑	❑	❑	❑	❑
Bicycle signal heads	❑	❑	❑	❑	❑	❑
Left turn phasing to promote safety of bicyclists	❑	❑	❑	❑	❑	❑
Left turn prohibition to promote safety of bicyclists	❑	❑	❑	❑	❑	❑

Other traffic control countermeasures (please describe including effectiveness)

Has your jurisdiction implemented the following facility and bicycle engineering enhancements to improve bicyclist's safety? If yes, please check the effectiveness level (if not implemented, please indicate so).

Facility and bicycle engineering enhancements	Not implemented	Very effective	Effective	Somewhat effective	Not effective	I don't know
School zone enhancement (warning signs, crossing guards, high visibility crosswalks, and speed humps)	❑	❑	❑	❑	❑	❑
Prevention or restriction of on-street parking	❑	❑	❑	❑	❑	❑
Lighting	❑	❑	❑	❑	❑	❑
Enhancement of sight distance at driveways (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	❑	❑	❑	❑	❑	❑
Roadway maintenance (street sweeping, landscaping, pavement maintenance)	❑	❑	❑	❑	❑	❑
Bicyclists use of warning lights (white headlight, red-rear reflector, and backlight)	❑	❑	❑	❑	❑	❑
Signage improvements for bicyclists	❑	❑	❑	❑	❑	❑
Signage improvements for motorists	❑	❑	❑	❑	❑	❑
Pavement marking improvements to increase awareness	❑	❑	❑	❑	❑	❑

Other facility enhancement countermeasures (please describe including effectiveness)

Have you seen (or heard of) the following enforcement countermeasures in use in your area to promote bicyclists safety? If yes, please provide your opinion on the effectiveness of the improvement on improving safety (if not seen/heard, please indicate so).

Enforcement countermeasures	Not seen/heard	Very effective	Effective	Somewhat effective	Not effectiv e	I don't know
Enforcement of laws on bicyclists failure to yield	❑	❑	❑	❑	❑	❑
Enforcement of laws on motorists failure to yield	❑	❑	❑	❑	❑	❑
Enforcement of laws on bicycle warning lights use at night time	❑	❑	❑	❑	❑	❑
Enforcement of law on alcohol and/or drug use while riding (bicyclists)	❑	❑	❑	❑	❑	❑
Enforcement of law on alcohol and/or drug use while operating (motorist)	❑	❑	❑	❑	❑	❑
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	❑	❑	❑	❑	❑	❑

Other enforcement countermeasures (please describe including effectiveness)

Have you seen (or heard of) the following education and outreach countermeasures in use in your area to promote bicyclists safety? If yes, please provide your opinion on the effectiveness of the improvement on improving safety (if not seen/heard, please indicate so).

Education and outreach countermeasures	Not seen/heard	Very effective	Effectiv e	Somewhat effective	Not effective	I don't know
Safe Routes to School Program	❑	❑	❑	❑	❑	❑
Bicycle Ambassadors Program	❑	❑	❑	❑	❑	❑
Education programs for motorists	❑	❑	❑	❑	❑	❑
Education programs for bicyclists	❑	❑	❑	❑	❑	❑
Workshops for parents	❑	❑	❑	❑	❑	❑
Road safety training or safety classes in schools	❑	❑	❑	❑	❑	❑
Introducing education safety programs for pedestrians with language background other than English	❑	❑	❑	❑	❑	❑
Media campaigns on cyclists safety	❑	❑	❑	❑	❑	❑
Safety messages and free classes for how to bike safely.	❑	❑	❑	❑	❑	❑
Posters promoting the safety of cycling	❑	❑	❑	❑	❑	❑
Maps for cyclists routes	❑	❑	❑	❑	❑	❑

Other education and outreach countermeasures (please describe including effectiveness)

What are additional countermeasures that you recommend to enhance the safety of pedestrians?

What are additional countermeasures that you recommend to enhance the safety of bicyclists?

Would you be willing to provide contact information for additional follow-up if needed? If yes, please provide below.

1. Yes
2. No

First Name

Last Name

Phone

Email Address

B. Implementation results from the survey

Appendix B

Implementation of Countermeasures

Implementation of Pedestrian countermeasures:

Percentage of implementation of infrastructure engineering countermeasures for pedestrian countermeasures

Infrastructure Engineering Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Sidewalk	82%	92%	85%
Crossing island	44%	46%	44%
Road diet	62%	36%	56%
Conversion of intersection to roundabout	47%	36%	60%
Pedestrian overpass/underpass	35%	30%	50%
Raised median	32%	30%	48%
Raised median with crosswalk	21%	30%	46%
Raised pedestrian crossing	21%	18%	46%
Installing paved shoulder	82%	59%	73%
Curb extension or ramp	67%	36%	78%
Fence along the median to prevent midblock pedestrian crossing	12%	18%	27%
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, serpentine design)	35%	50%	63%

Percentage of implementation of traffic control engineering countermeasures for pedestrian countermeasures

Traffic Control Engineering Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Traffic signals	79%	86%	81%
Pedestrian Signals	76%	81%	77%
Right-Turn-on-Red restrictions	44%	65%	58%
Advanced stop lines at traffic signals	65%	69%	44%
Left turn phasing	68%	49%	58%
Left turn prohibition	35%	48%	46%
Leading Pedestrian Interval	18%	31%	44%
Pedestrian push buttons	79%	86%	81%
Pedestrian Hybrid Beacon (PHB)	18%	30%	23%
Rectangular Rapid Flashing Beacon (RRFB)	32%	27%	27%

Percentage of implementation of traffic signs and marking engineering countermeasures for pedestrian countermeasures

Traffic Signs and Marking Engineering Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Marked crosswalk	91%	97%	85%
Unmarked crosswalk	74%	70%	73%
High visibility crosswalk (high visibility pavement markings, marking Pattern, signs)	64%	67%	62%
Intersection illumination	70%	72%	73%
Intersection markings	70%	74%	76%
On-street parking restriction	44%	58%	68%
Pedestrian warning signs	88%	73%	77%
Pedestrian crossing mounted flags with high visibility colors	18%	13%	31%

Percentage of implementation of facility engineering enhancements for pedestrian countermeasures

Facility Engineering Enhancements	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Lighting	64%	86%	76%
Street furniture (e.g., street trees, bus shelter, bench, trash/recycling receptacle)	52%	47%	83%
Driveway enhancement (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	61%	38%	71%
Transit stop enhancement (concrete pad, concrete curb, metal bench, chair, trash can, shelter)	41%	41%	67%
Snow removal on sidewalks	50%	83%	80%
Bridge and overpass access	47%	35%	71%
Tunnel and underpass access	28%	21%	38%

Percentage of implementation of enforcement countermeasures for pedestrian countermeasures

Enforcement Countermeasures	% of Seen/heard "Engineers"	% of Implemented "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Enforcement of pedestrians failure to yield	18%	32%	12%
Enforcement of motorists failure to yield	39%	74%	31%
Enforcement of alcohol and/or drug use law (pedestrian)	26%	34%	38%
Enforcement of alcohol and/or drug use law (motorist)	73%	95%	85%
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	47%	74%	46%

Percentage of implementation of education and outreach countermeasures for pedestrian countermeasures

Education and Outreach Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Safe Routes to School Program	85%	58%	62%
Education programs for motorists	44%	55%	42%
Education programs for pedestrians	35%	49%	27%
Safe Streets for Seniors	12%	26%	23%
Workshops for parents	18%	21%	31%
Road safety training or safety classes in schools	47%	52%	42%
Maps for pedestrian routes	50%	29%	50%
Introducing education safety programs for pedestrians with language background other than English	21%	12%	36%
Media campaigns for pedestrian safety	35%	26%	24%

Implementation of Bicycle countermeasures:

Percentage of implementation of infrastructure engineering countermeasures for bicycle countermeasures

Infrastructure Engineering Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Dedicated bicycle lane	71%	60%	79%
Shared bicycle lane	64%	53%	68%
Grade separated cycle path	38%	26%	54%
Bridge or tunnel access	41%	29%	54%
Road diet	56%	33%	61%
Refuge island	24%	26%	36%
Raised median	24%	26%	37%
Traffic calming (e.g., speed humps, chokers, chicanes, speed tables, mini-circles, visual narrowing)	29%	38%	57%
Installation of paved shoulder	71%	57%	78%
Wide curb lane	53%	41%	54%
Bicycle Trails	79%	75%	89%

Percentage of implementation of traffic control engineering countermeasures for bicycle countermeasures

Traffic Control Engineering Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Traffic signals	58%	69%	64%
Optimizing signal timing for bicyclists	3%	15%	25%
Bicycle signal activated by cyclists	12%	18%	29%
Right-Turn-on-Red Restrictions	33%	35%	43%
Advanced stop lines at traffic signals	42%	44%	29%
Bicycle signal heads	12%	3%	32%
Left turn phasing to promote safety of bicyclists	12%	15%	25%
Left turn prohibition to promote safety of bicyclists	9%	9%	21%

Percentage of implementation of facility and bicycle engineering enhancements for bicycle countermeasures

Facility and Bicycle Engineering Enhancements	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
School zone enhancement (warning signs, crossing guards, high visibility crosswalks, and speed humps)	71%	83%	82%
Prevention or restriction of on-street parking	44%	74%	57%
Lighting	76%	86%	78%
Enhancement of sight distance at driveways (appropriate curb radius, prevent on street parking, appropriate right angle at entries)	65%	47%	57%
Roadway maintenance (street sweeping, landscaping, pavement maintenance)	85%	74%	64%
Bicyclists use of warning lights (white headlight, red-rear reflector, and backlight)	47%	68%	89%
Signage improvements for bicyclists	53%	34%	54%
Signage improvements for motorists	79%	49%	61%
Pavement marking improvements to increase awareness	76%	50%	64%

Percentage of implementation of enforcement countermeasures for bicycle countermeasures

Enforcement Countermeasures	% of Seen/heard "Engineers"	% of Implemented "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Enforcement of laws on bicyclists failure to yield	35%	32%	26%
Enforcement of laws on motorists failure to yield	47%	67%	44%
Enforcement of laws on bicycle warning lights use at night time	18%	41%	23%
Enforcement of law on alcohol and/or drug use while riding (bicyclists)	26%	26%	33%
Enforcement of law on alcohol and/or drug use while operating (motorist)	64%	91%	74%
Enforcement of laws on aggressive or inappropriate passing maneuver by motorist	38%	71%	37%

Percentage of implementation of education and outreach countermeasures for bicycle countermeasures

Education and Outreach Countermeasures	% of Implemented "Engineers"	% of Seen "Law Enforcement Officers"	% of Seen "Advocacy Groups"
Safe Routes to School Program	82%	47%	57%
Bicycle Ambassadors Program	18%	6%	30%
Education programs for motorists	35%	26%	36%
Education programs for bicyclists	48%	38%	46%
Workshops for parents	19%	12%	26%
Road safety training or safety classes in schools	41%	41%	32%
Introducing education safety programs for pedestrians with language background other than English	18%	3%	36%
Media campaigns on cyclists safety	41%	32%	39%
Safety messages and free classes for how to bike safely.	35%	26%	43%
Posters promoting the safety of cycling	35%	36%	39%
Maps for cyclists routes	74%	26%	68%