THE EXAMINATION OF FACTORS ASSOCIATED IN MOTORCYCLE CRASHES IN WORK ZONES

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for the
Ohio Department of Transportation
Office of Research and Development

State Job Number 134627

FHWA Report No. FHWA/OH-2013/1

January 2013

1. Report No. FHWA/OH-2013/1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Examination of Factors Associated in Motorcycle Crashes in Work Zones		5. Report Date January 2013
		6. Performing Organization Code
7. Author(s) William H. Schneider IV Brandon Stakleff Alex Maistros		8. Performing Organization Report No. N/A
9. Performing Organization Name and Address The University of Akron 302 Buchtel Common Akron, Ohio 44325-2102		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. State Job Number 134627
12. Sponsoring Agency Name and Address Ohio Department of Transportation 1980 West Broad Street Columbus, Ohio 43223		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Ohio Department of Transportation and the Federal Highway Administration.

16. Abstract

This paper analyzes the factors associated with motorcycle crashes in work zones. This analysis was completed through the collection and inspection of three types of data: 1) practices used throughout the country on this topic, 2) crash reports and the construction documents pertaining to these crashes, and 3) a survey of the motorcycling community. The state of the practice was studied over the implementations in use throughout the United States. The crash related information was obtained through the Ohio Department of Transportation and the Ohio Department of Public Safety. The survey data were obtained through survey participants attending twenty-four events throughout the state of Ohio. These events were located in areas of concern identified through a hot spot analysis. The crash related information and the survey results were inspected and analyzed through the use of a mixed logit model. Recommendations for both rider and roadway based implementations are suggested from the analysis of the crash related documents and the surveys.

17. Key Words		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 148	22. Price $ 38,000.00

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

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Prepared in cooperation with the
Ohio Department of Transportation
and the
U.S. Department of Transportation,
Federal Highway Administration

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Ohio Department of Transportation (ODOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification or regulation.

ACKNOWLEDGMENTS

This project was conducted in cooperation with ODOT and FHWA.

The authors would like to thank the the following ODOT Subject Matter Experts:

- Mr. Michael McNeill, ODOT Office of Systems Planning and Program Management,
- Mr. Reynaldo Stargell, ODOT Office of Traffic Engineering, and
- Mr. Derek Troyer, ODOT Office of Systems Planning and Program Management

The time and input provided for this project by the Subject Matter Experts were greatly appreciated. In addition to our Subject Matter Experts, the authors would like to express their appreciation to Ms. Vicky Fout, Ms. Jill Martindale, Ms. Kelly Nye and Ms. Cynthia Gerst from ODOT's Office of Research and Development for their time and assistance. In addition, the authors would like to thank Mr. William Holik and Ms. Maggie Pekersoy of The University of Akron for their help on this project.

Customary Unit	SI Unit	Factor	SI Unit	Customary Unit	Factor
Length			Length		
inches	millimeters	25.4	millimeters	inches	0.039
inches	centimeters	2.54	centimeters	inches	0.394
feet	meters	0.305	meters	feet	3.281
yards	meters	0.914	meters	yards	1.094
miles	kilometers	1.61	kilometers	miles	0.621
Area			Area		
square inches	square millimeters	645.1	square millimeters	square inches	0.00155
square feet	square meters	0.093	square meters	square feet	10.764
square yards	square meters	0.836	square meters	square yards	1.196
acres	hectares	0.405	hectares	acres	2.471
square miles	square kilometers	2.59	square kilometers	square miles	0.386
Volume			Volume		
gallons	liters	3.785	liters	gallons	0.264
cubic feet	cubic meters	0.028	cubic meters	cubic feet	35.314
cubic yards	cubic meters	0.765	cubic meters	cubic yards	1.308
Mass			Mass		
ounces	grams	28.35	grams	ounces	0.035
pounds	kilograms	0.454	kilograms	pounds	2.205
short tons	megagrams	0.907	megagrams	short tons	1.102

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LIST OF ABBREVIATIONS

ABATE	American Bikers Aimed Towards Education
ADT	Average Daily Traffic
AMA	American Motorcyclist Association
CLOGIT	Conditional Logit
FHWA	Federal Highway Administration
GHSA	Governors Highway Safety Association
GPS	Global Positioning System
HSA	Hot Spot Analysis
IIA	Independent Irrelevant Alternatives
IID	Independently and Identically Distributed
Inc/Fat	Incapacitating or Fatal
IRB	Institutional Review Board
LEO	Law Enforcement Officer
MNL	Multinomial Logit
MOT	Maintenance of Traffic
MUTCD	Manual on Traffic Control Devices
NLF ID	Network Linear Feature Identification
Non	Non-Incapacitating Injury
ODOT	Ohio Department of Transportation
ODPS	Ohio Department of Public Safety
OMUTCD	Ohio Manual on Traffic Control Devices
PCB	Portable Concrete Barrier
PCMS	Portable Changeable Message Signs
PDO	Property Damage Only
Poss	Possible Injury

SLM	Straight Line Mileage
VMT	Vehicle Mile Traveled
VTRC	Virginia Transportation Research Council

CHAPTER I:

INTRODUCTION

Motorcycle crashes are an increasing concern, as the ratio of motorcycle fatalities to all motor vehicle fatalities is not proportional to the registration rates of these vehicles. In the United States in the year 2006, there were 4,837 motorcycles involved in fatal crashes, while the total number of motor vehicles involved in fatal crashes was at 38,648 (FARS, 2012). These numbers show that 12.5% of all fatal crashes involved motorcycles. This amount of fatal motorcycle crashes was about 5.4 times higher than when comparing the motorcycle registrations to all motor vehicle registrations (FHWA, 2006). Through the following years to 2010, the ratio of fatal crashes involving motorcycles versus all motor vehicles increased to 14.9% (FARS, 2012). These growing amounts of crashes have become an increasing concern to a number of various organizations including states departments of transportation, state departments of public safety, and the Federal Highway Administration (FHWA).

Authorities in Ohio are interested in decreasing the amount of motorcycle crashes in the state, since Ohio has the fifth largest number of registered motorcycles in the United States (FHWA, 2011). From 2006 to 2010, the number of motorcycles involved in fatal crashes in Ohio has increased from 166 to 175 per year, while the number of motor vehicles involved in fatal crashes in the state has decreased from 1526 to 1296 over the same period (FARS, 2012). These numbers demonstrate an increase in motorcycle involvement in fatal crashes in Ohio from 10.9% to 13.5% of all fatal crashes over this time period.

The majority of Ohio's motorcycle activity occurs during the short riding season, observed between the holidays of Memorial Day through Labor Day (from roughly May through September). This riding season coincides with the majority of repair work on roadways. Roadway work zones alter the roadway surface, resulting in reduced traction between the wheel and the road. In comparison to cars and trucks, motorcycles have a limited surface area where the tire is in contact with the road, and this lower surface area magnifies the importance of maintaining traction of the motorcycle. In addition, work zones also alter vehicles' paths of travel, which may take riders' focus off of important hazards. Therefore, efforts to increase riders' awareness of the upcoming surroundings and to decrease pavement degradation may increase the safety of motorcycle riders.

1.2 Objectives

The overall goal of the proposed research is to evaluate motorcycle work zone related crashes and provide the Ohio Department of Transportation (ODOT) and the riding community with the most current knowledge on the contributing factors associated with motorcycle-related work zone crashes. Within this overall goal, there are four technical objectives that are required for the successful completion of this project. These four objectives include:

1) **Conduct a national survey on the state of practice on special treatments used with motorcyclists and work zones:**

   This objective consists of contacting states throughout the country to determine practices that are used in the special treatment of motorcyclists and work zones. The practices, which are collected through this survey, are being aggregated to a common database and may be considered to combat similar issues throughout Ohio.

2) **Collect available data associated with the crash characteristics associated with the crash:**

   In this objective, crash reports (forms OH-1 and OH-2), construction plans, and construction diaries associated with motorcycle crashes in work zones in Ohio are collected. These documents are analyzed for the extraction of variables relevant to motorcycle crashes in work zones.

3) **Conduct interviews with the riding community:**

   In this objective, motorcycle riders are asked a series of questions to determine an alternative perspective on the causation and solution to motorcycle crashes in work zones. The questions relate to rider experience, perceived hazards, and potential solutions. The hazards and solutions correspond to the findings from the first two objectives.

4) **Synthesize the findings from the report:**

   This objective statistically analyzes the data from objectives #2 and #3. The analysis results in the identification of specific areas of concern, in regards to motorcycle safety in work zones, and the identification of implementations to resolve and reduce the number of crashes in these areas.

1.3 Overview of Report

The following subsections briefly describe the contents of each chapter of this study. The goals, methods, and outcome of each section are summarized below.

1.3.1 Chapter II: Background Information

Chapter II discusses the current conditions regarding motorcycle crashes in work zones. The chapter opens with insight to the general topic of motorcycle crashes, and it then narrows the focus to the specific topic of motorcycle crashes in work zones. The chapter continues by providing knowledge of practices on the special treatment of motorcyclists and work zones, and it concludes with a discussion of the ways that states throughout the nation are using various treatments to reduce motorcycle crashes in these areas.

1.3.4 Chapter III: Crash and Construction Documentation

The information provided in Chapter III relates to previous motorcycle crashes in work zones that have occurred throughout the state of Ohio. The information available is found in the OH-1 and OH-2 crash reports, work zone construction plans, and daily construction diaries. This information is analyzed and broken down into in-depth variables that enable a comparison of the crashes and work zones.

1.3.5 Chapter IV: Rider Survey

In Chapter IV, the information determined in Chapters II and III are compared to motorcyclists' views towards Ohio work zones, as obtained from surveys of members of the motorcycle riding community. The surveys were collected at motorcycle events throughout the state of Ohio. The events chosen were not randomly selected; they were located in areas of increased crash activity as identified through the use of a hot spot analysis.

1.3.6 Chapter V: Results from Mixed Logit Modeling

Chapter V provides an econometric statistical analysis for the databases in Chapters III and IV. This analysis was completed through the use of mixed logit modeling and determined the sensitivity of a set of parameters to the remaining parameters. Three models were created through this analysis: two models for the data obtained in Chapter III and one model for the data obtained in Chapter IV.

1.3.7 Chapter VI: Conclusion and Recommendations

Through the analysis of the databases completed in Chapters II, III, IV, and V, conclusions about various hazards affecting motorcycles in work zones and their potential solutions are drawn. Implementations are suggested based on the findings from these conclusions. The goal of these implementations is to reduce the number and severity of the motorcycle crashes occurring in work zones.

CHAPTER II:

BACKGROUND INFORMATION

2.1 Motorcycle Crashes

Motor vehicle crashes are unfortunate occurrences that not only negatively impact those involved but also society. The cost of a crash depends on its severity. The definitions for the severity of motor vehicle crashes (ODPS, 2012) and the cost to society of motor vehicle crashes (FHWA, 1994) are seen in Table 2.1.

Table 2.1: Crash Severity Definitions

Cost	Injury Severity	Definition
$1,581,912	Fatal	Any injury that results in a death within a 30-day period after the crash occurred.
$141,478	Incapacitating Injury	Any injury, other than a fatal injury, which prevents the injured person from walking, driving, or normally continuing the activities the person was capable of performing before the injury occurred.
$53,213	Evident Injury	Any injury, other than fatal or incapacitating, that is visible to observers.
$36,068	Possible Injury	When there is a complaint of pain without visible injury.
$8,128	Property Damage Only (PDO)	When there is no information about the individual being injured, including a hit-skip driver.

Note: Cost information was obtained from Higway Safety Manual Crash Cost Adjustment-Human Capital Costs (ODOT 2011) and their corresponding definitions were obtained from FHWA (1994).

In the year 2000, for instance, the economic cost of motor vehicle crashes was $230.6 billion and injuries included 41,821 fatalities, 5.3 million non-fatal injuries, and 28 million property damage only (PDO) crashes (Blincoe et al., 2002).

Motorcycle crashes have become a focus in the effort to reduce motor vehicle crashes. Motorcycles are 5.4 times more likely, per vehicle mile traveled (VMT), to be involved in a crash than other vehicles (Mannering and Grodsky, 1995). In 2010, motorcycles in the United States are more than 21 times more likely, per VMT, to be involved in a fatal crash than passenger cars (FARS, 2012).

Motorcycle crashes have been continuously studied for many years. The amount of available data on each crash continues to change as the technology available for recording and distributing data increases and as changes occur in recording standards, roadways, safety improvements, and driver mentality. The data acquired for this study included crashes from 2006 through July 2012. This study period is similar to a study previously conducted on motorcycle fatalities in Ohio by Eustace et al. (2011), which covered a five-year period.

To understand motorcycle crashes, research has been conducted on the impact of legislation on helmet use (Branas and Knudson, 2001; Ichikawa et al., 2003; Coben et al., 2007; Houston, 2007; Houston and Richardson, 2008; Mayrose, 2008; Hill et al., 2009; Ranney et al., 2010), while other studies have looked at helmet use (Li et al., 2008; Gkritza, 2009; Donate-Lopez et al., 2010) and the protective benefit of wearing a helmet (Keng, 2005; Nakahara et al., 2005; DeMarco et al., 2010). Other studies are predictive in nature, comparing a specific aspect of roadway design. Examples of predictive studies are Quddus et al. (2001) and Haque et al. (2010), which considered intersections and horizontal curves and their relation to motorcyclist crashes. Another avenue of study is to identify causative factors associated with risky behavior (Horswill et al., 2003; Lin et al., 2004; Dandona et al., 2006; Chen, 2009; and Wong et al., 2010).

2.2 Work Zone Safety

Safety in roadway work zones has always been a high priority, and various states use different strategies to complete the work in a safe and cost-effective manner. Since work zones are non-permanent designs, new and existing users to the roadway may be unaware of the obstacles ahead of them. This has led to studies on the setup of the work zones to determine their safety. The "Iowa Weave" – a setup where there is a lane closure with a left-hand merge and shift – was found to reduce the crash rate, although it did not significantly affect crash severity (See, 2008). Other studies analyzed the effects of the time of day to determine whether work zones active during the day or at night were safer. It was found that the work operations occurring at night were coincident with lower traffic volumes and contained a much lower number of crashes (Ullman et al., 2008).

2.3 Motorcycle Safety in Work Zones

The majority of the motorcycle and construction seasons occur during the same period of the year, during the months where temperatures are warmer. The greater likelihood for a motorcycle driver to encounter work zones, as well as the hazard each location presents, will increase the number of crashes that occur for motorcycles. Combine a shorter season for these events in northern latitudes with a large motorcycling community in Ohio (which is one of the top five states in number of motorcycle registrations [FHWA, 2011]), and the exposure of motorcycles to work zones is drastically increased. FHWA has identified motorcycle safety in work zones as an issue and has sought continued safety enhancements (FHWA, 1995). This large amount of exposure creates problems for motorcyclists due to the inherent design of two wheeled vehicles, which have a smaller contact patch with the pavement and travel on a single track with two tires.

Motorcycles contain a smaller contact patch with the surface of the roadway than other vehicle types; because of this, motorcycles are more adversely affected by degradations in the pavement. The difference in the contact patch of a motorcycle tire and a passenger vehicle tire is seen in Figure 2.1.

Motorcycle Tire Contact Patch | Passenger Vehicle Tire Contact Patch

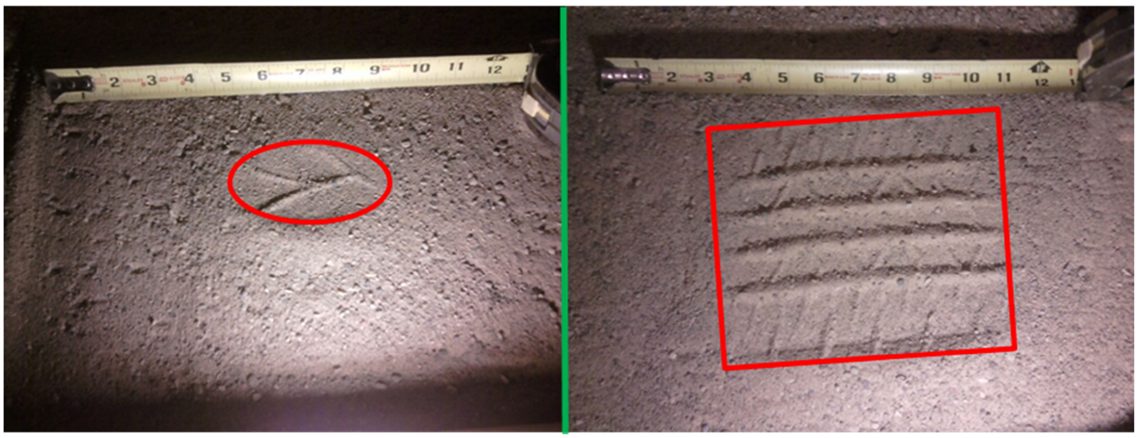

Figure 2.1: Motorcycle and Passenger Vehicle Tire Contact Patch (picture taken by B. Stakleff)

From this figure, it may be seen that the motorcycle tire contact patch is approximately six times smaller than the passenger vehicle tire. Furthermore, there are only two tires on a motorcycle, while there are no fewer than four tires on a passenger vehicle. Because of this difference in the size of the contact patch, smaller amounts of debris or degradations to the pavement will allow the motorcycle tire to lose traction more easily. Loss of traction could result from traveling over various objects in the roadway (such as debris, steel plates, manhole covers, or paint tape).

The design of the motorcycle (a vehicle with two tires aligned on a single track) makes the transition over longitudinal pavement disruptions, which are changes to the pavement that occur parallel to the direction of travel, more difficult for motorcycles than for vehicles with tires aligned on multiple tracks in a side-by-side pattern. Longitudinal pavement disruptions could occur from multiple changes or objects in the roadway: uneven lanes, parallel joints, steel plates, man hole covers or other hazards.

Potts et al. (2008) identified common surface irregularities and the hazards they possess as part of the National Cooperative Highway Research Program (NCHRP) Report 500. The identified surface irregularities include the following:

- pavement drop-offs, which are often abrupt and difficult to see;

- gravel roads, which present a difficult riding surface, especially when they are loosely packed;
- gravel on the roadway, which may create traction problems;
- steel plates, which create an abrupt edge and a slick surface that may be difficult to see in low-light conditions;
- pre-grinding of asphalt, which creates an undulating surface parallel to the path of travel; and
- large grooves, gaps, or seams parallel to the direction of travel, which may trap the tires and cause a motorcycle to crash.

To alleviate these issues, Potts et al. (2008) also identified possible countermeasures:

- using signage to identify the presence of pavement drop-offs;
- repaving by providing a tapered edge that does not catch a motorcycle's tires;
- paving no farther, during the work day, than the adjacent lane is also able to be paved;treating steel plates with a non-slip surface material;
- including a contrasting color on the edge of steel plates for increased visibility; and
- including a tapered pavement edge for steel plates to reduce the risk of the edge catching a motorcycle's tire.

Additional possible countermeasures were identified for surface irregularities that are unavoidable, such as chip and seal and pavement grinding.

The Roadway Safety Consortium in 2010 outlined potentially dangerous roadway surfaces that could affect a motorcyclist. Their focus areas included surface conditions such as pavement milling, unpaved surfaces, rough pavement sections, rumble strips, loose gravel, liquids on pavement surface, blackout tape, large pavement markings, steel plates, uneven lanes, rough pavement joints, and manholes. Solutions for these potentially hazardous surface conditions were as follows:

- implement standards which reduce the height of vertical pavement edges;
- in temporary alignment changes, keep design speeds within 10 mph of existing design speed;
- specify motorcycle-related static warning signs in advance of identified pavement degradations;
- use motorcycle-targeted warnings on portable changeable message signs (PCMS);
- mitigate edge transitions and other temporarily elevated obstructions;

- consider motorcycles when choosing in-lane pavement markings;
- incorporating motorcycle-specific practices into project designs, traffic manuals, and contract documents; and
- increase emphasis of continuous pavement condition monitoring.

The Texas Department of Transportation (TXDOT, 2008) published a technical advisory identifying the use of notched wedge joints. This treatment is to be used on pavement depth differences of 1½ to 3 inches. The wedge transition is able to reduce vertical surfaces down to a height of 0 to ¾ of an inch. The dimensions of the wedge transition are seen in Figure 2.2.

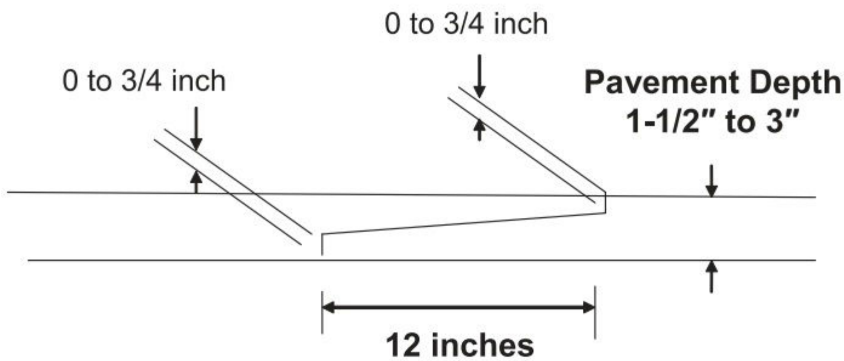

Figure 2.2: Notched Wedge Joint (From TXDOT, 2008)

Studies have been conducted to measure the ability of a motorcyclist to clearly identify the oncoming obstacle in the roadway. Cottrell (2006) of the Virginia Transportation Research Council (VTRC) investigated the use of reflective marking tape on steel plates under low light conditions at multiple angles and distances. This resulted in a low-cost (estimated $30) solution that uses the reflective marking tape at the corners of the steel plates and placing a warning sign “STEEL PLATE AHEAD” in advance of the work zone. The dimensions of the reflective markings recommended by Cottrell are seen in Figure 2.3.

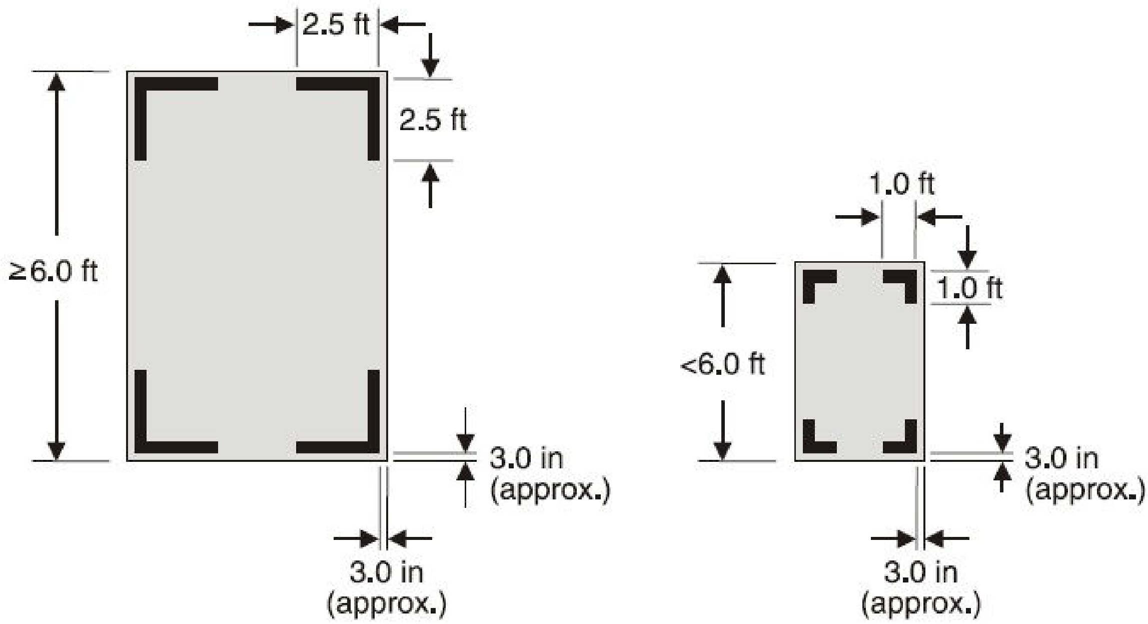

Figure 2.3 Reflective Marking Tape on Steel Plates (From Cottrell, 2006)

In the figure above, the steel plate depicted on the left refers to a steel plate of six feet in length or greater. The steel plate depicted on the right refers to a steel plate less than six feet in length. This study only recommended the use of the reflective tape in combination with the sign and did not analyze the number of associated motorcycle crashes to find if crashes were reduced.

The above listed issues and solutions are suggestions that are thought to reduce the amount of motorcycle crashes that occur in work zones. These suggestions are not necessarily being used by any or all states and municipalities. In order to determine which implementations were being used, further research into what each state has applied was needed.

2.3.1 National State of Practice

To determine what solutions are in use throughout the country to reduce the hazards of work zones for motorcyclists, an investigation of the national state of practice was conducted. The first basis on the national state of practice was acquired from the Governors Highway Safety Association (GHSA), which conducted a survey in 2008 of states' motorcycle-related safety measures used in work zones. Some of the common solutions involved the use of signage for various road conditions; one solution is to identify grooved pavement that is a result of the roadway being milled (planned), which is the process of grinding and removing the existing roadway surface. Additional information was found in alterations to the construction specifications and in documents explaining how the construction should proceed. The responses from the GHSA survey are seen in Table 2.2.

Table 2.2: GHSA Findings for Implementations of Motorcycle Safety in Work Zones

State	Implementation
Colorado	• Warning signs for roto-milled or barren sections of road and wheel traps such as uneven lanes.
Florida	• Requirement for a grooved pavement ahead sign 500 feet in advanced of a milled or grooved surface.
Hawaii	• Use products that decrease skidding or increase traction on the construction steel plates. • Include motorcycle safety in their work zone safety workshops.
Kansas	• Signs are required in works zones for milled and uneven pavement.
Kentucky	• Signs are used to warn motorcyclists of rumble strips and dips in the road.
Maine	• Considers placement of rumble strips and sign placement in roadway design.
Massachusetts	• Use of highway message boards to warn motorcyclists of issues in construction zones.
Michigan	• Signs are placed on roads to warn motorcyclists of construction hazards.
Minnesota	• Address motorcycle safety issues in traffic control training for construction and design engineers. • Construction projects have expedited timelines to reduce motorcyclists' exposure to milled surfaces, uneven lanes and drop offs.
Montana	• Construction reports for projects with unpaved sections must contain an advisory for motorcyclists and suggest that they take an alternate route.
Nebraska	• Warning signs for rumble strips are used in work zones.
New Hampshire	• Signs are used to warn motorcyclists of dangerous road conditions.
New York	• Signs are required to warn motorcyclists where the pavement is grooved or uneven. • Changes in road condition are communicated to motorcyclists by signs, far enough in advance of the change to give the operator time to make the necessary adjustments. • Specification included in the design manual that state extra precaution should be taken to ensure that no construction materials, steel plates, or debris reaches the traffic lanes, especially at night.
North Carolina	• Surface design (markings, warning strips, etc.), edge transformation, side road barriers and signs are used to warn motorcyclists of dangerous road conditions.
Rhode Island	• Work zone signs are used to warn motorcyclists of impending grade changes that wouldn't impact other motor vehicles.
South Carolina	• The state DOT considers motorcycle issues in its construction projects.
South Dakota	• Provides road designs that accommodate a large number of motorcycles and provides signs with drawings of exits and roads to ease navigation. • The South Dakota Office of Highway Safety operates a yearlong road hazard hotline with assistance from South Dakota's chapter of American Bikers Aimed Towards Education (ABATE) that enables motorcyclists to call a toll free line to report a road hazard.
Vermont	• State construction standards require motorcycles use a caution sign in the advanced warning sign package for cold planing.
Virginia	• Steel plates used to cover holes in roadways must be secured to the pavement and marked with reflective materials on the four corners.

Washington	• State law requires that all construction sites be marked as hazardous road conditions for motorcycles.
Wyoming	• Warning signs and updates on the Wyoming DOT website are used to note where grades and road surfaces would be difficult for motorcyclists.

These responses were a part of a complete study of states' motorcycle programs including state education, licensing requirements, helmet laws, and program funding.

2.3.1.1 National Survey

To update and identify additional current practices, 30 states (of which 14 responded) were contacted and surveyed regarding their use of implementations correlating to motorcycle crashes in work zones. The responses from the contacted representatives are seen in Table 2.3.

Table 2.3: National State of Practice

State	Implementation
Illinois	• There are no motorcycle specific implementations in use in work zone areas. • Signs are used to depict the presence of edge drop offs. These signs contain statements such as: "UNEVEN LANES", "LOW SHOULDER", "SHOULDER DROP-OFF", and "ROUGH GROOVED PAVEMENT".
Maryland	• For all construction zones, a sign indicating "MOTORCYCLES BE AWARE" is used, along with an optional reduced speed sign. • Steel plates have temporary asphalt build ups (a "wedge") to give motorcycles a smooth transition from pavement to steel plate. • New pavement is tapered to eliminate edge drop-offs. • An 800 number is available for riders to call to report roadway issues for repair. • Signs are used to depict expansion joints for motorcycles (the sign has a motorcycle symbol with line to indicate the expansion joint).
Michigan	• Signs are in use for work zones warning motorcyclists of the presence of transverse rumble strips.
Minnesota	• There are no motorcycle specific implementations in use in work zone areas. • To alleviate grooved pavement and uneven lanes, the use of a "mill and fill" technique were adopted. This technique requires the pavement to be paved immediately after being milled before traffic is allowed to travel over its surface. • Transverse rumble strips feature an open gap in the center of the strip for the passage of motorcycles. This is not a requirement, but this practice is becoming more widely adopted: 60-70% of the rumble strips statewide now contain this open gap.
Nebraska	• There are no motorcycle specific implementations in use in work zone areas.
Nevada	• Signs indicating expected conditions are used to warn motorcyclists. These conditions include: loose gravel, uneven pavement, and grooved pavement.
New Hampshire	• "Safety Edge" is used for the application of new pavement. This equipment tapers the edge of new pavement upon installation to provide a less drastic edge. • Where possible, grooved pavements sections are kept as short as possible. • Electronic message boards (both permanent and moveable) are used when necessary to inform motorcyclists of dangerous road conditions. • Motorcycle specific signs (such as "MOTORCYCLES USE CAUTION"),

	warnings for rumble strips, and warnings for grooved pavements are in use.
North Dakota	• A website is currently used to warn riders about roadway construction areas.
Oregon	• Use of “BUMP” and “GROOVED PAVEMENT” signs at grinding locations. • Specifications state "keep road free of debris". • Steel plates are not used when pre-construction speeds are greater than 35 mph. • Signs stating "BUMP" and "ROUGH ROAD" are installed for transverse excavations.
Tennessee	• There are no motorcycle-specific implementations in use in work zone areas. • General signs identifying uneven pavement and grooved pavement conditions are currently in use in applicable areas.
Texas	• There are no motorcycle-specific implementations in use in work zone areas. • General signs identifying uneven pavement and grooved pavement conditions are currently in use in applicable areas. • Longitudinal wedge transitions are occasionally used with uneven lanes.
Vermont	• Signs are in use for work zones stating "MOTORCYCLES USE CAUTION". • Warnings for longitudinal rumble strips are used.
Washington	• Signs are in use for work zones stating “MOTORCYCLES USE EXTREME CAUTION”. This sign is used in conjunction with a sign depicting the road condition to be faced. These road conditions include grooved pavement, abrupt lane edges, steel plates, and gravel or earth surfaced roadways.
Wyoming	• Signs indicating expected conditions are used to warn motorcyclists. These conditions include loose gravel, uneven pavement, and grooved pavement. These road signs are used in conjunction with a sign stating “MOTORCYCLES USE ALTERNATE ROUTES”. • There are date restrictions for construction around the Sturgis Bike Rally.

In addition to the responses from each state, FHWA includes a plaque (W8-15P) in a May 2012 revision of the 2009 Manual on Uniform Traffic Control Devices (MUTCD), to be used in conjunction with “GROOVED PAVEMENT” or “METAL BRIDGE DECK” signs, which are directed towards motorcyclists (FHWA, 2012). However, the availability of this plaque does not mean that it is frequently used. The MUTCD states that the plaque may be mounted if the warning is directed towards motorcyclists (FHWA, 2012). This statement has led some states to avoid using the plaque, based on an idea similar to one received by Nebraska’s Department of Roads Traffic Control Engineer, who was interviewed by the research team. This engineer noted that the plaque has not been used in Nebraska because the attention of the sign should not be directed specifically towards motorcycles if other vehicles act similarly while traveling over grooved pavement. Therefore, some states indicated in their responses that they do not use motorcycle specific implementations in work zones.

Along with the new use of the W8-15P signage, Ohio utilizes additional implementations which are able to prevent motorcycle related crashes from occurring in work zones. One focus of these implementations relates to pavement markings in which Ohio gives consideration in the selection of material that will minimize the loss of traction for motorcycles and other vehicles (FHWA, 2012). Through this consideration for motorcycles, the length of use for blackout tape, which covers existing pavement markings, is limited to a length of fifteen days (ODOT, 2010). Another implementation is the use of an optional wedge transition when a difference in the pavement height of a drop-off is between 1½ and 3 inches (ODOT, 2012b).

2.3.2 Motorcycle Crashes in Work Zones Background Information Summary

There are a wide variety of solutions that have been identified and are in use to increase the safety of motorcyclists in work zones. These solutions span several types of implementations: signs, websites, reporting hotlines, surface treatments, design specifications, and design methods. The employment of these solutions range widely in price and ease of application, and their effectiveness in reducing the number of crashes has not been investigated. Even though the effectiveness has not been analyzed, the solutions are well taken by the community with little to no negative comments. Many of the solutions have been studied to gauge their ability to be adequately understood by motorists. For example, the motorcycle plaque (W8-15P) in the MUTCD was analyzed for its understanding and was determined to be the best solution from a group of similar alternative signs (Hawkins, et al. 2009).

The results from the national survey may be synthesized into two main areas for improving motorcycle safety. These areas are consistent with the survey and include rider and roadway characteristics. The rider based solutions relate to implementations that increase the awareness of the presence of roadway degradations or the need to alter the path of travel. These potential implementable solutions include:

- installing signs giving a general warning such as “MOTORCYCLES BE AWARE” or “MOTORCYCLES USE EXTREME CAUTION”;
- installing signs stating notices specific to the upcoming conditions “BUMP”, “GROOVED PAVEMENT”, and “ROUGH ROAD”;
- installing signs with images depicting certain conditions, such as expansion joints or longitudinal rumble strips;
- using electronic message boards (both permanent and moveable) that state conditions specific to unusual work zones;
- providing an 800-number for riders to call and report road conditions thought to be hazardous;

- creating a webpage or website to inform riders of the location of work zones and the condition of the roadway;
- increasing the visibility of steel plates;
- suggesting that motorcyclists use an alternative route around work zones; and
- specifying motorcycle related static warning signs in advance of identified pavement degradations.

These implementations are generally lower in cost than roadway based solutions, because they inform the rider rather than mitigate the effect of the hazard. These rider based implementations are directed towards the rider and do not involve a major impact to the other vehicles traveling through the area.

Roadway based solutions are implementations that alter the surface of the roadway being traveled, the specifications stating when and how the work is to occur, or the design of the work zone. These types of implementations include:

- installing temporary asphalt wedges to give a transition from the pavement to an obstruction such as a steel plate or an exposed manhole cover;
- tapering new pavement to eliminate edge drop-offs;
- reducing the length of grooved pavement and the time that grooved pavement is exposed;
- creating specifications stating that the roadway must be kept free of debris;
- reducing the height of vertical pavement edges;
- mitigating edge transitions and other temporarily elevated obstructions;
- increasing emphasis of continuous pavement condition monitoring;
- incorporating motorcycle specific practices into project designs, traffic manuals, and contract documents;
- adding skid resistant material to steel plates;
- leaving a gap in transverse rumble strips for motorcyclists to pass through;
- creating provisions avoiding design speeds greater than 10 mph below existing design speed in temporary alignment changes; and
- creating provisions within the design manual that restricting the presence of steel plates, particular construction materials, and debris within the traffic lanes, especially at night.

These implementations are alterations to the roadway that require the addition or removal of material from the roadway. As such, they affect not only a motorcycle rider but other travelers, too.

The previously mentioned implementations vary in size, cost, extent of use, and impact to the motorcycling community. All of the implementations are thought to have a positive impact, according to the state representatives that were interviewed; however, it may not be feasible to employ all of the implementations at the same time. The various solutions in use by other states apply to a variety of roadway hazards. To determine which implementation(s) would best be suited for Ohio, an investigation of the crashes occurring throughout the state was required.

CHAPTER III:

CRASH AND CONSTRUCTION DOCUMENTATION

3.1 Introduction

Information regarding a crash is contained in a crash report, which is completed by the responding law enforcement officer and filed with the Ohio Department of Public Safety (ODPS). Additional insights about a crash in a construction zone may be gleaned from information obtained from ODOT, which keeps records on construction activities occurring in the work zone at the time of the crash.

3.2 Data Collection Methodology

The data used in this study is based on crash reports provided by ODPS and information about construction zones provided by ODOT. A flowchart showing the use of the collected data sets in this study is shown in Figure 3.1.

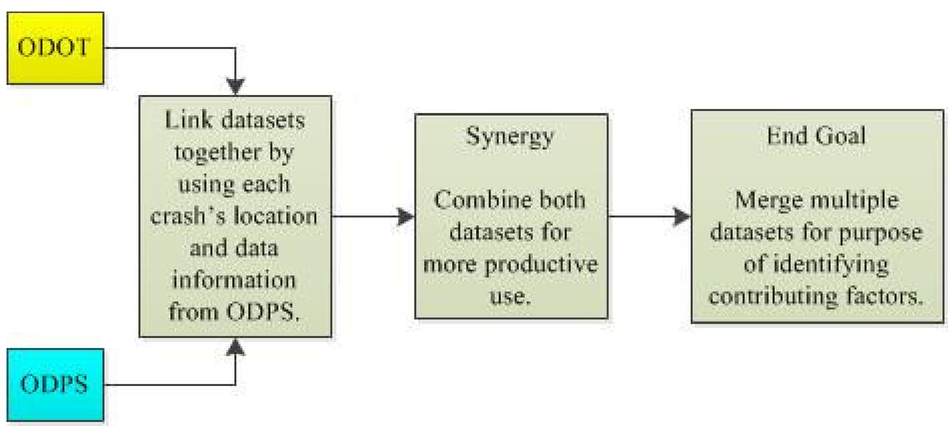

Figure 3.1: Methodology for Using Work Zone Related Crash Information

3.2.1 ODPS Data Sets

Crash information for this study is derived from crash reports (reported on forms OH-1 and OH-2) that are maintained by the ODPS. Seven important pieces of information are contained in reports (see Figure 3.2). Each of these core areas will be described in more detail in the following subsections.

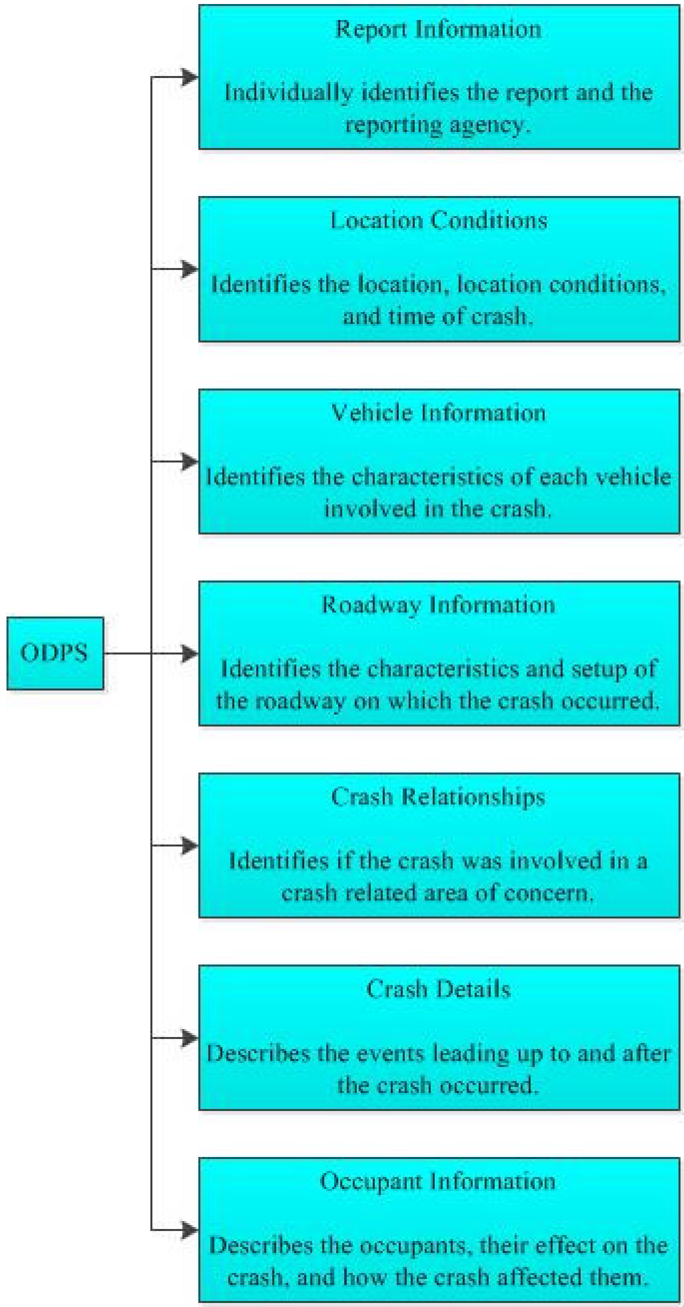

Figure 3.2: ODPS Data Sets

3.2.1.1 OH-1 Crash Data

When a crash occurs, the attending law enforcement officer (LEO) will complete a report to describe the situation of the occurrence. The first portion of this report is the OH-1 crash report. This report contains information pertaining to several categories including: report information, location conditions, roadway information, crash details, crash relationships, vehicle information, and occupant information. The parameters included in each of these categories describe valuable information that depicts the events occurring in each crash. A full list of the parameters identified in this crash report may be found in Appendix A.

3.2.1.1.1 Report Information

The report information category on the OH-1 contains the information that may individually identify each crash. The document number variable in this category is unique for each OH-1 report. This document number allows for a specific crash to be recognized and found when comparing crashes to each other or locating other documents related to the crash, such as the acquired ODOT data sets that correlate the document number to a construction project.

3.2.1.1.2 Location Condition

The location condition category of parameters identifies when the crash occurred, the location of the crash, and conditions present at the time of the crash. An indication of when the crash occurred is defined through the time, day, month, and year in which the crash occurred. The time of the crash may be assigned to one of four categories: morning, afternoon, evening, and night. The time of day of the crashes may reveal specific hazards affecting the handling of the motorcycles. The times associated of day and the corresponding numerical times are seen in Table 3.1.

Table 3.1: Categorized Times of Crashes

Time of Day	Corresponding Numerical Time
Morning	5:00 AM - 12:00 PM
Afternoon	12:00 PM - 5:00 PM
Evening	5:00 PM - 11:00 PM
Night	11:00 PM - 5:00 AM

This categorized time of day also coordinates with an adjusted day of week variable, where a crash occurring between the hours of 12:00 AM and 5:00 AM is considered to be related to the night before the day of the crash. For example, a crash occurring at 1:00 AM on a Sunday is considered to be a crash occurring on a Saturday night.

The location of a crash is determined using one of three sets of parameters: 1) latitude and longitude, 2) crash location and reference point, or 3) Network Linear Feature Identifier (NLFID) and Straight Line Mileage (SLM) Log referencing system. The latitude and longitude data are acquired through the use of a Global Positioning System (GPS) and are recorded in either degrees, minutes, and seconds or in decimal degrees. The crash location and reference point system (obtained from the OH-1 data set) requires the use of several parameters, which are seen in Table 3.2.

Table 3.2: Parameters Used in the Crash Location and Reference Point System

Parameter	Description
Federal Information Processing Standard (FIPS) Place Name	Identifies the municipal area in which the crash occurred.
Crash Prefix	A prefix used if a street is divided into north/south or east/west sections.
Street Designation	Identifies the type of road on which the crash occurred (i.e. avenue, boulevard, lane, road, etc.).
Type of Location Point Used	Identifies the type of roadway on which the crash occurred, may either be a named street, numbered street, or numbered route.
Distance from Reference	Indicates the distance the crash occurred from the reference location.
Direction from Reference	Indicates the direction from the reference location that the crash occurred.
Reference Prefix	A prefix used if a reference street is divided into north/south or east/west sections.
Reference Point	A reference location used to identify the location of the crash, may either be a street address, milepost marker, or intersection.
Reference Designation	Identifies the type of road on which the crash occurred (i.e. avenue, boulevard, lane, road, etc.).
Reference Point Used	Identifies the type of reference point that was used (i.e. state line, intersection, house number, mile post, etc.).

The NLFID and SLM Log referencing system (obtained from the OH-1 data set) requires the use of the respectively named parameters NLFID and SLM Log. The NLFID is a series of fourteen characters that uniquely identifies a roadway (ODOT, 2012a), and the SLM Log is a mile distance measurement from the beginning of a roadway segment (ODOT, 2012a), starting from the most eastern/southern end of the roadway.

The conditions present during the crash relate to the two parameters: weather and light conditions. These conditions may vary widely, depending on the day and time when the crash occurred. These conditions also have the potential to influence the ability of motorcyclists to handle their vehicles, as these conditions may alter the riders' perception of the upcoming roadway.

3.2.1.1.3 Vehicle Information

The vehicle information category identifies and describes each motor vehicle involved in a crash. Each motor vehicle involved in an incident is given a unit number, which is a number assigned for each vehicle for identification purposes, and a unit type, which is a designation for the classification of each vehicle. Each unit's make, model, year, and state of origin are also recorded. Additional information may be included if the unit contains defects or carries hazardous materials. The unit type is important, as it may be used to identify the crashes that contain motorcycles.

3.2.1.1.4 Roadway Information

The roadway information category identifies the characteristics and setup of the roadway on which the crash occurred. The roadway characteristics identified are the functional class of the roadway, Average Daily Traffic (ADT), intersection type, road contour, road condition, and road surface. The setup parameters describing the roadway depict the width of the lanes and shoulders, the speed limit, the number of lanes, and traffic control used on the roadway.

3.2.1.1.5 Crash Relationships

The crash relationships category identifies common crash related areas of concern. These areas involve crashes involving school buses, work zones, alcohol, drugs, animals, bicycles, motorcycles, speed, pedestrians, and other factors. It was essential in this study to isolate crash reports that were work zone related and indicated the involvement of a motorcycle. Isolation of reports that include both “motorcycles” and “work zone” factors resulted in finding 454 motorcycle crashes in work zones from January 2006 through July 2012. In addition to the areas of concern, the work zone related crashes contained additional information that aided in clarification of the work zone’s presence. This additional information included the work zone type, work zone location, and presence of workers. Each of these factors identifies a type of change from the normal operation of the roadway.

The work zone type describes the setup that is incorporated at the work zone. The types of work zones are defined in Table 3.3.

Table 3.3: Work Zone Types from OH-1 Crash Reports

Work Zone Type	Description
Lane closure	One or more lanes are closed, resulting in a merger of traffic from the lane closing to the remaining open lane(s).
Lane shift or crossover	One or more lanes move laterally, without any of the lanes closing. The lanes may also split or stay adjacent and may cross over the median of the roadway.
Work on the shoulder or median	The location of the work being completed is occurring on either the shoulder or the median of the roadway.
Intermittent or moving work	The work is being completed using vehicles that are either making frequent short-term stops or are moving at a slow speed.

In this table, it may be seen that when approaching each of the types of work zone, different precautions need to be taken. These precautions are related to the hazards of merging traffic, altered lane movements, close quarters with work, and approaching work in traffic at large speed differences. The setup of the work zone may have been unfamiliar, confusing, or unexpected for the motorcyclist, and it is feasible that the setup may have been a factor in a particular crash.

The work zone location identifies the area within the work zone where the crash occurs. This location may be identified as being in a known location: before the first work zone warning sign, the advanced warning area, the transition area, the activity area, or the termination area. The location may be unknown, if no specific information is noted in the crash report. A diagram showing work zone locations is seen in Figure 3.3.

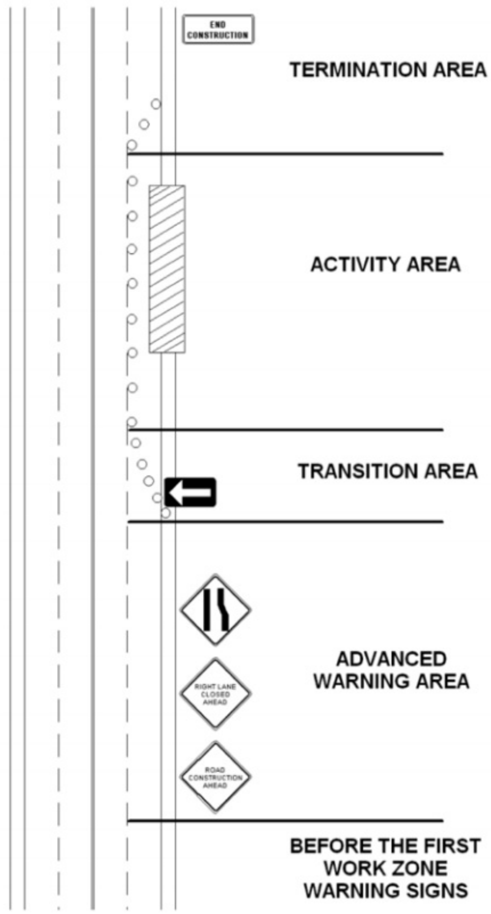

Figure 3.3: Work Zone Locations (reprinted from ODPS, 2012)

The identification of the location of the crash contributes insight to determine whether a specific location in the work zone is causing increased problems for motorcyclists. A location containing higher amounts of crashes may be an ideal location for the use of a crash reducing implementation. The work zone locations are studied in the analysis of work zone crashes. For all motor vehicles, the majority of crashes are found to occur in the activity area of work zones, with the majority of the crashes due to rear-end collisions (Garber and Zhao, 2002).

3.2.1.1.6 Crash Details

The crash details category describes the events leading up to the crash, the crash itself, and events following the crash. The parameters describing the events leading up to the crash include the unit's direction of travel, unit speed, pre-crash actions, circumstances, and sequence of events. The parameters describing the act of the crash include unit in error, number of units, occurrence, collision type, unit damage, point of impact, action, and harmful events. The parameters describing the after-effects of the crash include crash severity, total injured, total killed, and emergency use. A description of the main events throughout the entire sequence of a crash is presented in Table 3.4.

Table 3.4: Crash Event Descriptions

Parameter	Description
Occurrence	Where the crash occurred (i.e. on the roadway, on the shoulder, in the median, etc.).
Collision Type	Indicates the manner in which the collision occurred (i.e. head-on, rear-end, angle, etc.).
Point of Impact	The portion of the vehicle that was first impacted in the crash.
Pre-crash Action	What the motorists were doing immediately prior to the crash.
Action	Describes whether the vehicle collided with, was struck by, or was striking another vehicle.
Circumstances	Identifies the actions of the motorists which contributed to the crash.
Sequence of Events	Describes what the vehicle did (i.e. ran off road right, collided with a deer, overturned, etc.) throughout the occurrence of the crash; allows for up to four events in sequence.
First Harm	Indicates which sequence of events produced the first property damage, injury, or death.
Most Harmful Event	Indicates which sequence of events produced the most severe injury or death.

The parameters listed above tell a story of how a crash occurs and the actions taken by drivers in each vehicle. These actions may relate to a driver's attempt to avoid a particular hazard or the effects of the hazard on the vehicle. Work zone setups that reduce the need for a driver to avoid a hazard or that will mitigate the effects of the hazard on the vehicle will reduce the amount of motorcycle crashes.

3.2.1.1.7 Occupant Information

The occupant information category describes the occupants, how they may have affected the crash, and how they may have been affected by the crash. This category covers both the driver and any passengers for each vehicle. Each occupant is described through their age, gender, seating position, use of safety equipment, and use of an air bag. The occupants may potentially increase the effect of a crash through the use of alcohol or drugs, which is indicated within this category of parameters. Any indication of how the occupants may have been affected by the crash is described – such as being ejected, injured, or trapped – is noted. These parameters may correlate to the actions of each driver and may indicate why the crash occurred in the manner in which it did.

3.2.1.2 OH-2 Crash Data

The OH-2 crash report provided by ODPS is a supplement to the OH-1 crash report. The OH-2 report provides narratives and descriptions of the events that occurred during the crash that the OH-1 reports could not adequately explain. Unfortunately, the reports associated with the crashes included in this study did not contain useful information regarding the explanation of the occurrence of the crashes.

3.2.2 ODOT Data Sets

In order to understand the decisions being made by each driver in the area of the work zone, the setup of the work zone needs to be identified. The setup includes the type of work occurring, the hazards that could affect each vehicle, and the arrangement of the roadway. Information regarding setups was obtained from ODOT, and it was broken down into the components associated with each work zone. ODOT provided three sets of data: construction plans, daily construction diaries, and a database of the construction dates. A breakdown of the data sets obtained from ODOT is presented in Figure 3.4.

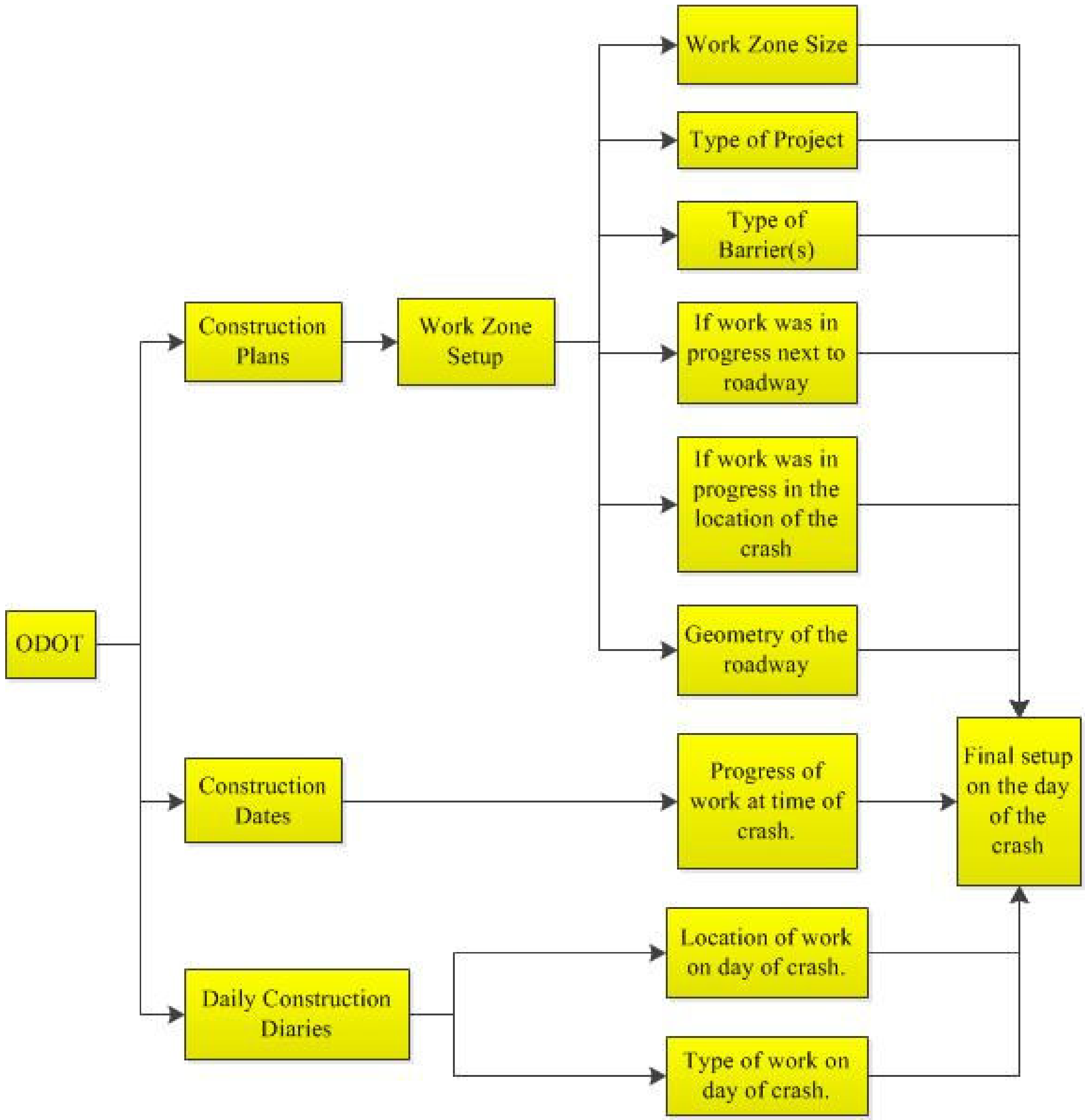

Figure 3.4: ODOT Data Sets

3.2.2.1 Work Zone Construction Plans

In order to better understand the setup of the work zone, the construction plans identifying the setup are obtained from ODOT. These construction plans contain a title sheet, notes, summaries, and maintenance of traffic (MOT) plans and cross sections. The title sheet identifies the type of project that the work is covering, the length (distance) of the work, the project's boundaries, and the standard construction drawings that coincide with the plans. The notes contain a variety of information including a sequence of the work to occur, detailed drawings identifying specific locations throughout the construction site, directions for installing traffic control devices, traffic signal timing, the use of barriers and shoulder treatments, notices for lane closures, and lane closure restrictions. The summaries identify the location and quantity of barriers, pavement markings, and pavement. The MOT plans and cross sections depict the setup of the roadway throughout each phase of construction. The phases of construction correlate to the setups of pavement markings, paths of travel, and location of barriers that are in use at the same segment of the roadway during different times in the construction process. The plans show various aspects of the roadway such as the lane lines, placement of portable concrete barriers (PCB), impact attenuators, drums, and the pavement being constructed.

The plans and cross sections are the most descriptive section of the construction plans. This portion of the plans depicts the setup of the work zone and identifies potential hazards near the path of travel. Through the analysis of the plans and cross sections, several variables are derived to enable each work zone to be compared to other zones. These variables (which may be seen in Figure 3.4 under the group "Work Zone Setup") include the work zone size, type of project, type of barrier(s) present, if work was in progress next to the roadway, if work was in progress in the location of the crash, and the geometry of the roadway.

A portion of the plans obtained for this study did not contain all of the information the research team was seeking. Some plans would only contain a title page, which is capable of displaying minimal amounts of information. Others contained more than the title page but were still lacking important information regarding the lane and shoulder widths in both the roadway cross sections and the plan views. This led to some variables being left with unknown values. The projects associated with these plans may have been more routine tasks, which do not require an in-depth description of the roadway; in addition, some variables (such as the type of barrier used) may change based on how the work is completed. For example, in a resurfacing project, the type of barrier used depends on the amount of pavement that is removed in the adjoining lane; more drastic changes in elevation require more robust barriers.

3.2.2.1.1 Work Zone Size

The size of the work zone is obtained in order to compare the amount of construction involved in each of the work zones. The work zone size is determined based on factors such as the length of the project, the number of phases and changes in MOT setups, and the complexity of the work being completed. The size of the work zones is described as small, medium, or large. Small projects generally had one to two phases and a length of up to three miles; while large projects consisted of more than four phases at all project lengths or consisted of two to four phases and a project length of seven miles or more. Medium-sized projects contain between two and four phases and a length of up to seven miles.

3.2.2.1.2 Type of Project

The type of project identifies the main focus and the majority of the work occurring on the project. This information is determined from the project description section of the title page of the construction documents. Depending on the extent of the work being completed, there is the possibility that a project may contain multiple types of work occurring at the same time. Some of the types of work include alignment change, bridge construction, pavement marking, and resurfacing.

3.2.2.1.3 Type of Barrier(s) Present

Barriers are used to separate the traffic on the roadway from the work being completed. Various types of barriers may have a different effect on motorcyclists in the event of a crash and collision with a barrier. Portable drums, for instance, may move into the travel path and may become an obstruction if contacted by another vehicle or if they are not adequately anchored. The types of barriers present in work zones in this study included PCB, portable drums, a combination of PCB and portable drums, or a barricade (which was used for a closed road).

3.2.2.1.4 Presence of Work in Progress Next to the Roadway

The presence of work in progress next to the roadway may contribute to crashes within a work zone. The proximity of the work to the roadway may lead to motorcyclists being distracted by the work, other vehicles being distracted by the work, changes in the roadway surface, or debris entering the path of travel. These issues may result in evasive action by a driver or loss of control by either the motorcyclist or the driver of another vehicle. The work is determined to be completed next to the roadway if the work occurred on the roadway or within a distance equal to the original width of the roadway as measured from the edge of the roadway.

3.2.2.1.5 Presence of Work in Progress in the Location of the Crash

Work is considered to be in progress in the location of the crash if the work occurred within 1,365 feet of the location of the crash. The 1,365 feet is the decision sight distance needed for a vehicle traveling at a speed of

65 mph (AASHTO, 2004). The decision sight distance is used when conditions are complex and driver expectancies differ from the actual situation. The maximum designated speed of 65 mph is used, because it is the maximum posted speed limit identified on the OH-1 crash reports. This provided the maximum length needed for a speed, path, or direction change on an urban road.

3.2.2.1.6 Geometry of the Roadway

The width of each lane, the width of shoulders, and the number of lanes for a roadway are recorded from the construction plan views or cross sections provided, and they relate to the traffic occurring in the same direction of travel as the crashing motorcycle. The variables recorded in the ODPS data set (original geometry) may fluctuate from the geometry values at the time of the crash (during construction). The geometry of the roadway during construction is based on the MOT setup used. For example, the roadway may originally contain three lanes with a twelve foot width and a five foot shoulder; however, the MOT for the construction reduced the path of travel to two lanes with an eleven foot width and a two foot shoulder. The width of each lane is the amount of space between pavement markings available for each vehicle to travel. If a lane shows variation in size, the smallest width is recorded for the lane. The shoulder width is determined as the shortest distance from the lane on the outside of the roadway to the edge of the pavement or barrier. The number of lanes is recorded for one direction of travel only. If each direction of travel occupies the same lane (using flaggers or signals), the number of lanes is recorded as 0.

3.2.2.2 Work Zone Daily Construction Diaries

In order to determine where and what type of work is occurring at the location of each crash, the research team obtained construction diaries from ODOT. A breakdown of the information obtained from the daily construction diaries is indicated in Figure 3.4. The diaries are notes from the construction site that state which contractors are on the site and what type of work they did. In order to obtain a clear understanding of what type of work is occurring for a given work site around the time of the crash, the research team looked at construction diaries for the two months preceding the month of the crash, in addition to those for the month in which the crash occurred.

The notes for any given day in the daily construction diary will occupy at least one page but may fill several pages depending on the type of work that was occurring. An example of the information provided in a daily construction diary is seen in Figure 3.5.

Project	Diary Date
05-0106	5/24/2007

County/Route/Section	PE/PS	District	Diary Entry Date	Diary Approved	Approval Date	Potential Claim
SAN SR-53 010.15		02	5/30/2007	Y	5/30/2007	N

Temp	Precipitation	Lost Day Due to Weather	Lost Day Due to Other Reasons	Remarks
60-85	NONE	N	N	

General Remarks
NUKE TESTING OF 304 AGG. SANDUSKY COUNTY WORK FORCE ON PROJECT TODAY TO REMOVE EMERGENCY ACCESS ROAD PUT IN (2006). SOUTH OF MUSK. BRIDGE, RT SIDE.

Contractor	Sublet	Work Stat	Superintendent	Work Hours
	0 0	WO		700AM-500PM
GRADING 304 AGG. AT NORTH SIDE OF R/R. WATERING AND COMPACT- ING. INSTALLED UNDERDRAINS AT SOUTH SIDE OF R/R. ALSO INSTALLED C.B., HEADWALL, AND 12" CONDUIT AT 496+74 LT.				

Supervisors	Skilled	Other	Alt1	Alt2	Alt3	Total Personnel for the Day
3	5	2	0	0	0	10

SubContractor	Sublet	Work Stat	Superintendent	Work Hours
	8 0	WO		700 AM TO 400PM
WEATHER CONDITIONS CHECKED IN AM AND, OK TO WORK. TOUCHED UP A FEW DEFICIENT AREAS WITH FINISH PAINT. APPLYING EPOXY FINISH COAT TO CONCRETE AT #1064 BRIDGE. THEN WENT TO R/R BRIDGE TO APPLY EPOXY PRIMER TO CONCRETE.				

Supervisors	Skilled	Other	Alt1	Alt2	Alt3	Total Personnel for the Day
1	3	2	0	0	0	6

State Employee Name	Hours Worked	Work Code	License Number
	10.5	5192	
	0.0	5192	
	0.0		
	0.0	5192	
	10.0	5192	
	0.0	5192	
	0.0	5192	
	0.0	5192	

Ref No.	Extra Work	Part Code	Item	Description	Location	Quantity/Amt ($)	Unit	Inspector ID
59	0	1	602E20000	CONCRETE MASONRY	496+74.1 LT	1.600	CY	JR
66	0	1	603E04600	12" CONDUIT, TYPE C	496+74.1 LT	63.000	FT	JR
83	0	1	604E00800	CATCH BASIN, NO. 3A	496+74.1 LT	1.000	EACH	JR
93	0	1	605E11100	6" SHALLOW PIPE UD	494+35-496+69,495+50-496+69LT	353.000	FT	JR

Figure 3.5: Work Zone Daily Construction Diary

From Figure 3.5, it may be seen that on May 24, 2007, workers from Great Lakes Construction Company compacted aggregate, installed underdrains, and installed sewer conduit. Also on this day, a subcontractor (Standard Contractors Inc.) was at work, painting a bridge. The location where the work was being performed may be seen at the bottom of the diary entry; for each item, there is a corresponding station location, and the side of the station is identified. The time that the work is being completed may also be seen for each of the contractors. The longest time range for a contractor was from 7:00 AM until 5:00 PM.

3.2.2.2.1 Location of Work on the Day of the Crash

The location of the work in relation to the crash is determined by the stationing associated with each item that is included in the construction process for the day. This stationing is coordinated with the construction plans in order to identify the specific location, since the construction plans are labeled with the same stationing identification. The work activities identified the station at which the work occurred; however, the lack of an offset distance from the center of the alignment made it difficult to pinpoint the exact location of the work. This leads to the possibility that work could have occurred on one side of the center alignment, but the knowledge of how far from the center alignment the work is located is unknown.

3.2.2.2.2 Type of Work in Progress on the Day of the Crash

The research team is able to identify the type of work performed on the day of the crash from information presented in the construction diaries. In order to reduce the loss of information regarding work that may have occurred around the day of the crash, if the crash occurred on a weekend or on a day with poor weather, the diaries for up to two days prior to the day of the crash are analyzed. For purposes of this study, the work occurring on these days is considered to have occurred on the day of the crash. The wide variety of projects that contribute to motorcycle crashes leads to a full spectrum of types of work occurring on the day of each crash. For some projects, multiple types of work occurred during the days around the crash. The wording for the type of work indicated in the construction diaries is generally able to be used as a collected variable. For example, aggregate placement had been written as "PLACED 304 AGG". Bridge construction, on the other hand, dealt with items involved in constructing a bridge, but the wording in the daily construction diaries contained a wide variety of terms (e.g. welding bearing pads to beams).

3.2.2.3 Database of Work Zone Construction Dates

The database of work zone construction dates is a table used to organize the dates of the crashes, construction projects, and construction diaries. As shown in Figure 3.4, this database is used to determine the progress of the work at the time of the crash. The database identified and indicated the project's beginning and ending dates (by month and year), the crash's date (by month and year), and the construction diary's beginning and ending dates (by month and year). The combination of this information and the provided dates enabled the research team to locate the point during the construction project when each crash occurred. This allows the research team to determine a timeline within the duration of the construction project for each crash to be compared. The timeline categories are broken down into several groups, as may be seen in Table 3.5.

Table 3.5: Occurrence of Crashes through the Duration of a Project

Category	Description
Short Duration	Project only listed as occurring for one calendar year.
Pre-construction	Crash occurred before the listed start date of the project.
Beginning	Crash occurred during the first third of the project duration.
Middle	Crash occurred during the middle third of the project duration.
End	Crash occurred during the last third of the project duration.
After Construction	Crash occurred after the listed ending date of the project.
Project in Progress	Project only listed a beginning date but no ending date.

These variables allow the team to determine that the amount of time that passed since the work zone was established showed a correlation with a crash occurring. Newer projects may show more crashes because the work zone may be unfamiliar to travelers, or existing projects may have conditioned travelers to not pay as close attention to the work zone as time passes.

3.2.2.4 Final Setup on the Day of the Crash

In order to determine the setup of the MOT, the research team must correlate the construction plans and the daily construction diaries. The process of determining the phase of the work is a time intensive process that involves comparing the work being completed on the construction diaries to the various layouts on the different phases in the construction plans. This process is very difficult because the construction diaries did not clearly identify the phases when a change in the MOT setup occurred and because the diaries lack specificity regarding the location of work being completed. For example, there may be paving listed at one side of a particular station in the construction diaries, but there may be paving that is done on this same side of the noted station in several phases throughout the construction plans. Even though the work is being completed on the same side of the alignment for multiple phases, the traffic may travel through different paths throughout these phases. The identification of the phase is essential in gaining the knowledge of a specific setup of the work zone. Also, notes may have been made that identify changes in the MOT and the setup of various barriers, but the location and phase of the MOT are not specified. Since the construction diaries lacked the specifics for the location, the diaries are sometimes compared to the different phases in the weeks or months prior to the date of the crash in order to determine a definitive phase of the project.

3.2.3 Linking ODPS and ODOT Data Sets Together by the Location and Date of the Crash

Information in ODPS data set is important to the acquisition of the ODOT data set. The location and date information for crashes found on the OH-1 reports is extracted and provided to ODOT, so that information on work zones could be extracted from ODOT's database.

The locations of the 454 motorcycle crashes in work zones are first determined by using the latitude and longitude data from the crash reports. The latitudinal and longitudinal data is either identified in degrees, minutes, seconds and decimal seconds (displayed as DD: MM:SS.SS), or decimal degrees (displayed as dd.dddddd). The degrees, minutes, seconds and decimal seconds need to be converted to decimal degrees in order to determine the exact location within the state of Ohio. Once the longitudes and latitudes were converted to decimal degrees for each crash point, the crash points are plotted in relation to the state of Ohio; all points that fell outside of the boundaries of the state were compiled for later relocation. As a result of this process, the precise locations of 334 crashes are identified, with the remaining 120 crashes to be located using other means.

The remaining 120 crashes are located manually by using the crash location and reference method. This method employed parameters from the location condition category of the OH-1 crash report and, through a time-consuming process consisting of several steps, used the parameters to place the crash at the correct location. The sequence of this process is seen in Figure 3.6.

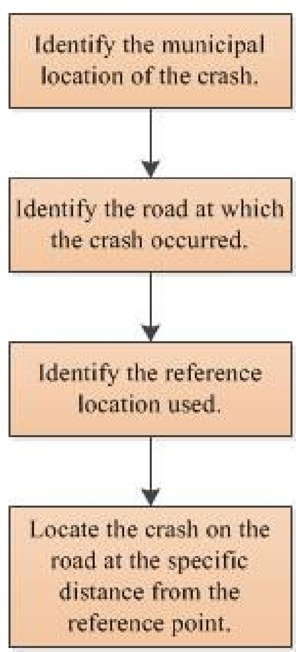

Figure 3.6: Manual Crash Location Process

To locate a crash manually, the FIPS Place Name is first identified in order to find the municipal location of the crash. Next, the municipal location is inspected to identify the road at which the crash occurred. This task was accomplished by using the following variables: crash location, crash prefix, street designation, and the type of location point used. Next, the road at which the crash occurred is inspected to identify the reference location used. This task was accomplished by using the following variables: Reference Prefix, Reference Point, Reference Designation, and Reference Point Used. Finally, the location of the crash was identified by using the length recorded for the variable Distance from the Reference and by using the direction recorded in the variable Direction from the Reference.

Of the 120 crash locations that were originally compiled for later relocation, only nine are not able to be located via the manual location process. This is due to the lack of information in both the longitude and latitude data and the crash location referencing. The remaining locating information is in the variable NLF ID and the Log distances available; however, in each of the nine remaining missing location crashes, the Log distance was insufficient to provide the relevant identification.

Of the 454 motorcycle crashes occurring in work zones, 98% are located. A summary of the efforts to determine the crash locations is seen in Table 3.6.

Table 3.6: Methods for Locating Crashes

Number of Crashes	**Locating Method**
311	Latitude and longitude data
133	Crash location and reference method
10	Not located
454	**Total**

The table above shows that 24% of the crashes had to be located by manually identifying the road on which the crash occurred, the reference location indicated, and the distance from that reference location. The location of each crash was important in identifying both the work zone associated with the crash and the setup of the work zone at the time of the crash.

The precise location of the motorcycle crashes in work zones allows the research team to obtain the construction plans corresponding to these crashes from ODOT. ODOT compiled the plans by cross-referencing the location of the crash and the date the crash occurred on with a database of construction documents. The cross-referencing process identified work zones that occurred at the same location and during the same time interval as the crash. This process resulted in the collection of 170 projects, which attributed to 219 of the 454 total crashes.

Projects associated with the remaining 235 crashes could not be immediately found. These remaining crashes are often located on a cross street or intersection that is not listed as part of the project, on a detour route, in an area where an ODOT work crew is performing routine tasks such as pothole patching, or in places where a utility crew or site developer may have disrupted the flow of traffic. In some cases, the team may still be able to determine additional information, as with a crash that occurs on a cross street. If a crash is seen to occur in close proximity to a known project, it is analyzed to determine its relation to the adjacent project. In the instance of a detour route, the location for each crash with an unknown project would need to be compared to the locations of all projects that occurred in the surrounding areas. In the instance of an ODOT work crew performing routine tasks, there are no plans associated with this type of project, and traffic control would be set up according to the Ohio Manual of Uniform Traffic Control Devices (OMUTCD). In the instance of a utility crew or site developer disrupting the flow of traffic, there will be no plans that are associated with this type of project.

In order to retrieve missing plans, the local municipalities (as listed on the OH-1 crash reports) are contacted. Unfortunately, no additional construction projects are able to be located. The City of Berea indicated that their construction plans are not kept for more than 90 days after the work is completed, and this response is similar to those of other municipalities that are contacted. In other cases, plans are not able to be obtained because the crash did not occur directly on the roadway being worked on, the work which occurred is not required to have plans associated with it, or the plans may not be available for various other reasons.

While this lack of plans may have contributed to the lack of other information important to characterizing motorcycle crashes in work zones, lack of completeness of existing construction plans was also an issue. Two obstacles that are commonly identified as hazards to motorcyclists are steel plates and rumble strips; however, there was no information regarding these two types of obstacles in the construction plans that were obtained.

3.2.4 Synergy of ODPS and ODOT Data Sets

The partnership of the ODPS and ODOT data sets allows the research team to perform an in-depth analysis of the factors contributing to motorcycle crashes in work zones. In order to use the ODOT data sets, information from the ODPS data set is needed. Information from the OH-1, construction plans, and daily construction diaries may be coordinated. The research team used the date, location, and direction information provided in the OH-1 crash reports to collect information from the ODOT data sets. The construction plans are useful, but the research team relied on the OH-1 reports to determine the location of the crash within the work zone. The phase of the construction plans was determined from the construction diaries, which identified the work occurring on and around the date of the crash (as obtained from the OH-1 report).

3.2.5 End Goal

The collaboration of the two data sets provided an extensive amount of information, allowing an in-depth study of the contributing factors in motorcycle crashes in work zones. This aggregation of data sets allowed for ten new variables, specific to the work zone, to be combined with the OH-1 reports. The variables collected result from data sets that have not previously been analyzed together for motorcycle crashes. The exploration of the OH-1 crash reports has been examined in prior studies, but the combination with the work zone construction plans, daily construction diaries, and construction dates is a new avenue of investigation.

3.3 ODOT and ODPS Data Sets Results

The collection of data from the ODOT and ODPS data sets provided in-depth information on the occurrence of each crash. The research team analyzed the crashes in two different ways, using descriptive statistics and a multinomial logit model.

3.3.1 Descriptive Statistics

The descriptive statistics identify factors related to each crash. These factors summarize the conditions and any related events which occurred throughout all of the crashes. The descriptive statistics are broken down into three different groups: general crash related, rider related, and work zone related.

3.3.1.1 General Crash Statistics

The general crash related categories identify aspects of the crash related to the occurrence, roadway, and conditions present at the time of the crash. This section of the descriptive statistics identifies the relation of the work zone crashes to the time of day, roadway functional class, speeding, pre-crash actions, and contributing circumstances.

The work zone crashes are spread throughout each of the four different time categories: morning, afternoon, evening, and night. The majority of the crashes occurred during the afternoon and evening time periods; each accounted for about 35% of the crashes (Figure 3.7). The amount of morning crashes contained the next highest amount of crashes at about 21%. The remaining 10% of the crashes occurred in the night time.

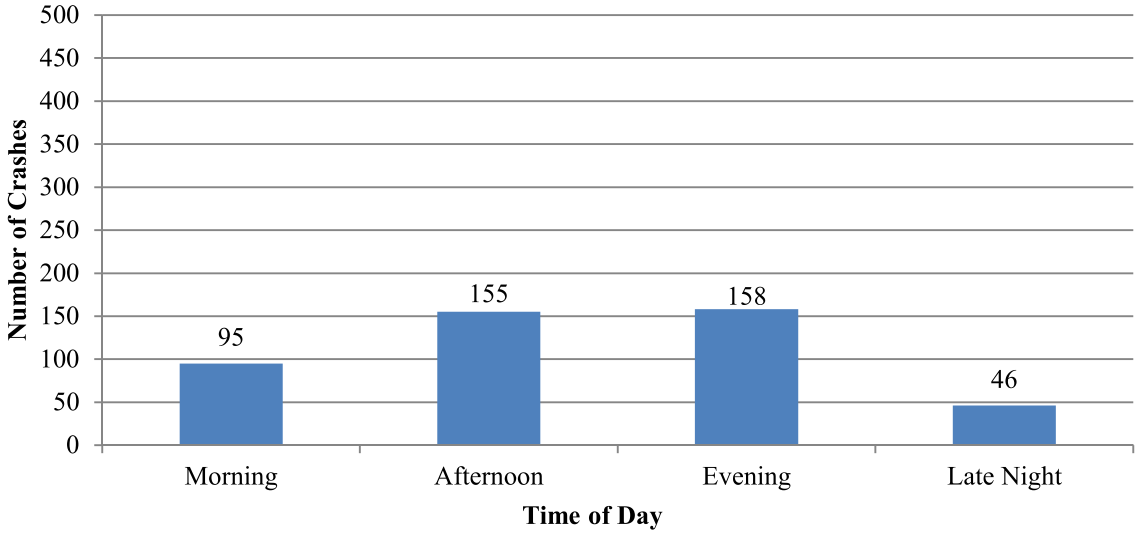

Figure 3.7: Crashes Based on Time of Day

The motorcycle crashes in work zones occurred throughout all types of roadway functional classes. Approximately 20% of the total amount of crashes occurred on principal arterial interstates in urban locations. Principal arterial roadways in urban locations that are not interstates, freeways, or expressways or that are minor arterial roadways in urban locations returned the next highest amount of crashes at about 12% of the crashes each. The remaining types of roadways accounted for a maximum of 5% of the crashes for each category. The distribution of crashes over all of the roadway functional classes is seen in Figure 3.8.

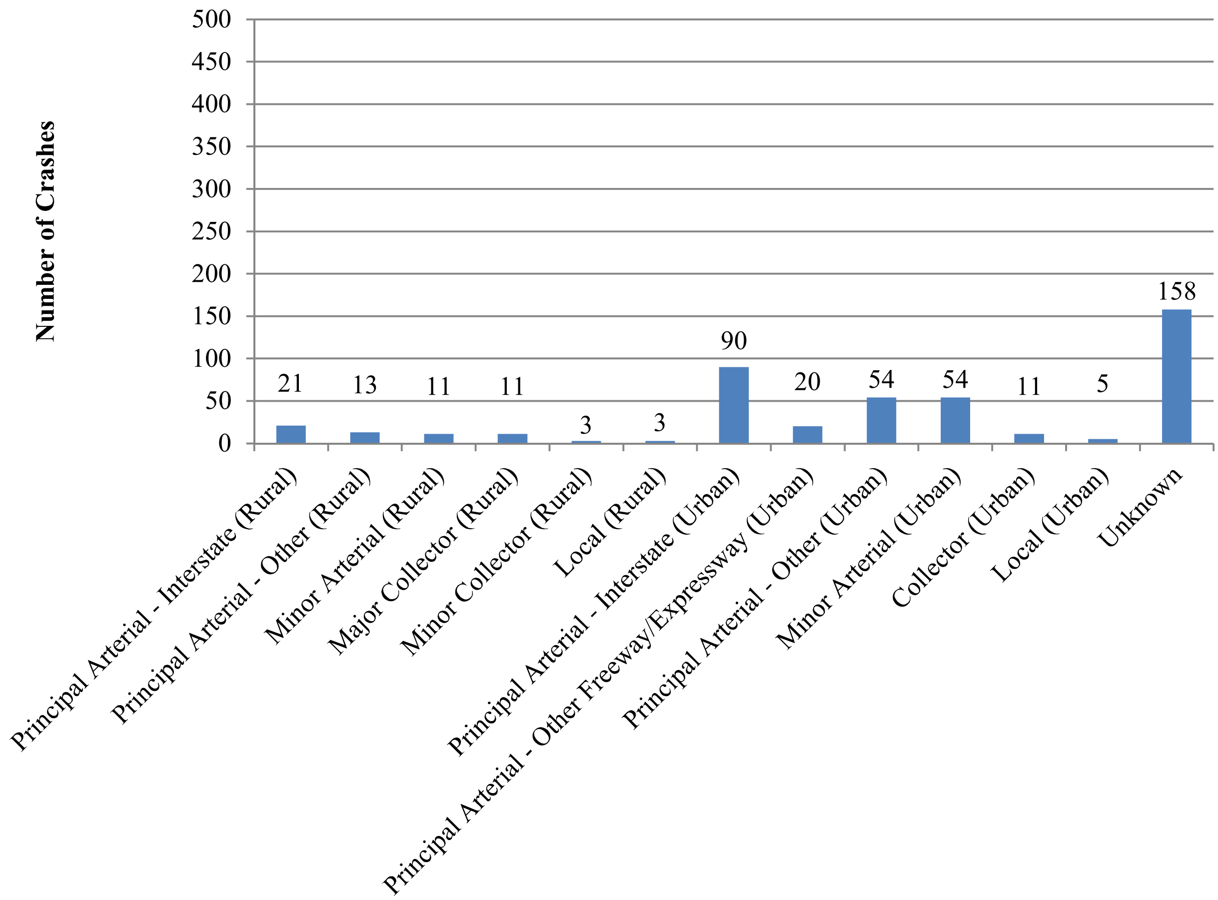

Figure 3.8: Crashes Based on Functional Class

The vast majority, 96%, of the crashes occurring in the work zones are not related to speeding (Figure 3.9).

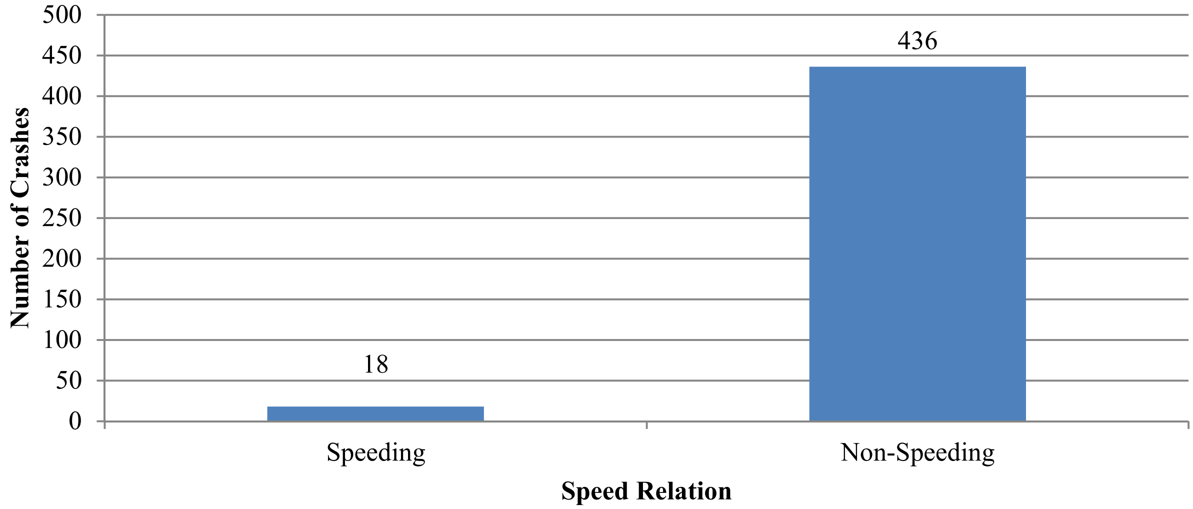

Figure 3.9: Speeding Related Crashes

The majority of the crashes, 73%, occur when the motorcyclist is moving essentially straight ahead in relation to the motorcyclist turning, backing, changing lanes, or performing other movements (Figure 3.10). Only 11% of the crashes occur with the motorcyclist slowing or stopping in traffic. An even smaller amount of the crashes, 5%, occurred when the motorcyclist was changing lanes. The remaining pre-crash actions contributed a maximum of 2% each of the total number of crashes.

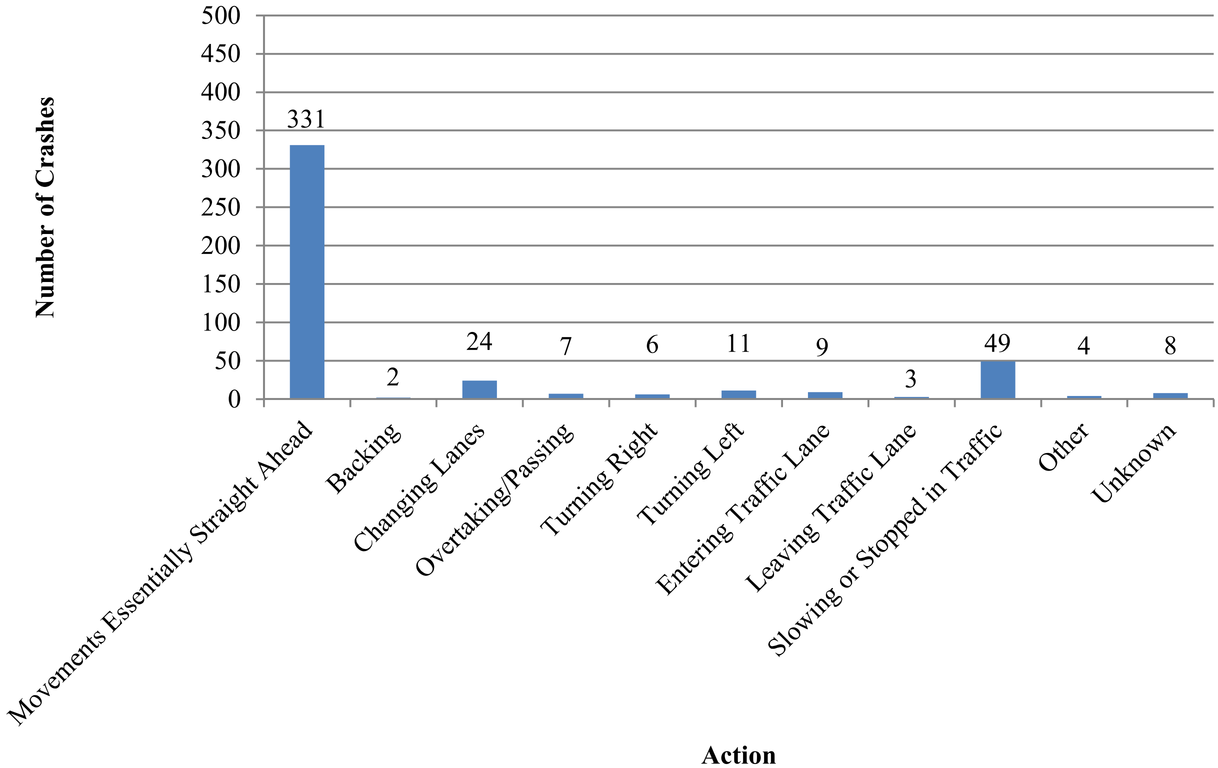

Figure 3.10: Crashes Based on Pre-Crash Actions

A total of 32% of the crashes did not contain a contributing circumstance (Figure 3.11). Of the crashes that did, a motorcyclist having a failure to control is the most common type of circumstance, at 22% of all of the crashes. The next significant type of crash circumstance is following too closely, which accounted for about 17% of all crashes. The remaining crash circumstances (such as failure to yield, left of center, unsafe speed, driver inattention, improper lane change, or unknown) each accounted for 6% or less of the total number of crashes.

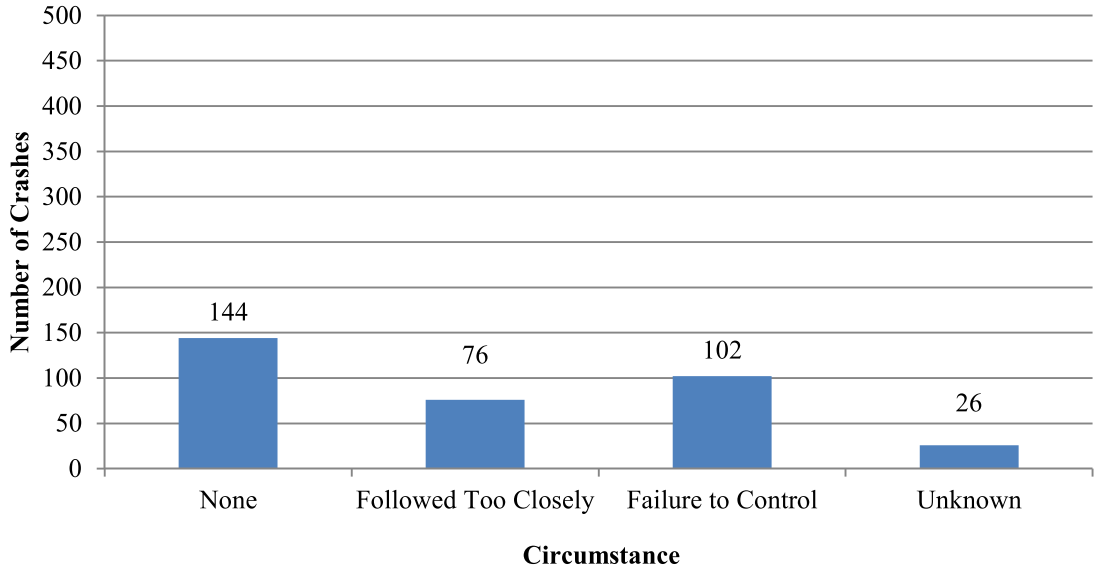

Figure 3.11: Crashes Based on the Top Contributing Circumstances

3.3.1.2 Rider Related Statistics

The rider related categories pertain to the characteristics of the persons involved in the crash. These characteristics contain general information about the riders and their mental states at the time of the crash. This section of the descriptive statistics identifies the relation of the work zone crashes to the gender of the driver, age of the driver, presence of a passenger, and the driver's use of alcohol.

Figure 3.12 indicates that the overwhelming majority of the crashes, 91%, contained a motorcycle driver who was a male. A total of 4% of crashes were related to female motorcycle drivers. In the remaining 5% of crashes, the gender of the driver was unknown.

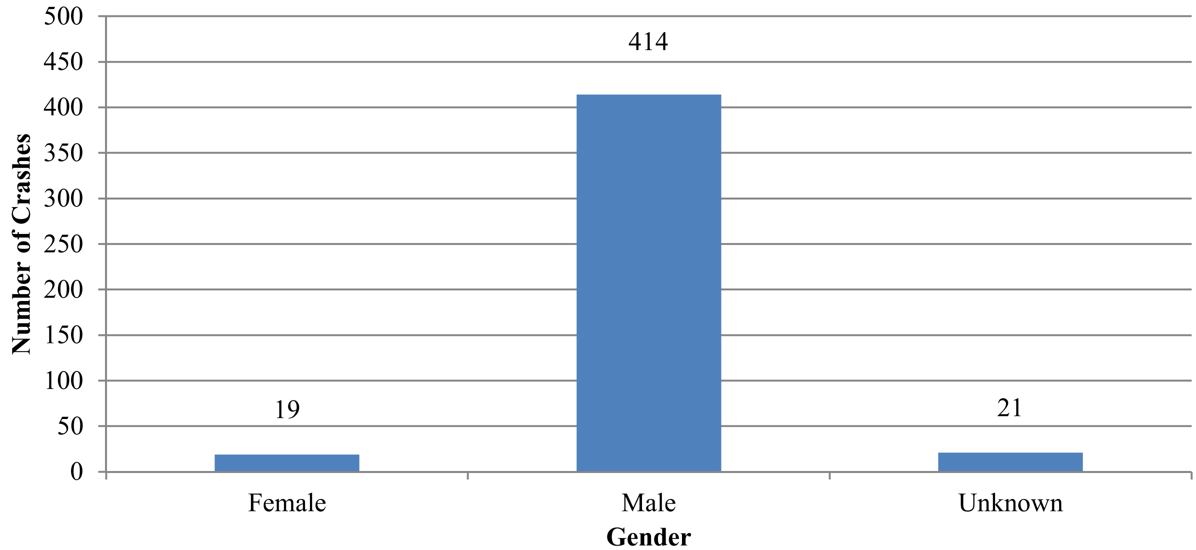

Figure 3.12: Crashes Based on Gender

The frequency of work zone crashes for all of the age groups is presented in Figure 3.13. The age range of the motorcyclists is fairly spread out through several age ranges. The 40-49 year old age range contained the most crashes at 26% of the crashes. The 50-59 year old and the 29 and younger riders contain the next highest amount, at 20% of the crashes each. The 30-39 year old range follows closely with about 17% of the crashes. Falling well behind the others are the 60-69 year old and 70 and over drivers, who resulted in 10% and 2% of the crashes respectively. There are 5% of the crashes in which the driver's age is unknown.

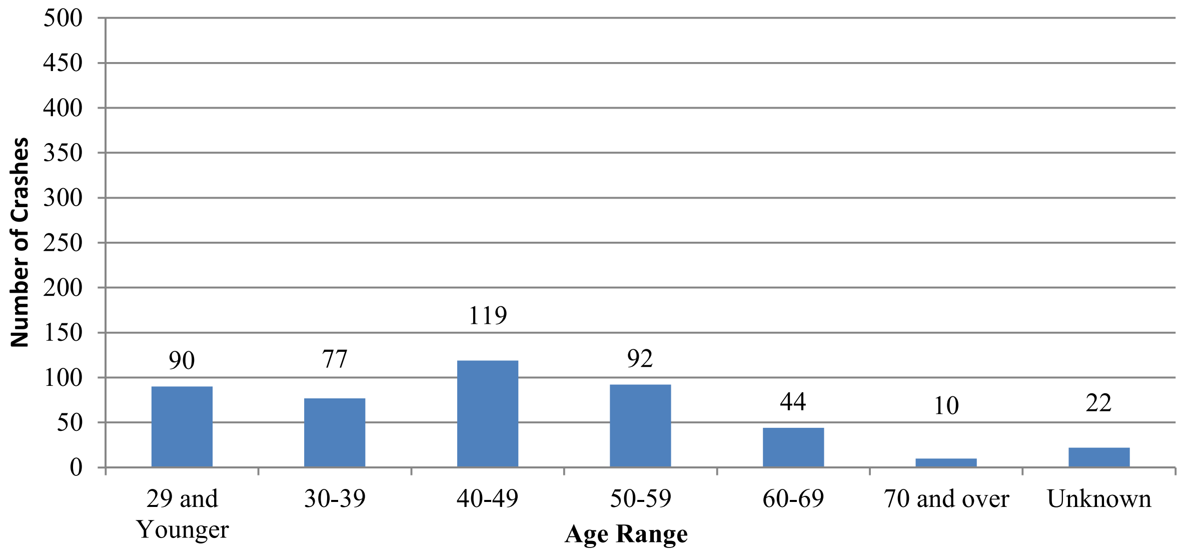

Figure 3.13: Crashes Based on Age

A vast amount of the crashes, 92%, occurred with motorcycles containing only a driver (Figure 3.14). Crashes involving a passenger on the motorcycle accounted for 8% of the crashes.

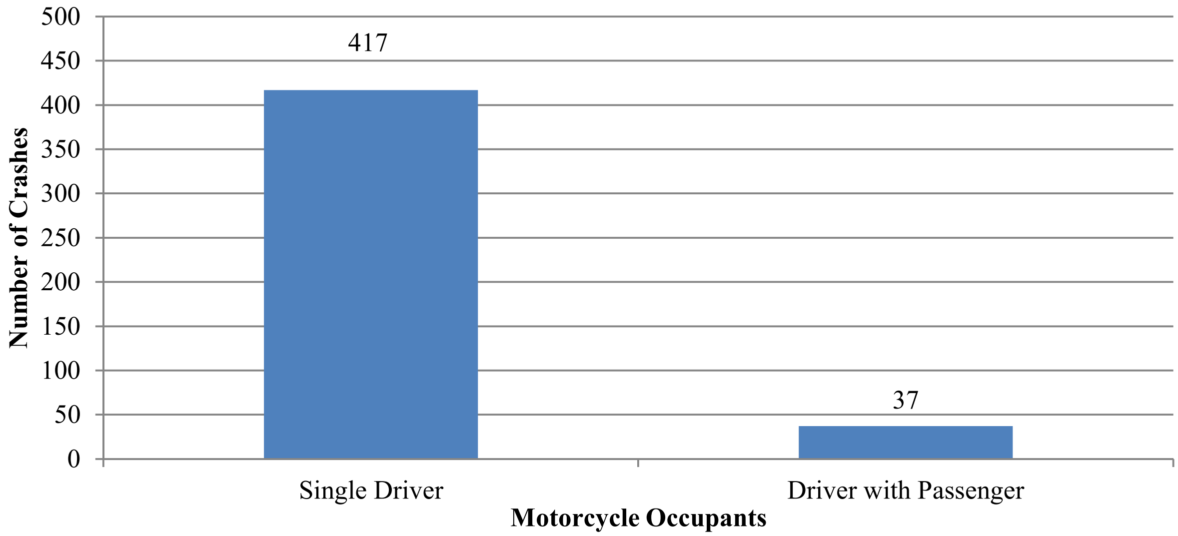

Figure 3.14: Crashes Based on Presence of a Passenger

As may be seen in Figure 3.15, only 9% of the crashes are alcohol related. The majority of the crashes, about 83%, are not related to the involvement of alcohol. In the remaining 8% of the crashes, the involvement of alcohol is unknown.

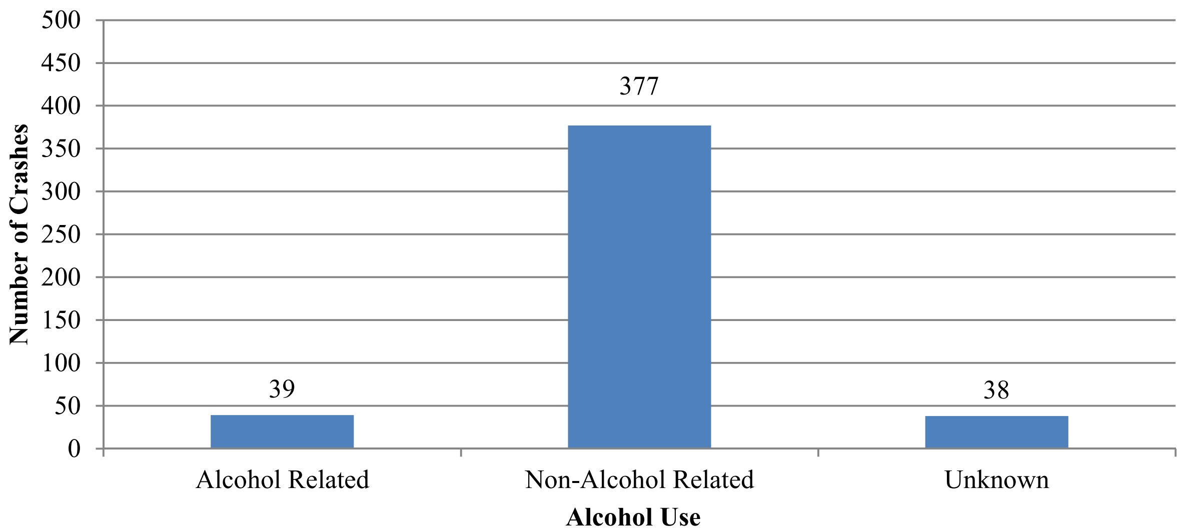

Figure 3.15: Crashes Based on Alcohol Use

3.3.1.3 Work Zone Related Statistics

The work zone related categories refer to the setup of the traffic control in the work zones and the work occurring in these locations. These categories are obtained from both the OH-1 reports and the construction documents obtained from ODOT. This section of the descriptive statistics identifies the relation of the work zone crashes to the type of work zone, the location within the work zone, the work zone size, barrier use within the work zone, and the type of work being performed in the work zone.

Lane closures are the most common type of work zone where motorcycle crashes occur (Figure 3.16), representing 37% of the crashes. Work on the median or shoulder returned the second highest level of work zone crashes, with 19% of the crashes. Lane shifts and crossovers follow closely behind, with 16% of the crashes. Of the known work zone types, intermittent or moving work resulted in the lowest amount of crashes at 12%. The unknown and other types of work zones correlated to about 17% of the crashes.

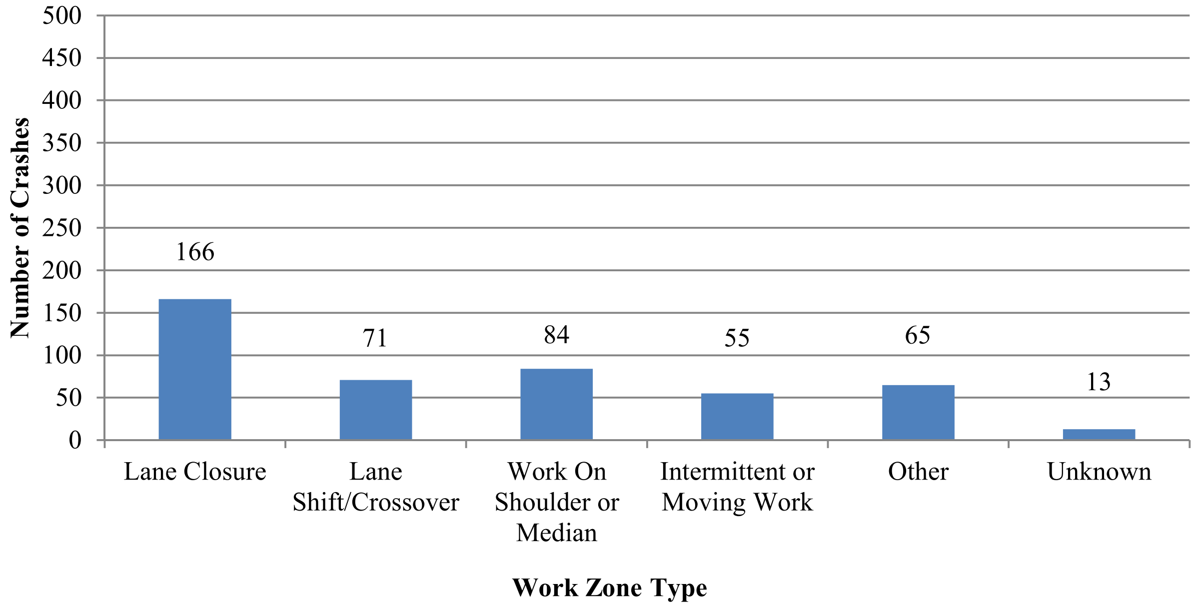

Figure 3.16: Crashes Based on Work Zone Type

The distribution of the location of the crashes within the work zones is seen in Figure 3.17. A large difference is noted for crashes occurring in the activity area of a work zone, as opposed to other sections of the work zone. The majority of the crashes occurred in the activity area of the work zone, which accounted for 58% of the crashes. The transition area returned the next highest number of crashes, at 19% of work zone location crashes. The advanced warning area followed not far behind, with 11% of the crashes. The area before the first work zone warning sign returned the second lowest number of crashes, with 7%. The last of the identified areas was the termination area, which included about 1% of the crashes. The remaining crashes occur in an unknown area within the work zone, and these accounted for only 4% of the crashes.

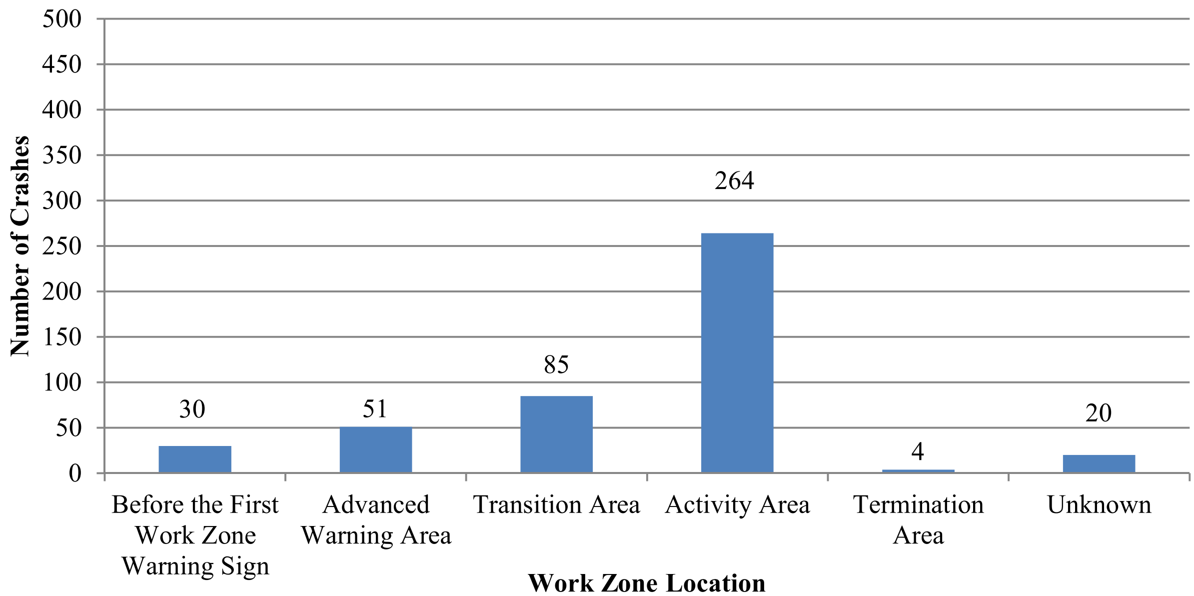

Figure 3.17: Crashes Based on Work Zone Location

Of the crashes where the work zone size is identified, the sizes of the work zones were fairly similar. Most of the identified work zones, about 20%, end up being medium sized zones (as may be seen in Figure 3.18). Large work zones contained about 14% of the crashes, while small work zones accounted for about 13% of the crashes. In 53% of the crashes, the size of the work zone was not known.

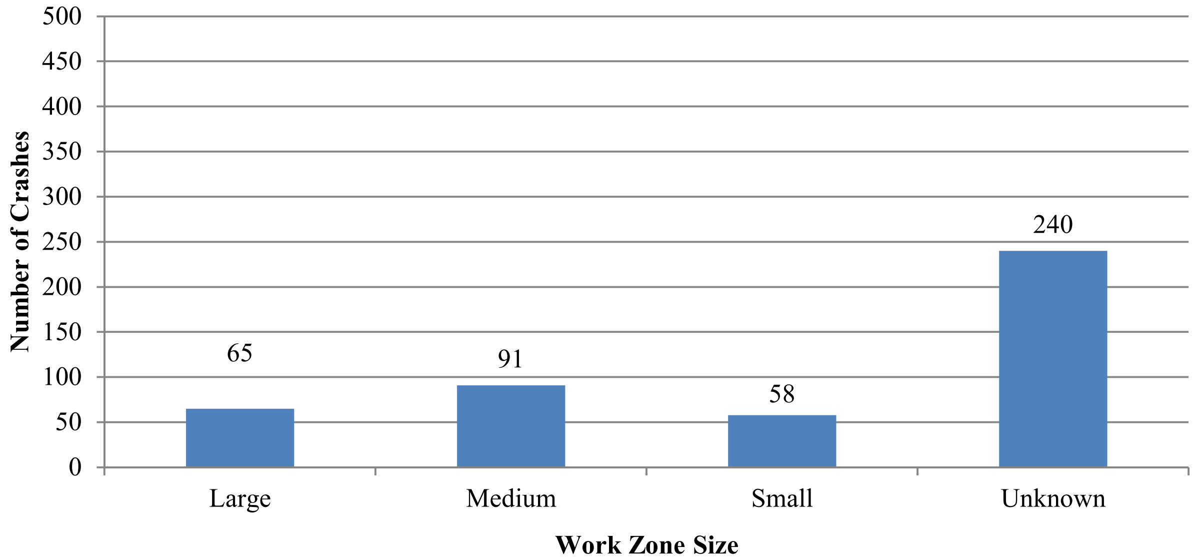

Figure 3.18: Crashes Based on Work Zone Size

The types of barriers used in the work zones in which crashes occurred are summarized in Figure 3.19. Drums are the most commonly used barrier, and they are found in work zones in 24% of the crashes. PCBs are used in work zones in 10% of the crashes. The combination of drums and PCBs is the barrier system found in work zones with the least amount of crashes, at 6%. Only one crash is attributed to a barricade closing off a roadway, and this represented less than 1% of all of the crashes. Only 3% of the crashes did not involve a barrier within the proximity of the crash. In 57% of all of the crashes, the use of barriers in the work zone is unknown.

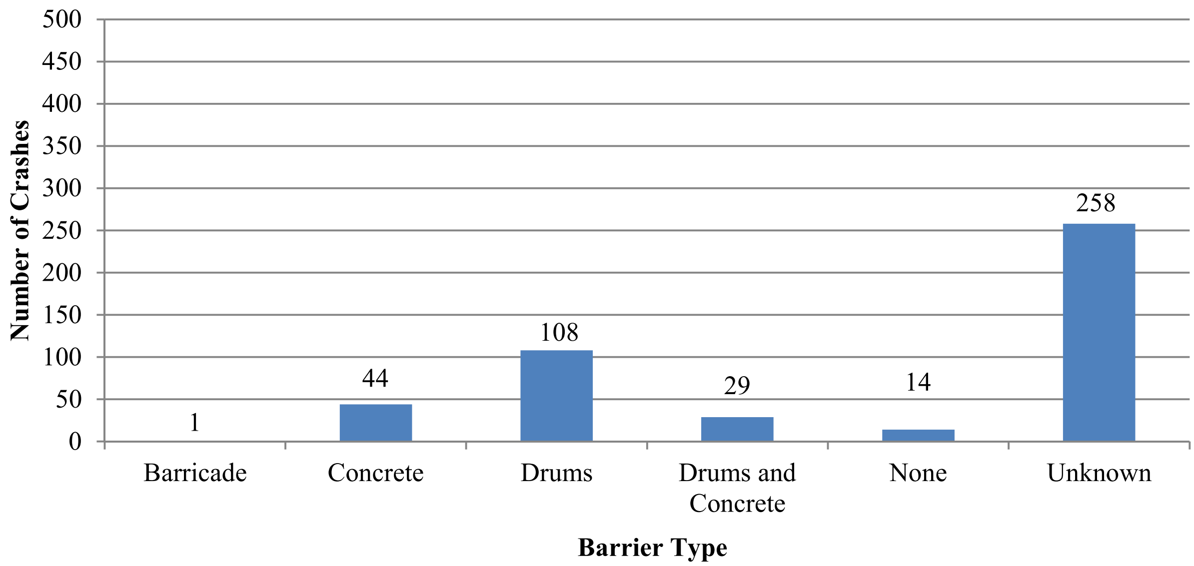

Figure 3.19: Crashes Based on Presence of Barrier

In the 454 crashes considered in this study, there are 44 different types of work being completed on the day of the crash. Several of these types of work are associated with a larger number of the crashes than the remaining types of work, and Figure 3.20 identifies and quantifies the crashes for these outstanding types of work. Paving is occurring during 20% of the crashes, which is the most of all of the types of work being performed. Excavation is occurring during 14% of crashes, and 12% of the crashes occurred in zones where pavement marking is taking place on the day of the crash. Pavement milling activities are taking place during 10% of the crashes. Aggregate placement occurs during one less crash but still at 9% of the total amount of crashes. Bridge construction and pouring concrete follow close behind, occurring during 9% of the crashes. For 5% of the crashes, no work is being performed on the day of the crash. Unfortunately, for 57% of the crashes, there is no information relating to the type of work occurring on the day of the crash.

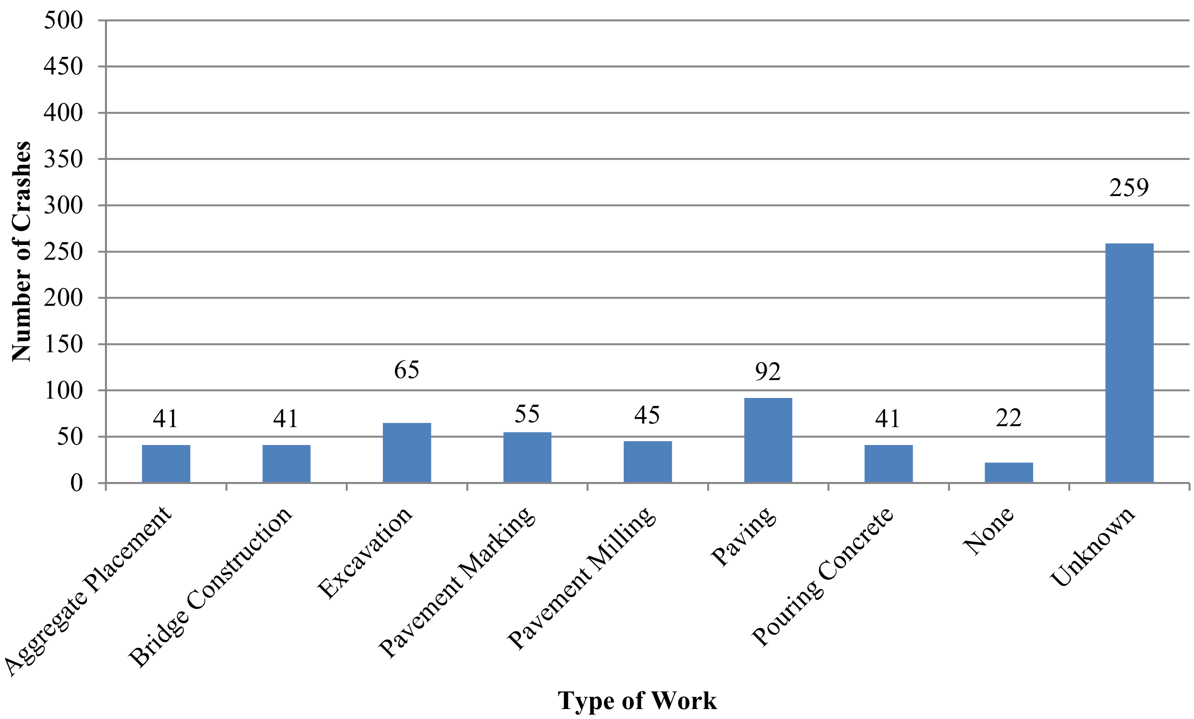

Figure 3.20: Crashes Based on the Most Common Work Occurring on Day of Crash

3.3.1.3.1 Grouped Type of Work and Project Type

To facilitate adequate modeling of the type of work being performed on the day of the crash, the types of work are combined into groups where similar duties are performed. These groups are also similar in the location of the work being performed and the materials being used. If the types of work are analyzed prior to grouping, using a large number of work types with small numbers of crashes would not result in an acceptable model. Grouping of the types of work resulted in eight groups: seven new groups, plus one type of work that could remain in its own group. The grouping of the project types resulted in five new grouped project types and one project type remaining by itself. The crashes are broken down into the number of the crashes that occur for the type of work being performed and the severity of the crash. Since a crash may occur during a project with multiple types of work, each crash is counted only once; this avoids the possibility of counting one crash multiple times. These crashes are additionally recognized by the number of crashes that are not related to the type of work or project. The amount determined is derived from the number of crashes where a type of project or work was identified and was correlated to a crash. Not all of the 170 identified projects contained both a construction diary and construction plans; therefore, for the type of work occurring on the day of a crash, there were a total of 271 crashes that did not have a construction diary associated to them. In all, there were 183 crashes that contained a type of work attributed to the crash. For the type of project, there were 242 crashes that did not contain construction plans to identify the project type associated to them. In all, there were 212 crashes that contained a project type attributed to the crash. The severity of the crash, for each type of work and project, is attributed to the injury occurring to the driver of the motorcycle.

3.3.1.3.1.1 Work Type Grouping

The new group named "bridge work" is a combination of any type of work being completed on the structure of a bridge. The types of work combined for this new group are: bridge construction, bridge demolition, and sand blasting. The number of crashes for each type of work and their injury severity with the new group's combined value are seen in Table 3.7. This group related to 43 crashes, two of which were fatal.

Table 3.7: Bridge Work Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Bridge Construction	41	142	3	1	18	12	2	5
Bridge Demolition	3	180	1	0	1	1	0	0
Sand Blasting	7	176	0	0	3	2	0	2
Totals* **	**45**	**138**	**4**	**1**	**19**	**13**	**2**	**6**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

The combined group named “aggregate work” is created by grouping work that involved the use of aggregates. The types of work included aggregate compaction and aggregate placement. Table 3.8 indicates the number of crashes attributed to each type of work and the severity of the injury in the associated crash. This group is associated with 49 crashes, two of which are fatal.

Table 3.8: Aggregate Work Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Aggregate Compaction	17	166	3	1	10	2	0	1
Aggregate Placement	41	142	6	3	17	11	2	2
Totals***	**51**	**132**	**9**	**3**	**23**	**12**	**2**	**2**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

The mixture of work that involved the movement and containment of soil is used to create a new group named “earthwork.” This group contains the following types of work: backfilling, compacting of backfill, embankment construction, subgrade compaction, seeding and mulching, clearing and grubbing, grading, erosion control, and excavation. The crashes involved with each type of work, the injury severity for each, and the injury severity associated with the new group’s combined values are seen in Table 3.9. The earthwork group related to 77 crashes and contained the highest number of crashes with fatal injuries (a total of four) of all of the new grouped types of work.

Table 3.9: Earthwork Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Backfilling	4	179	0	0	3	1	0	0
Compacting Backfill	1	182	0	0	0	1	0	0
Embankment Construction	10	173	0	0	5	2	1	2
Subgrade Compaction	7	176	3	0	1	3	0	0
Seeding and Mulching	12	171	1	2	5	4	0	0
Clearing and Grubbing	3	180	1	0	0	1	0	1
Grading	7	176	0	1	2	1	2	1
Erosion Control	2	181	1	0	1	0	0	0
Excavation	65	118	9	4	27	18	2	5
Totals*	**79**	**104**	**10**	**5**	**30**	**23**	**4**	**7**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Work that occurs just off of the edge of the roadway, either on the median or on the shoulder, is combined into a new group named "median or shoulder work." This group includes the following types of work: guardrail construction, concrete barrier construction, median construction, PCB installation, noise wall construction, surveying, and retaining wall installation. This new group's combined value, related crashes, and associated injury severity are seen in Table 3.10. This group was related to 21 crashes and was associated with only one fatality.

Table 3.10: Median or Shoulder Work Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Guardrail Construction	8	175	2	0	0	2	1	3
Concrete Barrier Construction	4	179	1	0	2	1	0	0
Median Construction	1	182	0	0	1	0	0	0
PCB Installation	3	180	0	0	1	1	0	1
Noise Wall Construction	6	177	1	0	2	2	0	1
Surveying	1	182	0	0	0	1	0	0
Retaining Wall Installation	1	182	0	0	0	1	0	0
Totals* **	**21**	162	**3**	**0**	**5**	**7**	**1**	**5**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

The inclusion of work that is completed towards the creation or removal of either asphalt or concrete pavements is used for the formation of the new “pavement work” group. This group contains the following types of work: pavement cleaning, pavement inspection, applying tack coat, obtaining core samples, saw cutting, concrete curing, concrete removal, power washing, pavement repair, milling, and paving. The crashes attributed to the types of work and the associated injury severities for the new group are seen in Table 3.11. This grouped project type related to 122 crashes and contained the second highest number of crashes with fatal injuries (a total of three) of all of the new grouped types of project.

Table 3.11: Pavement Work Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Pavement Cleaning	16	167	2	1	4	8	0	1
Pavement Inspection	1	182	0	1	0	0	0	0
Applying Tack Coat	4	179	1	1	1	1	0	0
Core Samples	1	182	0	0	0	1	0	0
Crack Sealing	2	181	1	0	0	1	0	0
Saw Cutting	12	171	0	0	5	5	0	2
Concrete Curing	4	179	0	1	2	1	0	0
Concrete Removal	5	178	1	1	2	0	0	1
Power Washing	6	177	0	0	3	3	0	0
Pavement Removal	14	169	0	0	4	6	0	4
Pavement Repair	5	178	1	0	4	0	0	0
Milling	45	138	8	4	17	13	1	2
Paving	92	91	9	4	42	26	3	8
Totals***	**130**	**53**	**15**	**8**	**56**	**37**	**3**	**11**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Work being performed on the surface of the pavement in terms of directing the movement of traffic is combined to form the “traffic control” group. This group includes the following types of work: pavement marking, pavement marking removal, change in MOT, traffic control installation, and LEO on site. The crashes pertaining to these types of work and the severity of injury associated with for the new group are seen in Table 3.12. The traffic control group related to 68 crashes, two of which were fatal.

Table 3.12: Traffic Control Grouped Work Type

			Crash Severity*					
Type of Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Pavement Marking	55	128	5	3	26	14	2	5
Pavement Marking Removal	2	181	0	0	1	1	0	0
Change in MOT	9	174	0	0	4	3	0	2
Traffic Control Installation	8	175	2	1	3	2	0	0
LEO on Site	23	160	5	3	7	7	0	1
Totals* **	**71**	**112**	**10**	**4**	**31**	**20**	**2**	**6**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Types of work completed on various utilities and connections to those utilities are joined to form a new group named "utility work". This group includes the work of sewer construction, underdrain installation, utility work, and lighting installation. The types of work, the crashes related to each, and the severity of injuries associated with each are seen in Table 3.13. The utility work group related to 45 crashes with a total of only one fatality.

Table 3.13: Utility Work Grouped Work Type

Type of Work	Crashes Related to Work	Crashes Not Related to Work**	Crash Severity*					
			Property Damage Only	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown
Sewer Construction	22	161	4	0	13	3	1	1
Underdrain Installation	21	162	3	2	8	5	1	2
Utility Work	14	169	1	1	5	5	0	2
Lighting Installation	1	182	0	0	1	0	0	0
Totals* **	**47**	**136**	**7**	**2**	**21**	**12**	**1**	**4**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Because the pouring of concrete is included in a wide range of work activities, it is difficult to assign this type of work to one particular combined group. For this reason, pouring concrete remains in a group of its own. This type of work is associated with 38 crashes and only one fatality. The number of crashes attributed with this type of work and the severity of the injuries associated with these crashes are seen in Table 3.14.

Table 3.14: Pouring Concrete Work Type

Type of Work	Crashes Related to Work	Crashes Not Related to Work**	Crash Severity*					
			Property Damage Only	Possible	Non-Incapacitating	Incapacitating	Fatal	Unknown
Pouring Concrete	41	142	6	1	16	14	1	3

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.

The highest number of fatal injury crashes occurs during the earthwork group type of work, with four fatalities. The second highest number of fatal crashes occurs during the pavement work grouped type of work, with three fatalities. These two groups of work also contain the highest numbers for the incapacitating injury crashes. A summary of the number of crashes and the severity of injuries associated with these grouped types of work are seen in Table 3.15.

Table 3.15: Grouped Work Type Summary

			Crash Severity*					
Grouped Work	**Crashes Related to Work**	**Crashes Not Related to Work****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Bridge work	45	138	4	1	19	13	2	6
Aggregate work	51	132	9	3	23	12	2	2
Earthwork	79	104	10	5	30	23	4	7
Median and Shoulder work	21	162	3	0	5	7	1	5
Pavement Work	130	53	15	8	56	37	3	11
Traffic Control	71	112	10	4	31	20	2	6
Utility work	47	136	7	2	21	12	1	4
Pouring Concrete	41	142	6	1	16	14	1	3

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of work out of the total number of crashes, 183, that contained the ability to obtain relevant information from the daily construction diaries.

3.3.1.3.1.2 Project Type Grouping

Projects where the design of the roadway is altered or where there are changes in how traffic is directed are combined into a new group named "traffic configuration." This new group includes projects involving an alignment change, realignment, widening, changes in traffic control, and interchange construction. These types of projects, the crashes associated with the projects, and the severity of associated injuries may be seen in Table 3.16. This group was associated with 103 crashes and one fatality.

Table 3.16: Traffic Configuration Grouped Project Type

			Crash Severity*					
Project Type	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Alignment Change	3	209	3	0	0	0	0	0
Realignment	2	210	0	0	2	0	0	0
Widening	93	119	17	7	40	20	1	8
Change in Traffic Control	6	206	2	0	3	1	0	0
Interchange Construction	28	184	5	0	8	14	1	0
Total*	**105**	**107**	**19**	**7**	**41**	**29**	**1**	**8**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Projects that only involved work on pavements without the use of a new alignment are included in a group named “pavement work”. This new group of project types includes crack sealing, resurfacing, roadway construction, and pavement marking. Types of projects, the crashes associated with these projects, and the severity of injuries associated with each may be seen in Table 3.17. This group is associated with 164 crashes and contains the highest number of fatal injury crashes (a total of four) of all of the new groups.

Table 3.17: Pavement Work Grouped Project Type

			Crash Severity*					
Project Type	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Crack Sealing	5	207	1	0	1	2	0	1
Resurfacing	132	80	24	11	57	24	4	12
Roadway Construction	36	176	1	2	14	16	0	3
Pavement Marking	4	208	0	1	1	1	0	1
Total***	**172**	**40**	**26**	**14**	**70**	**42**	**4**	**16**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Projects that include work being completed just off the edge of the roadway are combined into a group named “median or shoulder work.” This new group includes projects that involve barrier construction, noise wall construction, and retaining wall installation. The crashes pertaining to these types of projects and the severity of injuries for the new combined group are seen in Table 3.18. This group is associated with 31 crashes and did not contain a single fatality.

Table 3.18: Median or Shoulder Work Grouped Project Type

			Crash Severity*					
Project Type	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Barrier Construction	28	184	4	2	16	3	0	3
Noise Wall Construction	4	195	0	1	1	1	0	1
Retaining Wall Installation	1	198	0	0	0	1	0	0
Grading	1	198	0	0	0	1	0	0
Landscaping	2	197	0	0	1	1	0	0
Total***	**35**	**164**	**4**	**3**	**18**	**6**	**0**	**4**

**Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Projects that involve work on utilities or connections to utilities are combined into a group named "utility work." The projects include in this new group include sewer construction, signal installation, and lighting replacement. The crashes associated with these types of projects and the severity of the associated injuries may be seen in Table 3.19. This group related to 34 crashes, which did not contain a single fatal.

Table 3.19: Utility Work Grouped Project Type

			Crash Severity*					
Project Type	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Sewer Construction	28	184	6	3	10	4	0	5
Signal Installation	7	205	4	0	1	2	0	0
Lighting Replacement	11	201	2	2	5	1	0	1
Total***	**35**	**177**	**10**	**3**	**11**	**6**	**0**	**5**

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.
***Each crash is only counted once in the total to prevent a single crash that is connected to multiple types of work from being counted multiple times.

Projects involving bridge construction are not applicable to any of the four new groups; therefore, bridge construction remained its own group. The number of crashes occurring on a project with bridge construction and the severity of these crashes may be seen in Table 3.20. Bridge construction projects are associated with 78 crashes and three fatalities, which is the second highest number of fatal injury crashes of the new groups.

Table 3.20: Bridge Construction Project Type

			Crash Severity*					
Project Type	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Bridge Construction	81	131	8	10	26	26	4	7

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.

The pavement work and bridge construction grouped project types returned the highest number of fatal crashes, with four fatal injury crashes each. This was similar to the groups containing the highest number of incapacitating injury crashes, where the pavement work contained the highest number, with 42, and bridge construction contained the third highest number, with 26. The traffic configuration grouped project type returned slightly higher numbers of incapacitating injuries than the bridge construction, with 29. A summary of the number of crashes and the injury severity for each grouped project types are seen in Table 3.21.

Table 3.21: Grouped Project Type Summary

			Crash Severity*					
Project Group	**Crashes Related to Project**	**Crashes Not Related to Project****	**Property Damage Only**	**Possible**	**Non-Incapacitating**	**Incapacitating**	**Fatal**	**Unknown**
Traffic Configuration	105	107	19	7	41	29	1	8
Pavement Work	172	40	26	14	70	42	4	16
Median or Shoulder Work	35	177	4	3	18	6	0	4
Utility Work	35	177	10	3	11	6	0	5
Bridge Construction	81	131	8	10	26	26	4	7

*Crash severity is based on the injury occurring to the operator of the motorcycle.
** The crashes not related to a type of project out of the total number of crashes, 212, that contained the ability to obtain relevant information from the construction plans.

CHAPTER IV:

RIDER SURVEY

4.1 Introduction

In order to evaluate potential implementations that would be used to alleviate motorcycle crashes in work zones, it is important to obtain the motorcycle riding community's thoughts and feelings towards various hazards and ideal solutions. To acquire these opinions, a survey of the motorcycle riding community is conducted. The survey's targeted audience included motorcyclists who travel in the areas where motorcycle crashes in this study had occurred. The riders did not need to be Ohio residents, but they must have ridden their motorcycles within the areas of concern. Having rider feedback would ensure that the suggested implementation would be tailored for motorcyclists who travel in these areas.

4.2 Survey Methodology

There are a various ways to contact the motorcycling community to achieve responses to a survey. The motorcyclists could be reached by telephone, sent a survey in the mail, or contacted in person. Using the telephone to conduct surveys may create difficulties in contacting motorcyclists who travel through the areas of interest and may introduce bias in the survey participants (Seufert, Yoder, and Walton; 2005). This process would also leave out motorcyclists who may not live within the state of Ohio but travel on Ohio's roadways. Motorcyclists may also be left out through the distribution of surveys through the mail to motorcycle magazine subscribers, as Mannering and Grodsky (1995) found. While targeting magazine readers would allow for a distribution that covers a wide area, the coverage of motorcyclists would be limited to the readers of a specific magazine. Those problems may be avoided by conducting face-to-face surveys of the participants, as did Dissanayake and Shaheed (2012). The face-to-face surveys allow the targeting of motorcyclists in locations of interest, once the research team identifies locations where they may come into contact with all types of motorcyclists.

The need to target a wide variety of motorcyclists in the riding community in areas of concern required the team to conduct the survey in a face-to-face manner. The surveys in this research effort are distributed in a manner similar to that of Dissanayake and Shaheed (2012), who contacted approximately 270 participants in 14 cities. In this study, responses are collected by approaching and verbally communicating with the riders.

4.2.1 Site Selection

The crash areas of concern are identified using a statistical method called a hot spot analysis (HSA), which identifies locations where crashes are more likely to be clustered together. A map indicating the cluster levels of the crashes and the crash locations is seen in Figure 4.1.

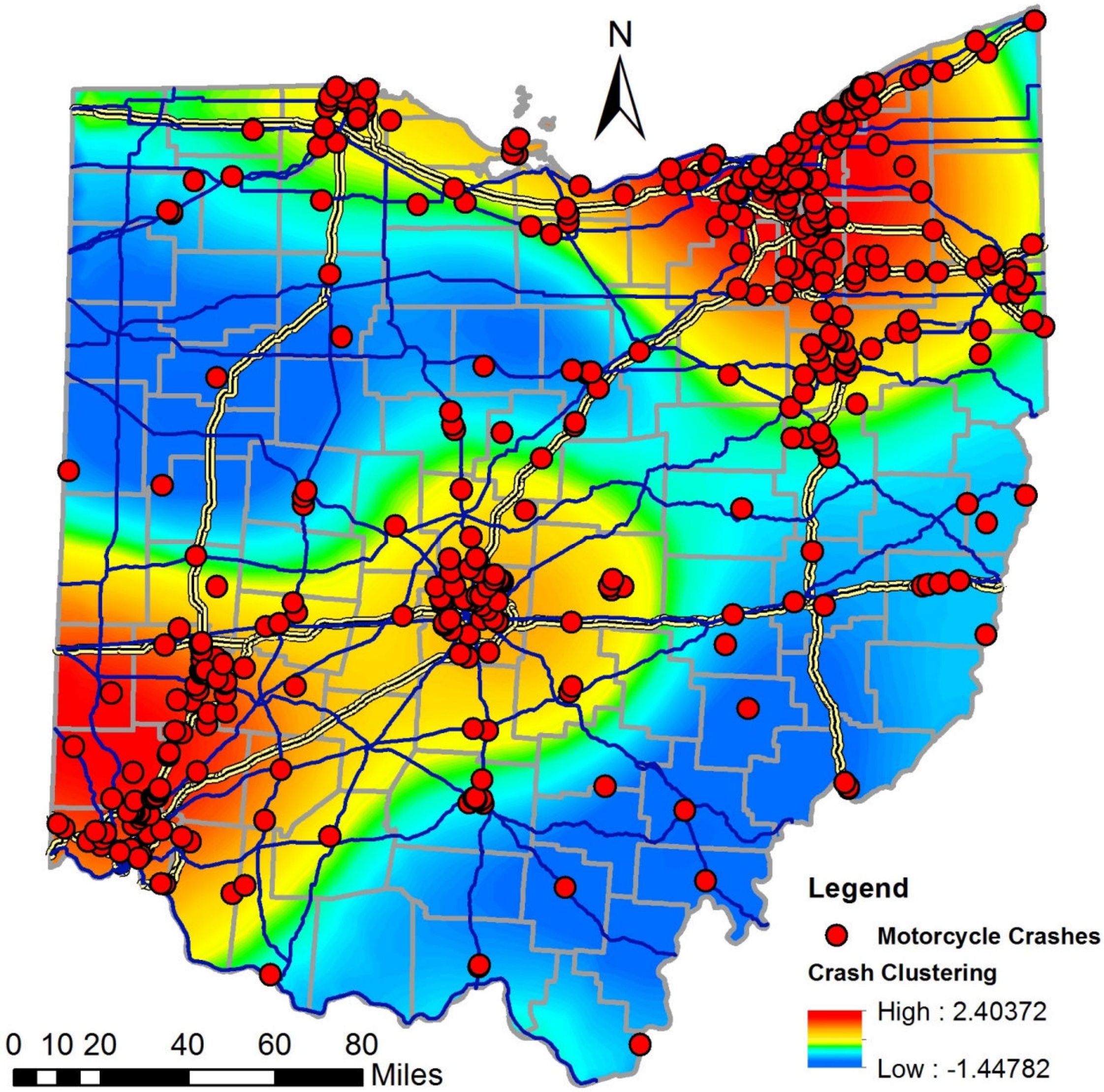

Figure 4.1: Hot Spot Map of Motorcycle Crashes in Work Zones

The areas highlighted in red on the map in Figure 4.1 contain crashes that are highly clustered together. The colors resulting from this analysis range from blue to red, which correlate to areas with statistically lower areas of crashes (shown in blue) to statistically higher areas of crashes (shown in red). The process of completing this analysis required that nearby crashes be grouped together, that the statistical significance of each grouped crash location be determined, and that this significance be interpolated throughout the state of Ohio.

4.2.1.1 Grouping of Crashes

Crashes occurring within a chosen X and Y cluster distance are aggregated together to make individual features coincident. The X and Y cluster distance is determined by finding a length in which the majority of the clustered points contained more than two crashes aggregated together. This cluster distance is determined to be a length of 5 miles. The aggregating process collected nearby crashes to one new point that contained a value equal to the number of crashes that are combined. Each crash originally contained a weight of one, which represented the specific crash event. Crashes within a distance of $\sqrt{2}$ times the cluster distance are then combined. This distance is used to account for crashes that occurred within an XY grid coordinate system, as shown in Figure 4.2.

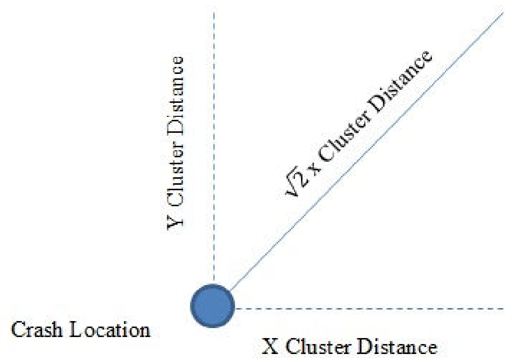

Figure 4.2: $\sqrt{2}$ Cluster Distance

The process of combining two crash points began with each crash containing a value of one. Next, a new point is introduced that replaces the original two. This new point then obtained a value of 2 and is centered between the two initial points that are combined. This process is called a cluster step. The next closest point, within $\sqrt{2}$ times the cluster distance, is then combined to this new point using another cluster step. The cluster step sequence is repeated until no more points are within $\sqrt{2}$ times the cluster distance from each other. This grouping of crashes resulted in a series of points that are fewer in the number of points, but contained values equal to the original number of crash points.

4.2.1.2 Clustered Point Statistical Significance

The aggregated crash points are subsequently used in the HSA, when the calculation of the Getis-Ord Gi* statistic is found for each point. Lees (2006), using Equations 4.1-4.3, explained that result of the Gi* is a z-score. The calculated z-score represents the number of standard deviations the point is from the mean. This z-score is calculated as the difference between the sum of the local sample and the weighted global mean, divided by the weighted global standard deviation. The Gi* z-score, which is either positive or negative, represents whether the features have a higher or lower rate of clustering as compared to the mean. As the value of the Gi* increases, so does the clustering of similar points. The z-score, found as the Gi* statistic, was calculated through the use of the following equation:

$$G_i(d) = \frac{\sum_j w_{ij}(d)x_j - W_i^* x}{s\left[\frac{W_i^*(n-W_i^*)}{(n-1)}\right]^{1/2}} \tag{4.1}$$

where:

$$W_i^* = \sum_j w_{ij}(d) \tag{4.2}$$

$$s^2 = \frac{\sum_j x_j^2}{n} - x^2 \tag{4.3}$$

and where x_j is the value of feature j, $w_{i,j}$ is the spatial weight between feature i and j, and n is the total number of features (Lees, 2006). An aggregated point having a high z-score represents a location that contains a significant amount of crashes clustered closely together.

4.2.1.3 Interpolation of Cluster Point Significance

In order to relate the Gi* z-score throughout all locations within the state of Ohio, an interpolation of each Gi* must be interpolated. There are several methods of interpolation that could be used to complete this task. The possible interpolation methods are shown in Figure 4.3.

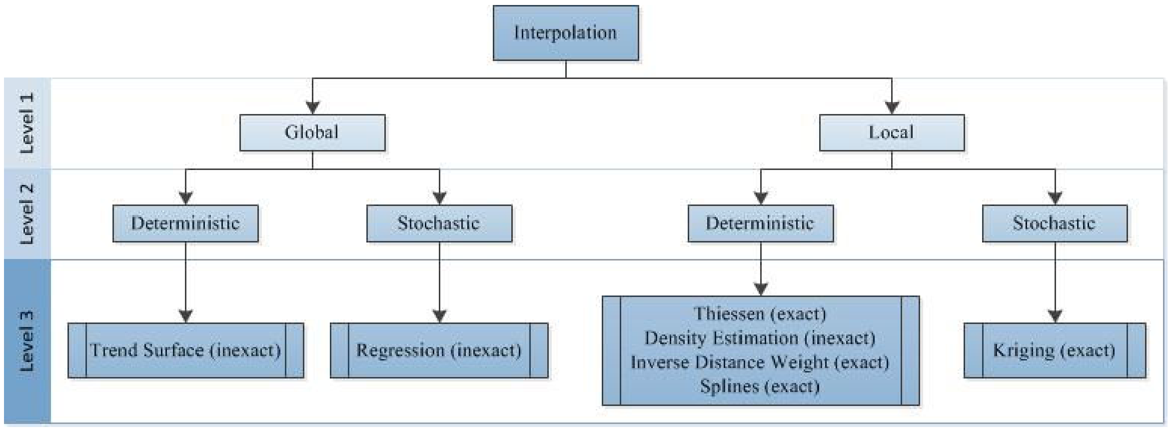

Figure 4.3: Interpolation Methods

Figure 4.3 breaks down the selection process of the methods into three different levels.

In Level 1, the team determines if the interpolation method is going to be a global or local interpolation method. Chang (2010) describes how these two options vary through the amount of points used to determine the estimated value. Global interpolation uses all available points, even ones that are farther away and do not have as much of an impact on the estimated value. Local interpolation requires only a portion of the known points to create the estimated value, since the use of distant values (as in global interpolation) has the potential to misconstrue the estimated value. For this study, local interpolation was determined to be the method of choice.

In Level 2, the team then determines if a deterministic or stochastic interpolator should be used. Chang (2010) explains that the difference between these two options is the use of an evaluation of errors in the estimated values. Stochastic interpolation applies an evaluation of the errors in the estimated values, while deterministic interpolation does not. Stochastic interpolation also calls for the assumption of the events, crashes, to be a random occurrence. Stochastic interpolation was chosen for this study.

In Level 3, the team determines the use of an exact or an inexact interpolation method. Chang (2010) indicates that these two options differ based on whether or not a point's known value is used as that point's predicted value. Exact interpolation uses the point's previously known value as its predicted value. However, inexact interpolation does not, and it creates a new value at the point's original location. Exact interpolation is chosen for this study, and the exact interpolation method known as Kriging was selected as the final interpolation method.

Kriging creates weights from surrounding measured values to predict values at unmeasured locations. The Kriging process, as explained by Chang (2010), begins by defining the semivariance, using the following equation:

$$\gamma(h) = \frac{1}{2} [z(x_i) - z(x_j)]^2 \qquad (4.4)$$

where γ(h) is the semivariance between known points, x_i and x_j, which are separated by the distance *h*, and *z* is the attribute value (Chang, 2010). A plot of the semivariance for all points, which is called a semivariogram cloud, may be seen in Figure 4.4.

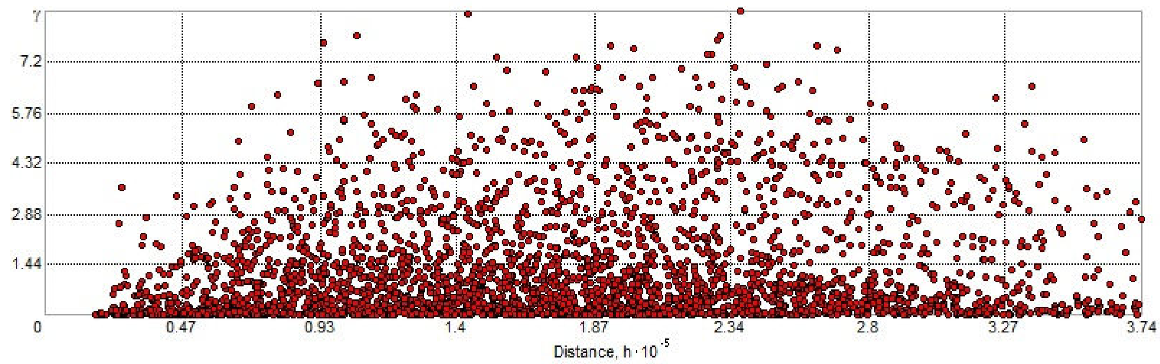

Figure 4.4: Semivariogram Cloud

As seen from this figure, the plot was congested, and it was difficult to differentiate each value.

To achieve a better understanding of the semivariogram, the process of binning semivariance values is completed. The binning process averages semivariance values that are collected according to their distance and direction from each other. This is first completed by grouping points into lag classes by distance. Lag classes contain points in groups of similar distance from the originating point. For example, if the lag size is a distance of 1000 feet, the first lag class will be from 0 to1000 feet. The next lag class will be from 1000 to 2000 feet, followed by another lag class from 2000 to 3000 feet. For the motorcycle crashes in work zones, the lag size, 17.0 miles, is determined by averaging the distance between each point and the closest neighboring point. The second part of the binning process requires the grouping of points by their direction from each other. Each point that coincided in a similar distance and direction was then averaged together. The averaged points are calculated using the equation:

$$\gamma(h) = \frac{1}{2n} \sum_{i=1}^{n} [z(x_i) - z(x_i + h)]^2 \qquad (4.5)$$

where γ(h) is the average semivariance between sample points separated by lag *h*; *n* is the number of pairs of sample points sorted by direction in the bin; and *z* is the attribute value (Chang , 2010). These averaged points, the binned data, are then plotted to form a semivariogram, shown in Figure 4.5, which is easier to interpret. This plot displays the binned points by their distance from each other and their values. The values located at the same distances represent the directions related to each of the points. The binned semivariance values (indicated by red points) are also averaged (with averages indicated by blue crosses) for a clearer identification of any trends in the data. The average of the binned semivariance values are located at a distance related to the middle of each of the lag classes.

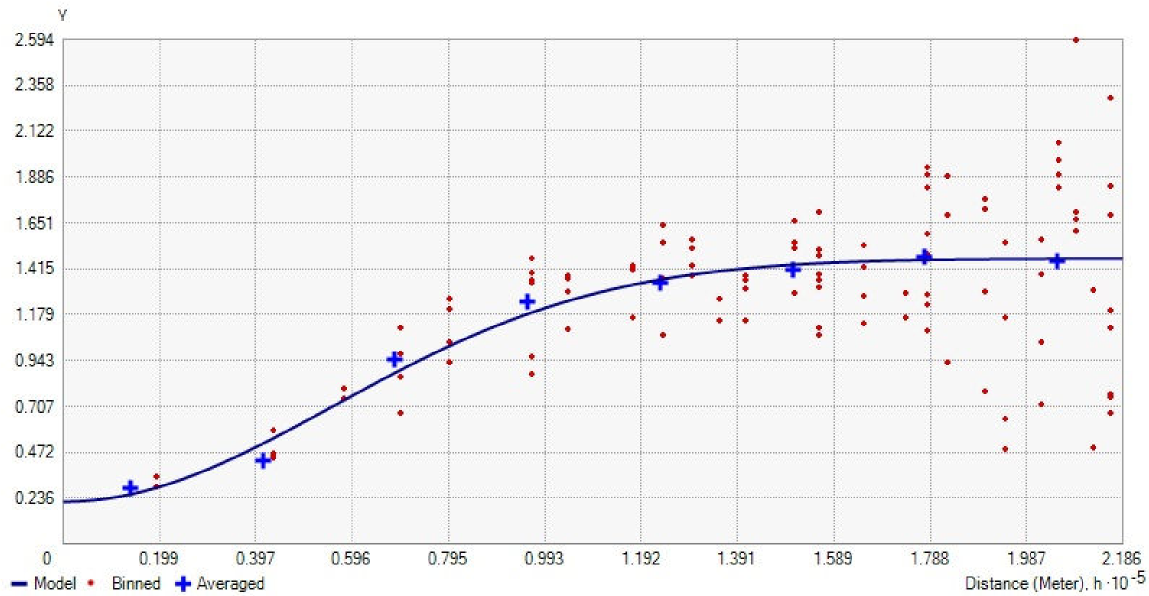

Figure 4.5: Semivariogram of Binned Data

Also seen in Figure 4.5 is the model that is fit to represent the trend of the data. This model influenced the prediction of unknown values. To be its most efficient, the model needs to pass through the center of the cloud of semivariances. A Gaussian model is used to best represent this data. In order to tailor the model to the semivariance data, the nugget, sill, and range need to be established. The nugget is the semivariance at a distance of 0, similar to a y-intercept. The sill is the semivariance at the distance of the range, which is the distance where the semivariance starts to level off. These variables are presented in Figure 4.6.

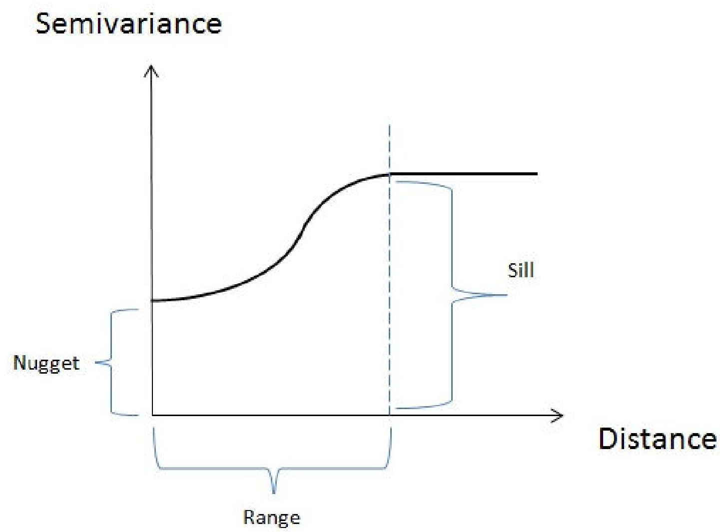

Figure 4.6: Model Variables

For the model to provide the best fit of the averaged binned data, the nugget and sill are located at semivariance values of 0.217 and 1.468, respectively, and the range is set at a distance of 84.78 miles.

This model was able to calculate a predicted value, Gi* z-score, for any location that did not already have a value. This value was identified as γ(h) in the model's calculations using the equation:

$$\gamma(h) = c_0 + c\ [\ 1 - \exp\ (\ - h^2 / r^2\ )],\ h > 0 \tag{4.6}$$

$$\gamma(0) = 0 \tag{4.7}$$

where c_0 is the nugget, r is the range, c is the sill, and h is the distance between neighbors (Chang, 2010). The prediction value was determined from the relationship between the Γ, W, and γ matrices seen in the following equation:

$$[\Gamma] * [W] = [\gamma] \tag{4.8}$$

Equation 4.8 was used to solve for the W matrix (Chang, 2010). The γ matrix is determined as follows:

$$\gamma = \begin{bmatrix} \gamma_{0,1} \\ \vdots \\ \gamma_{0,n} \\ 1 \end{bmatrix} \tag{4.9}$$

where the subscript value of 0 related to the prediction location and the subscript n determined the neighbor to which the distance was calculated to (Chang, 2010). Similarly, the Γ matrix is determined as follows:

$$\Gamma = \begin{bmatrix} \gamma_{1,1} & \cdots & \gamma_{1,n} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \gamma_{n,1} & \cdots & \gamma_{n,n} & 1 \\ 1 & \cdots & 1 & 0 \end{bmatrix} \tag{4.10}$$

using the values for each neighbor and a Lagrange multiplier, λ, with a value equal to 1 (Chang, 2010). Once the Γ and γ matrices were calculated, the matrix for the weights was solved as follows:

$$W = \begin{bmatrix} W_1 \\ \vdots \\ W_n \\ \lambda \end{bmatrix} \tag{4.11}$$

where W_n represented the weight of each point (Chang, 2010). Once the weights for each point were determined, the value at the predicted location was solved by:

$$z_0 = \sum_{i=1}^{s} z_x W_x \tag{4.12}$$

where z_0 is the estimated value, z_x is the known value at point x, W_x is the weight associated with point x, and s is the number of sample points (Chang, 2010).

In order to verify that the chosen model is the best model to use, a cross validation of the selected model is completed and compared to other tested models. The cross validation process compares the measured value of every semivariogram point with a predicted value at the same point. The predicted value is calculated by removing one data point and calculating the value at same location using the specified model. This process of removing one measured value and determining its predicted value is completed for each semivariogram point. The difference between the measured and predicted values is then used for the determination of various statistical benchmarks, including the following: the mean of the error, the root-mean-square of the error, the mean of the standardized error, the root-mean-square of the standardized error, and the average standard error. The values and ideal values of these statistical benchmarks for the optimum chosen model are shown in Table 4.1.

Table 4.1: Cross Validation Statistical Benchmarks

Benchmark	Chosen Model	Optimum Value
Mean	0.0052	0
Root-Mean-Square	0.4653	Minimize
Standardized Mean	0.0086	0
Standardized Root-Mean-Square	1.0524	1
Average Standard Error	0.4320	Minimize

It is seen in the table above that the mean and the standardized mean are very close to zero and that the standardized root-mean-square value is close to one. Also, the root-mean-square and average standard error are small; in fact these numbers are lower in value for the chosen model than for any other model tested. Through the use of the cross validation, it is determined that the earlier described Gaussian model would be used to interpolate the Gi* z-score throughout all areas of the state of Ohio.

4.2.2 Event Selection

Once the areas of concern are identified via HSA, the team turned its attention to identifying events where motorcyclists could be surveyed. There are various types of locations in which contact with motorcyclists could be made. These places could either be a specific location (e.g., gas stations or stores) or a location by the side of the road. At either of these places, there would be a need to wait for motorcyclists to arrive. At a specific location, the motorcyclists would have a better chance of randomly stopping. Because motorcyclists would be resistant to pull over and stop at the side of the road, the best option would be to identify and attend specific locations and events in which large amounts of motorcyclists would stop. Attending specific locations, however, creates a bias in the motorcyclists contacted, as the riders who attend such events are targeted, while motorcyclists who avoid certain types of events are not. The events selected for this study are locations which cater towards motorcyclists, such as bike nights, rallies, runs, and community events. Taken together, these types of events attract a diverse spectrum of motorcyclists, as some motorcyclists may attend one type of event and not another. A brief description of each of the types of events is presented in Table 4.2.

Table 4.2: Event Descriptions

Event Type	Description
Bike Night	Regularly scheduled evening events at restaurants or bars
Bike Rally	Daytime events which are often located at retail locations
Bike Run	Daytime events which often relate to or support a charitable cause
Community Event	Events not tailored to motorcyclists but to the community as a whole

During a motorcycle run, motorcyclists meet at a location and ride to one or more additional locations. The run may end by returning to the initial location or to a different one. There is generally a set time to allow the motorcyclists to register for the event, a time by which all of the motorcycles would have departed from the initial location, and a time by which all of the motorcycles are expected to return. Motorcyclists are expected to return if they are attempting to win prizes; those who are not interested in prizes may not return. Due to the possibility that fewer motorcyclists will be returning than departing, the aim is to be in contact with the riders before the run departs the initial location. At this type of event, the motorcyclists would typically arrive, locate the registration table, and have conversations with the other riders once they complete their registrations.

Bike nights are events that are usually held on some type of regular schedule, either once a week or once a month, and they are typically held at the same location each time. The location for most bike nights tends to be some type of restaurant or bar. These events typically last from approximately 6:00 PM to 9:00 PM, and they often occur on weekday evenings. At these events, the motorcyclists would show up at the location randomly throughout the given time period and would stay for various lengths of time, depending on who they knew or might meet at the event. The patrons spend the majority of their time walking around the parking lot where the motorcycles are parked, looking at the various motorcycles and talking to other motorcyclists. The remaining time is spent ordering food or beverages from the event location. Bike nights also contain some sort of riding competition for motorcyclists, and these competitions are focused around slow speed riding skills.

Motorcycle rallies are daytime events that occur from approximately 10:00 AM to 5:00 PM. These events are less frequent and are held on an irregular basis, normally only once per year. The main purpose of these events is for motorcyclists to ride to a location, then mingle with other motorcyclists or shop at the event. These locations are generally retail stores, swap meets, or non-commercial areas (not restaurants or bars as with bike nights). These events have the possibility of spanning multiple days, and they usually occur on weekends. If the location attended is a retail store, the motorcyclists are mainly focused on shopping and buying various motorcycle related items; for non-retail locations, motorcyclists are focused mainly on socializing.

Community events typically occur in a municipal area and are not focused specifically on the motorcycling community. These events tend to randomly draw motorcyclists, and they provide the opportunity for contact with motorcyclists who normally would not attend other types of events. Community events cover a wide range of occasions: fairs, festivals, sporting events, and automotive shows. These events generally contain a large portion of non-motorcyclists; however, the known strong presence of motorcyclists at these events create a good opportunity to reach out to the motorcycling community. The motorcyclists are at times difficult to distinguish from the rest of the community, but are often interested in this study because it is usually the only motorcycle related attraction at the event. The patrons attending these events normally park their motorcycles, roam around the event, and only return to their motorcycles when they are ready to leave.

The research team attended all of these types of events in critical locations identified in the HSA for this study. A map of the attended event locations in coordination with the hot spot analysis is seen in Figure 4.7.

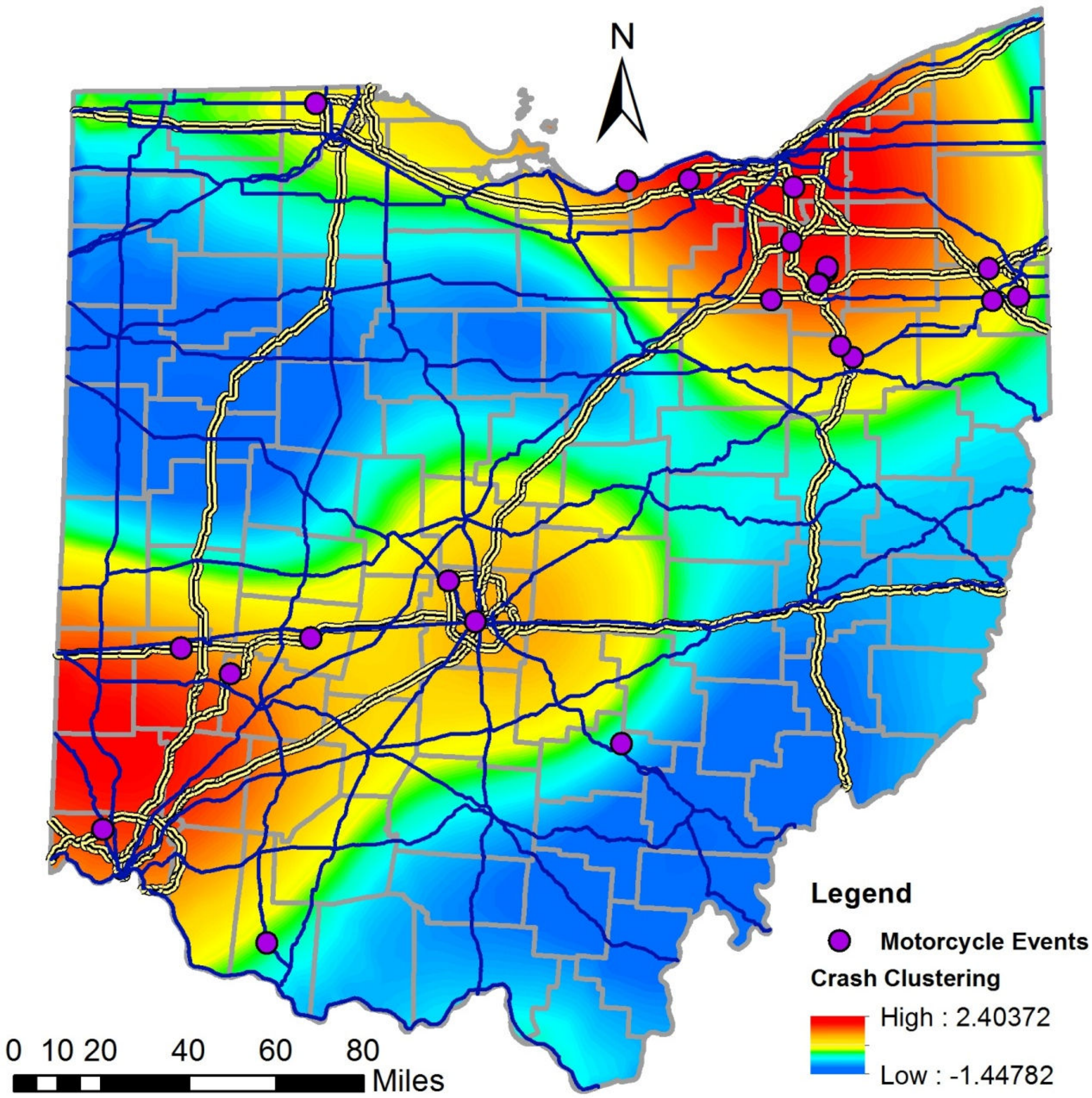

Figure 4.7: Event Locations in Relation to Motorcycle Crash Areas of Concern

From this figure, it may be seen that the highly clustered areas of crashes occurred around the northeast (Cleveland, Akron, and Youngstown), central (Columbus), southwest (Cincinnati), and northwest (Toledo) areas. These areas are the main regions of focus for distributing the surveys. The surveys are collected from 24 different events totaling 612 responses and three additional test trial locations totaling 76 responses. A list of the attended events is seen in Table 4.3.

Table 4.3: Attended Events

Event Type	Event Name	City	Region
Poker Run	Burgers, Bikers, and Blessings	Georgetown	Southwest
	Biker Sunday	Canton	Northeast
	Ohio Run to Wall	Wadsworth	Northeast
	Musketeers M.A.D. Ride Poker Run	Richfield	Northeast
Bike Night	Quaker Steak and Lube	Beavercreek	Southwest
	Quaker Steak and Lube	Austintown	Northeast
	Quaker Steak and Lube	Boardman	Northeast
	Quaker Steak and Lube	North Canton	Northeast
	Quaker Steak and Lube	Valley View	Northeast
	Quaker Steak and Lube	Colerain	Southwest
	Legends Sports Bar	Uniontown	Northeast
	Quaker Steak and Lube	Vermillion	Northeast
	Quaker Steak and Lube	Sheffield Village	Northeast
	The Bluestone	Columbus	Central
Rally	A.B.A.T.E. June Jam	Logan	Southeast
	Ohio H.O.G. Rally	Englewood	Southwest
	Walneck's Swap Meet	Springfield	Southwest
	Rubber City Harley Davidson Lot Party	Cuyahoga Falls	Northeast
	Toledo Harley Davidson Open House	Toledo	Northwest
Community Event	Italian-American Fest	Akron	Northeast
	Canfield Fair	Canfield	Northeast
	Arthritis Foundation Classic Auto Show and Cruise In	Columbus	Central
	Akron Aeros	Akron	Northeast
	Rockin on the River	Cuyahoga Falls	Northeast

The research team attended these events to communicate with each rider, distribute the surveys, and collect any comments regarding the survey.

4.2.3 Collection of Surveys

The distribution of the surveys is a time-intensive task, and the average time spent completing the survey was approximately five minutes. Some motorcyclists are uninterested in discussing motorcycle safety while they attend an event to which they rode their motorcycle. When being told about the survey, the motorcyclists are asked if they rode a motorcycle (as opposed to being a passenger), if they are 18 years of age, and if they would like to participate in a survey that did not collect any personal identifying information. The motorcyclists are told that the completion of the survey would serve as their consent.

The approach used to contact motorcyclists varied for each location according to the setup of the event. The methods included having researchers staff a booth, walking around with the surveys on clipboards, or a combination of the two. A combination of the two is used if the booth was not attracting very many motorcyclists. The change in the type of distribution may have permitted interaction with more patrons. Also, some of the hosts of the events preferred the research team to use of one type of setup verses another.

The booth setup consisted of five clipboards, a 10’ by 10’ tent, a 6’ table, and posters relating to motorcycles and motorcycle safety. The booth allowed multiple people to complete the survey at one time, and it enabled participants to begin the survey at various times as they came and left the booth. This type of setup encourages motorcyclists to become interested in the information and activities presented without being aware of the survey until they are asked to participate. This setup also provides a presence for the motorcyclists who are walking up to all of the booths at an event or those who are merely searching for registration for the event and thought that the survey booth is the correct place to register. An additional benefit of using a booth is that when participants are completing the survey, other patrons would become interested and would approach the booth. Occasionally, the response rate slows down due to a lack of patrons approaching the booth. This is due in some cases to a lack of foot traffic in general; in other cases, motorcyclists do not seem interested in approaching any of the booths at the event.

Having the research team walk around the event with clipboards only requires the clipboards and the surveys. This method allows for greater mobility to reach the motorcyclists at the event, and many of the motorcyclists who would not approach the booth setup are able to be interviewed. The potential participants could be targeted at nearly any location at the event, and the research team did not have to wait for them to approach the booth. There are downsides to using this method, relating to avoidance of the survey and the possibility of completing multiple surveys. The clipboards gave away the presence of a survey or information being handed out, and some motorcyclists made an effort to avoid being approached: they either walk away or immediately decline to participate, before the research team could explain the nature of the survey. Also, the amount of surveys that could be completed at one time was more limited, due to the size of the group of patrons participating. The research team made an effort to approach each motorcyclist during his/her most available time and to not approach the same person twice. The motorcyclists were usually approached just after they had finished parking and were leaving their motorcycles.

In addition to distributing surveys, the research team also distributed motorcycle safety information to the motorcycling community. Posters and other information presented helped to raise the motorcyclists’ interest in completing the survey, by introducing another gateway to draw in the motorcyclists and create interest for participants.

4.2.4 Question Generation

To gain an understanding of the motorcyclists and their thoughts about riding, the survey was designed to collect information regarding rider experience, riders' perceived hazards, and rider perceptions towards potential implementations. The goal was to recruit participants, both males and females, who were over the age of 18 and who had driven a motorcycle (rather than riding as a passenger) to complete the survey.

4.2.4.1 Test Trials

In order to identify any problems in the survey questions and to obtain a feel for the motorcycling community's response to the survey, three test trials of the survey were completed. These trials occurred at two bike rallies and one bike night. The trials allowed for a learning process regarding the setup of the booth and the manner of approaching the motorcyclists. Through these three locations, a total of 76 surveys were completed. Based on the completed surveys of the trial, the survey was modified: the format of the questions was changed, and five additional questions were inserted.

4.2.4.2 Final Survey

The final version of the survey was created to obtain the greatest amount of information in the least amount of time, so that the motorcyclist would not be unduly inconvenienced and decline to participate or fully complete the survey. The questions were limited so that the survey would fit on one side of a standard 8.5" by 11" sheet of paper, with text that was large enough to be legible for riders who may have trouble reading without the use of glasses for farsightedness. To comply with both of these requirements, the survey was created with a total of 20 questions that were printed in size 10 Times New Roman type. The questions and formatting of the survey were submitted to the Institutional Review Board (IRB) at the University of Akron for approval. The IRB's permission letter is presented in Appendix B.

4.2.4.2.1 Rider Experience Questions

The questions for the rider experience portion of the survey are designed to obtain an idea of the rider's experience, habits, and ability. Several of the questions in this section are based on a telephone study covering motorcycle characteristics, riding habits, the Motorcycle Ohio Safety Course, and motorcycle safety (Seufert, Yoder, and Walton, 2005). The questions are used to classify a rider based on gender, concern of motorcycling safety, experience in motorcycle riding, and exposure on roadways. This section, which constituted the first nine questions of the survey, is presented in Table 4.4.

Table 4.4: Rider Experience Survey Questions

Number	Question	Response Options	Assessment
1	What is your gender?	• Male • Female	Does gender affect the decisions made by a motorcyclist?
2	What level of endorsement do you currently have?	• None • Temporary • Novice • Full endorsement	Does the level of motorcycle license endorsement affect the decisions made by a motorcyclist?
3	Have you completed any Motorcycle Ohio courses?	• No • Yes	Has motorcycle training affected work zone related decision making?
4	How often do you wear a helmet?	• Always • Sometimes • Never	Do helmeted riders react differently to work zone related hazards than non-helmeted riders?
5	How many years have you been riding?	• 0 - 2 • 3 - 5 • 6 - 10 • 11 - 20 • 20+	Does the amount of years spent riding affect the rider's perceptions towards work zones?
6	How many miles do you average per year?	• 0 - 1,000 • 1,001 - 5,000 • 5,001 - 10,000 • 10,001+	Does an increase in exposure affect the decisions being made by a motorcyclist?
7	Which areas do you most often ride your motorcycle?	• Urban • Suburban • Rural • Unknown	Do the areas mostly ridden have an effect on a rider's approach towards work zones?
8	What type(s) of motorcycle do you ride?	• Cruiser • Dual Purpose • Scooter • Sidecar • Sport bike • Sport-touring • Standard • Touring • Trike • Other	Does the type of motorcycle ridden affect the decisions being made in work zones?
9	How often do you ride?	• Every day • Almost every day • A few days a week • A few days a month • Rarely	Does the frequency of rides affect the judgments made by motorcyclists in work zones?

4.2.4.2.2 Perceived Hazards Questions

The questions pertaining to the rider's perceived hazards are created to understand the types of hazards that cause the most concern for a motorcyclist. The questions are based on the findings of the hazards that are connected with the most crashes in the analysis of the ODPS and ODOT data sets, which is discussed in Section 3.3.1.3 of this report. The hazards in question correlate to dangers in the surface of the roadway, in the setup of the MOT, and in passing by work in progress. This section, which constitutes Questions 10 through 14 the survey, is presented in Table 4.5.

Table 4.5: Perceived Hazards Survey Questions

Number	Question	Response Options	Assessment
10	What type of roadway hazard is of most concern?	• Grooved Pavement • Uneven Lanes • Pavement joints parallel to the direction of travel • A roadway that has a shoulder that is 1½ feet wide or smaller	Are the common crash hazards thought to be dangerous by motorcyclists?
11	Which type of work zone is the most dangerous?	• Lane Closures • Lane Shift or Crossover • Work on Shoulder or Median • Intermittent or Moving Work	Do the types of work zones appear as dangerous as they were found to be in the work zone crashes?
12	What most accurately happens while passing road work in progress?	• You are distracted by the work • Other vehicles tend to slow down • Other vehicles tend to swerve or drift to the side of the lane • Traffic flows as it would if the work was not occurring	Do motorists seem distracted when passing by work in progress?
13	While traveling through a work zone, which type of work seems to be the most dangerous/ distracting?	• Excavation • Paving • Pavement Milling • Pavement Marking	Do motorcyclists have safety concerns about the type of work being performed in a work zone?
14	Which of the following barriers appears to be the most dangerous?	• Portable Concrete Barriers • Portable Drums • Combination of Portable Concrete Barriers and Drums	Are motorcyclists disturbed by one type of barrier vs. another?

4.2.4.2.3 Potential Implementations Questions

The questions pertaining to the perceptions of potential implementations are created to obtain an idea of how the motorcyclists view potential implementations that would be used to reduce the number of motorcycle crashes in work zones. The implementations used in these questions are adapted from solutions obtained from the national state of practice that are currently in use by various other states. These potential implementations offer options in both the rider and roadway categories of solutions. This section, which constitutes the final six questions of the survey, is presented in Table 4.6.

Table 4.6: Potential Implementations Survey Questions

Number	Question	Response Options	Assessment
15	When work is occurring next to your path of travel, which do you feel would increase your safety the most?	• Changing the barrier between you and the work • Increasing the distance between you and the work • Increasing the warning of the work being completed	Which type of change in a work zone would improve the rider's safety the most?
16	What would be considered the best solution when traveling through a work zone that is resurfacing the roadway?	• Keep the lane being worked on closed until it is repaved again • Having the option of a detour around the work zone • Using a wedge transition between the grooved pavement and the existing/new pavement • Being able to travel over the grooved pavement	How does the motorcycling community feel towards various implementations to improve their safety in work zones containing roadway resurfacing?
17	When a work zone suggests that motorcyclists take an alternative route, which would you do?	• Follow the advice and find another route • Continue and travel through the work zone	Do riders feel that a motorcycle specific detour around a work zone would be helpful?
18	For which work zone condition would you most likely follow an alternative route if offered?	• Grooved Pavement • Uneven Lanes • Loose Gravel • Asphalt Paving • Where work is occurring close to the roadway	Which type of hazards would motorcyclists use a detour to avoid?
19	Up to how many minutes would you be willing to travel to avoid dangerous roadway conditions?	• 5 • 10 • 15 • 20 • Over 20	How long should a detour take before the rider believes that it has become excessive?
20	If a website was offered to show the location of work zones and their roadway conditions, how often would you check the website to choose an alternative route?	• Always • Sometimes • Never	Would motorcyclists go to a website to become aware of roadway conditions before being approached?

The questions included in this survey were provided to ODOT, ODPS, and the American Motorcyclist Association (AMA). The comments received resulted in minimal changes. ODOT suggested the rewording of two of the questions, which resulted in an alteration of the survey.

4.3 Survey Results

A total of 612 surveys were completed by participants throughout the state of Ohio. This study analyzed the three different sections of questions of the survey in two different ways. The first method of analysis is the identification of the general findings of the survey, which identifies the results for each question. The second method of analysis is a discrete outcome analysis, which will be presented in Chapter V.

4.3.1 General Findings

The general findings directly show the results for each question in the survey. The results identify the number of responses for each available answer. The following sections present the findings for the three different sections of the survey.

4.3.1.1 Rider Experience

The first question of the survey inquired about the gender of the motorcyclist. The bulk of the surveys returned are from males, about 86%. The difference in the responses is shown in Figure 4.8.

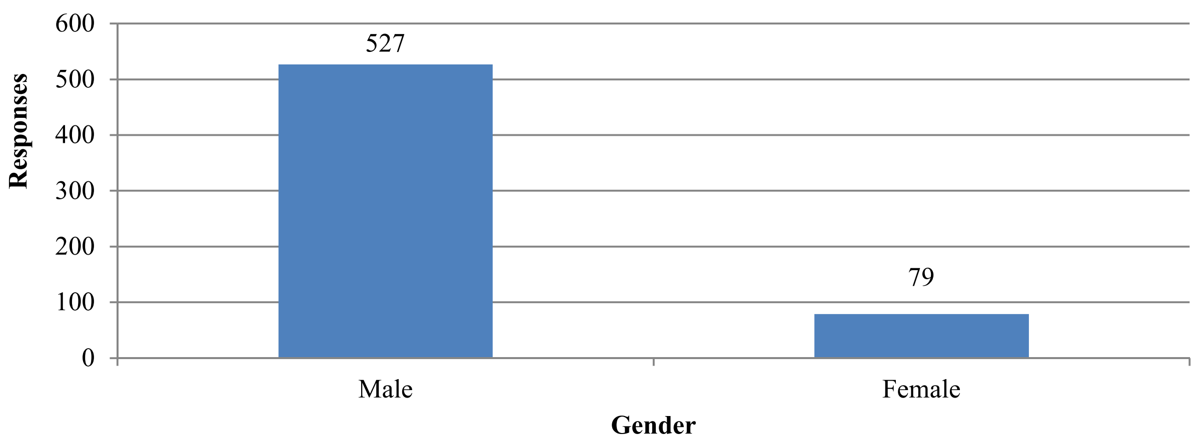

Figure 4.8: Gender of Riders Surveyed

Next, the motorcyclists are asked the motorcycle endorsement level obtained by the rider. The overwhelming majority, 90%, did have a full motorcycle endorsement. Two of the other options, temporary and novice, are short-term (one year) levels of endorsement and represent small portions of the participating motorcyclists. Only a small portion of the motorcyclists did not obtain a motorcycle endorsement. The results correlating to these responses are seen in Figure 4.9.

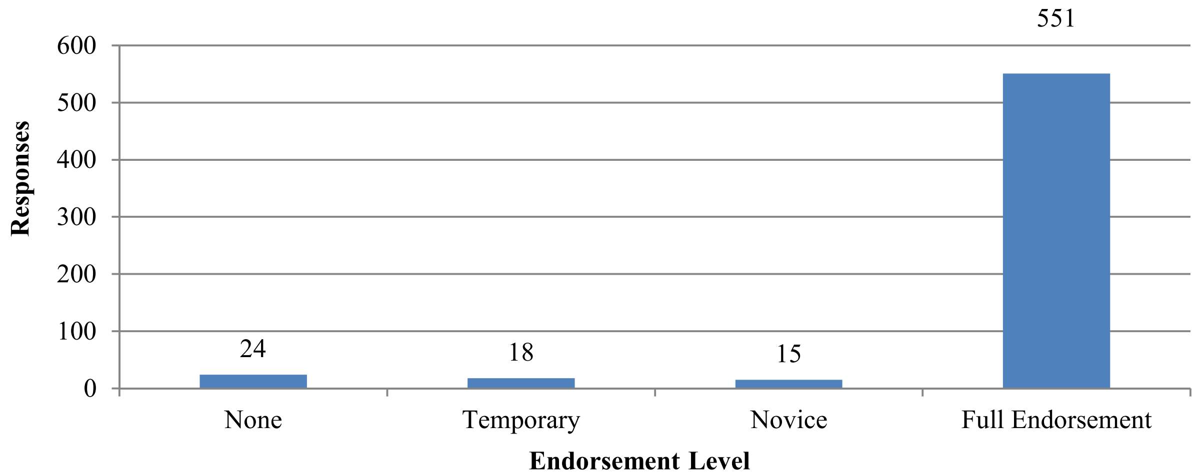

Figure 4.9: Riders' Endorsement Level

When asked whether a Motorcycle Ohio riding course had been taken by the rider, the responses are fairly similar. Just over half of the participants, about 52%, had completed some type of Motorcycle Ohio training (Figure 4.10).

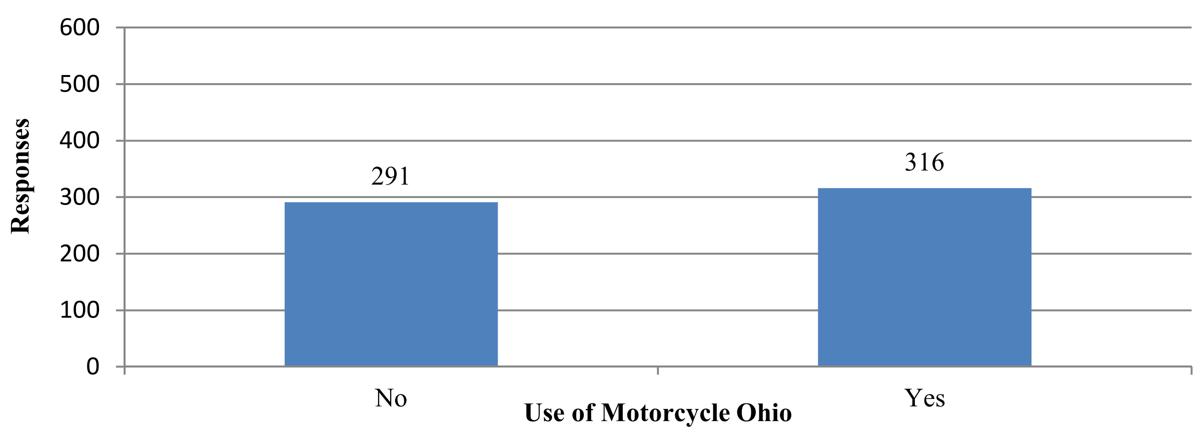

Figure 4.10: Riders' Motorcycle Ohio Training

Figure 4.11 identifies the motorcyclists' use of safety equipment, focusing on helmets. The responses of "always" and "sometimes" were nearly equal at 40% and 38%, respectively. Motorcyclists who do not wear a helmet trailed slightly at 21%.

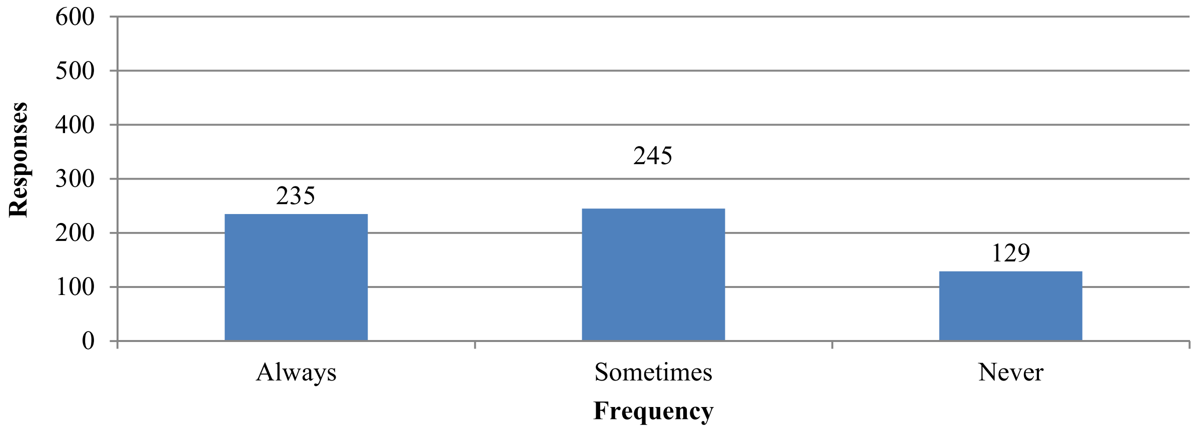

Figure 4.11: Helmet Use

Figure 4.12 indicates the number of years the motorcyclist had been riding. Half of the motorcyclists who responded had been riding for over twenty years. The remaining responses decrease with the level of rider experience, from 15% at the 11-20 year range to 9% at the 0-2 year range.

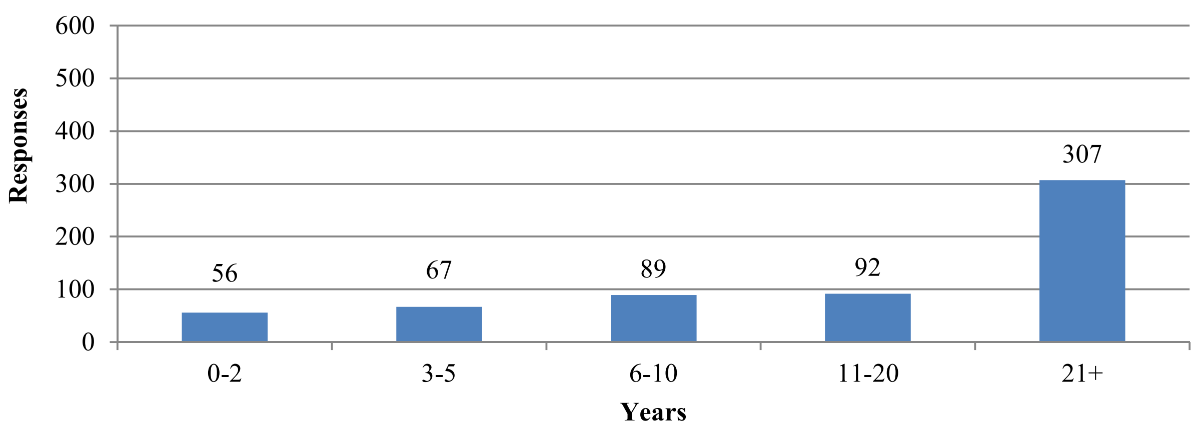

Figure 4.12: Years Spent Riding a Motorcycle

The average number of miles ridden per year (shown in Figure 4.13) is mirrored around the 5,000 mile marker. The 1,001-5,000 mile category and the 5,001-10,000 mile category are both around 38%. The amount of responses tapered off at both the low (0-1,000) and high (10,000+) categories.

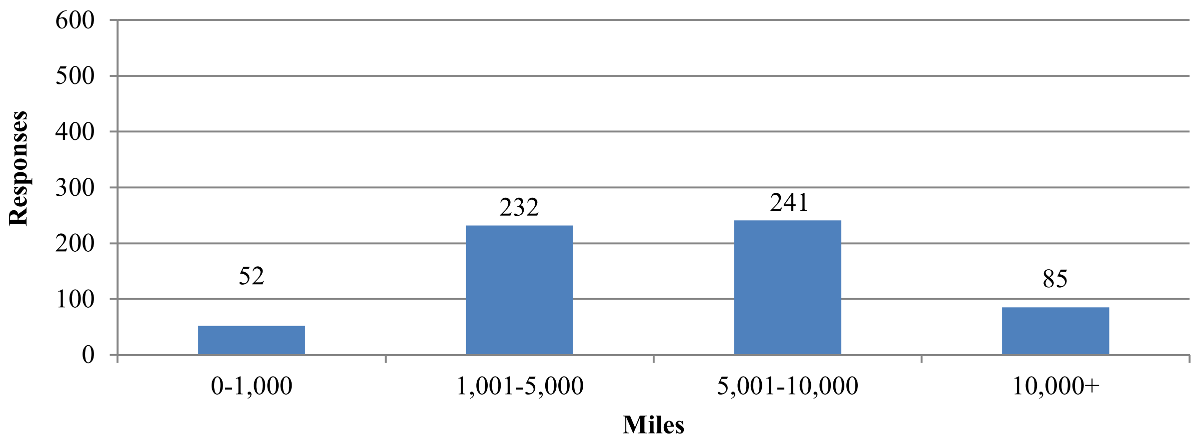

Figure 4.13: Miles Averaged Per Year

Motorcyclists mainly prefer to ride (see Figure 4.14) in areas where the population is lower. Rural locations are sought after by 60% of the participants. This is followed by suburban areas at 29% and urban areas at 19%.

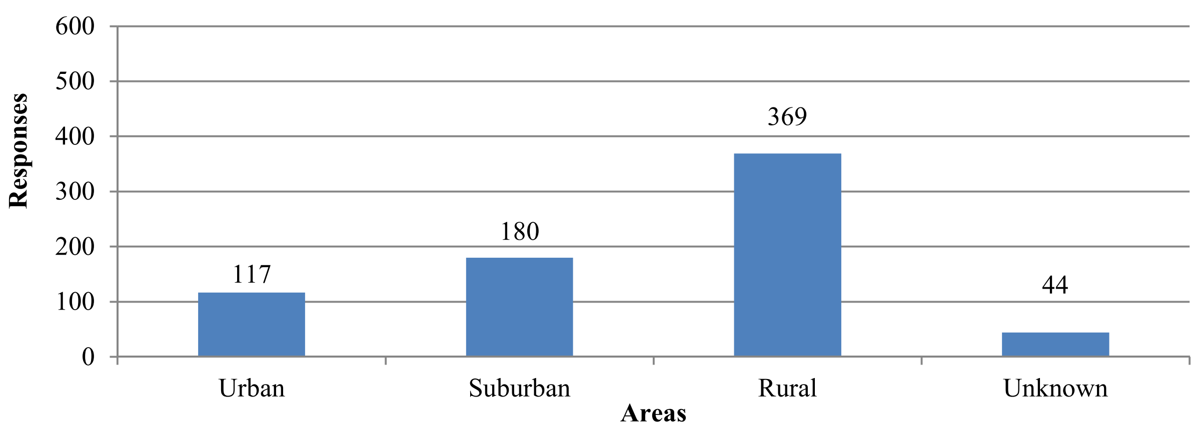

Figure 4.14: Type of Area Mostly Ridden

The range of the types of motorcycles ridden covered all of the available options listed in the survey. The two main types of motorcycles ridden are the cruiser and the touring motorcycle at 35% and 27%, respectively. The remaining motorcycle types are much lower (under 10% for each). The distribution of the types of motorcycles ridden is presented in Figure 4.15.

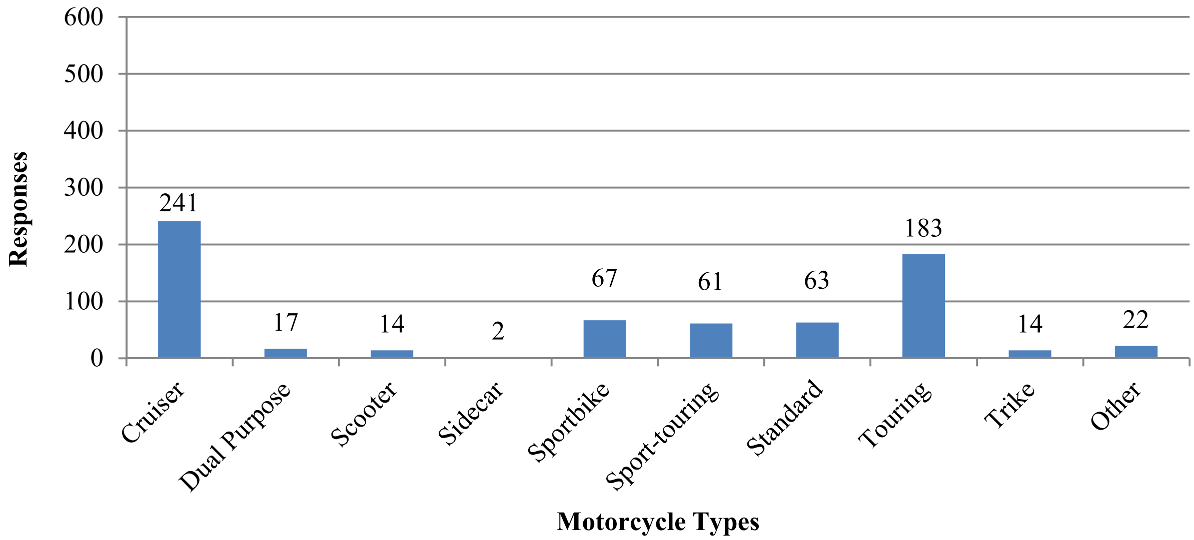

Figure 4.15: Types of Motorcycles Ridden

As shown in Figure 4.16, a total of 41% of motorcyclists ride only a few days each week. As the frequency of rides increases from there, the percentage of results tapers off to lower amounts. As the frequency decreases from riding a few days a week, the percentage of results drops off more dramatically.

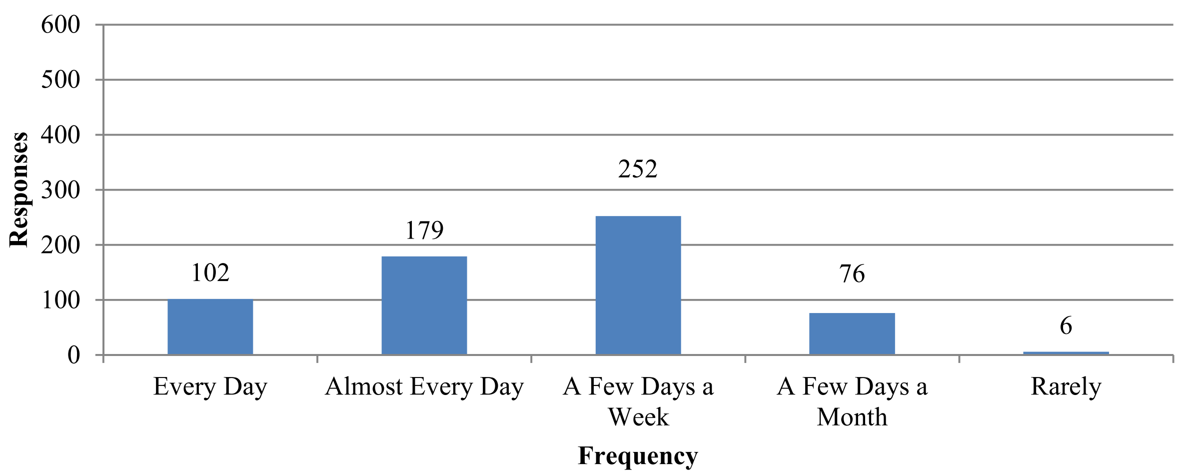

Figure 4.16: Frequency of Rides

4.3.1.2 Perceived Hazards

Grooved pavement is identified by 46% of the participants as the main hazard of concern (as shown in Figure 4.17). This is followed by uneven lanes and longitudinal joints at 26% and 20%, respectively. Reduced shoulder width is the least of the riders' concerns, being identified as the main hazard by only 7% of the survey participants.

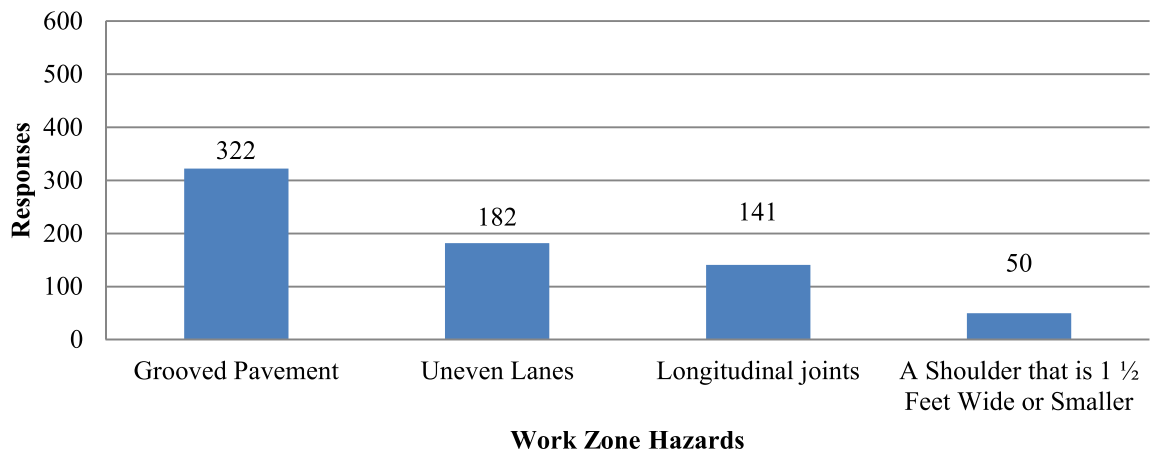

Figure 4.17: Roadway Hazard of Most Concern

The work zone type that is of most concern (as presented in Figure 4.18) is the lane shift or crossover, which is identified by 46% of the motorcyclists. The next type of work zone of concern, intermittent or moving work, is identified by less than half as many riders (21%), followed closely by lane closures (20%). The work on the median or shoulder was the least of the riders' concerns, with only 12% of motorcyclists choosing this option.

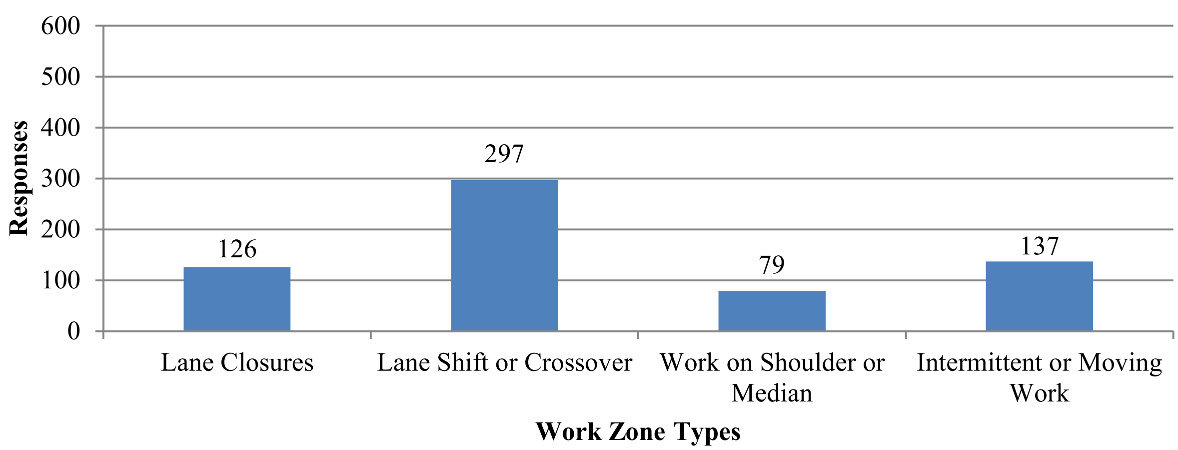

Figure 4.18: Most Dangerous Work Zone Type

While passing work in progress, motorcycle riders indicate that swerving/drifting or slowing down of other vehicles as the top two actions, chosen by 53% and 32% of riders, respectively (as shown in Figure 4.19). A total of 11% of respondents indicated that the traffic flows normally, as if the work is not occurring. A smaller percentage, 4%, specified that they become distracted when passing work in progress.

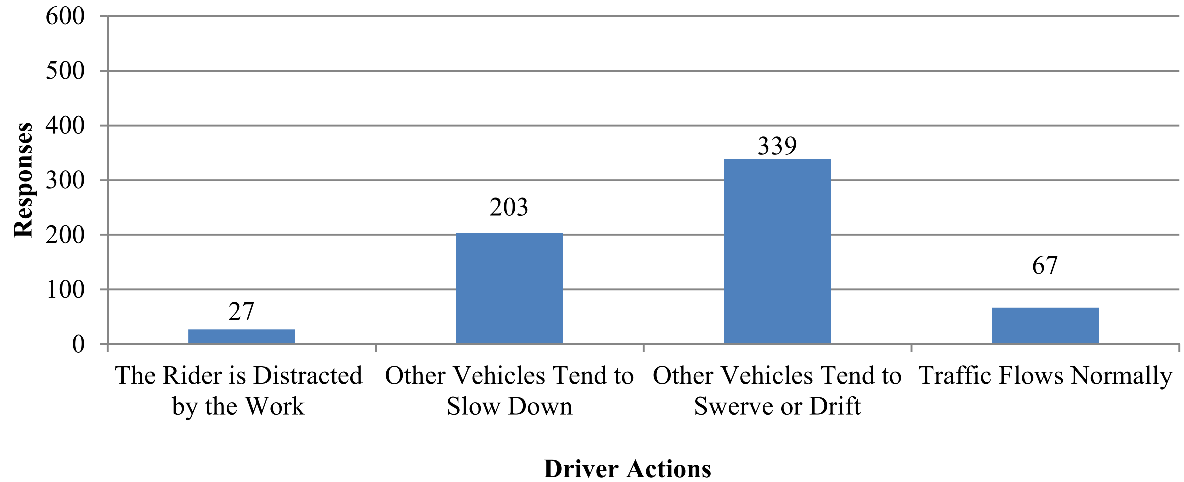

Figure 4.19: Occurrences While Passing Work in Progress

The occurrence of pavement milling is acknowledged by 41% of the respondents as the type of work that is of most concern. About a quarter of the riders (27%) identify excavation as a dangerous or distracting type of work, which is followed closely by paving (24%). Only 8% of respondents believed that pavement marking is the most dangerous or distracting type of work. The distribution of these findings is seen in Figure 4.20.

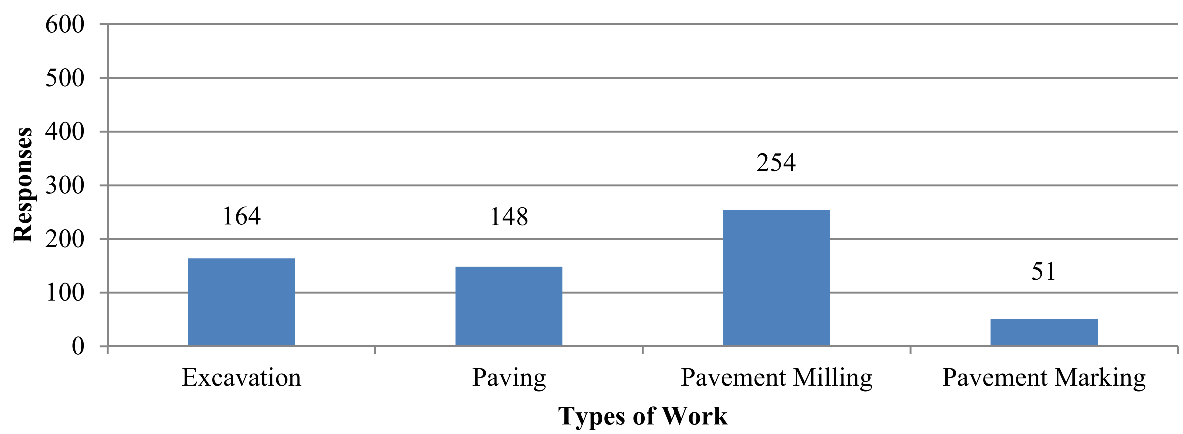

Figure 4.20: Most Dangerous or Distracting Type of Work Occurring

The combination of the PCB and portable drums topped the list of apprehensions of barrier type, with 52% of the motorcyclists (Figure 4.21) choosing this option. Portable drums are cited by 28% of the riders. The use of PCBs is a concern for 21% of the survey participants.

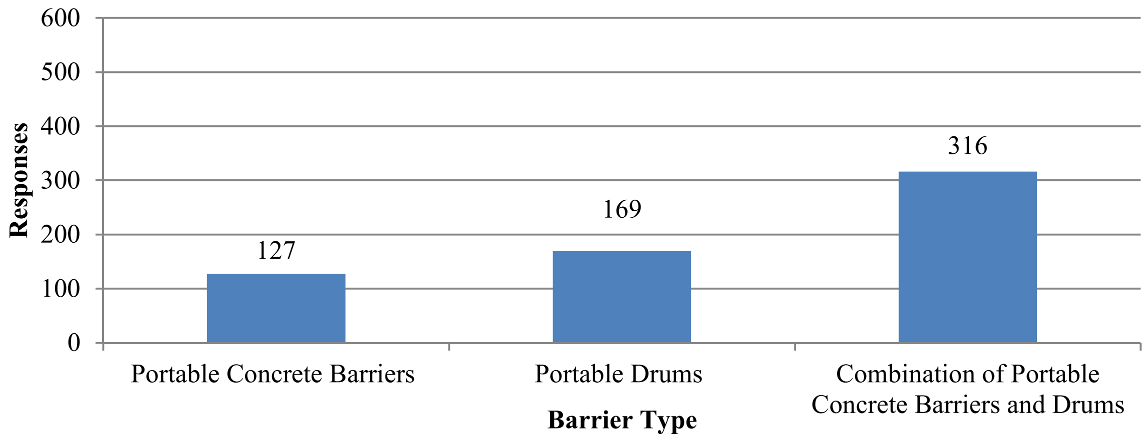

Figure 4.21: Most Dangerous Type of Barrier

4.3.1.3 Potential Implementations

To increase safety in a work zone, 60% of the motorcyclists preferred the option of increasing the distance between the driver and the work (Figure 4.22). Alternatively, the option to increase the warning of the work being performed is favored by 24% of the motorcyclists. Changing the barrier between the driver and the work, chosen by 16% of the survey participants, is the least liked option.

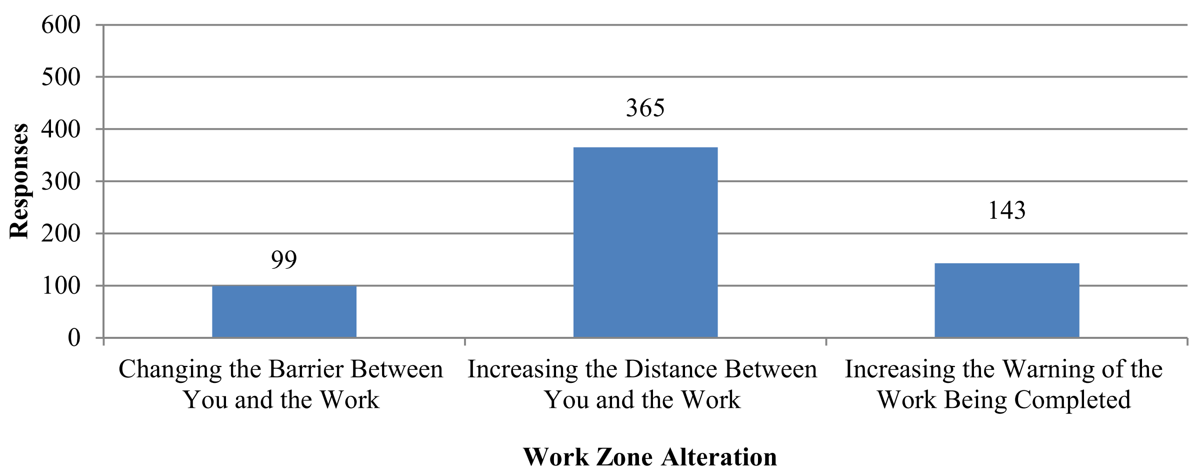

Figure 4.22: Best Way to Increase Safety When Passing Work

When traveling through a work zone where the roadway is being resurfaced, the option to close the section being worked on until it was milled and repaved (i.e., mill and fill) before being reopened to travelers is chosen by 44% of the motorcyclists to be the most advantageous. The suggestion to detour around the work zone is chosen as the best option by 30% of the riders, and 17% of the motorcyclists prefer the option of using a wedge transition. Only 9% of the survey participants want the ability to travel over the resurfaced road without the use of a new implementation. The preferences of the riders are shown in Figure 4.23.

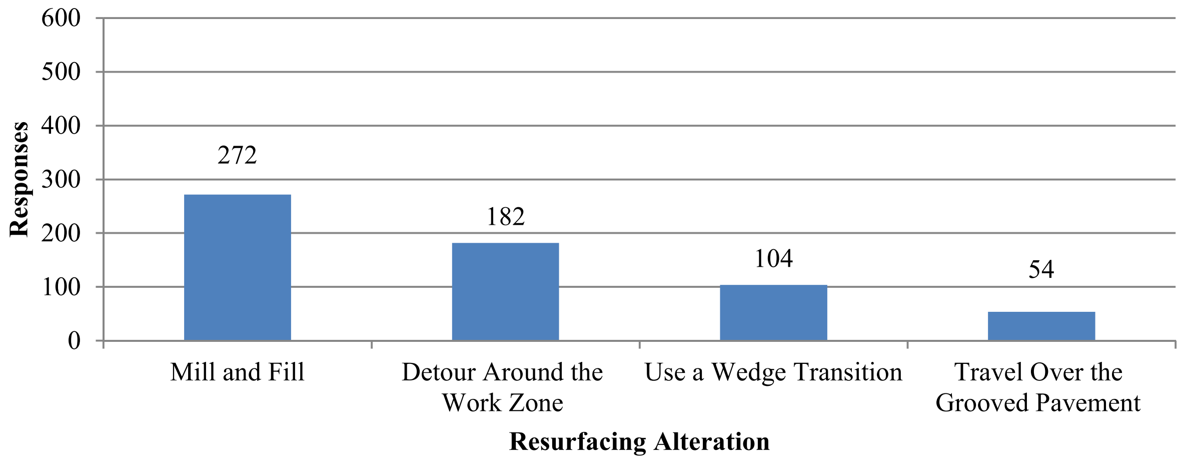

Figure 4.23: Best Way to Increase Safety during Roadway Resurfacing

A total of 77% of the motorcyclists would choose to follow a motorcycle specific detour to avoid the work zone hazard (Figure 4.24). The remaining 23% want to continue to travel through the work zone.

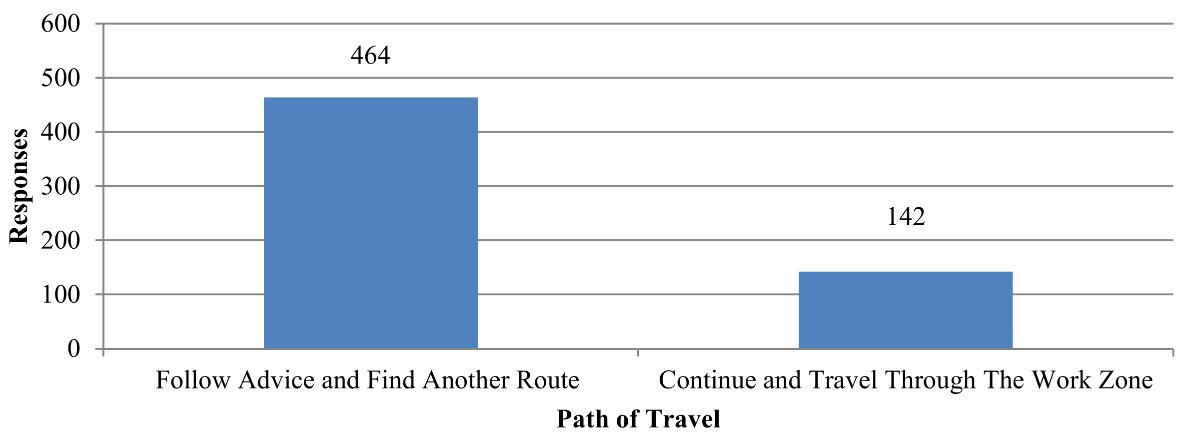

Figure 4.24: Use of a Suggested Alternative Route for Motorcyclists

Loose gravel is the roadway hazard that 61% of motorcyclists would use an alternative route to avoid (see Figure 4.25). Grooved pavement is determined by 20% of the motorcyclists to be the hazard to be most avoided, which is double the percentage who chose uneven lanes. Only 6% of the survey participants believe that passing work occurring close to the roadway is to be avoided, and this is double the percentage that chose asphalt paving.

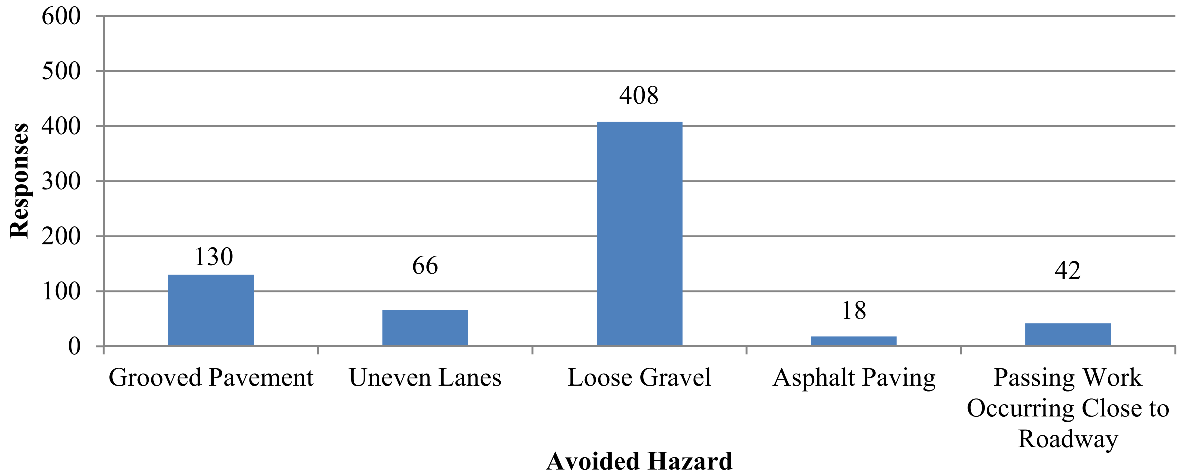

Figure 4.25: Roadway Hazard Most Likely to Use Alternative Route

The option for a motorcyclist to only travel up to 5 minutes on an alternate route is preferred by 13% of the respondents. A total of 25% of motorcyclists would travel up to 10 minutes on an alternative route, and 23% would travel up to 15 minutes. Fewer respondents (10%) are willing to travel up to 20 minutes, while 29% of the motorcyclists responded that they would be willing to travel over 20 minutes to avoid hazardous conditions. The distribution of responses regarding travel times are shown in Figure 4.26.

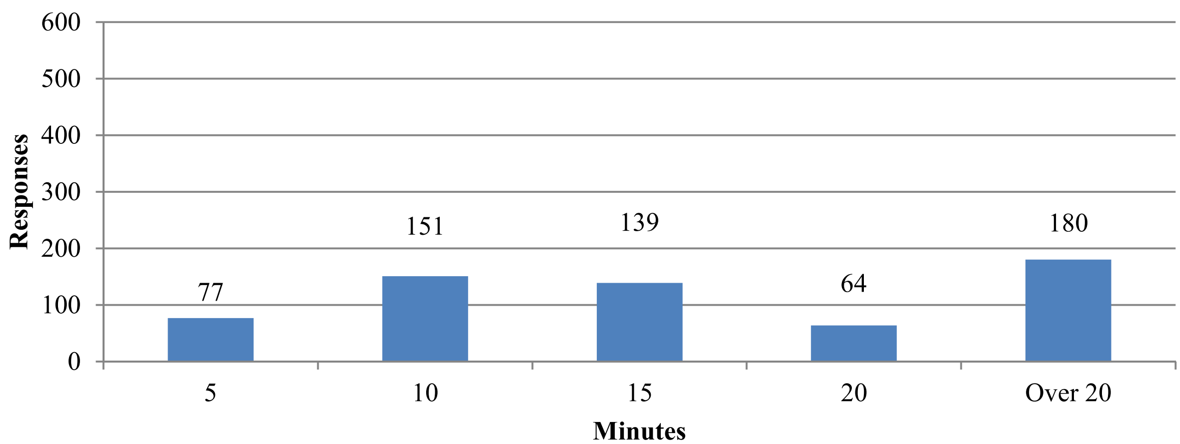

Figure 4.26: Time Willing to Travel on Alternative Route

When asked if motorcyclists would check a website to determine the roadway conditions (see Figure 4.27), the majority (58%) of the riders identified that they would sometimes check a website in order to potentially alter their traveled routes. A total of 31% of the riders indicated that they would always inspect a website before leaving for a ride on their motorcycle, while 11% of motorcyclists indicated that they would never review a website.

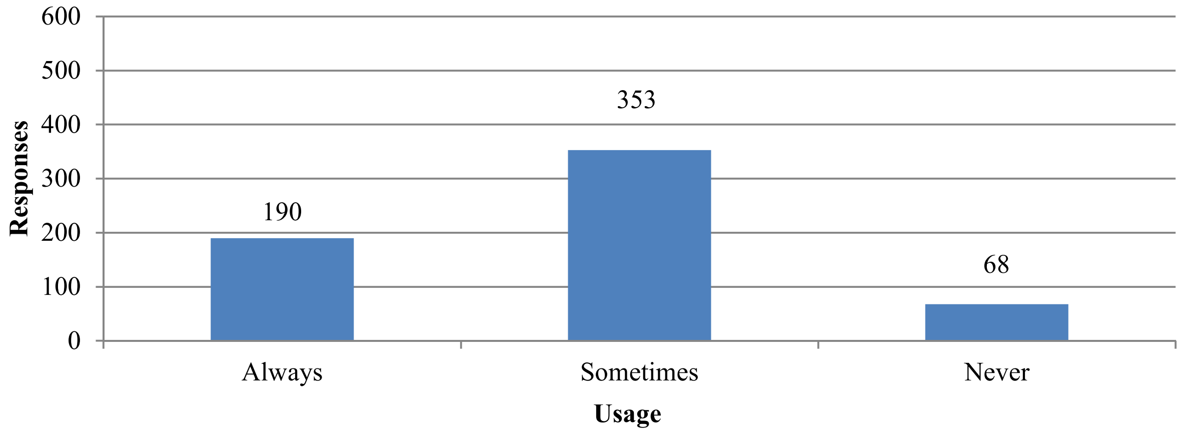

Figure 4.27: Use of a Website to Identify Dangerous Work Zone Conditions

There is a wide variety in the responses obtained in the survey. The most frequent survey responses cover several different types of hazards and implementations. The implementations thought by the motorcyclists to be useful cover both the rider and roadway based solutions. A summary of the survey questions, along with the most popular responses, can be seen in Table 4.7.

Table 4.7: Most Frequent Survey Responses

Questions and Responses	Response Rate
Gender of Motorcyclist	
Male	87%
Female	13%
Endorsement Level	
None	4%
Temporary	3%
Novice	2%
Full Endorsement	91%
Completion of Motorcycle Ohio Course	
No	48%
Yes	52%
Helmet Usage	
Always	39%
Sometimes	40%

Never	21%
Years of Riding	
0 - 2	9%
3 - 5	11%
6 - 10	15%
11 - 20	15%
21+	50%
Average Yearly Mileage	
0 - 1,000	9%
1,001 - 5,000	38%
5,001 - 10,000	40%
10,000+	14%
Most Frequented Area	
Urban	16%
Suburban	25%
Rural	52%
Unknown	6%
Type of Motorcycle Ridden	
Cruiser	35%
Dual Purpose	2%
Scooter	2%
Sidecar	0%
Sportbike	10%
Sport-touring	9%
Standard	9%
Touring	27%
Trike	2%
Other	3%
Frequency of Rides	
Every day	17%
Almost every day	29%
A few days a week	41%
A few days a month	12%
Rarely	1%
Roadway hazard of most concern	
Grooved Pavement	46%
Uneven Lanes	26%
Longitudinal joints	20%
A shoulder that is 1 ½ feet wide or smaller	7%
Most dangerous work zone type	
Lane closures	20%

Lane shift or crossover	46%
Work on shoulder or median	12%
Intermittent or moving work	21%
Occurrences while passing work in progress	
The rider is distracted by the work	4%
Other vehicles tend to slow down	32%
Other vehicles tend to swerve or drift	53%
Traffic flows normally	11%
Most dangerous type of work occurring	
Excavation	27%
Paving	24%
Pavement Milling	41%
Pavement Marking	8%
Most dangerous type of barrier	
Portable concrete barriers	21%
Portable drums	28%
Combination of portable concrete barriers and drums	52%
Best way to increase safety when passing work	
Increasing the warning of the work being completed	24%
Increasing the distance between you and the work	60%
Changing the barrier between you and the work	16%
Best way to increase safety during a resurfacing project	
Mill and fill	44%
Detour around the work zone	30%
Use a wedge transition	17%
Travel over the grooved pavement	9%
Use of a suggested alternative route for motorcyclists	
Follow the advice and find another route	77%
Continue and travel through the work zone	23%
Condition to most likely use alternative route	
Grooved Pavement	20%
Uneven Lanes	10%
Loose Gravel	61%
Asphalt Paving	3%
Passing by work occurring close to roadway	6%
Time willing to travel on alternative route	
5	13%
10	25%
15	23%
20	10%
Over 20	29%

Use of website to identify dangerous work zone conditions	
Always	31%
Sometimes	58%
Never	11%

In comparing the survey results to the ODPS data set, a few of the perceived hazards vary from the occurrences in the crash reports. The survey identifies lane shifts and crossovers to be the most dangerous work zone type. This contradicts the crash results, which are attributed mostly to lane closures; in the crash results, lane shifts and crossovers contribute to the third highest number of crashes. The survey also indicates that motorcyclists believe the combination of PCB and drums are the most dangerous type of barriers. This also varies from the ODPS data set: drums accounted for the largest amount of crashes, followed by the use of PCBs, followed by a combination of the two. The motorcyclists also feel that the most dangerous type of work occurring in a work zone is pavement milling; however, pavement milling falls behind the other three survey options in the ODPS data set, when attributing a crash with the type of work occurring.

CHAPTER V:

RESULTS FROM MIXED LOGIT MODELING

5.1 Introduction

An econometric statistical analysis is used to investigate relationships in the variables on both the survey and the work zone crash data. The econometric analysis of the survey is used to determine the sensitivities of various parameters to the remaining parameters. The data collected through the survey is statistically analyzed in order to determine what characteristics of rider experience, perceived hazards, and potential implementations may be predicted to determine what course of action is most likely to have the greatest impact. This analysis is also used on the work zone crash data to determine the critical factors affecting the motorcyclists. To perform the analysis, the data need to be put into electronic form and correctly formatted. A series of statistical models, three in this case, are then run to determine a set of coefficients related to the model utilities. Once the coefficients are determined, probabilities and elasticities are calculated to relate the findings of the survey parameters to solutions and conclusions that may be implemented by ODOT.

5.2 Logit Modeling

Motorcycle safety surveys in the past have covered information ranging from motorcycle gear associated with crash injury severity (de Rome et al., 2010) to information based on helmet usage (Gkritza, 2009; Ranney et al., 2010) to hazard perceptions (Cheng et al., 2011). The statistical analysis of these data is conducted in a variety of tests and procedures, including but not limited to odds ratio tests, logistic regression models, and t-test. The common issue with the processing method of the survey data is the inappropriate focus on user choice or, more specifically, how user choices correlate throughout a survey in the form of model errors. Econometric models, more specifically logit models, focus on user selections, associated correlations, and associated errors.

The initial step in the analysis is to collect the survey data in electronic form. The key in organizing the data is to take categorical discrete choices made by individuals and assign a numerical value to the data that will then be interpreted by computer software. In the case of the twenty questions posed in the motorcycle work zone survey, the number of answers for each question is not a set number. As such, it is important to create a key indicating to which question the answer correlates. The data for all surveys are then entered with one numeric value for each question, indicating the answer selected by the survey participant. As a side note, the method used in the survey plays a part in the final data itself. With the surveys being administered in person via a handout and a writing utensil, survey participants have the chance to select more than one option for any question despite the instructions of only selecting one answer. Discrete choice modeling, as conducted in this study, requires that the selector to choose one option when the presence of more than one option is available. When the selector makes more than one choice for any given decision, the data is no longer discrete and cannot be evaluated with discrete choice models.

The first step in the modeling process is to create a logit model. The logit model is essential in creating a starting point for a mixed logit model. The logit model is a method for determining choice probabilities based on observed correlations, and it is focused on maximizing utility to the user (McFadden and Train, 2000). The general equation for utility is defined by Greene and Hensher (2006) as seen in the following equation:

$$U_{in} = B_{in} x_{in} \tag{5.1}$$

where U_{in} is utility for *i* selection and *n* selector, and B_{in} is the observed parameter associated with x_{in} attribute. The major decision to be made in building the logit model is to determine the form of logit that satisfies as a starting point for the mixed logit model. There are several forms of model to choose from that encompass the logit model. The research directed by Hensher and Greene (2001) indicates that a multinomial logit (MNL) model cannot be used to accurately represent and predict a mixed logit model. This basis is made mainly on the structure of the models the MNL model restricts model specification to the same sets of parameters and attributes be included into each of the utility functions in a model. The conditional logit (CLOGIT) model was chosen as the basis for model prediction.

The CLOGIT model allows for unique utility functions within one model. This approach means that a choice attribute (answer to a question) or its associated parameter (observed or unobserved relation to user choices) do not need to be evaluated in each utility function. For this research, there are three models: two utilizing the survey data and one focused on motorcycle crash data. The attributes used are not simply the answer of a, b, c, etc., but what the answers signify. In the survey data, for example, one of the questions relates to the completion of Motorcycle Ohio courses. The answer to the question is either yes or no. The attribute in a model that relates to the responses is YESMO and NOMO, making the information stand out within the model. The associated parameters are numerical coefficients. All of the parameters are given in the raw data coefficient tables, presented as Tables 5.1, 5.4, and 5.7. The specifications of the utility functions are the critical portions of creating the CLOGIT model. These utility functions will be the same functions, with the same parameters and attributes as the mixed logit model. The

CLOGIT model is made up of *n* number of utility functions as previously defined in Equation 5.1. The entire CLOGIT model takes the structure seen in following equation:

$$\begin{aligned} U_1 &= B_1 x_1 \\ U_2 &= B_2 x_2 \\ &\vdots \\ U_n &= B_n x_n \end{aligned} \tag{5.2}$$

where parameters are the observed patters in choices by the selector and the choice is the answer for a given question. The general equation for utility includes an error component, as seen in the following equation:

$$U_{in} = B_{in} x_{in} + \varepsilon_{in} \tag{5.3}$$

where ε_{in} is an error component that is independently and identically distributed over all parameters. The CLOGIT model is run primarily to determine the parameters and attributes that will be evaluated for choice probabilities. The results of the CLOGIT model may be interpreted by post estimation of elasticities to determine the importance of variables, but this only applies in a special case where errors are evenly distributed and the choice alternatives are not redundant. The choice probabilities of the special case defined by McFadden (1981) are as follows:

$$Pn(i) = \frac{\exp[\beta_{in} X_{in}]}{\sum_I \exp[\beta_{in} X_{In}]} \tag{5.4}$$

where *Pn(i)* is the probability of a utility function (alternative) *i* for selector *n*.

The limitations of the CLOGIT model for post estimation focus on the violation of two assumptions: 1) the assumption of independent irrelevant alternatives (IIA); and 2) the assumption of independently and identically distributed random parameters (IID). IIA violations occur when there are alternatives that are perfect replacements for each other that exist in the choice set. For example, the data set for surveys have information regarding motorcycle type. There are functional differences between a touring motorcycle and a sport bike within the context of the survey and among motorcycle riders. The functional differences make them valid alternatives to individuals taking the survey. If, however, the researcher captured color of motorcycle in the survey, they would have alternatives for red sport bikes and blue sport bikes. There are no functional differences that would cause these bikes, or riders, to behave differently within a work zone, thus making them identical and irrelevant alternatives to each other (Train, 2009).

Identical and irrelevant alternatives cause the logit model to incorrectly calculate the options as viable alternatives instead of calculating the choice probabilities of the attributes as one. If the total population of motorcycles captured in the survey consists only touring motorcycles, red sport bikes and blue sport bikes, the logit model would predict that each of motorcycles would be a third of the total. What the logit model indicates is that two thirds of the population are now preferential to sport bike tendencies, when in fact there are only two types of motorcycles, with each accounting for half. IIA restrictions must be tested to check for the validity of a logit model to ensure that the results do not improperly place an emphasis on options that do not indicate varying information. The IID assumption states that error components of the model are independent of specific parameters and are instead equal and identical across all parameters in the model.

The relaxation of the IIA and IID restrictions results in the introduction of randomization to the logit model. Random effects for parameters take the logit model and make it practical in the real world by introducing the interactions of the parameters and unobserved effects in the form of errors specific to each parameter that is modeled by a distribution. The overall error component of the general utility function indicates the unobserved factors in the model that apply equally to all parameters (IID assumption). Error components are introduced into individual parameters as the unobserved interactions of each parameter of a normal utility function, disregarding the subscripts for selector and selection, in the following equation:

$$U = (ax + r) + (bx + p) + e \tag{5.5}$$

where *r* and *p* are the unobserved effects of each parameter, and all other information is previously defined. The preferential and observational differences vary in the sample population as a density function denoted by Train (1999) in the following equation:

$$Pin = \int \frac{\exp[\beta_i X_{in}]}{\sum_I \exp[\beta_i X_{In}]} f(\beta|\varphi) d\beta \tag{5.6}$$

where φ is the error parameters of the distribution that describe the preferences and the behavior of the selector. The equation for the mixed logit model is weighted for the densities function for different values of β, where β may vary between the decisions that a selector makes. The parameters are only weighted by the density function if they are random; otherwise, the density function goes to one, and the probability is estimated as listed in Equation 4.

5.3 Mixed Logit Modeling

The estimation of the mixed logit model starts with the utility functions defined by the CLOGIT model previously estimated. The results of the mixed logit model estimated from the survey data for helmet use and miles ridden are shown in Table 5.2 and Table 5.5. The raw data coefficients based on the Ohio work zone crash information may be seen in Table 5.8. The steps in defining the mixed logit model are to select: 1) the type of draws,

2) the number of max iterations needed for the model to converge, 3) the number of points required for the model to converge, 4) the parameters that are random, and 5) the distribution of the random parameters.

The type of draw is first selected. The types of draws from the population that are available are shuffle, random, and Halton. The variations in the three types of draws are based around how the data are sampled. Bhat (2003) describes the benefits of using Halton draws over other standard methods as a savings in computational time. In the study, it was seen that Halton draws required 10% of the calculation time to determine the same results as other methods. Based on the information from Bhat (2003), amongst others including Train (1999) and Hensher (2001), Halton draws are chosen for all of the models in this study.

Next, the number of iterations and points are selected. The number of sampling points is the number of draws utilized in each iteration of the model. The appropriate number of draws is where the model log likelihood, defined by Hess and Train (2011), does not improve by adding one more iteration to the model simulation. The amount of computation time may increase significantly based on the number of points used. There are quite a few numbers shown in literature, ranging from as few as 200 (Bhat, 2003) to as many as 2000 (Hensher and Greene, 2001). This research focused on 500 points, in line with similar research and model testing.

The fourth step is the selection of parameters that are random. While there is no single accepted process for the determination of random parameters within the practice, there are a few widely utilized procedures. The processes put forth in McFadden and Train (2000), indicate that a series of LaGrange multiplier tests may be used to estimate which parameters should be tested as random parameters. Another option outlined in Gkritza and Mannering (2008) is to analyze the standard error of the parameters and compare them to zero. Standard errors that are significantly different from zero should be tested as random parameters.

The final step is to select the distribution of random parameters. The distribution of parameters is how the error component of the preferred specific choices and unobserved effects are spread across parameters. There are numerous distributions available including normal, triangular, logarithmic, and Wald, to name only a few. As was the case in the work of Milton et al. (2008) and Gkritza and Mannering (2008), normally distributed random parameters provide the best estimation of parameters in all three mixed logit models conducted with both the survey data and the work zone crash data.

Post estimation must be used in order to identify the effects of model parameters on the outcome of the user selections. Parameter elasticities are one measure of the effect of an attribute within a model. Elasticities indicate the effective change on a parameter's choice probability based on a 1% change in the model (Chang and Mannering, 1999). The calculation for elasticities is seen in the following equation:

$$E_{Xin}^{Pn(i)} = -P(j)\beta_{kj}x_{kj} \qquad (5.7)$$

where equation parameters are previously defined. These elasticities cannot be used to accurately estimate dummy variables, variables that only take on 1 or 0 values, as in the data used in both the survey models and the crash data models. In order to estimate the elasticities for such variables, it is necessary to estimate pseudo-elasticities (Chang and Mannering, 1999), as can be seen in the following equation:

$$E_{Xin}^{Pn(i)} = \frac{\exp[\Delta(\beta iXin)]\sum_{\forall I}\exp(\beta iXin)}{\exp[\Delta(\beta iXin)]\sum_{I=In}\exp(\beta iXin)+\sum_{I\neq In}exp(\beta iXin)} - 1 \qquad (5.8)$$

where *Xin* is the choice variable and B_{in} is the coefficient associated with that each *Xin*, for each *In*, selector and choice that the selector makes. Elasticities are developed to determine the sensitivity of a parameter with its model. For this research, there are three tables of elasticities (Tables 5.3, 5.6, and 5.9) developed for each model. The elasticities are calculated for a single model at a time, and as such may have different values in different models.

5.3.1 Mixed Logit Results

Three models are developed within this chapter. The first two models are based on the data from the survey. The third model is developed using the OH-1 reports from the ODPS.

5.3.1.1 Model One Mixed Logit Model for Mileage

The first model is constructed utilizing the motorcycle survey data. A summary of the variables that contributed to the creation of Model One are seen in Table 5.1.

Table 5.1: Model One Descriptive Statistics

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases	Missing
Rider Experience						
Male	0.86	0.35	0	1	607	0
No Endorsement	0.04	0.19	0	1	607	0
Temporary Permit	0.03	0.17	0	1	607	0
Novice Restriction	0.02	0.16	0	1	607	0
Full Endorsement	0.90	0.30	0	1	607	0
Riding 0 - 2 years	0.09	0.29	0	1	607	0
Riding 3 - 5 years	0.11	0.31	0	1	607	0
Riding 6 - 10 years	0.14	0.35	0	1	607	0
Riding 11 - 20 years	0.15	0.36	0	1	607	0

Riding 21+ years	0.50	0.50	0	1	607	0
0 - 1,000 miles averaged	0.09	0.28	0	1	607	0
1,001 - 5,000 miles averaged	0.38	0.49	0	1	607	0
5,001 - 10,000 miles averaged	0.39	0.49	0	1	607	0
10,001+ miles averaged	0.14	0.35	0	1	607	0
Cruiser	0.34	0.47	0	1	607	0
Sportbike	0.08	0.27	0	1	607	0
Standard	0.09	0.28	0	1	607	0
Touring	0.27	0.44	0	1	607	0
Other motorcycle type	0.14	0.75	0	5	607	0
Every day	0.16	0.37	0	1	607	0
Almost every day	0.29	0.45	0	1	607	0
Few days a week	0.41	0.49	0	1	607	0
Few days a month	0.12	0.32	0	1	607	0
Rarely	0.01	0.09	0	1	607	0
Perceived Hazards						
Excavation	0.25	0.43	0	1	607	0
Paving	0.23	0.42	0	1	607	0
Pavement milling	0.41	0.49	0	1	607	0
Pavement marking	0.08	0.27	0	1	607	0
Potential Implementations						
Change barrier	0.16	0.37	0	1	607	0
Close lane	0.44	0.50	0	1	607	0
Detour work zone	0.29	0.45	0	1	607	0
Use wedge transition	0.16	0.37	0	1	607	0
Travel over grooved pavement	0.08	0.27	0	1	607	0
Find alternate route	0.76	0.43	0	1	607	0
Grooved pavement	0.12	0.33	0	1	607	0
Uneven lanes	0.05	0.21	0	1	607	0
Loose gravel	0.56	0.50	0	1	607	0
Asphalt paving	0.09	0.29	0	1	607	0
Work close to roadway	0.05	0.22	0	1	607	0
Up to 5 minutes	0.12	0.33	0	1	607	0
Up to 10 minutes	0.24	0.43	0	1	607	0
Up to 15 minutes	0.23	0.42	0	1	607	0
Up to 20 minutes	0.11	0.31	0	1	607	0
Over 21 minutes	0.29	0.45	0	1	607	0

Only variables that are statistically significant are presented in Table 5.2. In the mileage model, there are four utility functions corresponding to three alternate specific constants (ASC). The model compares the amount of miles that riders will accumulate through an average riding season. The four categories are small (0 to 1,000 miles), mid (1,000 to 5,000 miles), medium (5,000 to 10,000 miles), and large (10,000+ miles). The mileage bins were set in order to capture information based on the frequency of riding in order to differentiate between casual riders and riders who spend a lot of time on their motorcycles and are thus associated with having more experience. By separating the survey data based on the amount of time spent riding, the research team may infer which factors of work zones are perceived as greater risks/solutions based on rider experience/comfort.

Table 5.2: Model One Coefficient Significance

Variable Name	Annual Mileage	Coefficient	S.E.	t-Ratio	p-Value
Alternate Specific Constants					
Small 0 - 1,000		2.64	0.66	4.00	0.00
Mid 1,001 - 5,000		3.83	0.68	5.63	0.00
Med 5,001 - 10,000		2.22	0.75	2.96	0.00
Large 10,001+					
Rider Experience					
No Endorsement	Small	2.16	0.56	3.86	0.00
Temporary Endorsement*	Small	2.12 (0.09)	0.65	3.25	0.00
Novice Endorsement	Small	2.36	0.75	3.14	0.00
20+ Years of Experience*	Large	1.10 (0.00)	0.38	2.89	0.00
Touring Bike*	Large	1.20 (0.03)	0.38	3.12	0.00
Rides Every Day	Large	3.19	0.50	6.34	0.00
Rides A Lot of Days*	Small	2.93 (0.01)	1.04	2.81	0.01
Rides A Lot of Days*	Med	4.09 (0.14)	1.08	3.77	0.00
Rides A Lot of Days*	Large	5.36 (0.08)	1.15	4.68	0.00
Male	Med	1.06	0.45	2.33	0.02
Perceived Hazards					
Lane Closure*	Small, Mid	0.71 (0.03)	0.25	2.81	0.01
Milling Work	Med	0.72	0.30	2.36	0.02
Milling Work*	Large	1.09 (0.04)	0.35	3.12	0.00
Potential Implementation					
Change Barrier*	Med, Large	0.71 (0.01)	0.35	2.06	0.04
Loose Gravel*	Large	0.82 (0.05)	0.35	2.35	0.02
10 Minute Travel	Small	1.52	0.55	2.78	0.01
10 Minute Travel	Mid, Med	1.24	0.45	2.75	0.01
15 Minute Travel	Mid, Med	0.60	0.32	1.87	0.06
Alternative Route*	Mid	0.58 (2.08)	0.28	2.05	0.04
Log Likelihood		-651.50			
Restricted Log Likelihood		-841.48			
Chi Squared		379.95			

* Indicates Normally Distributed Random Parameter

These raw data coefficients do not indicate the significance of even the sign of the final elasticity or sensitivity of the parameter within the model. The post estimation of the calculated elasticities (listed in the Table 5.3) is -46.4%.

Table 5.3: Model One Elasticity

Variable Name	**Annual Mileage**	**Pseudo Elasticity**
Rider Experience		
No Endorsement	Small	507.2%
Temporary Endorsement*	Small	487.6%
Novice Endorsement	Small	600.1%
20+ Years of Experience*	Large	164.0%
Touring Bike*	Large	180.1%
Rides Every Day	Large	1211.6%
Rides A Lot of Days*	Small	-46.4%
Rides A Lot of Days*	Med	63.6%
Rides A Lot of Days*	Large	486.1%
Male	Med	114.6%
Perceived Hazards		
Lane Closure*	Small, Mid	44.1%
Milling Work	Med	36.6%
Milling Work*	Large	98.5%
Potential Implementations		
Change Barrier*	Med, Large	39.3%
Loose Gravel*	Large	106.3%
10 Minute Travel	Small	52.4%
10 Minute Travel	Mid, Med	15.3%
15 Minute Travel	Large	14.2%
Alternative Route*	Mid	57.3%
Log Likelihood		-651.50
Restricted Log Likelihood		-841.48
Chi Squared		379.95
* Indicates Normally Distributed Random Parameter		

5.3.1.1.1 Model One Rider Experience

Model One has eleven parameters that exhibit random effects. These parameters are the ones indicated by asterisks in Table 5.3. In Ohio, there are three types of motorcycle endorsements: temporary, novice, and full. For the survey information and the model, it is important to consider the option that a rider may not have any endorsement, despite the current laws in Ohio. As seen in the descriptive statistics (Table 5.1) for the mileage model, the vast majority of riders participating in the survey have a full endorsement. The other two endorsement types (temporary and novice) and no endorsement all are considerably more likely to ride a small amount of miles per year than any other segment of miles per year. Riders with a temporary endorsement are 487.6% more likely to ride less than 1,000 miles per year. Riders with no endorsement are 507.2% more likely to ride less than 1,000 miles per year, while riders with a novice endorsement are 600.1% more likely to ride a small segment of miles every year. This indicates that the riders, who annually do not spend as much time on their motorcycle, are less likely to have fully developed their motorcycle skills. Therefore, it is reasonable to suggest that these groups of riders are less likely to have the same experience of riding through multiple work zones while encountering the situations associated with work zone hazards.

There are other rider characteristics captured in the model that identify the types of riders answering questions about their concerns and preferences in work zones. The riders that have been riding for more than twenty years are 160.4% more likely to ride more than 10,000 miles each year, compared to other amounts of miles traveled in a year. Riders who rode touring bikes were 180.1% more likely to ride 10,000 or more miles per year. Those riders that answered to riding their motorcycle every day are 1211.6% more likely to travel more than 10,000 miles per year, while riders that are male are 114.6% more likely to travel between 5,000 and 10,000 miles per year.

5.3.1.1.2 Model One Perceived Hazards

There are three work zone conditions in Model One that indicate the type of work zone condition encountered by the rider as least preferential. Riders who identified milling work as posing the greatest concern to their riding safety or comfort are 36.6% more likely to ride a medium amount of miles, and they are 98.5% more likely to ride a large amount miles each year compared to motorcyclists who ride a small or mid-level amount of miles each year. This indicates that milling work becomes more of a concern with increased amounts of riding and exposure to work zone conditions. The last statistically significant condition is the presence of loose gravel. Riders who identified loose gravel as their largest concern while traveling through a work zone are 106.3% more likely to ride a large amount of miles each year compared to any other amount of miles. This suggests that loose gravel is more of a concern to riders with more experience and with more yearly exposure to work zones.

5.3.1.1.3 Model One Potential Solutions

The next sets of parameters are concentrated on solutions that provide alternative routes or improve work zone conditions for motorcycles. Two model parameters focus on the amount of time that a rider is willing to travel to get to an alternative route. The two travel times from the survey that are modeled include a ten-minute travel time and a fifteen-minute travel time. As seen in the elasticities presented in Table 5.3, riders who would travel ten minutes for an alternative route are 52.4%, 15.3%, and 15.3% more likely to travel a small amount of miles, a mid-level amount of miles, and a medium amount of miles per year, respectively, when compared to riders who travel a large amount of miles per year. A rider who is willing to travel fifteen minutes to avoid a work zone is 14.2% more likely to travel either a mid-level or medium amount of miles per year rather than a small or large amount of miles. The riders who are willing to travel ten and fifteen minutes to avoid a work zone are the second and third lowest options to select for time to avoid a work zone. This implies that riders with less exposure to work zones are less likely to go out their way to avoid them. Riders who considered a full-lane closure as the best option for road work are 44.1 % more likely to ride either a small or mid-level amount of miles a year compared to riders who traveled either a medium or large amount of miles per year. Additionally, riders who prefer to travel an alternative route are 57.3% more likely to ride a large amount of miles per year. The finding that riders with more riding exposure per year are more likely to want to avoid a work zone, compounded with the willingness of these riders to travel a longer time to avoid a work zone, implies that riders with more experience are considerably more likely to avoid a work zone that those riders with fewer annual miles and less exposure to potential work zone hazards.

5.3.1.2 Model Two Mixed Logit Model for Helmet Use

The second model is constructed around the results of the survey are concerned with a rider’s use of a helmet. Ohio law requires any rider that does not have a full endorsement to wear a helmet at all times. Model Two is developed because many researchers believe that riders who do not wear a helmet are considered risk takers (Horswill et al., 2003) and that helmet use may be highly related to a specific manufacturer or motorcycle type. A summary of the variables that contributed to the creation of Model Two are seen in Table 5.4.

Table 5.4: Model Two Descriptive Statistics

Variable	Mean	Std.Dev.	Minimum	Maximum	Cases	Missing
Rider Experience						
No Endorsement	0.04	0.20	0	1	602	0
Temporary Permit	0.03	0.17	0	1	602	0
Novice Restriction	0.02	0.16	0	1	602	0
Full Endorsement	0.90	0.30	0	1	602	0
Always wears helmet	0.39	0.49	0	1	602	0
Sometimes wears helmet	0.40	0.49	0	1	602	0
Never wears helmet	0.21	0.41	0	1	602	0
Riding 0 - 2 years	0.09	0.29	0	1	602	0
Riding 3 - 5 years	0.11	0.31	0	1	602	0
Riding 6 - 10 years	0.14	0.35	0	1	602	0
Riding 11 - 20 years	0.15	0.36	0	1	602	0
Riding 21+ years	0.50	0.50	0	1	602	0
Urban	0.11	0.31	0	1	602	0
Suburban	0.20	0.40	0	1	602	0
Rural	0.50	0.50	0	1	602	0
Unknown areas	0.07	0.26	0	1	602	0
Everyday	0.16	0.37	0	1	602	0
Almost every day	0.29	0.46	0	1	602	0
Few days a week	0.41	0.49	0	1	602	0
Few days a month	0.12	0.32	0	1	602	0
Rarely	0.01	0.10	0	1	602	0
Perceived Hazards						
Grooved pavement	0.44	0.50	0	1	602	0
Uneven lanes	0.22	0.41	0	1	602	0
Pavement joints	0.19	0.39	0	1	602	0
Grooved pavement and uneven lanes	0.03	0.18	0	1	602	0
Grooved pavement, uneven lanes, and pavement joints	0.01	0.09	0	1	602	0
Grooved pavement, uneven lanes, pavement joints, and shoulder width	0.03	0.17	0	1	602	0
Grooved pavement and pavement joints	0.02	0.13	0	1	602	0
Rider is distracted	0.04	0.19	0	1	602	0
Others slow down	0.30	0.46	0	1	602	0
Others swerve	0.52	0.50	0	1	602	0
Traffic flows normally	0.10	0.30	0	1	602	0
Excavation	0.25	0.43	0	1	602	0
Paving	0.23	0.42	0	1	602	0
Pavement milling	0.41	0.49	0	1	602	0
Pavement marking	0.08	0.27	0	1	602	0

Potential Implementations						
Change barrier	0.16	0.37	0	1	602	0
Increase distance	0.59	0.49	0	1	602	0
Increase warning	0.22	0.42	0	1	602	0
Close lane	0.44	0.50	0	1	602	0
Detour work zone	0.29	0.46	0	1	602	0
Use wedge transition	0.16	0.37	0	1	602	0
Travel over grooved pavement	0.08	0.27	0	1	602	0

The choices in the model and in the survey are “I always wear a helmet,” “I sometimes wear a helmet,” and “I never wear a helmet.” These parameters, or statistical significance, are shown in Table 5.5 and are denoted by an asterisk, and the distributions of the random parameters are shown in parentheses.

Table 5.5: Model Two Coefficient Significance

Variable Name	**Helmet Usage**	**Coefficient**	**S.E.**	**t-Ratio**	**p-Value**
Alternate Specific Constants					
Always		1.52	0.23	6.46	0.00
Sometimes		0.92	0.25	3.64	0.00
Never					
Rider Experience					
0 - 2 Years Experience	Always	1.40	0.36	3.92	0.00
3 - 5 Years Experience*	Always	0.75 (0.10)	0.30	2.47	0.01
No Endorsement	Never	1.45	0.49	2.99	0.00
Suburban	Always, Sometimes	0.59	0.31	1.91	0.06
A Lot of Days	Always	-6.04	0.22	-2.76	0.01
Everyday*	Never	0.70 (0.07)	0.29	2.40	0.02
Perceived Hazards					
Grooved Pavement*	Sometimes	0.64 (1.35)	0.24	2.71	0.01
Grooved Pavement	Never	0.57	0.25	2.31	0.02
Other Vehicles Swerve	Sometimes	0.44	0.21	2.07	0.04
Excavation Work*	Sometimes	0.65 (0.42)	0.23	2.79	0.01
Grooved Pavement and Uneven Lanes	Never	1.18	0.50	2.35	0.02
Potential Implementations					
Change Barrier	Never	1.01	0.27	3.75	0.00
Detour*	Never	0.85 (0.01)	0.24	3.50	0.00
Travel Over Pavement*	Never	1.06 (0.28)	0.47	2.27	0.02
Log Likelihood		-588.30			
Restricted Log Likelihood		-661.40			
Chi Squared		146.10			
* Indicates Normally Distributed Random Parameter					

5.3.1.2.1 Model Two Rider Experience

The parameters regarding rider experience in the model include 0-2 years of experience, 3-5 years of experience, no endorsement, and the riding frequency . Riders having 0-2 years of experience are 101% more likely to always wear their helmet, while riders having 3-5 years of experience of are only 48% more likely to always were their helmet. Riders reporting that they have no endorsement are 162% more likely to never wear a helmet in comparison to always or sometimes. This result is further indication that riders not wearing helmets are more likely to take risks. Riders that usually travel in suburban areas are 12% more likely to always wear a helmet or sometimes wear a helmet in comparison to never wearing a helmet. As far a frequency of riding, riders who use their motorcycle every day are 73.2% more likely to never wear a helmet, while riders that ride a lot of days are 32% less like to always wear a helmet rather than sometimes or never wear a helmet.

Table 5.6: Model Two Elasticity

Variable Name	Helmet Use	Pseudo Elasticity
Rider Experience		
0 - 2 Years Experience	Always	101.1%
3 - 5 Years Experience*	Always	48.4%
No Endorsement	Never	169.2%
Suburban	Always, Sometimes	12.1%
A Lot of Days	Always	-31.7%
Everyday*	Never	73.2%
Perceived Hazards		
Grooved Pavement	Sometimes	29.6%
Grooved Pavement	Never	22.7%
Other Vehicles Swerve	Sometimes	28.7%
Excavation Work*	Sometimes	43.9%
Grooved Pavement and Uneven Lanes*	Never	129.8%
Potential Implementations		
Change Barrier	Never	117.5%
Detour*	Never	92.3%
Travel Over Pavement*	Never	122.7%
Log Likelihood		-588.30
Restricted Log Likelihood		-661.40
Chi Squared		146.10
* Indicates Normally Distributed Random Parameter		

5.3.1.2.2 Model Two Perceived Hazards

The work zone conditions that are considered by riders to be hazardous include grooved pavement, excavation work, other drivers swerving, and the combination of grooved and uneven lanes. Riders who identify grooved pavement as their main concern are 30% more likely to sometimes wear a helmet and 23% more likely to never wear a helmet. Similarly, those riders who identify the combined situation of grooved pavement and uneven lanes as their main concern are 129.8% more likely to never wear a helmet. Riders whose main concern in work zones is other vehicles swerving are 29% more likely to sometimes wear a helmet than always or never. Riders who identified excavation work as more concerning are 44% more likely to sometimes wear a helmet rather than always or never.

5.3.1.2.3 Model Two Potential Solutions

The solutions most preferred by riders that are statistically significant in the model include changing work barriers, choosing a detour, and traveling over pavement being worked on. Riders who prefer changing barriers are 117.5% more likely to never wear a helmet. Similarly, riders who would most prefer taking a detour are 92.3% more likely to never wear a helmet, while riders who would most prefer to travel over pavement under construction are 122.7% more likely to never wear a helmet.

5.3.1.3 Model Three Mixed Logit Model for Motorcycle Crashes in Work Zones

The third mixed multinomial logit model is developed from the crash data provided by the Ohio Department of Public Safety. The crashes analyzed within Model Three pertain to motorcycle crashes in work zones. The descriptive statistics for the model are shown in Table 5.7.

Table 5.7: Model Three Descriptive Statistics

Variable	**Mean**	**Std.Dev.**	**Minimum**	**Maximum**	**Cases**	**Missing**
Alcohol Related	0.09	0.29	0	1	348	0
Drug Related	0.01	0.12	0	1	348	0
Animal Related	0.01	0.09	0	1	348	0
Speed Related	0.17	0.37	0	1	348	0
Truck Related	0.10	0.30	0	1	348	0
Youth Related	0.25	0.44	0	1	348	0
Teen Related	0.14	0.35	0	1	348	0
Vehicle Speed	34.32	17.38	1	80	348	0
Driver Age	42.90	13.86	16	90	348	0

Day	0.70	0.46	0	1	348	0
Night	0.25	0.44	0	1	348	0
Speed 0 - 25	0.36	0.48	0	1	348	0
Speed 25 - 45	0.38	0.49	0	1	348	0
Speed 45 - 65	0.21	0.41	0	1	348	0
Speed 65+	0.05	0.22	0	1	348	0
Posted Speed 0 - 25	0.11	0.31	0	1	348	0
Posted Speed 25 - 45	0.40	0.49	0	1	348	0
Posted Speed 45 - 65	0.41	0.49	0	1	348	0
Posted Speed 65+	0.08	0.28	0	1	348	0
Male	0.96	0.20	0	1	348	0
Female	0.04	0.20	0	1	348	0
Incapacitating	0.21	0.41	0	1	348	0
Fatal	0.02	0.15	0	1	348	0
Helmet	0.48	0.50	0	1	348	0
No Helmet	0.52	0.50	0	1	348	0
Passenger	0.12	0.33	0	1	348	0

The model utility functions focus on the severity of the crashes based on property damage only (PDO), possible injury (Poss), non-incapacitating injury (Non), and incapacitating or fatal (Inc/Fat) injuries. Due to the low number of total crashes, incapacitating and fatal injuries were grouped together in the model. There three categories of parameters that are seen in the model: roadway, rider, and crash characteristics.

Table 5.8: Model Three Coefficient Significance

Parameter Name	Injury Severity	Coefficient	S.E.	t-Ratio	p-Value
Property Damage Only (PDO)		1.64	0.71	2.31	0.02
Possible Injury (Poss)		1.05	0.28	3.73	0.00
Non-Incapacitating Injury (Non)		0.44	0.20	2.21	0.03
Incapacitating or Fatal (Inc/Fat)					
General Crash Parameters					
Rollover	Poss, Non, Inc/Fat	-0.85	0.40	2.14	0.03
Diver Ejected	Poss, Non, Inc/Fat	1.27	0.35	3.67	0.00
Posted Speed <25 mph, Crash Speed 25 - 45 mph*	Poss,Non	0.75	0.33	2.27	0.02
Vehicle Totaled	Inc/Fat	1.53	0.40	3.79	0.00
Rider Parameters					
Helmet Worn By Rider	PDO	1.18	0.39	3.00	0.00
Helmet Worn By Rider	Poss	0.99	0.41	2.40	0.02
Helmet Worn By Rider*	Non	1.12	0.32	3.47	0.00
Passenger Present*	PDO	0.98	0.44	2.20	0.03

Work Zone Parameters					
Crash speed less than 25 mph	PDO	1.31	0.35	3.78	0.00
Straight Road Segment*	PDO	1.38	0.67	2.07	0.04
Signalized Intersection*	Poss, Inc/Fat	0.78	0.39	2.01	0.04
Log Likelihood					
Restricted Log Likelihood					
Chi Squared					
* Indicates Normally Distributed Random Parameter					

The most notable rider characteristic seen in the model is the use of helmets. Riders wearing helmets are 38% more likely to be in a PDO crash, 13% more likely to be in a possible injury crash, and 30% more likely to be in a non-incapacitating crash than to be involved in an incapacitating/fatal crash. The other operator related factor seen in the model is the presence of a passenger on board. Of the crashes included in the model, situations where a passenger is on board are 116% more likely to be a PDO crash than any other crash severity.

Table 5.9: Model Three Elasticity

Variable Name	**Crash Severity**	**Pseudo Elasticity**
General Crash Parameters		
Rollover	Poss, Non, Inc/Fat	14.8%
Diver Ejected	Poss, Non, Inc/Fat	25.4%
Posted Speed <25 mph, Crash Speed 25 - 45 mph*	Poss,Non	32.3%
Vehicle Totaled	Inc/ Fat	180.7%
Rider Parameters		
Helmet Worn By Rider	PDO	37.8%
Helmet Worn By Rider	Poss	13.6%
Helmet Worn By Rider*	Non	29.9%
Passenger Present*	PDO	115.5%
Work Zone Parameters		
Crash speed less than 25 mph	PDO	192.7%
Straight Road Segment*	PDO	239.3%
Signalized Intersection*	Poss, Inc/Fat	59.6%
Log Likelihood		-389.7%
Restricted Log Likelihood		-482.4%
Chi Squared		185.5%
* Indicates Normally Distributed Random Parameter		

The three roadway characteristics that are included in the model are the curvature of the road, the speed limit of the road, and signalized intersections. If the crash occurs on a straight segment of road, the crash is 240%

more likely to be a PDO crash. If the crash occurs at low speed, it is 194% more likely to be a PDO crash. Crashes occurring at a signalized intersection are 58% more likely to be either a possible injury crash or, more severely, an incapacitating/fatal injury. The high volume of vehicle interactions and turning movements indicates a higher potential for crashes.

The last sets of parameters included in the model concern crash factors. These characteristics include speeding, the rider being ejected, the motorcycle rolling over, and the motorcycle being totaled. Crashes that involve a posted speed limit of less than 25 miles per hour with the motorcycle traveling up to 20 miles per hour over the posted speed limit are 111% more likely to be possible injury and 21% more likely to be a non-incapacitating injury crash rather than a PDO or an incapacitating/fatal crash. Crashes involving a rollover are 14% more likely to be a possible injury, non-incapacitating, or incapacitating/fatal crash than PDO crash. Crashes where the rider is ejected from the motorcycle are 25% more likely to be anything but a PDO crash. Finally, crashes where the motorcycle is totaled are 182% more likely to an incapacitating/fatal crash than any other type of crash.

CHAPTER VI:

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

Chapter VI of this report discusses the potential solutions that may be implemented based on the findings of this research project. The overall conclusions and recommendations are divided into four areas:

- conclusions of the state of the practice,
- general crash conclusions from the construction work zone plans,
- survey results, and
- contributing factors as defined by the mixed logit model.

The remaining sections of Chapter VI will summarize selected findings from this study as well as present some recommendations as to potential implementation strategies to improve the overall safety for motorcyclists in work zones.

6.2 Conclusions from the State of the Practice

The state of the practice included in this report is based on journal articles and reports as well as personal interviews between the research team and other state DOTs. The overall findings are defined into two categories:

- rider based solutions, and
- roadway based solutions.

In general, rider based implementations are generally lower in cost than roadway based solutions, because they inform the rider rather than require major modifications to how the work zone construction is performed.

The general recommendations for the rider based solutions are to provide the rider correct information in a timely manner, allowing the rider to either prepare for the upcoming roadwork or select an alternative route around the roadwork. The most common application to increase rider awareness used in other states is the use of motorcyclist specific signs such as “Motorcycles Be Aware” or “Motorcycles Use Extreme Caution.” Unfortunately, some motorcycle advocates feel that these signs alone do not provide enough information to rider. Additional suggestions from the state of the practice include stating upcoming roadway conditions on signs such as “Bump,” “Grooved Pavement” or “Rough Road.” Although these signs are more general, in the sense that they are reminders that apply to all vehicle types, they do provide roadway condition information to the motorcyclist. Two other suggestions to help increase rider awareness are to increase the visibility of steel plates and, when possible, provide the rider with an alternative route around the work zone. Ultimately, the alternative route may be the best option for the rider because, in some cases, by the time the rider is aware of the upcoming work zone, it may be too late. The rider may already be within range of the work zone and may be forced to go over a bump, drive through loose gravel or encounter another condition that he or she may be uncomfortable riding through. Providing the rider with an alternative route and making the rider aware of the conditions within the upcoming work zone would allow the rider to make an informed decision based on his or her riding preference and ability.

The second set of findings from the national state of the practice is developed for roadway based solutions. Roadway based solutions are implementations that alter the surface of the roadway being traveled; these specifications state when and how the work is to occur or specify the design of the work zone. Some of the more common suggestions include reducing the length of sections of grooved pavement and providing asphalt transitions between the pavement and obstructions such as steel plates. Other implementation practices may be to reduce the height of the vertical pavement edges or to increase the coefficient of friction on the steel plates. A more comprehensive list of potential implementation strategies for improving the roadway based solutions can be found on page 14 of this report.

6.3 General Crash Conclusions

Based on the general findings from the state of the practice, the research team began to develop two sets of data within this research project. The first set involves the Ohio Department of Public Safety OH-1 crash records in concert with the Ohio Department of Transportation construction diagrams. The second data set is based on the survey results. As discussed in Chapter III of this report, the research team is successfully able to integrate many of the data provided by ODOT and ODPS. This incorporation of data allows the research team the ability to define some preliminary contributing factors that lead to motorcycle crashes within work zones. In total, the research team is able to review 454 motorcycle work zone crashes collected with the OH-1 crash report. Some of the general findings show the majority of crashes involve male riders under the age of 60 who are not riding with a passenger. Additionally, the majority of motorcyclists are not speeding through the work zone or driving under the influence of alcohol, and 42.7% are wearing a helmet.

In addition to the OH-1 crash report, the research team reviewed a total of 170 projects that identified and related to a total of 219 crashes. These documents are analyzed and broken down into ten different variables, which include the following: project size, type of barrier used, type of project, type of work occurring on the day of the crash, the presence of work in the location of the crash, the presence of work next to the roadway, the occurrence of the crash throughout the length of the project, the lane width, the shoulder width, and the number of lanes. Due to the high number of “types of work” on the day of the crash and “types of projects,” the individual results are aggregated together into a more user-friendly set of results and conclusions. The “types of work” on the day of the crash are combined into eight new groups, and the “types of projects” are combined into five new groups.

Earthwork and pavement work groups are the two groups of “types of work” occurring on the day of the crash that are of most concern. These two groups of work relate to the highest number of crashes and the highest number of fatal crashes. The earthwork group contains four fatal injury crashes and the second highest number of crashes. Of the four fatal crashes, two fatal crashes each occurred during both excavation work and grading work on the day of the crash. The pavement work group contains the second highest number of fatal injury crashes, with three, and the highest number of crashes for the grouped types of work. All three of these fatal injury crashes occurred during paving work on the day of the crash.

The three groups of “types of projects” that are of most concern are pavement work, bridge construction, and traffic configuration. These three groups of projects relate to the highest number of crashes and the highest number of fatal injury crashes. The pavement work group contains four fatal injury crashes that occurred during roadway resurfacing projects. The bridge construction projects also are involved with four fatal injury crashes, and the third highest number of crashes occurred during this type of project. The traffic configuration group contains only one fatal injury crash but contains the second highest number of crashes of all groups of projects. Within the traffic configuration group, roadway widening and interchange construction are the two types of projects that brought the most concern; each of these contributed to a fatal injury crash.

Pavement work, which is identified through both the type of project and the type of work on the day of the crash, is also considered to be a hazardous factor. Projects involving roadway resurfacing need to be addressed in order to eliminate the hazards for motorcyclists in the activity area, which is the location with the highest number of crashes. The implementations follow both the rider and roadway based solutions. The rider based solutions relating to this hazard are signs indicating “Motorcycles Use Extreme Caution” and an identification of the hazard “Grooved

Pavement," or "Uneven Lanes." The roadway based solution relating to this hazard includes the use of a wedge transition (however, if this implementation is used in Ohio, the vertical edge height would need to be decreased) or the implementation of "mill and fill," a process where the lane or segment of road is closed, milled, and then repaved before being re-opened to traffic.

6.4 Conclusions from the Survey Results

To obtain an idea of the feelings toward the hazards identified in the analysis of the crashes and the implementations identified in the state of the practice, a survey of the motorcycling community was undertaken. This survey targeted motorcyclists who travel in the areas pertinent to the work zone crashes studied. These areas were identified through the use of a hot spot analysis (HSA). The HSA identified areas of statistically high clusters of work zone related motorcycle crashes. Events in these identified areas were chosen for personal information gathering between the research team and the motorcycle community. Four types of events were targeted, including bike nights, bike rallies, poker runs, and community events. These events were selected to encompass a wide range of motorcyclists. Surveys were conducted at 24 locations throughout the state of Ohio, with the addition of three more events used as test trials to identify the best methods for conducting the survey. The survey returned a total of 612 participants. These participants were asked a series of twenty questions, which covered three different topics:

- rider experience,
- perceived hazards, and
- potential implementations.

The rider experience questions are designed to determine the type of exposure that the rider might best identify with. The perceived hazards questions are designed to relate the perceptions of the motorcyclists to the hazards identified from the crash information, and the potential implementations questions are designed to relate to the findings in the state of the practice. The general findings of the survey show the majority of the sample population are male and have a full endorsement. The responses are split regarding attendance at a Motorcycle Ohio class. The results of the survey suggest that the riders feel that grooved pavement and uneven lanes are the most dangerous hazards. The results also show that most riders feel that lane shifts, crossovers, and intermittent or moving work are the most dangerous work zone types.

Some additional interesting findings from this survey are the discontinuities in the perceived hazards section of the survey. The participants had some discontinuity between the perception of the hazard and the crash involvement rate of drums being used as a barrier, lane closure type work zones, and the presence of paving work. In all three of these cases, the number of crashes related to the hazard is the highest, while the perception of the hazard generally fell to third behind two other options as the most hazardous. This shows that the top perceived hazards are traveled through with more caution, resulting in a lower number of crashes as compared to the types of hazards that are causing the majority of the crashes. The implementation strategies that stand out as being supported by a large majority of the survey participants is the use of an alternative route to avoid a hazard, especially where the work zone has loose gravel on the roadway.

From the discontinuities identified in the perceived hazards portion of the survey, the riders are more cautious in the areas where they feel more comfortable. The areas where they are more comfortable are, however, the situations related to the most crashes. These areas in which there is a false confidence should be addressed to improve safety. These two areas are the process of paving and the use of portable drums. To reduce the crashes related to these two aspects, an effective implementation would be to increase education to the motorcycling community on these hazards.

6.5 Contributing Factors as Defined by the Mixed Logit Model

The final set of conclusions is developed specifically for the three mixed logit models that are presented in this research study. The first model compares the amount of miles that riders will accumulate through an average riding season. The four categories are small (0 to 1000 miles), mid-level (1,000 to 5,000 miles), medium (5,000 to 10,000 miles) and large (10,000+ miles). The mileage bins are set in order to capture information based on the frequency of riding in order to differentiate between casual riders and seasoned veterans. By separating the survey data based on the amount of time spent riding, the research team may infer which factors of work zones are perceived as greater risks, the best implementation solutions, and information about the riders' experience. The overall conclusions show the no endorsement, temporary, and novice riders are more likely to ride fewer than 1,000 miles per year. Other findings show riders with 20+ years of experience or riders who typically ride a touring motorcycle ride more miles per year. Riders who ride higher mileage feel that mill working is a greater hazard as compared to lower mileage riders, who are more concerned with lane closures. One possible conclusion from this outcome may be that an experienced rider is more comfortable with merging and, regardless of riding experience, if the traction under the wheel is suspect the rider may have trouble handling the motorcycle. Interestingly, most riders were willing to travel 10 to 15 extra minutes to avoid a work zone.

The second model is constructed around the results of the survey that concern a rider's use of a helmet. Model Two is developed because many researchers and practitioners believe that riders who do not wear a helmet are considered risk takers and that helmet use may be highly related to a specific manufacturer or motorcycle type. The results from Model Two show that riders with no endorsement never wear helmets while younger riders are more willing to wear a helmet. Riders who sometimes or never wear a helmet are more likely to perceive grooved pavement as a hazard. Finally, riders who never wear a helmet are more likely to be in favor of detours, changing the work zone construction barriers.

The third mixed logit model is developed from the crash data provided by the Ohio Department of Public Safety. The crashes analyzed within Model Three pertain to motorcycle crashes in work zones. Due to the size of the data set, the outcomes for the utility function are separated into property damage only, possible injury, non-incapacity injury, and the incapacity and fatal crashes are constrained together. The conclusions from this model suggest that helmet use, slower speeds through the work zone, and straight road segments will lead to lower injury severity levels for the rider.

While it may not be feasible to implement all the suggestions presented for the roadway based solutions, it may be possible to implement a combination of rider and roadway based solutions that will improve the work zone environment for a motorcyclist while providing a cost-effective solution for the road crew. At a minimum, the research team will recommend additional signage far enough away from the work zone to provide the motorcyclist the opportunity to modify his or her route, based on the upcoming roadway obstructions.

APPENDICES

APPENDIX A:

OH-1 CRASH REPORT PARAMETERS

Report Information	Document Number	Roadway Information	Functional Class	Crash Details	Crash Severity
	Local Report Number		Route		Total Injured
	Private Property		Lanes		Number of Units
	Hit Skip		Speed Limit		Vehicle in Error
	Photos Taken		County Begin Log		Occurrence
	NCIC		County End Log		Collision Type
Location Conditions	Date of Crash		Distance		Total Killed
	Year		Mod Begin Log		Emergency use
	Month		Mod End Log		Damage Scale
	Day		Mod Distance		Damage Area
	Time of Crash		Surface Width		Point Of Impact
	Time of Day		Roadway Width		Action
	Day of Week		Left Outside Shoulder		Override/Underride
	City/Village/Township		Left Surface Width		Pre-Crash Actions
	FIPS Place Code		Left Inside Shoulder		Circumstances
	FIPS Place Name		Right Inside Shoulder		Sequence of Events
	NLF ID		Right Surface Width		First Harmful Event
	NLF ID Number		Right Outside Shoulder		Most Harmful Event
	SLM Log		Median Width		Speed Detected
	County True Log		ADT		Unit Speed
	State True Log		Intersection Type		Posted Speed
	Latitude		Road Contour		Vehicle Direction From
	Longitude		Road Condition		Vehicle Direction To
	District		Road Surface	Occupant Information	Occupants
	County		Number of Lanes		Non Motorist Location
	Jurisdiction		Traffic Control		Driver Age
	Population	Crash Relationships	School Bus Related		Driver Gender
	Weather		Work Zone Related		Driver Seating Position
	Light Conditions		Work Zone Type		Driver Safety Equipment
	Crash Prefix		Work Zone Location		Driver Air Bag Usage
	Crash Location		Worker Present Flag		Driver Ejection
	Crash Road Type		Alcohol Related		Driver Trapped
	Type Point Used		Drug Related		Driver Injuries
	Miles from Reference		Animal Related		Driver Alcohol Drugs
	Direction Reference		Bicycle Related		Driver Alcohol Test Value
	Reference Prefix		Motorcycle Related		Driver Drugs Test Result
	Reference Point		Speed Related		Passenger Age
	Reference Type		Pedestrian Related		Passenger Gender
	Reference Point Used		Semi-Truck Related		Passenger Seating Position
Vehicle Information	Unit Number		Small Truck Related		Passenger Safety Equipment
	License Plate State		Youth Related		Passenger Air Bag Usage
	Vehicle Year		Teen Related		Passenger Ejection
	Vehicle Make		DUI 21 Related		Passenger Trapped
	Vehicle Model		Senior Related		Passenger Injuries

	Insurance Flag
	Unit Type
	Vehicle Defects
	Cargo Body Type
	Weight
	Hazard Placard
	Hazardous Spill

	Passenger Alcohol Drugs
	Passenger Alcohol Value
	Passenger Drugs Result

APPENDIX B:

NOTICE OF APPROVAL FROM IRB ADMINISTRATOR

Office of Research Services and Sponsored Programs
Akron, OH 44325-2102
(330) 972-7666 Office

NOTICE OF APPROVAL

July 11, 2012

Brandon Stakleff
1030 Sand Run Road
Akron, Ohio 44313

From: Sharon McWhorter, IRB Administrator

Re: IRB Number 20120703 "*Examination of Factors Associated with Motorcycle Crashes in Work Zones* "

Thank you for submitting your Exemption Request for the referenced study. Your request was approved on July 11, 2012. The protocol represents minimal risk to subjects and matches the following federal category for exemption:

☐ **Exemption 1** – Research conducted in established or commonly accepted educational settings, involving normal educational practices.

☒ **Exemption 2** – Research involving the use of educational tests, survey procedures, interview procedures, or observation of public behavior.

☐ **Exemption 3** - Research involving the use of educational tests, survey procedures, interview procedures, or observation of public behavior not exempt under category 2, but subjects are elected or appointed public officials or candidates for public office.

☐ **Exemption 4** – Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens.

☐ **Exemption 5** – Research and demonstration projects conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine public programs or benefits.

☐ **Exemption 6** – Taste and food quality evaluation and consumer acceptance studies.

Annual continuation applications are not required for exempt projects. If you make changes to the study's design or procedures that <u>increase the risk to subjects or include activities that do not fall within the approved exemption category</u>, please contact me to discuss whether or not a new application must be submitted. Any such changes or modifications must be reviewed and approved by the IRB prior to implementation.

Please retain this letter for your files. This office will hold your exemption application for a period of three years from the approval date. If you wish to continue this protocol beyond this period, you will need to submit another Exemption Request. If the research is being conducted for a master's thesis or doctoral dissertation, the student must file a copy of this letter with the thesis or dissertation.

☐ Approved consent form/s enclosed

Cc: William H. Schneider - Advisor
Cc: Stephanie Woods – IRB Chair

The University of Akron is an Equal Education and Employment Institution

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