A Summary of a Comprehensive Evaluation of Pedestrian and Bicycle Crashes and Causes in Michigan

Prepared for
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February 29, 2016

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Disclaimer

Acknowledgement

The authors would like to thank Mr. Chad Teachout, OHSP Project Manager, for his constant feedback regarding this research. Also, we would like to thank Ms. Carissa McQuiston (Michigan Department of Transportation, MDOT) for taking her time to participate in our research progress meetings and providing helpful feedback. Lastly, we would like to thank Dr. Zhanbo Sun (Western Michigan University) for his participation in this research project.

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1 Summary of Background and Study Goals

With global increase in the need for alternative active transportation modes, bicycling and walking modes are increasingly being used for commuting and recreational trips. In Michigan, walking, running, and biking continue to grow every year in popularity. Unfortunately, bicyclists and pedestrians are prone to more severe injuries when involved in a crash, and the number of non-motorized crashes is increasing in recent years. Actions of motor vehicle drivers, pedestrians, and bicyclists have been reported to be among the major causes of crashes. Understanding the root causes of pedestrian and bicycle crashes is very critical to identify and implement appropriate countermeasures. Most importantly, understanding risk behaviors of pedestrians, bicyclists and motorists that contribute to crash occurrence is imperative to formulating outreach and education as well as enforcement programs as countermeasures.

To reduce the number and severity of pedestrian and bicyclist crashes in Michigan, a comprehensive study was needed to identify causes, contributing factors, and potential countermeasures. Particularly, outreach and education as well as enforcement programs needed to be considered as they play an important role in reducing crashes involving pedestrians and bicyclists, in conjunction with engineering countermeasures. It was critical to identify Michigan-specific factors and risk behaviors associated with pedestrian and bicycle crashes in order to recommend specific countermeasures. Specifically, the objectives of this research were to:

i. Determine specific causes and risk behaviors for pedestrian and bicyclist crashes in Michigan,
ii. Examine best practices and successful countermeasures, and
iii. Provide recommendations on how to reduce pedestrian and bicycle involved crashes.

In order to accomplish the research objectives, a comprehensive literature review was performed with the goal of identifying the primary crash causes, risk behaviors and countermeasures that have been identified by previous research. The research team collected and utilized Michigan crash data from the most recent five years (2010 to 2014). This report provides a summary of data collection, analysis, and findings. Details can be found in the main research report for this project.

2 Summary of Data and Methodology

The research team utilized several methods to identify pedestrian and bicyclist risk behaviors as well as causes of pedestrian and bicycle crashes in Michigan. The greatest effort was put toward reviewing individual crash reports to extract more information than those provided in the crash databases. Crash databases lack information from the narrative provided by the police officers and the crash diagram. Narrative and crash diagram sections provide additional information needed to understand circumstances surrounding a crash. Figures 2.1 and 2.2 show the total number of crashes per year along with the percent fatal for pedestrian and bicycle crashes, respectively. In this study, all five-year fatal (K) crashes for both bicyclists and pedestrians were reviewed, plus a sample of incapacitating injury (A) and property damage only (O) crashes. The Pedestrian and Bicycle Crash Analysis Tool (PBCAT) was utilized to compile crash data and identify their types through crash typing. The tool was helpful in the efforts to ascertain crash causes and risk behaviors.

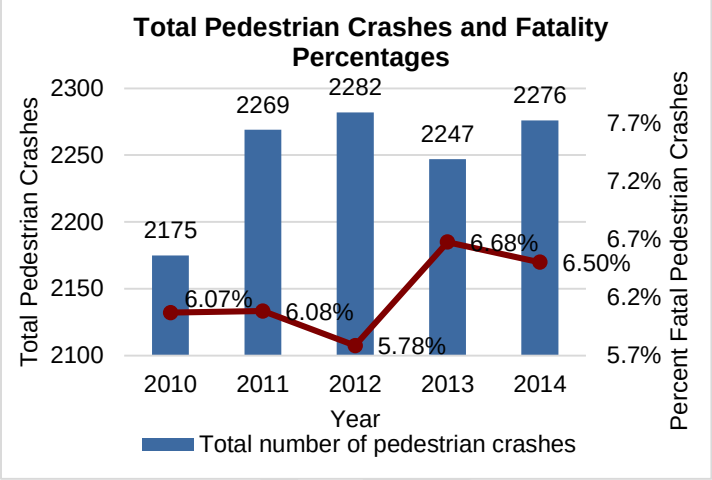

Figure 2.1 Total pedestrian crashes and percent fatal for five years (2010-2014).

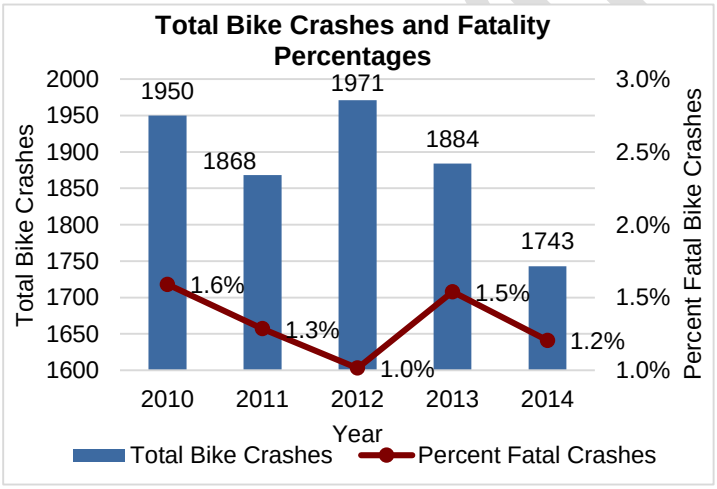

Figure 2.2 Total bicycle crashes and percent fatal crashes from 2010 to 2014.

Descriptive statistics analysis of crash data showed that the majority of pedestrian and bicycle crashes occur at intersection locations and on city streets. Higher proportions of fatal crashes than the total proportion occur at midblock locations for both pedestrian and bicycle crashes. Additionally, the most common conditions associated with pedestrian and bicycle crashes were daylight and clear weather. Crashes involving males exceeded those of female pedestrians or bicyclists. For bicyclists, higher percentages of fatalities were observed on Saturday, Sunday and Monday, while for pedestrians, Saturday and Sunday had relatively higher percentages of fatalities. Based on hotspot analysis, it was observed that bicycle and pedestrian crashes are concentrated in urban areas.

In order to identify the current countermeasures and their perceived effectiveness in Michigan, a survey was conducted. The targeted groups included transportation professionals (engineers, planners, etc.), law enforcement officers, and pedestrian and bicycle advocacy group members. The results were used in conjunction with other analysis results in order to most confidently identify and recommend appropriate countermeasures for the crash causes revealed by data analyses. The web-based tools, Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE) and the Bicycle Countermeasure Selection System (BIKESAFE), were also utilized to identify appropriate countermeasures.

Furthermore, the research team conducted statistical modeling to identify specific factors contributing to injury severity sustained by pedestrians and bicyclists involved in crashes. The ordered probability model was estimated to associate infrastructure, environmental, and behavioral factors with possible injury outcomes, namely (1) O - no injury, (2) C - possible injury, (3) B - non-incapacitating injury, (4) A - incapacitating injury, and (5) K - fatality.

To identify appropriate countermeasures and to facilitate plans to implement those countermeasures, it was imperative that target groups be identified. To that end, the research team associated crash causes and risk behaviors identified to demographic and socioeconomic factors of areas where the crashes occurred. Additional demographic and socioeconomic analysis focused on race and income of individuals living in areas where fatal and serious injury pedestrian crashes were recorded. Due to the randomness of fatal and serious injury crashes, demographic analysis was not possible for bicycle crashes. It should be clear that the race or income status used in this analysis is not necessarily that of the pedestrian involved in a crash since their race or income is not documented in crash reports. Rather, the race and income levels used represent demographics and income status of the area where a crash occurred. Percentage of different racial groups where determined for each county and correlated with the rate (per county population) of fatal and serious injury crashes associated with each of the risk behaviors and crash causes identified. By combining the results from literature review, crash analysis, PEDSAFE or BIKESAFE tools, and survey, applicable countermeasures to reduce pedestrian and bicycle crashes in Michigan were identified.

3 Summary of Pedestrian Crashes Analysis Results

3.1 Survey Results Related to Pedestrians

The survey results indicated that a number of infrastructure, traffic control, and facility enhancement countermeasures have been widely implemented in Michigan, although at varying levels. However, for all three categories of participants surveyed, the education and outreach countermeasure implementation or observation was ranked the lowest in terms of the percentage of the responses. Figure 3.1 shows the overall average level of perceived effectiveness for pedestrian countermeasures reported by survey respondents. In general, the most effective countermeasure category shown by an average of responses was the infrastructure engineering countermeasure while education and outreach countermeasures were generally perceived to be less effective by survey participants. Based on review of previous studies, an increase in education and outreach countermeasures may result in a reduction of crashes. In addition to engineering countermeasures being implemented in Michigan, the survey results suggest that efforts should be increased especially on implementing education and outreach countermeasures in order to have an impact on risk behaviors and therefore improve pedestrian safety.

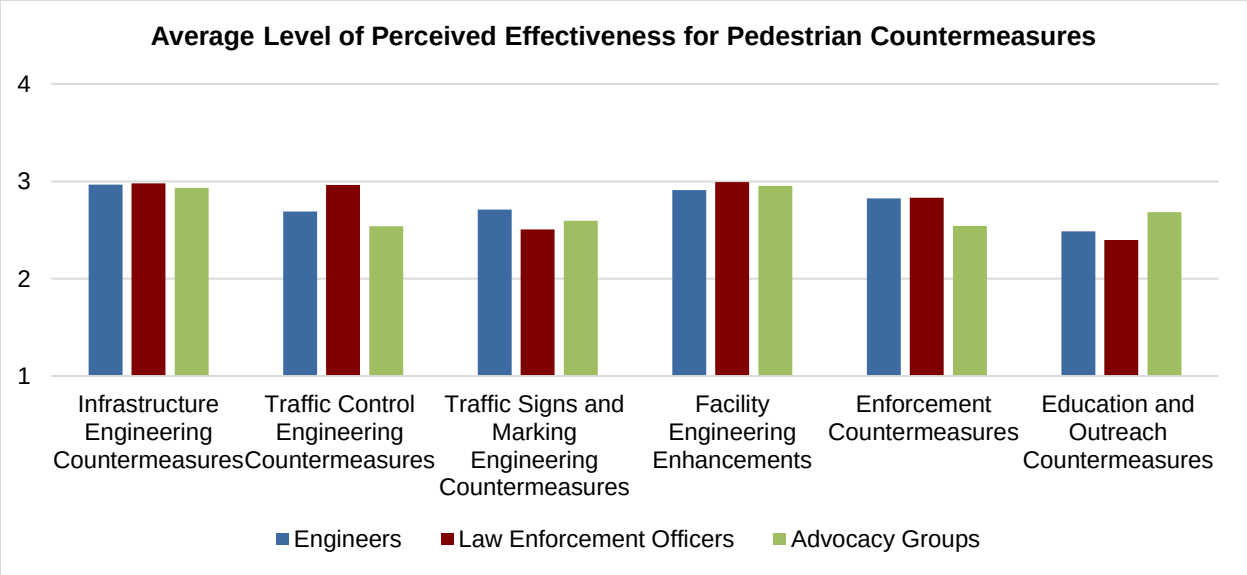

Figure 3.1 Overall average level of perceived effectiveness for pedestrian countermeasure groups.

3.2 Risk Behaviors and Causes for Pedestrian Crashes

Upon completion of reviewing UD-10 reports and crash analysis, it became apparent that the number of crash types was too large to be meaningful when suggesting countermeasures. It was also noted that specific behaviors by the motorist, pedestrian, or bicyclist could be identified as the main cause of the crash

based on crash types. This was a result of associating crash types with contributing factors and sequence of events leading to a crash documented in the UD-10 reports. In order to further define the crash causes, the crash groups and types were categorized by the behavioral cause of the crash. Six categories of risk behaviors and crash causes were identified for pedestrian crashes. These categories of risk behaviors and crash causes for pedestrian crashes (ranked by percent frequency) were as follows.

3.2.1 Failing to yield/Disregarding traffic control

This risk behavior may be committed by both pedestrians and motorists. The specific crash types that were identified using the crash typing tool and are associated with this behavior are pedestrian failed to yield, motorist failed to yield, motorist left turn – parallel paths, dash, crossing an expressway, multiple threat, dart-out, mailbox-related, backing vehicle – roadway, motorist right turn – parallel paths, backing vehicle – driveway, backing vehicle – driveway / sidewalk intersection, motorist left turn – perpendicular paths, motorist right turn – perpendicular paths, motorist right turn on red – parallel paths, motorist right turn on red – perpendicular paths, motorist turn / merge – other / unknown, motorist entering driveway or alley, motorist exiting driveway or alley, trapped, and backing vehicle – parking lot. Overall, 58 percent of analyzed pedestrian crashes were a result of this risk behavior.

3.2.2 Pedestrians being in roadway

These crashes resulted from pedestrian actions. The crash types include walking in roadway, lying in roadway, standing in roadway, working in roadway, playing in roadway, and play vehicle-related (i.e., pedestrian was struck while riding a play vehicle that was not a bicycle (e.g., skates, scooter, wagon, sled, etc.)). In total, 14 percent of all pedestrian crashes analyzed were resulting from pedestrians being in the roadway in one of the manners described in this sub-section.

3.2.3 Pedestrian being near vehicle

Crash types in this category include disabled vehicle-related, vehicle – vehicle / object, pedestrian on vehicle, entering / exiting parked vehicle, driverless vehicle, commercial bus-related, ice cream / vendor truck-related, and school bus-related. Overall, there was 10 percent of crashes associated with pedestrians being near a vehicle.

3.2.4 Pedestrian walking along roadway

Crashes in this group involved a pedestrian walking along the shoulder of the road due to a lack of sidewalk or the pedestrian not using available sidewalk. Specific crash types include walking along roadway with traffic – from behind, walking along roadway against traffic – from front, and walking along roadway – direction / position unknown. Pedestrian walking along the side of the road due to a lack of sidewalk or the pedestrian not using available sidewalk constituted 6 percent of all analyzed pedestrian crashes.

3.2.5 *Loss of control*

This group includes behaviors or actions committed by both the pedestrian and motorist. Crash types include motor vehicle loss of control, pedestrian loss of control, and off roadway – other / unknown. These types of crashes are often associated with other factors such as speeding, presence of alcohol, and bad weather conditions. Loss of control constituted 6 percent of all pedestrian crashes analyzed in this study.

3.2.6 *Other/Unknown*

Crashes within this group may have a lack of information due to being hit and run crashes or some other reason. Crash types included in this category are non-intersection – other/unknown, intersection – other / unknown, other unusual circumstances, dispute-related, other – unknown location, off roadway – parking lot, etc. They constituted nearly 7 percent of all analyzed crashes.

In order to describe the risk behavior of failing to yield or disregarding traffic control, further analysis of roadway features was performed on pedestrian crashes within that group. The results show that:

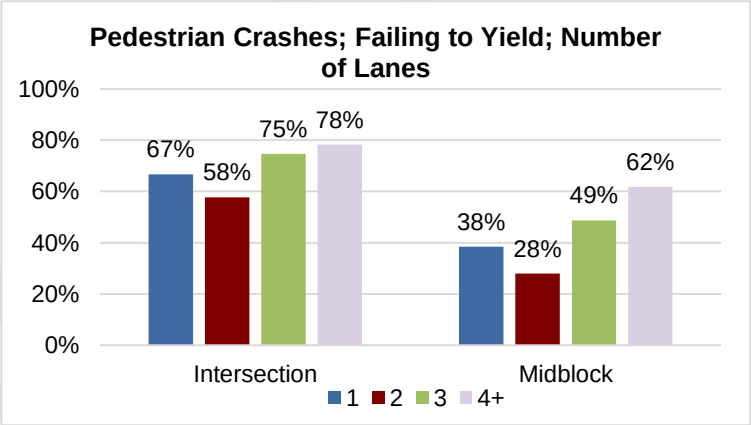

Figure 3.2 Proportion of pedestrian crashes by intersection or midblock and number of lanes.

- 78% of pedestrian crashes occurring at intersections with four or more lanes were classified as failure to yield or disregard traffic control.
- 62% of pedestrian midblock crashes occurring at areas with four or more lanes were categorized as failure to yield or disregard traffic control.

In addition, individual crash circumstances were evaluated to determine the distribution of pedestrian failure to yield/disregard traffic control crashes at intersections based on crosswalk presence. The results showed that:

- 45% of crashes analyzed had a marked crosswalk followed by 40% without a crosswalk.
- About 13% of all failing to yield/disregarding traffic control pedestrian crashes analyzed occurred when pedestrian were crossing a street with unmarked crosswalks.

Further analysis on crashes identified as failing to yield/disregarding traffic control was performed to understand how they relate to area type. Figure 3.3 shows the proportion of pedestrian crashes at intersection or midblock locations by area type. It shows that 75% of pedestrian crashes at an intersection within the area type considered small urban (population 5,000 to 49,999) were categorized as failure to yield/disregard traffic control. Also, 54% of pedestrian midblock crashes in large urbanized areas (population 200,000 or more) were considered failure to yield/disregard traffic control.

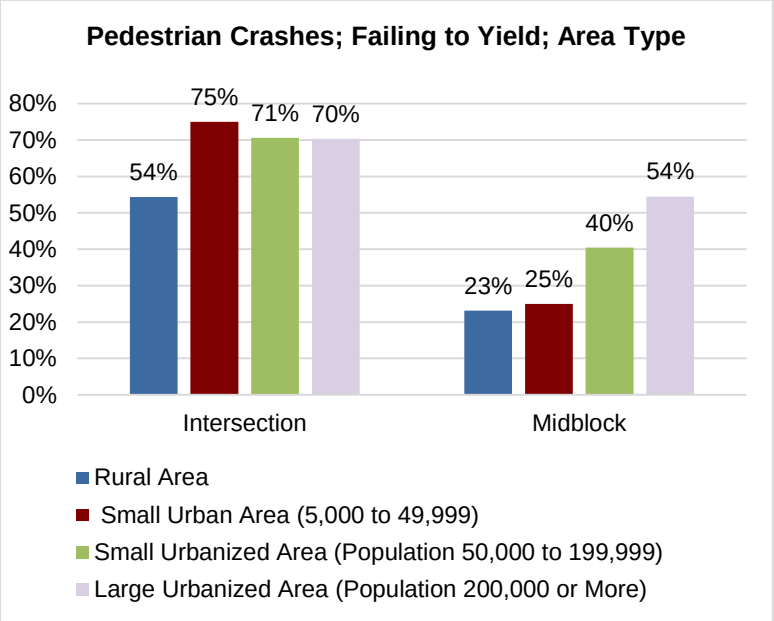

Figure 3.3 Proportion of pedestrian crashes at intersections or midblock by area type.

The results from modeling support these behaviors and causes while shedding light on other influential factors. Among others, the analysis results indicated that age of pedestrian or bicyclist influences the injury level, higher age increasing the likelihood of severe or fatal injury. Also, the results indicated that pedestrian or bicycle crashes involving alcohol and drug tend to be more severe or fatal. Other influential factors for the outcome of pedestrian crashes include gender, day of the week, time of the day, type of traffic control at intersection, speed limit, and roadway characteristics such as functional class and number of lanes.

Additional demographic and socioeconomic analysis focused on household income of individuals living in areas where fatal and serious injury pedestrian crashes were recorded. The results indicate that there is a statistically strong (at the 95% confidence level) positive correlation between failing to yield and percentage of households with income less than $20,000.

3.3 Countermeasures for Pedestrian Crashes

After compiling the results from various methods of analysis, countermeasures applicable to risk behaviors associated with pedestrian and bicyclist crashes in Michigan were identified. The main report (Chapter 6) presents a matrix of the countermeasures for pedestrian crashes. Analysis of risk behaviors and causes of pedestrian crashes in Michigan indicated that failing to yield and disregarding traffic control by both

pedestrians and bicyclists contributes to the most fatal and severe injury crashes. While there is a number of potential countermeasures to address this type of risk behaviors as shown in Chapter 6 of the main report (the matrix), it is worth pointing out that specific site conditions determine the most appropriate countermeasure for that site. The recommendations of this study are consistent with countermeasures that work for all pedestrians recommended by the National Highway Safety Administration (NHTSA). TNHTSA's recommendations include establishing pedestrian safety zones, reducing and enforcing speed limits, enhancing conspicuity of pedestrians, implementing targeted enforcement, providing driver training, and pedestrian training on gap acceptance (Goodwin, 2013).

By combining the recommendations by NHTSA with countermeasures identified in this study and their association with risk behaviors and causes of pedestrian crashes in Michigan, it is recommended that efforts to reduce pedestrian crashes be mainly focused on increasing yielding behaviors for both pedestrians and drivers through engineering design, enforcement and education/outreach. For example, the analysis showed that wider roads (3 or 4+ lanes) are relatively associated with the highest proportion of failing to yield and disregarding traffic control devices at both intersections and in the midblock (i.e., especially where there is STOP control on the minor street, but not the major street). Narrowing such roadways, especially at locations with high pedestrian activity should be considered. Also, targeting such locations for enforcing yielding laws or educating road users on the importance of yielding to one another, may likely have significant impact on reducing pedestrian crashes in Michigan.

The analysis also showed that divided highways without a barrier have the highest proportion of failing to yield pedestrian crashes (compared to roadways not physically divided, divided roadways with a barrier, and one way streets). Educating road users on how to cross such roadways may reduce pedestrian crashes in Michigan. Chapter 6 of the main report provides more details on potential countermeasures and their applicability to common risk behaviors and causes associated with pedestrian crashes in Michigan.

4 Summary of Bicycle Crashes Analysis Results

4.1 Survey Results Related to Bicycles

Similar to pedestrian results, the survey indicated that a number of infrastructure, traffic control, and facility enhancement countermeasures for bicycle crashes have been implemented in Michigan, although at varying levels. Similarly, for all three categories of people surveyed, the education and outreach countermeasure implementation or observation was ranked the lowest in terms of the percentage of the responses. Figure 4.1 shows the overall average level of perceived effectiveness for bicycle countermeasures. In general, the most effective countermeasure category shown by an average of responses was the infrastructure engineering countermeasures while education and outreach countermeasures were generally perceived to be less effective by survey participants. Based on review of previous studies, an increase in education and outreach countermeasures may result in a reduction of bicycle crashes. In addition to engineering countermeasures being implemented in Michigan, the survey results suggest that efforts should be increased especially on implementing education and outreach countermeasures in order to have an impact on risk behaviors and therefore improve bicyclist safety.

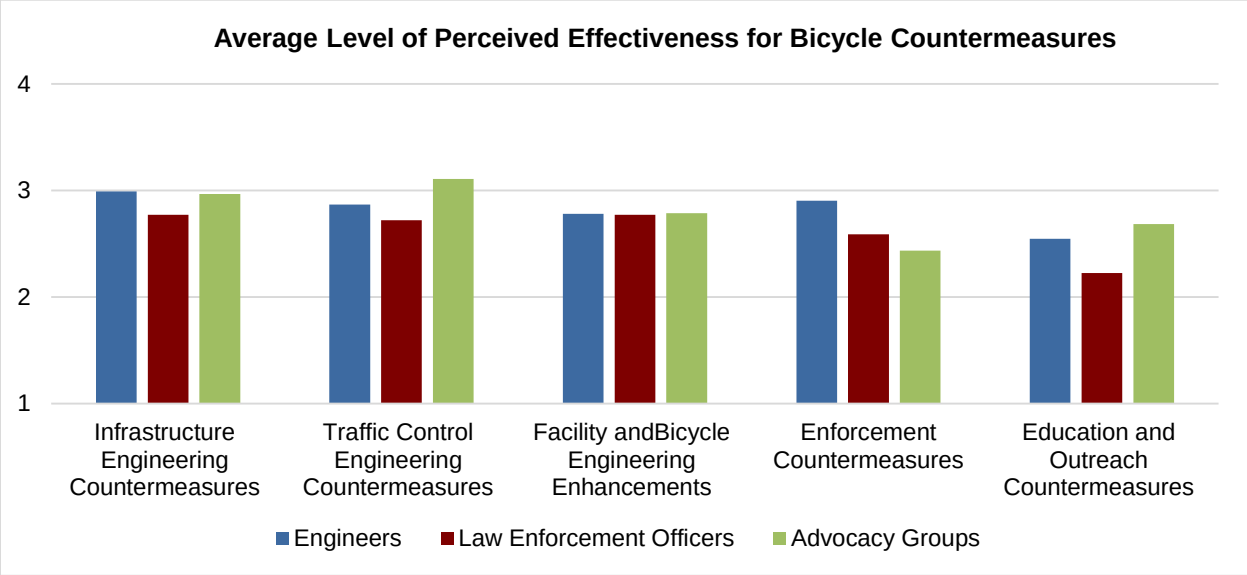

Figure 4.1 Overall average level of perceived effectiveness for bicycle countermeasure groups.

4.2 Risk Behaviors and Causes for Bicycle Crashes

Upon completion of the UD-10 reviews and crash analysis, it became apparent that the number of crash types was too large to be meaningful when suggesting countermeasures. It was also noted that specific behaviors by the motorist or bicyclist could be identified as the main cause of the crash based on crash

types. Again, this was a result of associating crash types with contributing factors and sequence of events leading to a crash involving bicyclist documented in the UD-10 reports. In order to further define the crash causes, the crash groups and types were categorized by risk behaviors causing the crash. Five categories of risk behaviors and crash causes were assigned to the bicycle crashes. The five categories of risk behaviors and crash causes for bicycle crashes were as follows.

4.2.1 Failing to yield/Disregarding traffic control

This risk behavior may be committed by both bicyclists and motorists. The specific crash groups that were identified using the crash typing tool and are associated with this behavior are bicyclist failed to yield – signalized intersection, bicyclist failed to yield – sign-controlled intersection, bicyclist failed to yield – midblock, motorist left turn / merge, bicyclist left turn / merge, motorist failed to yield – sign-controlled intersection, motorist right turn / merge, motorist failed to yield - signalized intersection, motorist failed to yield – midblock, crossing paths – other circumstances, bicyclist ride out – parallel path (i.e., a bicyclist who initially was on a sidewalk or other parallel path, rode into the roadway and into the path of a motor vehicle), backing vehicle, and bicyclist right turn / merge. There was 58 percent of bicycle crashes analyzed in which a bicyclist or motorist failed to yield or disregarded traffic control.

4.2.2 Overtaking

This action may be executed by the bicyclist or motorist. The crash groups within this category are motorist overtaking bicyclist and bicyclist overtaking motorist. Of all bicycle crashes analyzed, 27 percent were a result of overtaking maneuvers.

4.2.3 Loss of control/Turning error

This behavior may be observed by the bicyclist or motorist. The crash group included is loss of control / turning error. Overall, 6 percent of all analyzed bicycle-related crashes resulted from a loss of control or turning errors.

4.2.4 Bicyclists riding in a wrong direction

The crash group within this category is head-on. All crashes identified for this risk behavior involved the bicyclist riding the wrong way, not the motorist. They constituted 5 percent of all analyzed bicycle crashes.

4.2.5 Other/Unknown

Crashes within this category may have a lack of information due to a hit and run accident or other reason. Crash groups include other/unknown – insufficient details, parallel paths – other / unknown, non-roadway, and other / unusual circumstances.

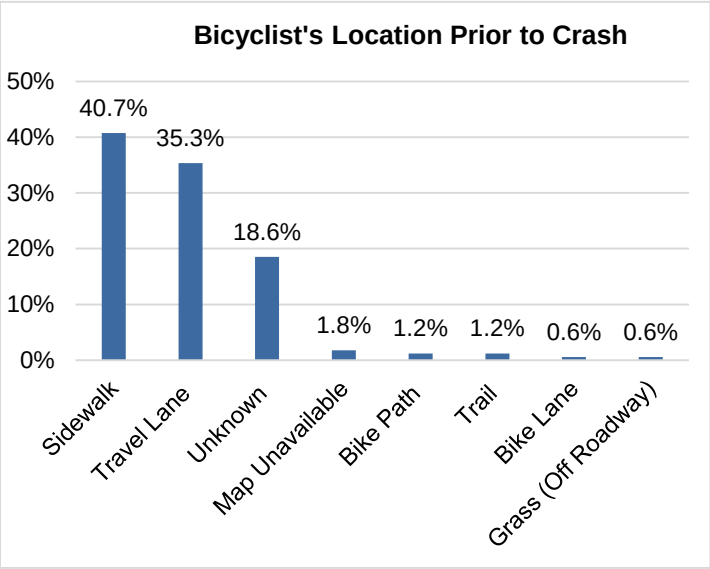

Figure 4.2 Distribution of bicyclist's position prior to crash.

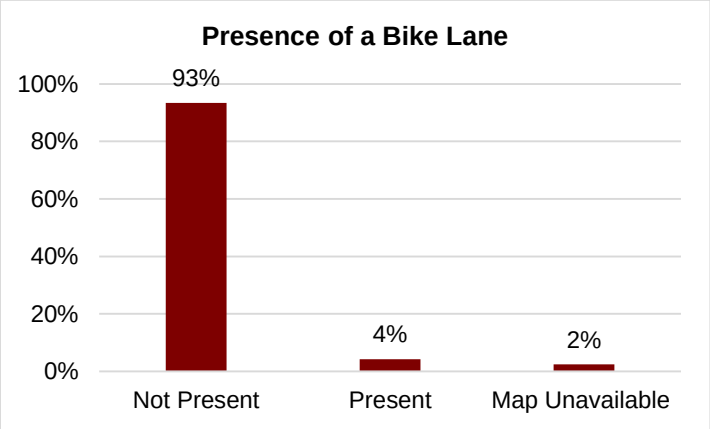

Figure 4.3 Distribution of crash sites by presence of dedicated bike lane.

In order to better understand bicyclist behavior, further analysis was done on bicycle crashes. Specifically, crashes involving a bicyclist that occurred at intersections and were classified as failure to yield/disregard traffic control were analyzed in order to identify trends in bicyclist behavior. Figure 4.2 shows the distribution of bicyclist crashes in the sample based on the bicyclist's location prior to the crash. Approximately, 41% of crashes analyzed involved the bicyclist riding on the sidewalk prior to the crash. This trend may suggest a correlation between bicyclists riding on the sidewalk and crashes involving a failure to yield or disregard of traffic control.

In addition to identifying the bicyclist's location prior to the crash, the available facilities were also analyzed for crashes within the sample. Figure 4.3 shows the distribution of the presence of a dedicated bike lane at the location of the crash. Approximately 93% of crashes categorized as failing to yield did not have a dedicated bike lane present. This observation may suggest a correlation between the lack of dedicated bike lanes and crashes involving a failure to yield or disregard of traffic control.

In addition to the previously mentioned factors, signage (e.g. “School Zone”, “Bike Lane”, “Bike Route”, “Share the Road”, etc.) was also investigated. While some signs are appropriate for areas with specific facilities (e.g., bike lane), the Michigan Manual on Uniform Traffic Control Devices (MMUTCD) recommends installation of “Share the Road” warning signs on areas where motorists need to be warned of presence of bicyclists traveling along the roadway. Figure 4.4 shows the distribution of bicycle crashes analyzed by the presence and type of bicycle signage at the crash location. According to the figure, 86% of crashes in the category of failing to yield did not have any signage present. A correlation may exist between a lack of signage and an increased chance of a failure to yield or disregard traffic control.

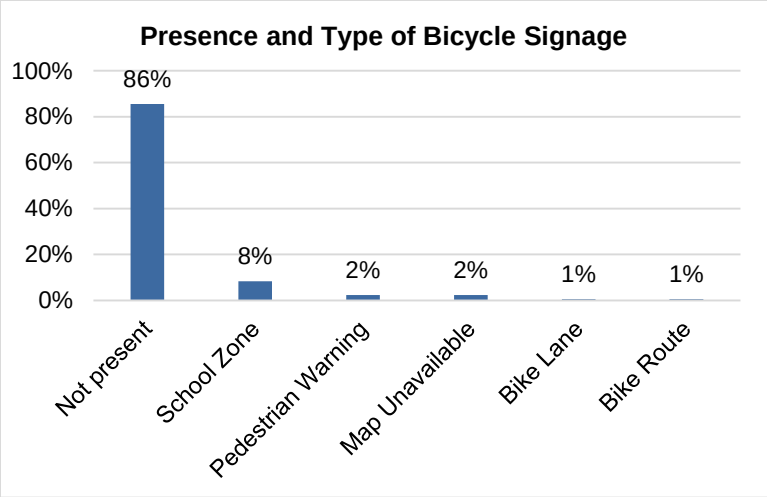

Figure 4.4 Distribution of bicycle crashes by presence and type of signage.

In addition to failing to yield/disregarding traffic control, another major category of bicycle crashes was observed to be overtaking which accounted for approximately 27% of bicycle crashes analyzed. In order to better describe this category, the shoulder type in the area of the crash was investigated. Figure 4.5 shows the distribution of shoulder type for the bicycle crashes categorized as overtaking. These proportions exclude any location with a dedicated bike lane. Of these crashes analyzed, 46% had an unpaved shoulder and 39% did not have a shoulder present.

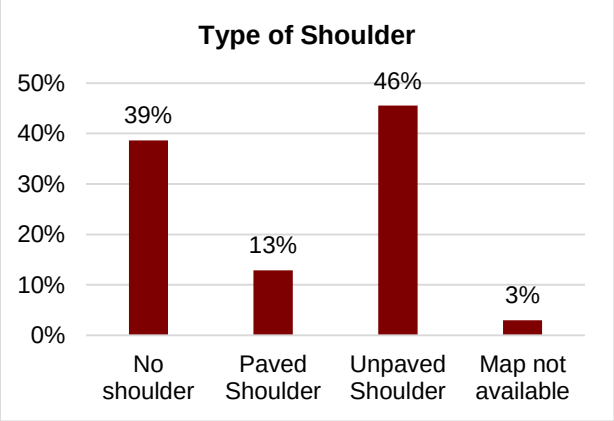

Figure 4.5 Distribution of overtaking bicycle crashes by shoulder type.

The modeling analysis results support other analyses results and point out other significant factors. Among others, the analysis results indicated that age of the bicyclist influences the injury level, higher age increasing the likelihood of severe or fatal injury. Also, it was determined that the highest proportion of crashes within the 25-44 age range was associated with overtaking risk behavior while those of age less than 16 had more failed to yield crash involvement. Also, the results indicated that bicycle crashes involving alcohol and drug tend to be more severe or fatal. For bicycle crashes, other factors found to significantly

impact the injury outcome were gender, road condition, speed limit, location (mid-block vs intersection), and time of the day. Due to the randomness of fatal and serious injury crashes, demographic analysis was not possible for bicycle crashes.

4.3 Countermeasures for Bicycle Crashes

The two major risk behaviors associated with bicycle crashes in Michigan are failing to yield and overtaking (both by bicyclists and motorists). The main report (Chapter 6) presents a comprehensive matrix that summarizes the countermeasures for bicycle crashes, as related to the risk behaviors and causes identified in this analysis. These countermeasures were categorized into engineering, enforcement, and education/outreach. Consistently, NHTSA identifies driver training and “Share the Road” awareness programs as countermeasures that work for drivers and bicyclists. It should be noted that the “Share the Road” program is rated very low and different studies have shown mixed results on its effectiveness. NHTSA further identifies active lighting and rider conspicuity, bicycle helmet use education, enacting and enforcing bicyclist passing laws, and general enforcement as countermeasures that work for all bicyclists.

Analysis of Michigan bicyclist crashes indicated that failing to yield and disregarding traffic control is highly associated with riders who ride in sidewalks, followed by those riding in travel lanes. In cases of bicyclists riding in sidewalks, it was found that a lack of dedicated bicycle facilities may have been among the reasons for bicyclists riding on the sidewalk. In some cases, there were discontinuities of sidewalks, which may have led to the bicyclists to move to travel lanes without yielding to motorists. Such cases may need to be corrected through engineering measures such as providing accommodation of bicyclists through dedicated bicycle facilities or shared facilities. This finding was echoed by another analysis of bicycle crashes resulting from failing to yield which showed that 93 percent of such crashes occurred at locations without a dedicated bicycle lane. Also, targeting education and outreach to educate bicyclists and motorists on sharing the space may be helpful in improving yielding behaviors.

5 Summary of Conclusions and Recommendations

Through literature review, analysis of crash data, as well as analysis of perception survey results, causes and risk behaviors were identified for crashes involving pedestrians and bicyclists in Michigan. Failing to yield/disregarding traffic control was the risk behavior causing the most pedestrian crashes. This behavior could be either by pedestrians or motorists. Wider roads (3 or 4+ lanes) were found to be associated with the highest proportion of failing to yield and disregarding traffic control devices at both intersections and midblock locations (i.e., especially where there is control on the minor street, but not the major street). Narrowing such roadways, especially at locations with high pedestrian activities should be given priority. Also, targeting such locations for enforcing yielding laws or educating road users on the importance of yielding to one another, may likely have significant impact on reducing pedestrian crashes in Michigan. For bicycle crashes, failing to yield/disregarding traffic control and overtaking were identified as the main risk behaviors and causes of bicycle crashes in Michigan. Analysis indicated that a lack of facilities that accommodate bicyclists (dedicated or shared) may encourage bicyclists to ride in sidewalks. Most of the "failing to yield/disregarding traffic control" bicycle crashes involved a bicyclist who was riding in a sidewalk prior to the crash. As supported by the analysis, emphasis on implementation of education and enforcement countermeasures is vital in reducing the frequency and severity of pedestrian and bicycle crashes.