ANALYSIS OF MOPED CRASHES AND RIDERS' FAULT INVOLVEMENT IN WISCONSIN

by

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ABSTRACT

The moped safety issue has become a serious problem in recent years. In Wisconsin, the number of mopeds registered has doubled between 2003 and 2012. The number of moped involved crashes increased even faster than the number of mopeds registered. In this case, there is a demand to better understand moped safety problems, which is the initial motivation for conducting this study.

Initial crash data were extracted from WisTransPortal. The moped-motor and single moped crashes were identified, as well as rider's fault involvement. One thousand eighty five crashes in Wisconsin and 251 crashes in Madison are identified as moped-motor crashes. Four hundred and sixty three and two hundred and fifty one accidents are identified as cases where someone was at-fault, respectively. Nine hundred and ninety crashes in Wisconsin and seventy-four crashes in Madison are identified as single moped crashes.

Common crash characteristics and logistic model are introduced to analyze the data. Major findings include that moped riders are more likely to be identified at-fault for crashes occurring at a non-intersection, during a weekend, negotiating a curve, overtaking a vehicle, and turning left or turning right. If the riders use protection gear, they are less likely to be involved in a rider at-fault crash. Riders are also less likely to be identified at-fault when they suffer minor injury, riding under bad light conditions, having a rear end or sideswipe in same direction crashes. Moped crashes are likely uncorrelated with adverse weather, bad road conditions or light conditions in terms of the number of crashes. The most moped crashes happened while riders were going straight.

The moped riders being at-fault attribute is being focused on due to three benefits. In the first place, moped riders can learn under which situation they are more likely to be determined at-fault and how to avoid these situations. In the second place, the law enforcement agencies can use our results to evaluate their policies and standards of determining fault and identify any bias within this process. In the third place, insurance companies can evaluate the driver characteristics and develop rates based on their vulnerability in being considered at-fault in moped crashes. By doing this research, an insight into the moped safety problem can be provided.

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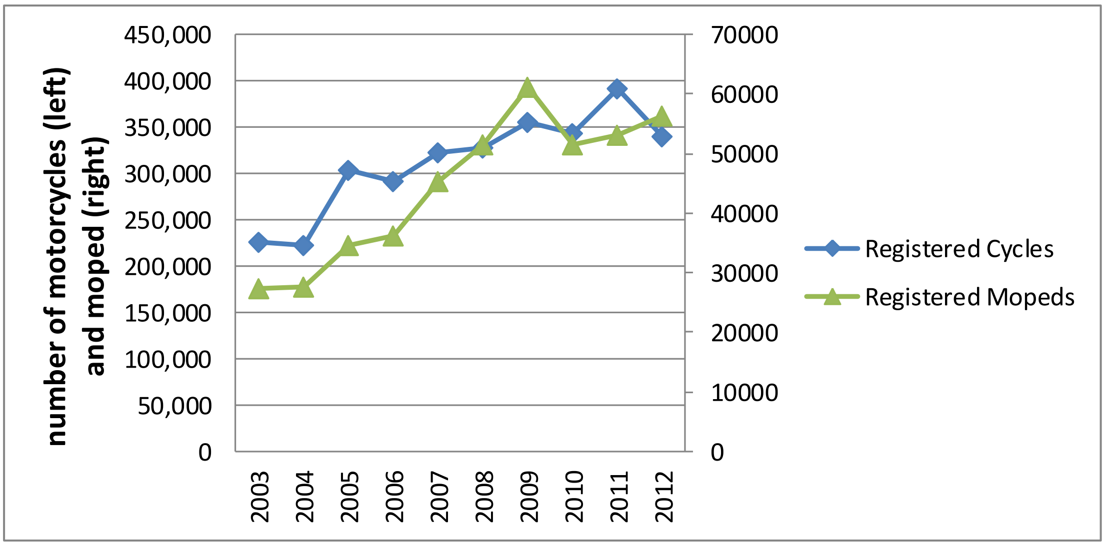
Chapter 1: Introduction

1.1 Background

Mopeds are a subcategory of powered two-wheelers similar to motorcycles. It is widely known that motorcyclists have a higher injury risk than other road users. “The traffic safety facts 2011 data” from National Highway Traffic Safety Administration (NHTSA) shows that the number of registered motorcycles kept increasing year by year nationwide, while, 4612 motorcyclists were killed in motor vehicle traffic crashes and the fatality rates were 54.66 per 100,000 registered vehicles and 24.93 per 100 million vehicle miles traveled, which is approximately 3 times and 22 times higher than the comparable death rate for automobile passengers [1]. This rate is consistent with the data from David, Allan and Robert’s research in 1995 [2], which means that the situation of high death rates has existed for decades.

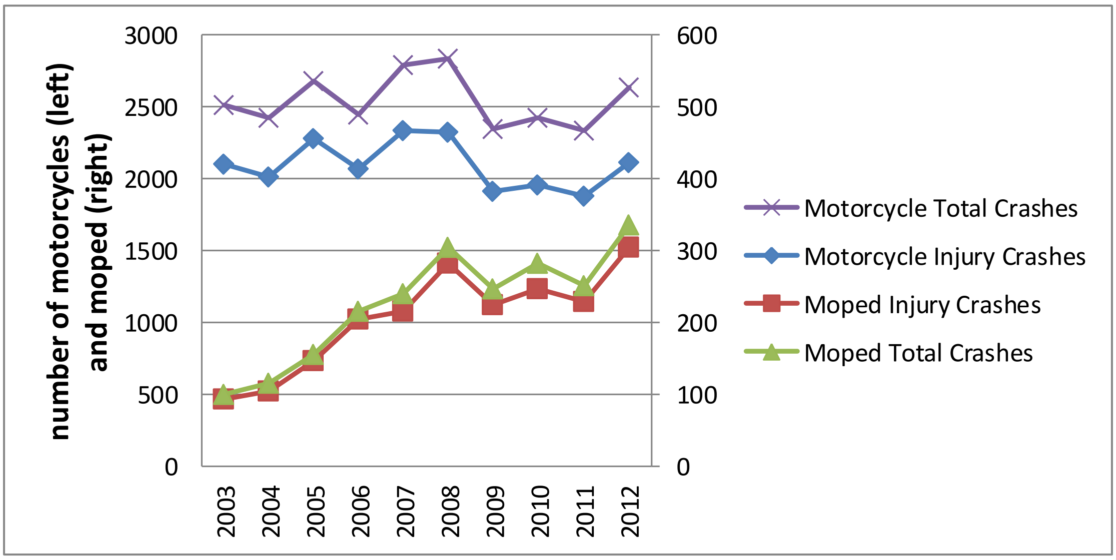
In Wisconsin, the number of registered cycles was doubled from 2003 to 2012. Moreover, the number of registered mopeds increased and the total number of mopeds in 2012 was double those in 2003[3]. This trend was shown in Figure 1.

Figure 1 Registered Number: Motorcycles versus Mopeds



Under this situation, the number of motorcycle injury crashes and the total number of motorcycle crashes remained almost constant in this decade, however, the numbers of moped injury crashes and the total number of moped crashes continually increased. In 2012, the number of moped injury crashes and the total number of crashes has tripled since 2003 [3]. This trend was shown in Figure 2.

Figure 2 Total Crash and Injury Crash Number: Motorcycles versus Mopeds



There are several reasons why the number of mopeds registered in Wisconsin has increased. Riders don't need to take special training after they get a drivers license in order to operate moped. The relatively short travel distances, low costs of fuel and convenience of parking make a moped a popular travel vehicle especially in urban and campus areas. In spite of the increased moped use, the safety performance seems not to have improved.

The number of crashes involving injury has increased faster than the increase in registered mopeds. The number of crashes involving injury has tripled from 2003 to 2012. Each year, more than 200 people were injured and approximately 5 of them were killed in Wisconsin [3]. Compared with operating other enclosed vehicles, unprotected moped riders are more likely to get injured [5].

Even though the numbers of mopeds and moped related injuries keep growing, there are few recent studies. In fact, mopeds are treated in the same category as motorcycle in many papers without pointing out their differences [6].

Various vehicle and operator characteristics can affect moped safety. Mopeds are significantly different from motorcycles, since the tires are much smaller offering far different balance and vehicle control than motorcycles. They usually have lower acceleration and maximum speed than larger motorcycles, which put the drivers in a position that they cannot catch up with other vehicles on the road or accelerate to avoid a dangerous situation. Also, due to their small shape, it’s hard for other drivers on the road to notice them. Some riders even make use of this character to pass around passenger cars when they queue up [6]. Few use helmets, eye protection, boots, leather jackets or other protective gears. Given the problems associated with inexperience, few operators have motorcycle licenses and they also lack the skills in operating a moped safely. Many collisions happened to inexperienced riders who borrowed a moped due to almost no restriction on its use. In addition, Wisconsin has special environmental hazards for moped riding, such as snowing often and harsh cold for four months per year. Even under this situation, the campus of the UW-Madison has the greatest number of registered mopeds of any college campus in the United State.

It appears to be important to know why and how these factors relate to crashes. There are two directions to investigate this: one from the perspective of risk and Crash Severity, the other considering the at-fault and not-at-fault information. Under which situations the moped riders are more likely to be identified at-fault need to be studied. Kim and Boski [7] have studied on finding fault in motorcycle crashes that happened in Hawaii. Kim also built models to analyze the relationship between fault and factors like environmental factors, roadway characteristics, motorcyclist's attributes, etc. [8] Xuedong, Essam, Mohamed [9] used fault information to investigate the correlation among road environment factors, vehicle factors, human factors and the risk of rear-end accidents. It is reported by Savolainen and Mannering [40] that riders in India who had taken training courses are more likely to be involved in crashes than those who had not, which, assuming the Indian course was properly developed and comprehensive, suggests that more than educational factors need to be studied and understood. Hence, the understanding on the fault of moped riders may be helpful in understanding the causal factors that contribute to crashes.

In this study, the aim is to identify the key factors that are significantly associated with moped riders being at-fault in crashes. A logistic model is carried out to explain the effect of environmental factors, moped condition, road condition and human factors on fault determination and crash involvement.

In order to better understand moped crash problems, the definition of moped is briefly referred [4]: "A moped, sometimes, called a motor scooter, is a motor vehicle capable of speeds not greater than 30 miles per hour with a 150-pound rider on a dry, level, hard surface with no wind”; If the vehicle has an automatic transmission, the engine must be certified at 50 cubic centimeters or less or an equivalent power unit; If the vehicle is equipped with fully operative pedals, the engine must be certified at not more than 130 cubic centimeters or an equivalent power unit.

1.2 Problem Statement

Common propositions hold that under certain situations, moped riders are more likely to be “at-fault.” Due to high-risk lifestyles, younger drivers are felt to be at-fault [41]. Elander, West and French stated that increased hazard-perception latency can affect older drivers [42]. However, much of the data in these studies comes from medical records, controlled experiments or attitudinal survey instruments. Few make use of large amounts of recorded moped involved crashes. Fewer studies distinguished the difference between motorcycle and moped. This paper is aiming to evaluate the associations between moped riders being at fault and other factors, including demographic factors, environmental factors, road condition, and human factors, by investigating a large sample of moped crash data. By focusing on fault, it is easier to understand driver performance and behavior and find out the true causation of crashes. Furthermore, more effective traffic safety countermeasure can be developed.

Regarding to fault information, the available data in our existing crash database does not contain absolute fault information. Police reports cover the description of the scene of the accident and their inclinations of identifying the at-fault party. There is definitely subjective bias existing in the police report and their process of assigning fault. Thus, there is a demand of identifying the bias.

The at-fault information can be identified by checking crash data manually. According to the fault determination rules from multiple sources [23], [24], [25], given driver factors, citations issued and vehicle maneuvers are checked in order to identify fault from police reports.

The common moped characteristics as well as the possibility of moped riders being at-fault in each characteristic category are investigated. Furthermore, the fault possibility could be used as the dependent variable of a logistic regression model. Karl Kim and Joseph Boski conducted a study focusing on motorcycle crashes in Hawaii [7]. They found that multiple logistic regression techniques are very useful in examining the interactions among vehicles, roadways, demographic, and environmental factors related to motorcycle crashes. Our model is built upon their work and adjusted to fit our data. By focusing on this model, the factors that are significantly related to riders being at-fault can be identified.

In sum, the goal of this study is to find an approach which use moped crashes characteristic factors and, especially, the at-fault factor as the major logistic model input to identify the significant factors associated with the situation where the moped rider was at-fault. In this proposal, the following questions are going to be investigated and addressed:

1. How to make use of the existing police report to get at-fault information?
2. How can moped crash factors be used to investigate riders being at-fault situations?
3. Is a logistic regression model suitable in this study?
4. How can the associations among the rider being at-fault factor and the moped crash factors be made use of and help create better safety condition for moped riders?

1.3 Research Objectives

According to the issues presented, the objectives of this research are listed below:

1. Identify all moped crashes from available Wistransportal MV4000 crash data from January of 2003 to December of 2012.
2. Analyze common moped characteristics as well as the possibility of moped riders being at-fault in each characteristic category.
3. Examine the relationships between moped riders being at-fault and characteristics of moped-involved crashes, such as human factors, environmental factors, vehicle factors and roadway factors by applying a logistic regression model.
4. Provide potential ways to make use of our results and improve moped safety condition.

1.4 Research Scope

The scope of this research includes reviewing all of the moped crashes in Wisconsin from January of 2003 to December of 2012. The analysis of moped crashes was made at the state wide level and also with specific attention given to the Madison area, since the University of Wisconsin Madison is located here, which has the highest moped total number among all campuses in United State.

The factors including human factors, environmental factors, vehicle factors and roadway factors are investigated.

At-fault factor is isolated to assess its association with other factors.

Crashes involving more than two vehicles are not covered.

Moped-bicycle crashes and moped-pedestrian crashes are not covered.

1.5 An Outline of The Thesis

This thesis includes five chapters. Chapter 1 introduces the research topic by explaining the background, problems, reason and aim of conducting this moped safety analysis. Chapter 2 shows the existing research concerning this topic. Chapter 3 introduces the methodologies and processes of conducting this research and the process of collecting and filtering data. Chapter 4 describes in detail the analysis results conducted on the identified data. Chapter 5 provides the details about the process of fitting the logistic regression model and the results are analyzed. Chapter 6 concludes the general findings and suggests the potential directions for future works on this topic.

Chapter 2: Literature Review

The analysis of moped crashes and fault involvement start with reviewing past literature in moped safety related fields. They are: Motorcycle and moped safety, identifying fault, modeling fault and countermeasures.

2.1 Motorcycle and Moped Safety

There is much research literature focusing on motorcycle crashes. Mopeds are just considered as another type of motorcycle and moped crashes were analyzed together with other large displacement motorcycles in most instances. It is important to have an insight of what kind of studies have been done on motorcycle crashes in order to have a general idea of the existing research status.

2.1.1 Motorcycle

Motorcycles are a small subset of all motor vehicles, but are involved in fatal crashes more than any other vehicles in the United States [2]. The death rate per registered motorcycle is 59 per 100,000, which is approximately twice more than the death rate per registered passenger car. The death rate for car passengers is estimated to be 22 times lower than the comparable death rate for motorcycle riders when the lower mileage driven by motorcycles is taken into account.

In general, decades old data are usually used as the foundation of many of the available motorcycle crash and injury analyses. There is an examination of 2,410 motorcycle crashes made in North Carolina during 1972, in which Griffin found that when a motorcycle crashes with a passenger car, the motorcyclist always seems to be hurt more seriously. He also found that passenger car drivers who were making a left turn were the most common action leading to a crash. Olson reported similar results in Texas during 1986 for studying daytime motorcycle involved crashes. 900 motorcycle crashes which happened in Los Angeles were examined by Hurt (1981) and the conclusion was that the major reason for the crash was vehicle drivers didn’t see the motorcycle in time to avoid a crash.

2.1.2 Moped Safety

Karl Kim, David Takeyama and Lawrence Nitz conducted a study in Honolulu, Hawaii about Moped Safety [6]. They found that there were several reasons why mopeds keep increasing in Honolulu and in other places all over the world. First, mopeds are cheaper and have higher mileage per gallon compared to other auto vehicles. The mopeds are also easier to park and operate in congested traffic situations than larger vehicles. Compared with heavier motorcycles, which requires special training and strength in order to operate, mopeds are much more appealing to students, tourists, some environmentalist, and budget-minded groups (Papacostas & Yoshioka, 1978). Second, the design of mopeds has been improved greatly, which include improvement in performance, styling, and reliability. It is also worth noticing the entertainment of riding a moped, which also results in moped use increasing.

These reasons have resulted in a large increase in the number of mopeds registered in Hawaii. There were approximately 11,000 registered mopeds running in Hawaii in 1990, which grew from 3,500 in 1977. The University of Hawaii had to require special moped parking permits in 1993 due to the rapid increase of registered mopeds. Approximately 2,200 permits were provided for users on the University campus [6].

As a cross between bicycles and motorcycles, the moped has the disadvantages of both, which contributes to numerous factors affecting moped safety (Kell, 1978). The moped is a low acceleration, low speed and lightweight vehicle compared with other heavy motorcycles and heavy vehicles. In this case, it's hard for mopeds to keep up with other road users. Furthermore, the moped riders are in a vulnerable position due to no protection like doors or windows, various roadway defects and protruding side view mirrors (Light, 1978). The moped is even less visible to other road users because of its lower silhouette than the bicycle or motorcycle [6]

Unlike a motorcycle, a moped could easily be operated by users with little or no experience. This characteristic makes mopeds popular among more female operators and young students and tourists who were seeking fun by renting a moped. In Hawaii, moped riders must obey the same road rules such as lane usage, traffic signals, and right of way as other motor vehicles. Most moped riders don't have enough moped safety knowledge and few have a motorcycle license. Protective gears like helmets or eye protection are not often used. Some riders even illegally carry passengers, which further limits their performance.

Additionally, the environmental factors significantly affect moped safety, besides vehicle and operator characteristics. It includes traffic condition, topography, roadway characteristics and other factors [6].

2.2 Identify Fault

Identifying who is at fault in a car accident is critical for deciding who is going to pay for the cost of damages and any other fees for the accident [23]. Insurance companies are mainly involved in final at-fault determination because of their demands of evaluating financial responsibilities [24]. They will judge the situation by talking with their customers and mostly checking the existing police report. It is never easy to identify fault, since it involves objective descriptions and subjective judgment. Many states have complicated methods to identify fault. The insurance companies are mainly in charge of identifying fault in an accident and the steps describing the general principles of this process are listed below [23]:

1. Check if there are violations of traffic law or traffic citations.

   If one of the drivers got a citation for running a stop light or sign, speeding, or other violations, he or she will be identified as at-fault. Any driver violating the traffic laws will be considered as the one who should be responsible for a car accident since they clearly committed an identifiable act.

2. Figure out if the accident is caused by a left-hand turn or a rear-end collision.

   The driver who hits another vehicle from behind or causes an accident by making a left turn is usually blamed at fault. Any driver who is likely to have failed to yield the "right of way" or who should have been in a position to see but did not through inattentive driving is more likely to be judged at-fault.

3. Go through any comments made by the driver after the accident.

   If one driver admitted the guilt after an accident, like saying "I'm sorry for hitting you" or "I didn't see you," he or she would be assigned all or most of the blame for the accident.

4. Ask witnesses questions about the accident.

   It is not usual for a driver to admit blame. Under this circumstance, witnesses' account of the accident can be a valuable and important evidence to be written in the police report and may help in identifying the fault.

5. Consider if drivers were negligent before the accident.

   Negligence means that the driver should have done something to prevent the accident happening but failed to do it. The negligence could be failing to obey the traffic law or driver's responsibility, like running a red light, making an illegal turn, failing to check the blind spots before turning, or simply not using a blinker at a turn. The negligence is the legal justification for requiring one driver to pay for another driver's damage cost in the accident.

Even though many criterions were used for identifying fault, the best way to identify fault in a specific case is to have solid evidence of negligence or traffic law violations.

In Auto Insurance Claims [24], it also mentioned that identifying car accident fault is never easy. One thing that should be noted is that the fault in a car accident is not identified by a policeman alone. Auto Insurance Claims says that the insurance investigators are in a better position to identify which party is at fault and the process includes looking into evidence collected by the police, like witness and driver statements, photographs and police report, etc. In this article, it mentioned that every person behind the wheel of a motor vehicle has the driver duty of protecting every road users and pedestrians. These are lookout, avoidance, courtesy and following the rules of the road. It is important for the driver to stay focused on driving and anticipate dangerous situations. If any emergency happens on the road, the driver should be able to react quickly and avoid the accident. It doesn't matter whose fault it was in the first place, every driver should put effort into avoiding an accident or, at the very least, minimizing the threat of injury and death. The most important aspect for a driver to follow is always following the rules of the road. Once you can prove you have met all these duties, you are safe to be considered as not at-fault.

From the Ontario Regulation 668 under the Insurance Act, fault determination rules were described by detailed text, pictures and notes. Though this document belongs to the government of Ontario, it is still worthy of studying.

In Wisconsin, no fault judgment would be explicitly stated by the police officer. Insurance companies will mainly rely on the police report to identify fault.

2.3 Modeling Fault

Md. Mazharul Haque, Hoong Chor Chin, Helai Huang studied Singapore crash statistics from 2001 to 2006 [27]. The results show that the motorcyclist is much more vulnerable than drivers of other vehicles. Their study was mainly focused on identifying the factors that result in the fault of motorcyclists involved in crashes. The binary logit model was used to differentiate between at-fault and not-at-fault situations. More studies were done by categorizing the location of the crashes, at intersections, not at intersections and on expressways. They found that night time crashes and the crashes which happened on single-lane roads or median lane of multi-lane roads were more likely to be not-at-fault crashes, while wet surface and driving on expressways contributed to at-fault crashes. Motorcycle with higher engine capacity and operated on roads with higher speed limit were more likely to be involved in at-fault crashes. They also found that old and young riders were more likely to be the at-fault party in accidents than middle age riders. At-fault or not-at-fault was used as the response variable of binary logit model. They believe that the rider is supposed to be identified either as the at-fault or not-at-fault party.

In another research study conducted by Karl Kim and Lei Li [8], they were motivated by a wide range of interests, like “Are bicycle collisions increasing or decreasing in Hawaii”, “What are the characteristics of bicyclists and motorists involved in collisions”, “What human and other factors are involved”, “Who is at fault, most of the time, in collisions between bicyclists and motorists”, “When are bicyclists most likely to be at fault” and “When are motorists at fault”. Approaching the answer of these questions was useful in the design of this whole research and getting a better understanding of the necessity of this study and the contribution. A logistic regression model was used to explain fault among motor vehicle drivers and bicyclists involved in crashes. Because of the study on contributing factors of motorcyclist being at-fault, the traffic safety situation in Hawaii and especially motorcycles safety had been improved.

Karil Kim and Joseph Boski focused on patterns of fault among driver and motorcycle riders, who were involved in crashes, in finding fault in motorcycle crashes in Hawaii [7]. In this paper, they described personal and behavioral characteristics of those who were involved in collisions. Attention was also paid to temporal, roadway, and environmental factors associated with crashes between motor vehicles and motorcycles. They discussed whether focusing on fault can provide a strategic starting point for traffic enforcement programs and education for drivers, motorcyclists and other road users. They used a fault model to predict the odds of fault for motorcycle riders and drivers who were involved in collisions. The fault model was based on logistic regression model. Further, the spatial distribution of at-fault motorcyclists and motor vehicle drivers was mapped. By doing this, the necessity of spatial enforcement and education can be identified.

2.4 Countermeasure

The ways to reduce motorcyclist Crash Severity and injury rate are different from place to place. There are some states in American using law to require all riders to use helmets in reducing serious injury (Watson 1981 and McSwain 1985), however, many states only require helmet use for young riders or have no helmet use law at all. Olson (1981) found that it was easier for other drivers to see motorcycles with their low beam headlights on during daylight. Zador found that there were fewer daytime motorcycle fatalities in those states requiring daytime motorcycle headlight use. Although less than half of states in the US have a requirement of motorcycle headlight use while riding, all manufacturers equip motorcycles with headlights that automatically turn on while the engines are working.

When people want to know if they can find more feasible countermeasures that can reduce motorcycle crashes and crash injuries, they need to have more insight of how and why these crashes occur and use recent data to analyze. The most common way to study how and why a crash occurs is crash type analysis. Snyder and Knoblaunch developed this technology and applied it to urban pedestrian crashes. They also applied this technology in analyzing other crash types including bicycles, rural pedestrian crashes, urban vehicle crashes and crashes on limited access highways.

Crash type analysis includes but is not limited to, definition development for identifying crash type with causal and characteristics of the crash maneuver, and movements of the involved vehicles [2]. People think crash resultants are less important than pre-crash driver behavior and vehicle movement under specific roadway situations, since crash resultants could be affected by any factors related to the crash itself. There are certain steps of developing crash types [2]: 1. Analyzing police crash reports and classifying crashes based on the pre-crash behavior and situation; 2. Read additional police crash reports to test the integrity of the preliminary classification; and 3. Make crash type definitions for each identified crash group.

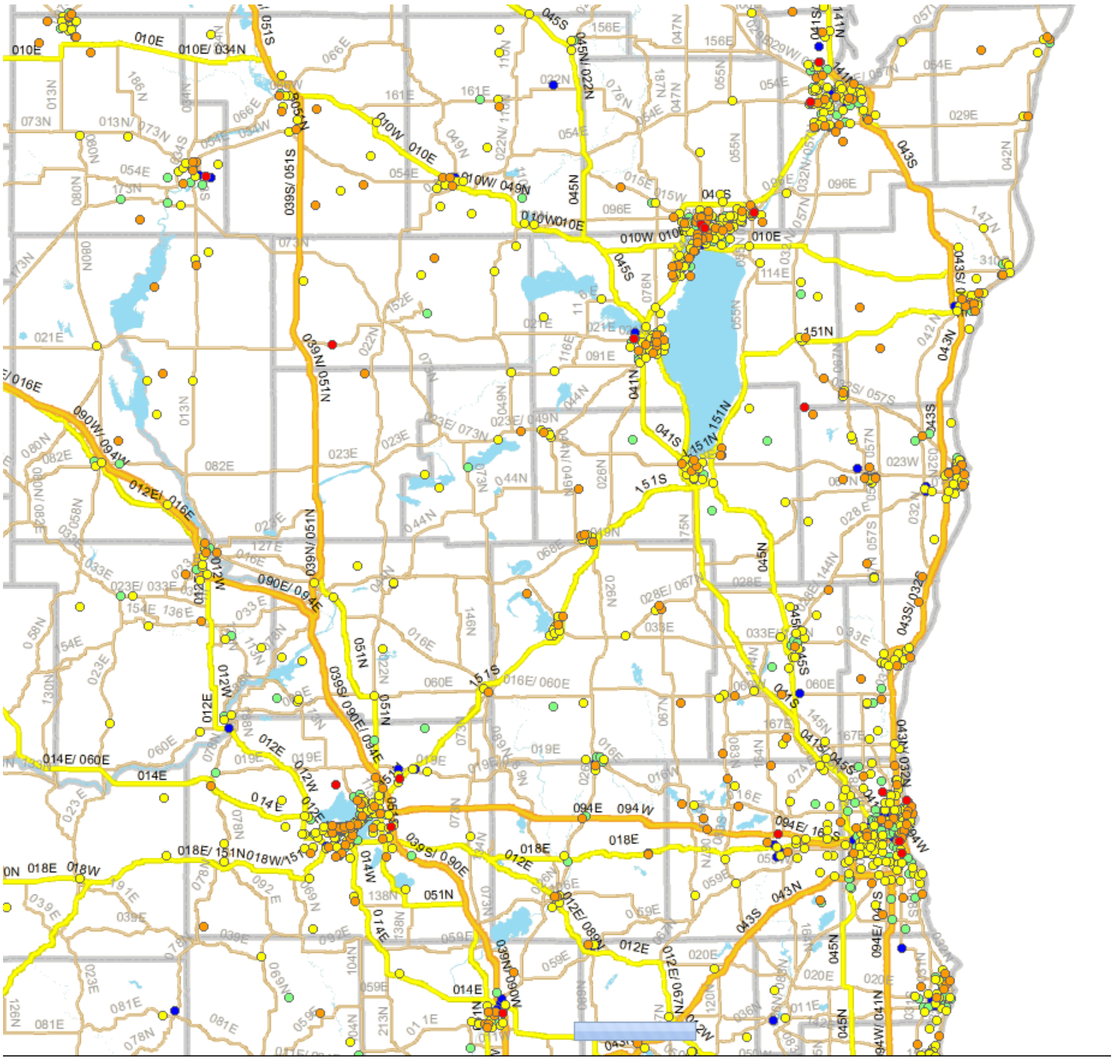
Countermeasures are proposed under Education-Enforcement-Engineering (3E)'s of traffic engineering framework.

Chapter 3: Study Design

3.1 Introduction

Officer of United States in department of transportation have reported moped and scooter crashes for more than 20 years. These vehicles have become popular with sales increasing more than 60% in recent years. The number of registered mopeds increased continually in Wisconsin from 2003 to 2012. [3] The moped injures also increased every year. The rate of increase of moped injuries is even faster than the rate of the number registered: The moped injuries rate has tripled in the last decade, while the number of mopeds registered has doubled. It is well known that safety issues are a hotspot in every aspect of our life. It is also the primary concern in the transportation field affecting planning, construction, etc. In the US, there is nationwide research on specific types of crash analysis, for example, second crash, work-zone related crash, on ramp/off ramp crash and motorcycle crash. Compared with other types of crash analysis, moped crashes are an area that gets less attention and research. From the historical data introduced in the beginning of this, it is not hard to tell that there are more and more people choosing mopeds as a convenient way to travel. Furthermore, moped crashes have their own characteristics, like location, age group, etc. From the map of moped crashes in Wisconsin shown in Figure 1, it is easy to notice that these crashes have highest density near urban areas, like Milwaukee, Madison, Appleton and Green Bay. From Wistransportal Crash Database, the number of moped crashes that happened between January of 2003 and December of 2012 is 2,558. 367 of them happened in Madison. In this case, Madison was chosen as urban area representative for studying the characteristics of moped crashes.

Figure 3 Moped Location Distributions in WI

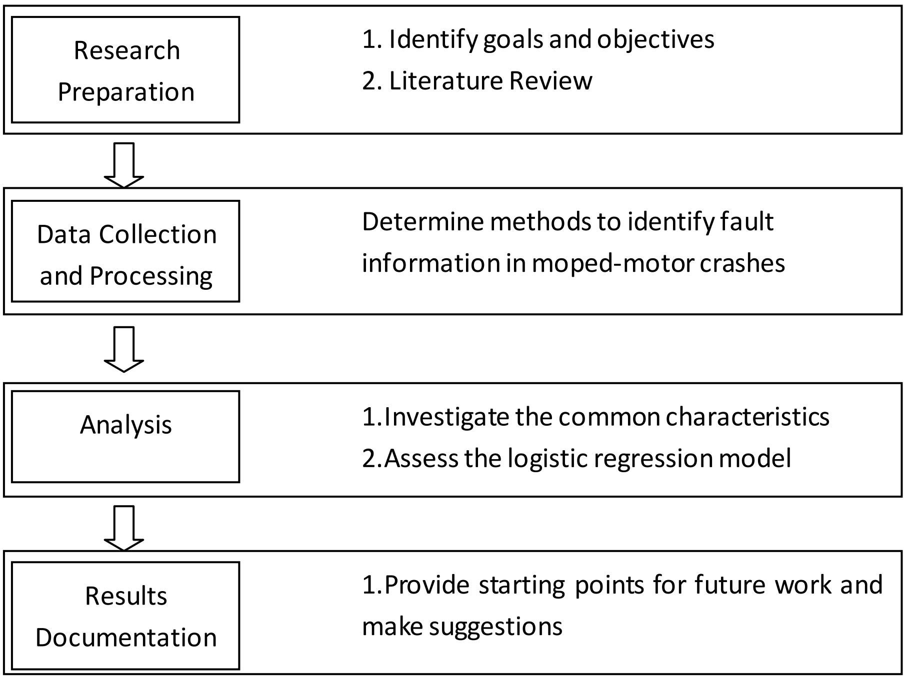


Given these circumstances, more attention will be paid to moped crash. This thesis was initiated and developed based upon these considerations and motivations. This chapter summarizes all relevant moped crash literature to give an insight to existing studies and efforts to analyze moped crashes. Four major research subjects have been addressed in the following topics: 1) Study mopeds safety based on character analysis 2) Identify fault among crashes 3) Investigate the significant contributing factors on moped riders being at-fault 4) Countermeasure based on the 3E's of traffic engineering framework.

3.2 Research Flowchart

The flowchart of this research is shown in figure 2. It shows the process to be used in this research. A systematic strategy was developed to understand the problem comprehensively and assess the task of analysis. The whole process can be roughly broken down in several steps.

Figure 4 Research Flowchart



3.3 Research Task

3.3.1 Research Preparation

Identifying goals and objectives are probably the most important work at the beginning of research. All moped involved crashes need to be identified. A comprehensive literature review was conducted to have an insight of what previous research was done on moped crashes and modeling fault among crashes.

3.3.2 Data

Data came from the Traffic Operations and Safety Laboratory (TOPS lab). The data were collected by police officers at the scenes and input by staff from Wisconsin Department of Transportation. Collecting and processing data is a critical step of this research, since the data quality and method of getting data affect the result greatly. It is also a time-consuming process. Based on the requirement of the data, initial crash data is queried from WisTransPortal database based on time, location, moped flag and deer flag (indicate if it is a moped involved crash or deer involved crash). After this step, the dataset will only contain the moped involved crashes occurring at specific time and location. Then further data processing is necessary to filter out moped crashes that were involved in more than two vehicles. Crash data has to follow the criteria: crashes must be identified and only two parties' crashes and only one vehicle crashes are qualified for analyzing. The two vehicles crashes must have one moped involved and the other vehicle involved must be a motor vehicle (rather than bicycle or pedestrian). The single vehicle crashes must have been a moped. A total of 2,075 identified single moped crashes that occurred in Wisconsin including 325 crashes that occurred in Madison between 2003 and 2012 have been collected and analyzed. The single moped crashes need to be analyzed separately and the at-fault party of moped-motor vehicle crashes need to be identified in order to get more detailed information and finally use the data to do the analysis. More detailed information and steps are described in section 3.4.

3.3.3 Methodology

After finishing processing the raw data the next step is data analysis. There are several characters that need to be classified and analyzed, including crash characteristics, highway characteristics, environment characteristics and human factors. Several variables are included in each category, like location distribution, time distribution, weather, road condition factors, age distribution, safety equipment factors and driver contributing factors. Figures and tables are shown accordingly so as to illustrate the process and details.

In this analysis of moped involved crashes, one basic question is whether the moped crashes should be analyzed separately as Wisconsin crashes and Madison crashes. As of the census of 2010, there were 233,209 people living in Madison, which is less than one twentieth of the population in Wisconsin (5,686,986 people), however, more than one sixth of the crashes in Wisconsin occurred in downtown Madison. Furthermore, this city has the biggest campus area in Wisconsin and the university with highest registered moped number nationwide. Based on these facts, it is definitely necessary to do some research in Madison. On the other hand, if characteristics of the two categories are not very different, there is no need to separately analyze each of them. Tables and Figures are prepared in order to compare moped and car driver involved crashes. Factors related to identifying fault were also closely analyzed.

Another question is how to reach a solid conclusion based on analyzing different distributions, like different crash involvers, different locations variables, etc. It is not sufficient and necessary to say that one large percentage of a certain category is significant in the given distribution of a variable. In these cases, the selected groups need to be further analyzed by statistical method. Both data sets should have the same time span and characteristics categories.

Two Proportion Z-test:

Among the selected groups, it is important to identify whether the differences in proportions of specific variables are statistically significant. Each pair is compared separately by using two proportion Z-test. The null hypothesis is that the two crash datasets are the same in terms of proportion for a specific variable. The alternative hypothesis is that there is difference in terms of proportion for a specific variable between the two crash datasets. The null hypothesis can be rejected when the following condition is met [34].

$$\left| \frac{\widehat{p_1} - \widehat{p_2}}{\sqrt{\frac{\widehat{p_1}(1-\widehat{p_2})}{n_1} + \frac{\widehat{p_2}(1-\widehat{p_1})}{n_2}}} \right| > Z_{1-\alpha/2}$$

Where:

p_1: The proportion of crashes that fall into one category of a variable in dataset 1.

p_2: The proportion of crashes that fall into one category of a variable in dataset 2.

n_1: The number of crashes in dataset 1.

n_2: The number of crashes in dataset 2.

$Z_{1-\alpha/2}$: The z-score under probability level 0.025.

The assumptions are:

1. Individuals in each sample are independent.
2. $n_1 p_1$>5 and $n_1(1-p_1)$>5
3. $n_2 p_2$>5 and $n_2(1-p_2)$>5

Although at-fault is somewhat a subjective variable and it is highly possible that more factors, as a combination or isolation, have effects on the crashes, assigning fault is still a reasonable and reliable way to examine, categorize, and analyze crashes.

Logistic regression model:

Logistic regression is used as probabilistic statistical classification method in our study. It is a powerful tool for measuring the relationships between moped fault and various factors, like demographic, vehicle, roadway, and environmental factors. The probability of moped riders being at-fault under certain situations can be predicted. The odds ratio of moped riders being at-fault is the dependent variable of the function that has independent factors, like demographic, behavioral, vehicle, roadway and environmental factors. This logistic regression model is shown as following form:

$$\log_e\{\mathbf{Pr}(\boldsymbol{i})\ /[1 - \mathbf{Pr}(\boldsymbol{i})]\} = a_0 + \boldsymbol{a_i}\boldsymbol{x_i}$$

Where:

$\boldsymbol{x_i}$: The vector of measurable characteristics that identify outcome i (e.g., roadway characteristics, environmental factors, moped riders attributes, etc.)

$\boldsymbol{a_0}$: The constant term of estimable parameters.

$\boldsymbol{a_i}$: The vector of estimable parameters.

$\mathbf{Pr}(\boldsymbol{i})$: The probability that the moped riders at fault have a particular discrete outcome category i under particular situation.

The fault is expressed as the odds of the moped riders being at fault over the odds of the moped riders not being at fault, by using a single dependent variable. In this study, the process being modeled is the determination of fault, which is dependent upon characteristics of moped crashes' demographic, environmental, roadway and human factors. The modeling process involves fitting various terms believed to be associated with fault in moped crashes. Both elimination and inclusion methods were used to fit the model, by dropping the non-significant variables from the model. The model fit is assessed by examining the concordance between observed and fitted pairs.

In order to understand the effect of coefficient estimation, exp(a_1-a_0) is calculated to obtain the odds ratio which indicates the effect of factor change between two conditions in particular variable. The percentage change in the predicted probabilities for each category is obtained by computing the effect of value change from 0 to 1 for a categorical variable while holding all other variables at their mean.

3.3.4 Results Documentation

With the tasks listed prior or previously accomplished, the final work is to document all data and analysis results to draw the conclusion. According to the summary, recommendations might be proposed, in order to improve the safety condition of moped riders. Problems met in the research process and more ideas for digging deeper into this research are listed in the future work.

3.4 Data Collection and Processing

A series of steps are used as the procedure of data collection and processing, which aims at picking all the moped crashes that took place in Wisconsin between 2003 and 2012. In the following sections, the whole procedure is described in detail.

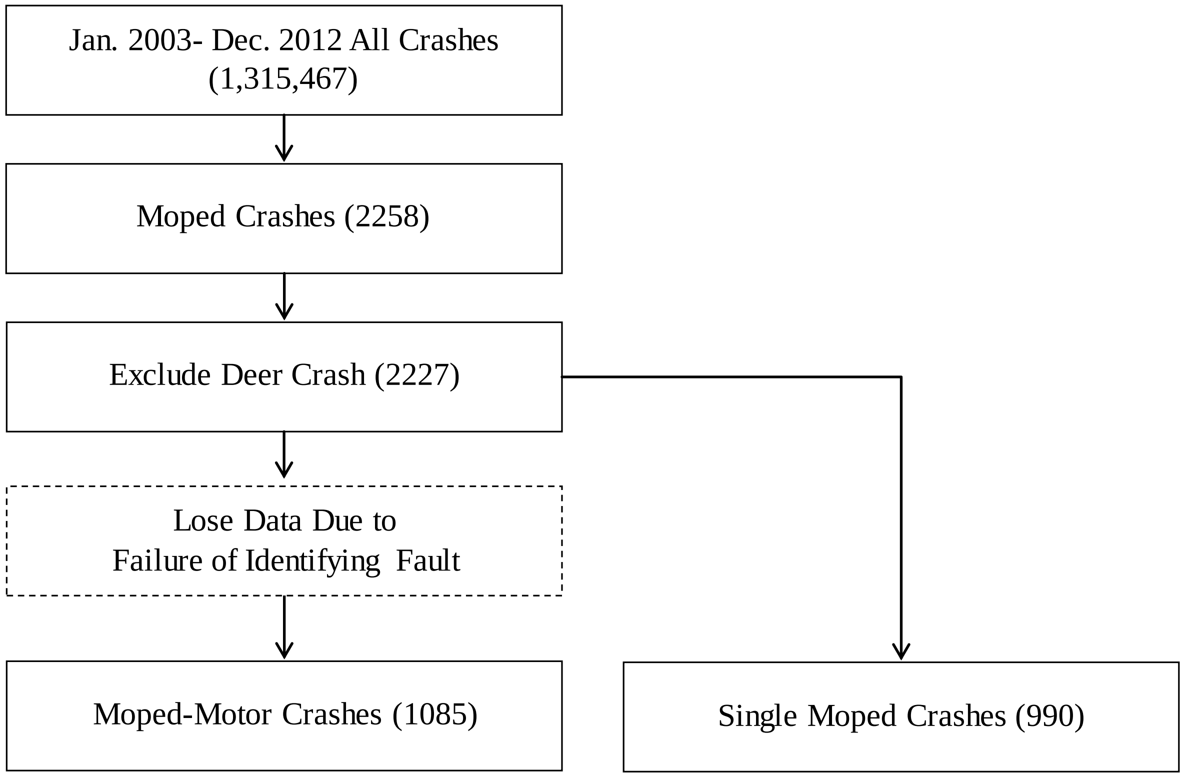
3.4.1 Data sources

The primary crash data comes from the WisTransPortal System, which serves the computing and data management needs of the Wisconsin Traffic Operations and Safety (TOPS) Laboratory. Intelligent Transportation System (ITS) data archiving, real-time traffic information services, transportation operations applications, and transportation research are included as the branch projects under this system. One of these projects aiming at crash data services is called, MV4000 Crash Database Query Tools. It is a complete database of Wisconsin MV4000 Traffic Accident Extract data from 1994 through the current year [35]. Information on all police reported crashes including the location of each crash, vehicles involved, and general crash attributes is contained in this database [35]. WisDOT division of Motor Vehicles traffic accident section is responsible for providing extracts, so that the TOPS lab can update data for the WisTransPortal crash database on a monthly basis.

3.4.2 Initial Data Selection

The time range of moped crashes is identified as a ten year period (2003-2012). Due to the small number of moped crashes occurring every year, a relatively longer time range can be useful for getting more crash data. The larger sample size in an experiment, the more significant the results will be and the less chance variation it will have. During this period of time, the number of mopeds registered consistently increased in Wisconsin, which was another reason for choosing this period of time as our research scope.

Figure 5 Filtering Steps

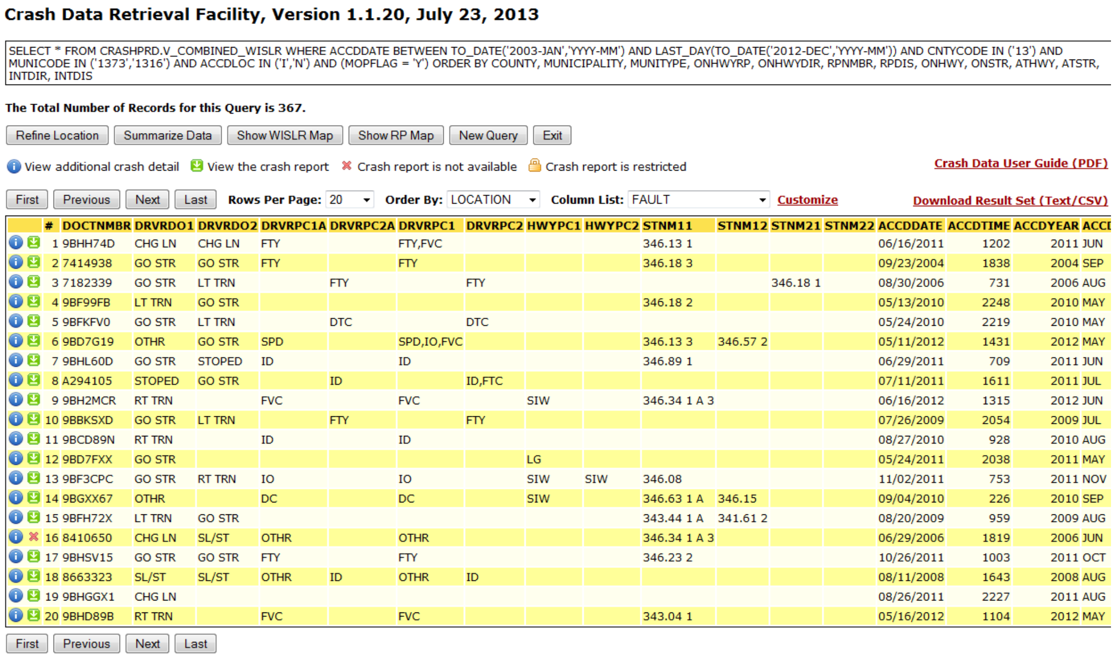


The location selection was decided at the beginning of this research. This scope is also the same as the scope of WisTransPortal project. Data for all moped crashes that occurred in Wisconsin or Madison is selected separately as the preliminary crash data. The reason for this separaton is because early analysis of some characteristics found that moped crash data from Madison are significantly different than data from Wisconsin. The full analysis is required to be done under different location selections.

Furthermore, animal related crashes should definitely not be included in the analysis, since those crashes are too fortuitous (It is hard to anticipate animal action, especially when you cannot see them). The crash flag is chosen as the last filter without fault identified. The moped flag is the only one being chosen. The fault identifying process causes data loss due to failure of identifying fault.

The screenshot of retrieved data website is shown as below.

Figure 6 Screenshot of Retrieved Data Website


Crash Data Retrieval Facility, Version 1.1.20, July 23, 2013

SELECT * FROM CRASHPRD.V_COMBINED_WISLR WHERE ACCDDATE BETWEEN TO_DATE('2003-JAN','YYYY-MM') AND LAST_DAY(TO_DATE('2012-DEC','YYYY-MM')) AND CNTYCODE IN ('13') AND MUNICODE IN ('1373','1316') AND ACCDLOC IN ('I','N') AND (MOPFLAG = 'Y') ORDER BY COUNTY, MUNICIPALITY, MUNITYPE, ONHWYRP, ONHWYDIR, RPNMBR, RPDIS, ONHWY, ONSTR, ATHWY, ATSTR, INTDIR, INTDIS

The Total Number of Records for this Query is 367.

Refine Location | Summarize Data | Show WISLR Map | Show RP Map | New Query | Exit

View additional crash detail View the crash report Crash report is not available Crash report is restricted Crash Data User Guide (PDF)

First | Previous | Next | Last **Rows Per Page:** 20 **Order By:** LOCATION **Column List:** FAULT Customize Download Result Set (Text/CSV)

#	DOCTNMBR	DRVRDO1	DRVRDO2	DRVRPC1A	DRVRPC2A	DRVRPC1	DRVRPC2	HWYPC1	HWYPC2	STNM11	STNM12	STNM21	STNM22	ACCDDATE	ACCDTIME	ACCDYEAR	ACCI
1	9BHH74D	CHG LN	CHG LN	FTY		FTY,FVC				346.13 1				06/16/2011	1202	2011	JUN
2	7414938	GO STR	GO STR	FTY		FTY				346.18 3				09/23/2004	1838	2004	SEP
3	7182339	GO STR	LT TRN		FTY		FTY					346.18 1		08/30/2006	731	2006	AUG
4	9BF99FB	LT TRN	GO STR							346.18 2				05/13/2010	2248	2010	MAY
5	9BFKFV0	GO STR	LT TRN		DTC		DTC							05/24/2010	2219	2010	MAY
6	9BD7G19	OTHR	GO STR	SPD		SPD,IO,FVC				346.13 3	346.57 2			05/11/2012	1431	2012	MAY
7	9BHL60D	GO STR	STOPED	ID		ID				346.89 1				06/29/2011	709	2011	JUN
8	A294105	STOPED	GO STR		ID		ID,FTC							07/11/2011	1611	2011	JUL
9	9BH2MCR	RT TRN		FVC		FVC		SIW		346.34 1 A 3				06/16/2012	1315	2012	JUN
10	9BBKSXD	GO STR	LT TRN		FTY		FTY							07/26/2009	2054	2009	JUL
11	9BCD89N	RT TRN		ID		ID								08/27/2010	928	2010	AUG
12	9BD7FXX	GO STR						LG						05/24/2011	2038	2011	MAY
13	9BF3CPC	GO STR	RT TRN	IO		IO		SIW	SIW	346.08				11/02/2011	753	2011	NOV
14	9BGXX67	OTHR		DC		DC		SIW		346.63 1 A	346.15			09/04/2010	226	2010	SEP
15	9BFH72X	LT TRN	GO STR							343.44 1 A	341.61 2			08/20/2009	959	2009	AUG
16	8410650	CHG LN	SL/ST	OTHR		OTHR				346.34 1 A 3				06/29/2006	1819	2006	JUN
17	9BHSV15	GO STR	GO STR	FTY		FTY				346.23 2				10/26/2011	1003	2011	OCT
18	8663323	SL/ST	SL/ST	OTHR	ID	OTHR	ID							08/11/2008	1643	2008	AUG
19	9BHGGX1	CHG LN												08/26/2011	2227	2011	AUG
20	9BHD89B	RT TRN		FVC		FVC				343.04 1				05/16/2012	1104	2012	MAY

First | Previous | Next | Last

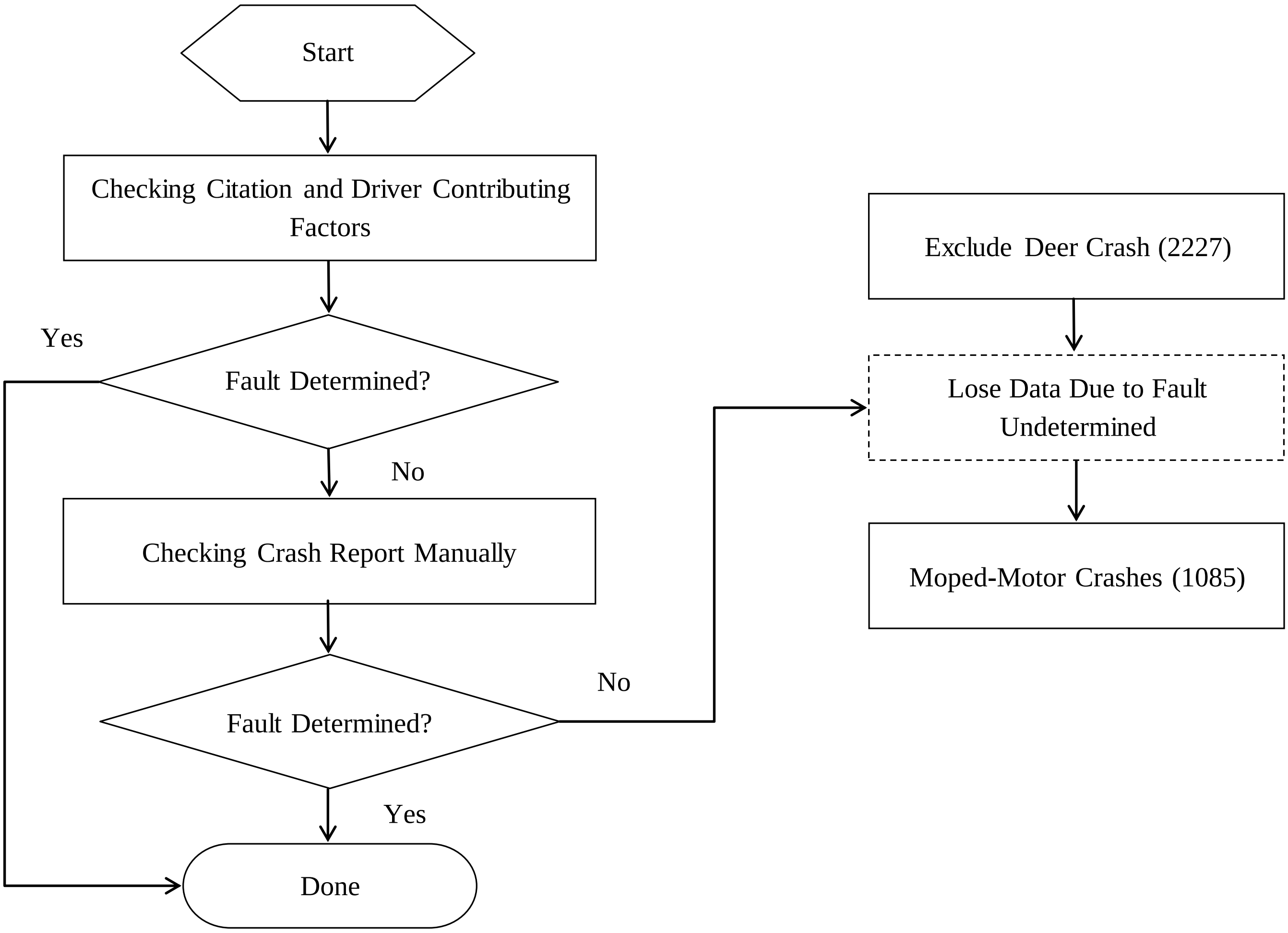
The total number of moped crashes that occurred between 2003 and 2012 is 2227 in Wisconsin and 367 in Madison. The next step is identifying the fault of moped riders.

3.4.3 Identify Fault

According to the literature review, it is known that at-fault information is somewhat a subjective concept, which is true whether the police or staff of the insurance company makes the conclusion. However, there are certain steps and criteria that are used for identifying fault. In the literature review section some criteria are presented. In this section, the detailed steps of the strategies for identifying fault are introduced. Though at-fault information is not objective enough, analyzing fault is still a good way to study the effect of comprehensive factors on moped riders and drivers.

In general, the police reports are checked manually to identify fault. In this paper, an alternative way to identify fault for moped related crashes on a systematic level are listed. Based on the implicit relationship among at-fault party, citation information and driver behavior, an algorithm was developed and tested to meet the requirement of this research. The flowchart for this identifying fault algorithm and its description are listed below.

Figure 7 Identify Fault Process



The flowchart for identifying fault is shown in figure 6. At the start point, the data which had been collected and filtered appropriately was provided. Moped crash data was input, both moped-motor vehicle crash and single moped crash were detected and identified whether moped rider was at-fault or not.

As mentioned in the literature review section, whether citations are issued was highly relevant to at-fault situation. Therefore, the citation number is considered somewhat as a flag of identifying fault. The general idea is comparing citation number between two parties. If one driver has citations more than the other driver, he/she is more likely to be marked as at-fault. In sum, there are 905 crashes in Wisconsin and 237 crashes in Madison where the at-fault party can be identified using these steps. In some cases, the fault cannot be assigned to either driver so these cases are dropped.

When fault cannot be identified we have three cases: the first one is that the moped rider fell by him/herself. The second case is that the moped rider and the other vehicle's operator both got same number of citations and made wrong maneuvers. Third, an argument arose between the two parties or there was insufficient information for the police to identify whose fault it is. In this case, the police report only represented the argument or stated all the facts he/she knew. In the first case, the moped riders can be identified as at-fault since nobody else was involved in crash. In the second case, both parties were at-fault so that riders were definitely at-fault in this case. In the third case, those crashes are unavailable accidents, whose data are dropped from further investigation.

In steps 2 and 3, in addition to fault determination, the vehicle type of at-fault party needs to be checked. If the vehicle type is moped, then these crashes are labeled as moped at-fault, otherwise, they are labeled as moped non-at-fault.

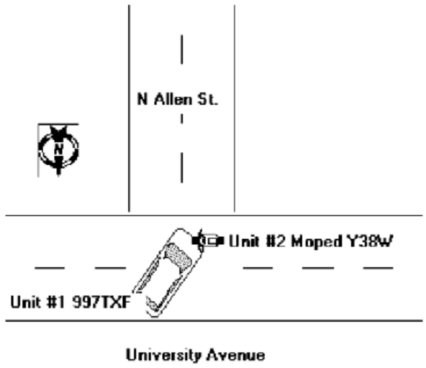
Single vehicle crashes can be separated from two vehicle crashes by checking total vehicle parameters in the crash data.

Figure 8 Crash Report Details

Diagram and Narrative

DIAGRAM AND NARRATIVE

105 - PHOTOS BY



UNIT #1 WAS TRAVELLING WESTBOUND ON UNIVERSITY AVENUE TURNING LEFT ONTO SOUTHBOUND N ALLEN ST. UNIT #2 WAS TRAVELLING EASTBOUND ON UNIVERSITY AVENUE APPROACHING N ALLEN ST. UNIT #1 COLLIDED WITH UNIT #2 IN A T-BONE FASHION CAUING MODERATE DAMAGE TO UNIT#2 AND MINOR DAMAGE TO THE FRONT OF UNIT #1.

Chapter 4: Data Analysis

Moped Crashes Data Summary

A number of crashes involving mopeds are identified by data collection and a reduction process. The process identified 2,075 and 367 moped crashes in Wisconsin and in Madison. Among these crashes, 1,085 crashes are identified as Moped-Motor Vehicle Crashes and 990 crashes are identified as Single Moped Crashes in Wisconsin; 251 crashes are identified as Moped-Motor Vehicle Crashes and 74 crashes are identified as Single Moped Crashes in Madison.

In terms of at-fault party, 463 and 92 crashes occurring in WI and Madison are identified as moped rider at-fault. However, there are some situations that more or less at-fault numbers are reported. The reasons were found out to be more than one moped involved in single crash and some data are missing.

Factors from all these data are classified into five big classes: moped rider characteristics, time characteristics, roadway characteristics, environmental characteristics and human factors. Each class contains several categories, for example, there are three in moped rider characteristics class. Furthermore, these categories are divided into more specific groups. In age distribution, five groups are defined as: age 15-24, 25-34, 35-44, 45-55, 55+.

The meaning of each column is list as below:

1. Frequency: both moped-motor vehicle and single vehicle crashes have their own frequency which is the number of occurrences of crashes classified into that particular group.

2. % of total: the percentage of group frequency divided by the total frequency in both moped-motor vehicle and single vehicle crashes.

3. % of MOP at-fault # to total: the percentage of moped riders' at-fault crashes in each group relative to total crashes for the group.

4. # of MOP at-fault: the number of moped riders' at-fault crashes in each group.

5. % of MOP at-fault: the percentage of moped riders' at-fault in each group divided by the group total.

All the variables and the description of variables are list in the table below.

Table 1 Variables and Descriptions

Explanatory variables	Description of the variables
AGE:	
AGE_24	if moped rider age smaller than 24 =1, otherwise =0.
AGE_25_34*	if moped rider age between 25 and 34 =1, otherwise =0.
AGE_35_44*	if moped rider age between 35 and 44 =1, otherwise =0.
AGE_45_54*	if moped rider age between 45 and 54 =1, otherwise =0.
AGE_55	if moped rider age older than 55 =1, otherwise =0.
GENDER:	
MALE*	if moped rider is male =1, female =0.
FEMALE	if moped rider is female =1, male =0.
INJURE SEVERITY:	
KILLED	if moped rider was killed =1, otherwise =0.
INCAPACITATING	if moped rider was incapacitating =1, otherwise =0.
NON_INCAPACITATING*	if moped rider was non=incapacitating =1, otherwise =0.
POSSIBLE	if moped rider was possible to be injured =1, otherwise =0.
UNREPORTED	if moped rider's Crash Severity was not reported =1, otherwise =0.
HAPPENING TIME IN TERMS OF HOURS:	
6_10	if crash occurred between 6:00 am to 10:00 am =1, otherwise =0.
10_15	if crash occurred between 10:00 am to 3:00 pm =1, otherwise =0.
15_19	if crash occurred between 3:00 pm to 7:00 pm =1, otherwise =0.
19_24	if crash occurred between 7:00 pm to 12:00 am =1, otherwise =0.
24_6	if crash occurred between 12:00 am to 6:00 am =1, otherwise =0.
HAPPENING TIME IN TERMS OF PEAK HOUR:	
PEAKHOUR	If crash occurred between 7:00 am to 9:00 am and 4:30 pm to 6:30 pm =1, otherwise =0.
NONPEAKHOUR*	If crash didn't occur between 7:00 am to 9:00 am and 4:30 pm to

	6:30 pm =1, otherwise =0.
DAY OF WEEK:	
SUNDAY	if crash occurred on Sunday =1, otherwise =0.
MONDAY	if crash occurred on Monday =1, otherwise =0.
TUESDAY	if crash occurred on Tuesday =1, otherwise =0.
WEDNESDAY	if crash occurred on Wednesday =1, otherwise =0.
THURSDAY	if crash occurred on Thursday =1, otherwise =0.
FRIDAY	if crash occurred on Friday =1, otherwise =0.
SATURDAY	if crash occurred on Saturday =1, otherwise =0.
WEEKEND	If crash occurred on Saturday or Sunday =1, otherwise =0.
WEEKDAY*	If crash didn't occur on Saturday or Sunday =1, otherwise =0.
MONTH OF YEAR:	
JANUARY	if crash occurred in January =1, otherwise =0.
FEBRUARY	if crash occurred in February =1, otherwise =0.
MARCH	if crash occurred in March =1, otherwise =0.
APRIL	if crash occurred in April =1, otherwise =0.
MAY	if crash occurred in May =1, otherwise =0.
JUNE	if crash occurred in June =1, otherwise =0.
JULY	if crash occurred in July =1, otherwise =0.
AUGUST	if crash occurred in August =1, otherwise =0.
SEPTEMBER	if crash occurred in September =1, otherwise =0.
OCTOBER	if crash occurred in October =1, otherwise =0.
NOVEMBER	if crash occurred in November =1, otherwise =0.
DECEMBER	if crash occurred in December =1, otherwise =0.
WINTER*	if crash occurred during December to March =1, otherwise =0.
NONWINTER	If crash occurred during April to November =1, otherwise =0.
LOCATION:	
CITY*	if crash occurred in City =1, otherwise =0.
TOWN	if crash occurred in Town =1, otherwise =0.
VILLAGE	if crash occurred in Village =1, otherwise =0.
HORIZONTAL:	
CURVE	if the horizontal road terrain was curve =1, otherwise =0.
STRAIGHT*	if the horizontal road terrain was straight =1, otherwise =0.
VERTICAL:	
HILL	if the vertical road terrain was hill =1, otherwise =0.
FLAT*	if the vertical road terrain was flat =1, otherwise =0.
PAVEMENT CONDITION:	
DRY*	if the surface condition of the road was dry =1, otherwise =0.
NOT_DRY	if the surface condition of the road was not dry =1, otherwise =0.
INTERSECTION:	
AT_INTERSECTION*	if the crash occurred at intersection =1, otherwise =0.
NOT_AT_INTERSECTION	if the crash occurred at non=intersection =1, otherwise =0.
WEATHER CONDITION:	

CLEAR*	if the crash occurred when the weather was clear =1, otherwise =0.
NOT_CLEAR	if the crash occurred when the weather was cloudy, rainy or windy =1, otherwise =0.
LIGHT CONDITION:	
DAYTIME*	if the crash occurred during daytime =1, otherwise =0.
DAWN_DUSK	if the crash occurred during dawn or dusk =1, otherwise =0.
DARK	if the crash occurred during dark and unlight condition =1, otherwise =0.
LIGHT	if the crash occurred during street light condition =1, otherwise =0.
BLANK	if the crash occurred during the unknown light condition =1, otherwise =0.
VEHICLE MANEUVER:	
CHANGING_LANES	If moped rider was chaning lane at the time of the crash =1, otherwise =0.
GOING_STRAIGHT*	If moped rider was going straight at the time of the crash =1, otherwise =0.
ILLEGALLY_PARKED*	If moped rider was illegally parked at the time of the crash =1, otherwise =0.
LEGALLY_PARKED	If moped rider was legally parked at the time of the crash =1, otherwise =0.
MAKING_LEFT_TURN	If moped rider was making left turn at the time of the crash =1, otherwise =0.
NEGOTIATING_CURVE	If moped rider was negotiating curve at the time of the crash =1, otherwise =0.
OTHER*	If moped rider was doing other thing at the time of the crash =1, otherwise =0.
OVERTAKING_ON_THE_LEFT	If moped rider was overtaking on the left at the time of the crash =1, otherwise =0.
OVERTAKING_ON_THE_RIGHT	If moped rider was overtaking on the right at the time of the crash =1, otherwise =0.
PARKING_MANEUVER	If moped rider was parking at the time of the crash =1, otherwise =0.
RIGHT_TURN	If moped rider was making right turn at the time of the crash =1, otherwise =0.
SLOWING_OR_STOPPED	If moped rider was slowing or stopped at the time of the crash =1, otherwise =0.
STOPPED_IN_TRAFFIC	If moped rider was stopped in traffic at the time of the crash =1, otherwise =0.
COLLISION TYPE:	
ANGLE*	If two vehicles approaching from non-opposing angular directions collided =1, otherwise =0.

HEAD_ON_COLLISION	If two vehicles approaching opposite directions and intending to continue in opposite directions collided in a frontal or angular manner =1, otherwise =0.
NO_COLLISION	If there was no collision =1, otherwise =0.
REAR_END	If two vehicles in a position of one behind the other and collided =1, otherwise =0.
SIDESWIPE_OPPOSITE_D	If two vehicles approaching opposite directions and intending to continue in opposite directions collide in a sideswiping manner =1, otherwise =0.
SIDESWIPE_SAME_D	If two vehicles moving alongside each other and collided, with at least one of the vehicles being struck on the side =1, otherwise =0.
UNKNOWN	If two vehicles collided with unknown reason =1, otherwise =0.
PROTECTION GEARS USE:	
HELMET	If moped rider worn helmet at the time of a crash =1, otherwise =0.
EYE_PROTECTION	If moped rider worn eye protection at the time of a crash =1, otherwise =0.
BOTH	If moped rider worn both helmet and eye protection at the time of a crash =1, otherwise =0.
NONE*	If moped rider didn't worn anything at the time of the crash =1, otherwise =0.

* Reference category for categorical independent variables.

4.1 Moped Rider Characteristics

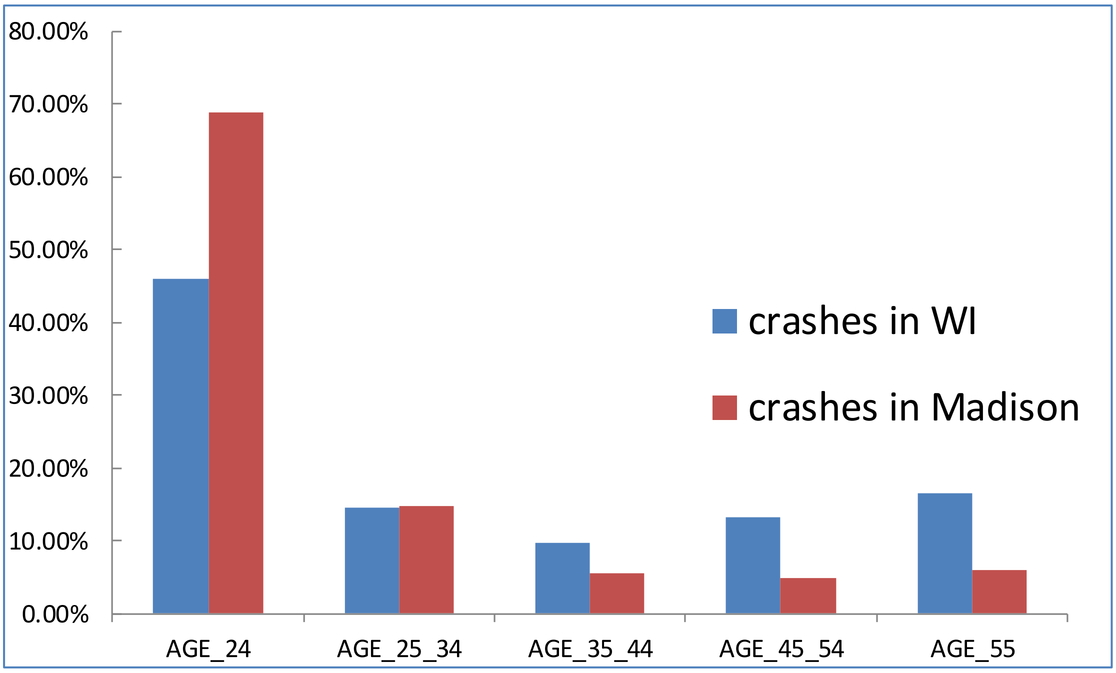
Characteristics of moped riders are summarized in the following sections. These characteristics are classified into three categories, including age, gender and Crash Severity characteristics.

4.1.1 Comparison of Age Distribution

Table 2 Comparison of Age Distribution

Age	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
AGE_24	498	45.90%	46.59%	232	50.11%	296	29.90%
AGE_25_34	158	14.56%	37.34%	59	12.74%	143	14.44%
AGE_35_44	106	9.77%	39.62%	42	9.07%	127	12.83%
AGE_45_54	144	13.27%	37.50%	54	11.66%	176	17.78%
AGE_55	179	16.50%	42.46%	76	16.41%	248	25.05%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
AGE_24	173	68.92%	38.73%	67	72.83%	44	59.46%
AGE_25_34	37	14.74%	21.62%	8	8.70%	17	22.97%
AGE_35_44	14	5.58%	42.86%	6	6.52%	3	4.05%
AGE_45_54	12	4.78%	33.33%	4	4.35%	3	4.05%
AGE_55	15	5.98%	46.67%	7	7.61%	7	9.46%

Figure 9 Age Distribution in Terms of Percentage of Total



From table 2, it is shown that the difference of age distribution between WI and Madison is significant. People at age 15 to 24 are the majority of moped riders involved in crashes. In Madison, riders from this age group have more crashes than any other age group. They have the lowest single to two vehicle crash ratio, which perhaps is due to their good capability to control the moped. In terms of the percentages of moped at-fault number to total number in Wisconsin, the z-test value is 2.08 between "AGE_24" and "AGE_25_34". And the z-test value is 1.97 between "AGE_24" and "AGE_45_54". It shows that young riders are generally more likely to be the at-fault party of crashes. In this case, more education and legislation is necessary.

4.1.2 Comparison of Gender Distribution in Moped Crashes

Table 3 Comparison of Sex Distribution

Gender	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
MALE	804	74.10%	41.67%	335	72.35%	658	66.46%
FEMALE	281	25.90%	45.55%	128	27.65%	332	33.54%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
MALE	171	68.13%	37.43%	64	69.57%	53	71.62%
FEMALE	84	33.47%	33.33%	28	30.43%	21	28.38%

From table 4, it is shown that the difference of sex distribution in moped crashes between WI and Madison is very obvious. The number of males having collisions in Madison and WI are double and triple those of females. It is noteworthy that based on rider's ratio of at-fault number over total number, women are more likely to be identified as at-fault party in WI but not in Madison area (the two proportion z-test value is 2.06). The reason may be explained by Karl Kim, Lei Li, James Richardson, and Lawrence Nitz's finding that the youngest males and the oldest females have more likelihood of being classified at-fault [15], since the average age of the population in Madison is smaller than in WI. Further analysis could be done by making a cross table to investigate the coefficient of gender and age variables.

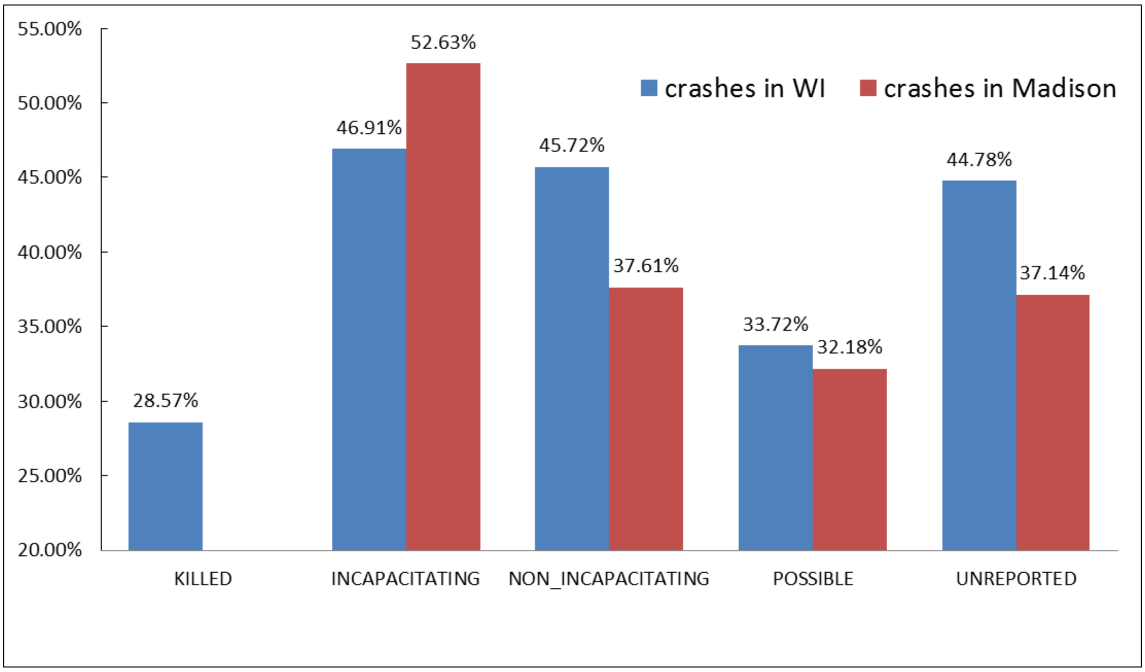
4.1.3 Comparison of Crash Severity

Table 4 Comparison of Crash Severity

Crash Severity	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
KILLED	14	1.29%	28.57%	4	0.86%	10	1.01%
INCAPACITATING	162	14.93%	46.91%	76	16.41%	228	23.03%
NON_INCAPACITATING	514	47.37%	45.72%	235	50.76%	583	58.89%
POSSIBLE	261	24.06%	33.72%	88	19.01%	141	14.24%
UNREPORTED	134	12.35%	44.78%	60	12.96%	28	2.83%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
KILLED	1	0.40%	0.00%	0	0.00%	0	0.00%
INCAPACITATING	19	7.57%	52.63%	10	10.87%	10	13.51%
NON_INCAPACITATING	109	43.43%	37.61%	41	44.57%	40	54.05%
POSSIBLE	87	34.66%	32.18%	28	30.43%	16	21.62%
UNREPORTED	35	13.94%	37.14%	13	14.13%	8	10.81%

The Table 5 shows that injured crashes account for more than 85 percent of all moped-motor crashes and around or more than 90 percent of single crashes. It is apparent that moped riders are highly vulnerable in crashes. In terms of moped rider's at-fault probability in each category, if the moped rider got injured, the more severe injury it is, the more likely he/she is considered at-fault. In this case, it is possible to say that if moped riders can be more cautious to avoid being identified at-fault, they are more likely to get less severely injured. However, moped riders being killed is another case. Due to the speed limit of moped (<40 mph), riders may not have the ability to cause a fatality crash in most cases.

Figure 10 Crash Severity in Terms of Percentage of Moped Riders Being At-fault



4.2 Time Characteristics

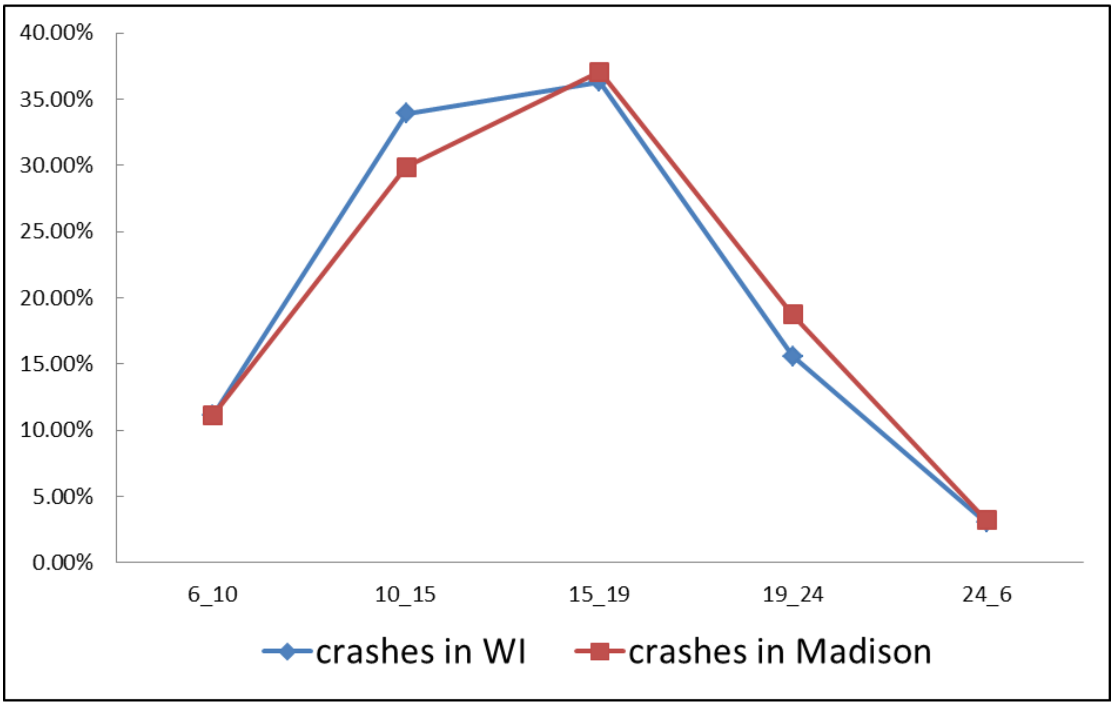
4.2.1 Comparison of Hourly Distribution

Table 5 Comparison of Hourly Distribution

Time	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
6_10	121	11.15%	35.54%	43	9.29%	74	7.47%
10_15	368	33.92%	42.39%	156	33.69%	305	30.81%
15_19	394	36.31%	45.18%	178	38.44%	347	35.05%
19_24	169	15.58%	42.60%	72	15.55%	195	19.70%
24_6	33	3.04%	42.42%	14	3.02%	69	6.97%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
6_10	28	11.16%	35.71%	10	10.87%	6	8.11%
10_15	75	29.88%	42.67%	32	34.78%	26	35.14%
15_19	93	37.05%	34.41%	32	34.78%	16	21.62%
19_24	47	18.73%	29.79%	14	15.22%	14	18.92%
24_6	8	3.19%	50.00%	4	4.35%	12	16.22%

From figure 11, it is shown that most moped crashes occurring during the daytime. In terms of at-fault involvement, those crashes occurring in the morning or at night are less likely to be riders' fault. Regarding to single crashes, the probability of moped riders having crashes between 12:00am and 6 am in Madison is 9.25 percent higher than in Wisconsin, which could probably be explained by the great amount of nightlife in the campus area and drinking culture.

Figure 11 Hourly Distribution in Terms of Percentage of Each Group over Total



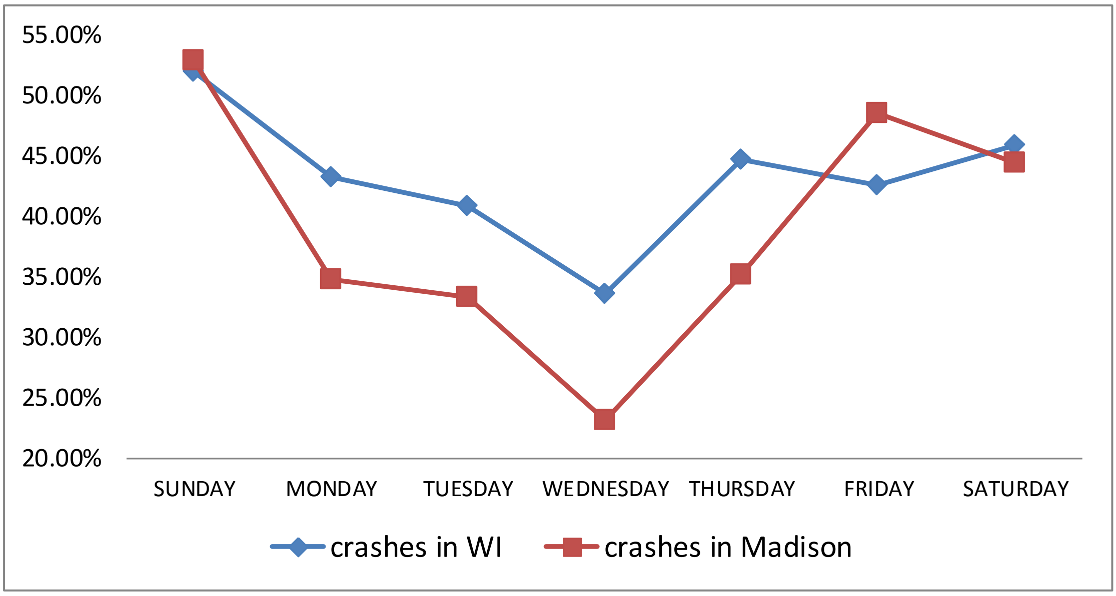
4.2.2 Comparison of Weekly Distribution

Table 6 Comparison of Weekly Distribution

Day of Week	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
SUNDAY	100	9.22%	52.00%	52	11.23%	158	15.96%
MONDAY	176	16.22%	43.18%	76	16.41%	122	12.32%
TUESDAY	196	18.06%	40.82%	80	17.28%	119	12.02%
WEDNESDAY	155	14.29%	33.55%	52	11.23%	118	11.92%
THURSDAY	170	15.67%	44.71%	76	16.41%	134	13.54%
FRIDAY	155	14.29%	42.58%	66	14.25%	150	15.15%
SATURDAY	133	12.26%	45.86%	61	13.17%	189	19.09%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
SUNDAY	17	6.77%	52.94%	9	9.78%	5	6.76%
MONDAY	46	18.33%	34.78%	16	17.39%	6	8.11%
TUESDAY	42	16.73%	33.33%	14	15.22%	13	17.57%
WEDNESDAY	39	15.54%	23.08%	9	9.78%	11	14.86%
THURSDAY	54	21.51%	35.19%	19	20.65%	12	16.22%
FRIDAY	35	13.94%	48.57%	17	18.48%	19	25.68%
SATURDAY	18	7.17%	44.44%	8	8.70%	8	10.81%

From the table above, moped-motor crashes have similar distributions of crashes on each individual day of the week in Wisconsin and Madison. Relatively more crashes occurred during the workweek day due to intensive moped use in transit among home, company or school. However, the weekend is found to be a significant influence upon the fault of moped riders involved in crashes. During the weekend, moped riders are more involved in at-fault crashes. This might be due to moped riders using fixed and familiar routes during the weekday and travel to unfamiliar places on the weekend.

Figure 12 Weekly Distribution in Terms of Riders' At-fault Percentage



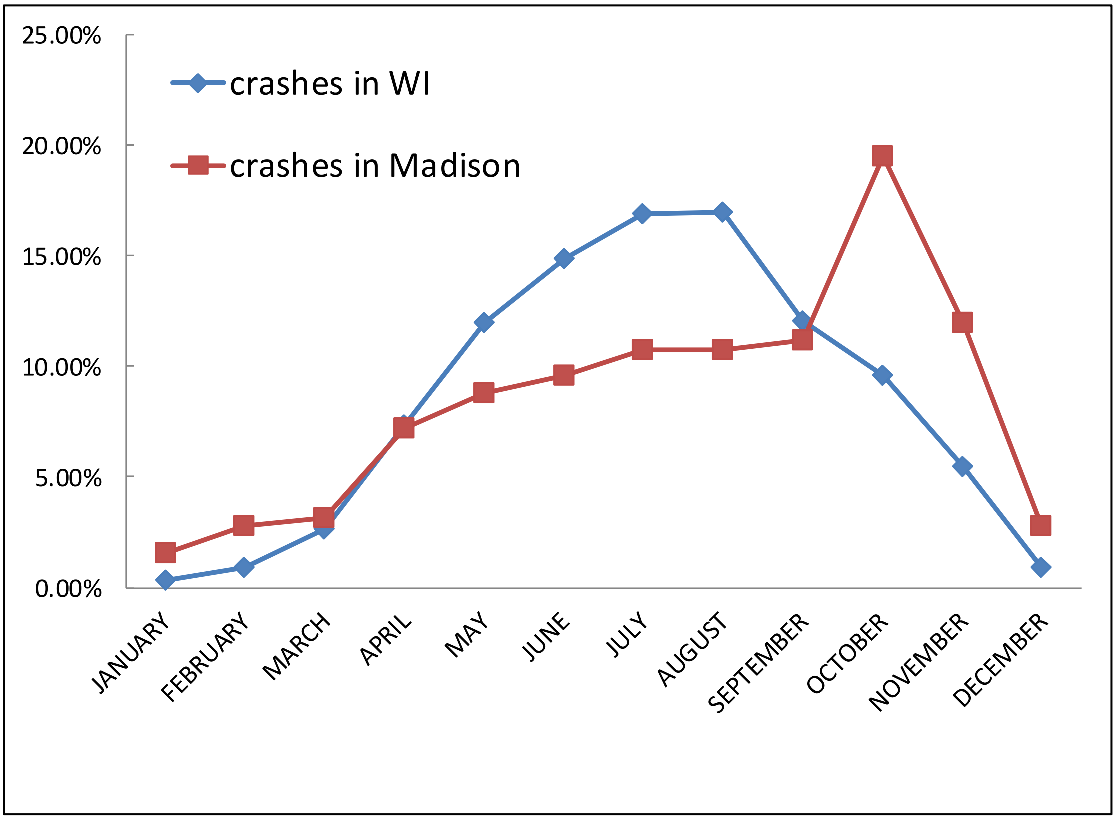
4.2.3 Comparison of Monthly Distribution

Table 7 Comparison of Monthly Distribution

Month	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
JANUARY	4	0.37%	25.00%	1	0.22%	1	0.10%
FEBRUARY	10	0.92%	60.00%	6	1.30%	5	0.51%
MARCH	29	2.67%	34.48%	10	2.16%	29	2.93%
APRIL	80	7.37%	45.00%	36	7.78%	59	5.96%
MAY	130	11.98%	43.08%	56	12.10%	118	11.92%
JUNE	161	14.84%	42.24%	68	14.69%	177	17.88%
JULY	183	16.87%	44.26%	81	17.49%	196	19.80%
AUGUST	184	16.96%	47.28%	87	18.79%	203	20.51%
SEPTEMBER	131	12.07%	46.56%	61	13.17%	129	13.03%
OCTOBER	104	9.59%	36.54%	38	8.21%	47	4.75%
NOVEMBER	59	5.44%	25.42%	15	3.24%	19	1.92%
DECEMBER	10	0.92%	40.00%	4	0.86%	7	0.71%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
JANUARY	4	1.59%	0.00%	0	0.00%	0	0.00%
FEBRUARY	7	2.79%	57.14%	4	4.35%	2	2.70%
MARCH	8	3.19%	25.00%	2	2.17%	6	8.11%
APRIL	18	7.17%	50.00%	9	9.78%	9	12.16%
MAY	22	8.76%	36.36%	8	8.70%	4	5.41%
JUNE	24	9.56%	29.17%	7	7.61%	11	14.86%
JULY	27	10.76%	48.15%	13	14.13%	9	12.16%
AUGUST	27	10.76%	44.44%	12	13.04%	7	9.46%
SEPTEMBER	28	11.16%	42.86%	12	13.04%	11	14.86%
OCTOBER	49	19.52%	36.73%	18	19.57%	7	9.46%
NOVEMBER	30	11.95%	16.67%	5	5.43%	6	8.11%
DECEMBER	7	2.79%	28.57%	2	2.17%	2	2.70%

From figure 13, it shows that there were fewer crashes happening during winter time, which has two explanations: moped use is not frequently in winter time or riders are much more careful during winter time. In Madison, October is the month that a lot of crashes took place. It may be due to a new semester starting and many inexperienced moped users begin to ride. In terms of rider at-fault involvement, the data in Wisconsin from May to October is examined, since during these months, more than 100 crashes happened. They are bigger samples and are more likely to reflect the truth. October is the only month that moped riders have a probability of being considered at-fault less than 40 percent. Combined with the fact that many inexperienced riders begin to ride, it, perhaps, implies that inexperienced riders probably do a good job in obeying traffic rules, but do not know how to drive defensively and watch out for others impropriate maneuvers.

Figure 13 Monthly Distribution in Terms of Percentage of Crashes in Each Month



4.3 Roadway Characteristics

4.3.1 Comparison of Location Distribution

Table 8 Comparison of Location Distribution

Location	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
CITY	887	81.75%	41.60%	369	79.70%	536	54.14%
TOWN	96	8.85%	51.04%	49	10.58%	335	33.84%
VILLAGE	102	9.40%	44.12%	45	9.72%	119	12.02%

From table 8, the frequency of moped-motor vehicle crashes shows that most moped-motor vehicle crashes occurred in a city. Compared with single moped crash frequency, fewer moped-motor crashes happened in a town. It could be explained by good road condition in city. In terms of fault involvement, riders in the city are less likely to be identified at-fault. Possible explanation could be that there is higher traffic volume in city and it is easier to obey the rules than to watch out every other road user.

4.3.2 Horizontal Terrain

Table 9 Horizontal Terrain

Horizontal	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
CURVE	76	7.00%	43.42%	33	7.13%	265	26.77%
STRAIGHT	1009	93.00%	42.62%	430	92.87%	725	73.23%

From table 9, it is shown that most crashes happened while the roadway is straight. More single moped crashes happened at curve compared with moped-motor crashes. There is no significant difference between curve and straight road condition in terms of riders fault involvement.

4.3.3 Vertical Terrain

Table 10 Vertical Terrain

Vertical	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
HILL	108	9.95%	38.89%	42	9.07%	143	14.44%
FLAT	977	90.05%	43.09%	421	90.93%	847	85.56%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
HILL	35	13.94%	37.14%	13	14.13%	12	16.22%
FLAT	216	86.06%	36.57%	79	85.87%	62	83.78%

From table 10, the Wisconsin data shows that under the situation where the collision happened on the hill, it is more likely that riders are not at-fault compared with the situation where the collision happened on the flat road. More than 85 percent of crashes occurred on a flat road.

4.3.4 Comparison of Road Way Surface

Table 11 Comparison of Road Way Surface

Road Way Surface	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
DRY	1010	93.09%	43.27%	437	94.38%	959	96.87%
NOT_DRY	75	6.91%	34.67%	26	5.62%	31	3.13%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
DRY	212	84.46%	37.74%	80	86.96%	62	83.78%
NOT_DRY	39	15.54%	30.77%	12	13.04%	12	16.22%

From the table 11, road way surface condition contributes a lot to moped riders fault involvement. Dry surface condition gives a higher likelihood of at-fault crash involvement. It clearly indicates that the fault of moped riders is increased when the road surface is dry. This is expected as the moped riders tend to ride more cautiously while the road condition is wet, ice, mud, etc. Crashes which took place on a dry roadway account for more than 90 percent of all crashes. This may also represent the moped riders' willingness to travel under good roadway conditions.

4.3.5 Comparison of Intersection Distribution

Table 12 Comparison of Intersection Distribution

Intersection	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
AT_INTERSECTION	654	60.28%	36.39%	238	51.40%	356	35.96%
NOT_AT_INTERSECTION	431	39.72%	52.20%	225	48.60%	634	64.04%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
AT_INTERSECTION	152	60.56%	32.24%	49	53.26%	35	47.30%
NOT_AT_INTERSECTION	99	39.44%	43.43%	43	46.74%	39	52.70%

From table 12, whether the crash occurs at an intersection or not is found to significantly influence the fault of moped riders in both Wisconsin and Madison. If riders are involved in a collision at an intersection, they are less likely to be identified at-fault. This is perhaps due to the situations that drivers have to watch out for so much information at intersections and don’t see the moped since it is a relatively smaller object.

4.4 Environmental Characteristics

4.4.1 Comparison of Weather Distribution

Table 13 Comparison of Weather Distribution

Weather	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
CLEAR	804	74.10%	43.16%	347	74.95%	705	71.21%
NOT_CLEAR	281	25.90%	41.28%	116	25.05%	285	28.79%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
CLEAR	167	66.53%	38.92%	65	70.65%	47	63.51%
NOT_CLEAR	84	33.47%	32.14%	27	29.35%	27	36.49%

From the table, it is shown that most crashes happened on clear days. The weather seems to have no influence on moped fault involvement.

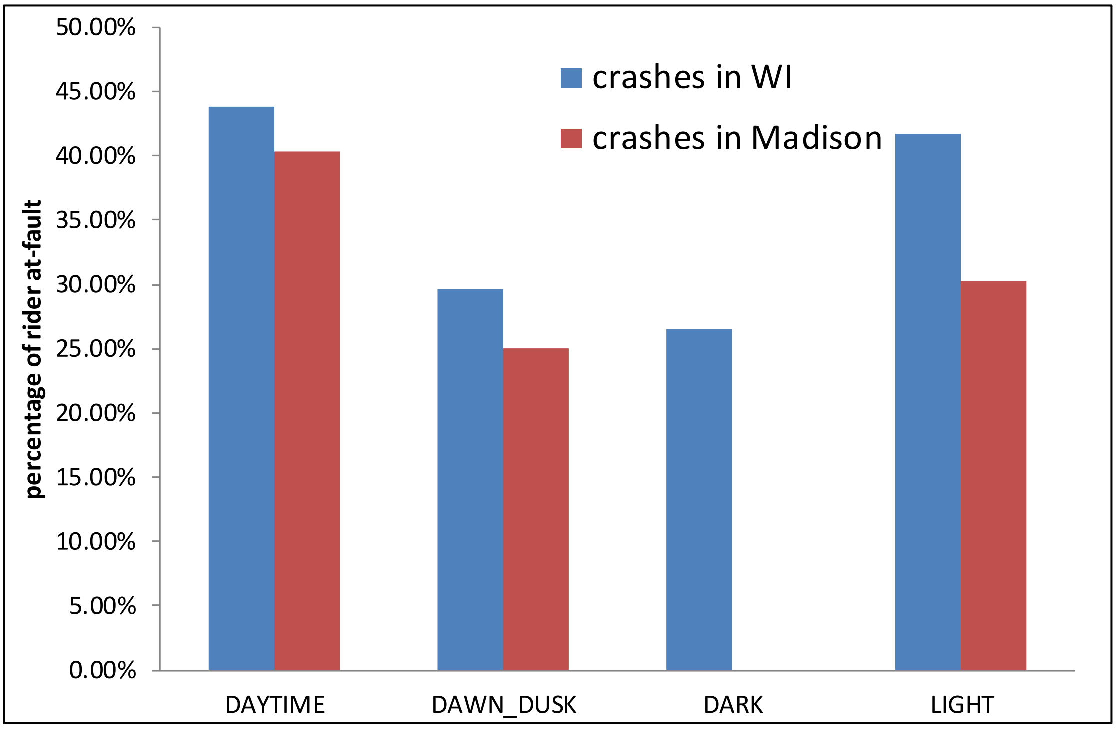
4.4.2 Comparison of Light Condition

Table 14 Comparison of Light Condition

Light Condition	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
DAYTIME	878	80.92%	43.85%	385	83.15%	780	78.79%
DAWN_DUSK	27	2.49%	29.63%	8	1.73%	41	4.14%
DARK	34	3.13%	26.47%	9	1.94%	58	5.86%
LIGHT	146	13.46%	41.78%	61	13.17%	111	11.21%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
DAYTIME	176	70.12%	40.34%	71	77.17%	50	67.57%
DAWN_DUSK	4	1.59%	25.00%	1	1.09%	1	1.35%
DARK	5	1.99%	0.00%	0	0.00%	4	5.41%
LIGHT	66	26.29%	30.30%	20	21.74%	19	25.68%

From the table, it shows that daytime is the time period that most crashes happened. At the place where there is no light at night or bad natural light condition, the riders are more likely to be the not at-fault party. However, mopeds may actually be more visible at night since their lights are so visible. The reasons why drivers are more likely to be identified at-fault need further investigation.

Figure 14 Light Condition Distribution in Terms of Percentage of Riders' At-fault Crashes



4.5 Human Factors

4.5.1 Vehicle Maneuver Prior to Crash

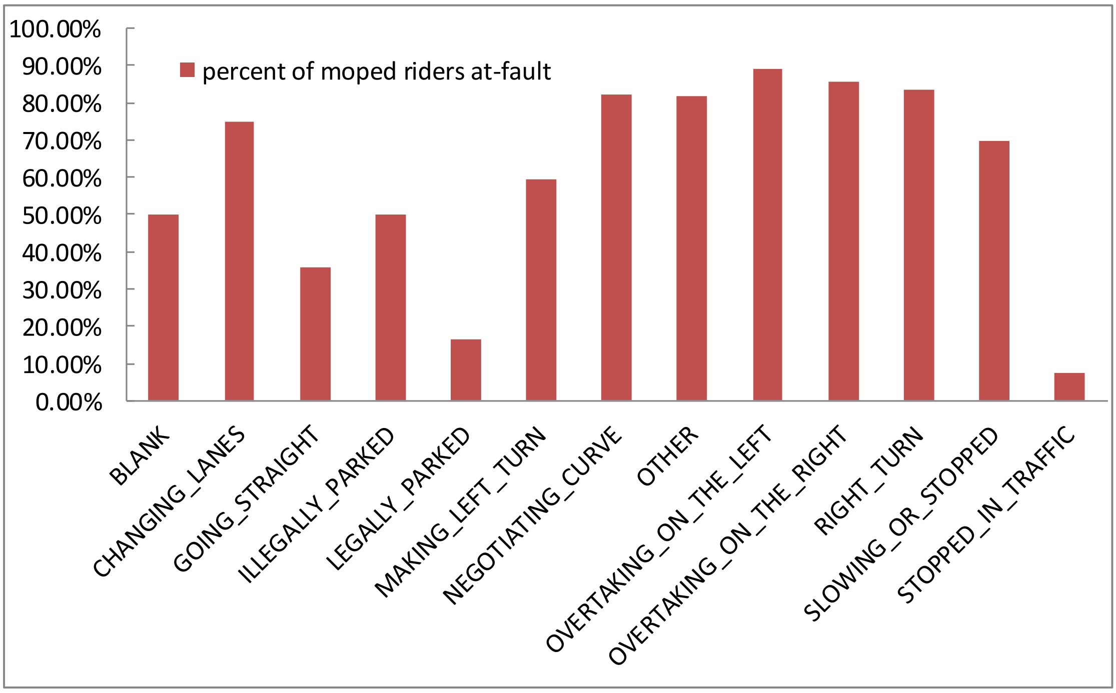
Table 15 Vehicle Maneuver Prior to Crash

Vehicle Maneuver	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100%	42.67%	463	100%	990	100.00%
BLANK	2	0.18%	50.00%	1	0.22%	3	0.30%
CHANGING_LANES	12	1.11%	75.00%	9	1.94%	8	0.81%
GOING_STRAIGHT	774	71.34%	35.92%	278	60.04%	481	48.59%
ILLEGALLY_PARKED	2	0.18%	50.00%	1	0.22%	0	0.00%
LEGALLY_PARKED	18	1.66%	16.67%	3	0.65%	0	0.00%
MAKING_LEFT_TURN	106	9.77%	59.43%	63	13.61%	155	15.66%
NEGOTIATING_CURVE	17	1.57%	82.35%	14	3.02%	147	14.85%
OTHER	11	1.01%	81.82%	9	1.94%	13	1.31%
OVERTAKING_ON_THE_LEFT	9	0.83%	88.89%	8	1.73%	1	0.10%
OVERTAKING_ON_THE_RIGHT	7	0.65%	85.71%	6	1.30%	2	0.20%
PARKING_MANEUVER	0	0.00%	NA	0	0.00%	1	0.10%
RIGHT_TURN	54	4.98%	83.33%	45	9.72%	110	11.11%
SLOWING_OR_STOPPED	33	3.04%	69.70%	23	4.97%	64	6.46%
STOPPED_IN_TRAFFIC	40	3.69%	7.50%	3	0.65%	5	0.51%
In Madison							
Total	251	100%	36.65%	92	100%	74	100.00%
BLANK	1	0.40%	0.00%	0	0.00%	0	0.00%
CHANGING_LANES	3	1.20%	100.00%	3	3.26%	1	1.35%
GOING_STRAIGHT	191	76.10%	28.27%	54	58.70%	39	52.70%
LEGALLY_PARKED	3	1.20%	0.00%	0	0.00%	0	0.00%
MAKING_LEFT_TURN	14	5.58%	57.14%	8	8.70%	14	18.92%
NEGOTIATING_CURVE	3	1.20%	100.00%	3	3.26%	6	8.11%
OTHER	3	1.20%	100.00%	3	3.26%	1	1.35%
OVERTAKING_ON_THE_LEFT	2	0.80%	100.00%	2	2.17%	0	0.00%
OVERTAKING_ON_THE_RIGHT	5	1.99%	80.00%	4	4.35%	0	0.00%

RIGHT_TURN	7	2.79%	85.71%	6	6.52%	8	10.81%
SLOWING_OR_STOPPED	11	4.38%	72.73%	8	8.70%	5	6.76%
STOPPED_IN_TRAFFIC	8	3.19%	12.50%	1	1.09%	0	0.00%

From the table, the data shows that going straight accounts for more than seventy percent of situations in moped crashes. In that situation, only 35 percent of cases identified moped riders at fault. This result suggests that riders need to keep alert when going straight. Even if the riders don't need to do anything, it is still highly possible that others might hit you or that you will hit a pothole or other road debris. Riders are more vulnerable than other vehicles because they are using a light vehicle. In order to avoid becoming the victim, the riders have to be aware of this situation. It is also revealed that stopped in traffic is a very dangerous maneuver, since the probability of moped at-fault is 12.5%, which means they are hit by other vehicles in most cases. This suggests that how the rider places himself at a stop sign is important – stay visible (not too close to another vehicle, avoid dangerous spots on the road (where someone may cut a corner too sharply and hit you) stay out of blind spots etc.

Figure 15 Vehicle Maneuver Distribution in Terms of Percentage of Riders' At-fault Crashes



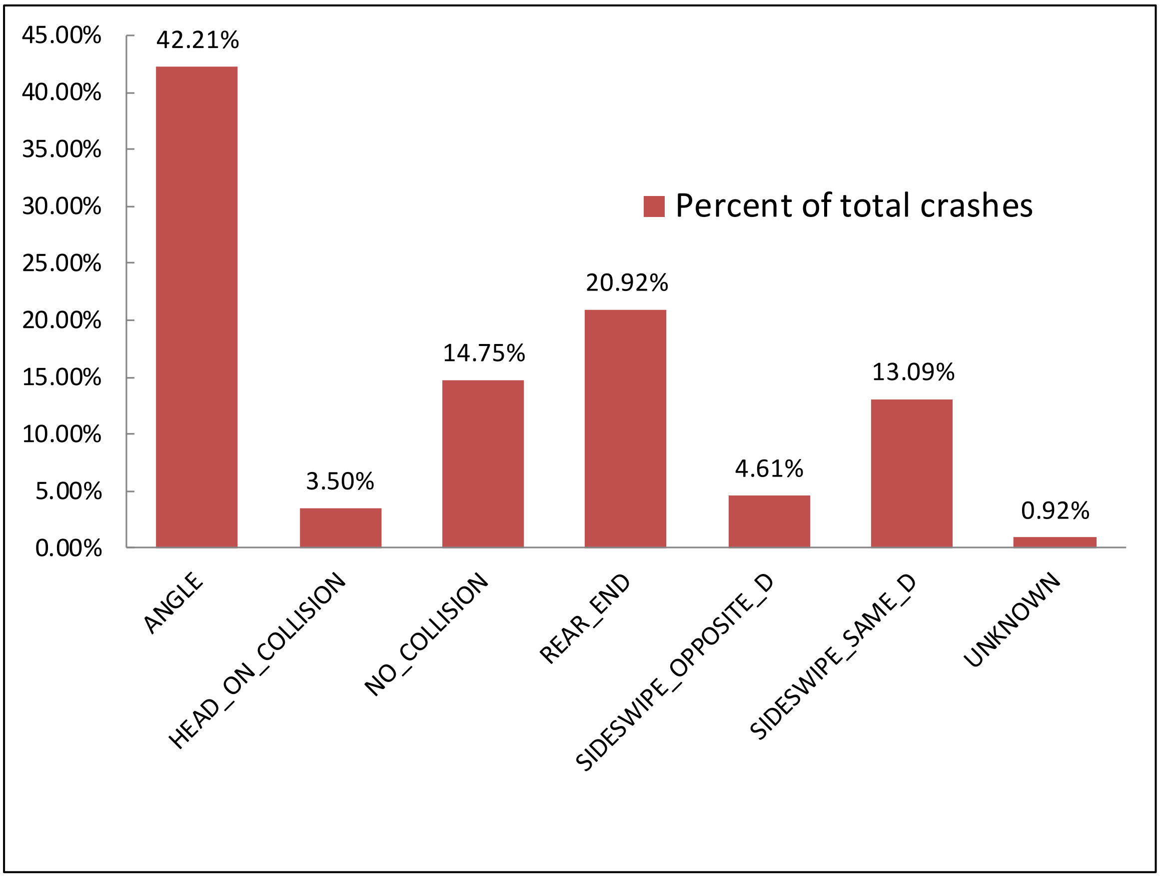
4.5.2 Manner of First Harmful Event

Table 16 Manner of first harmful event

Manner	Moped-Motor Vehicle Crashes				
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault
In Wisconsin					
Total	1085	100.00%	42.67%	463	100.00%
ANGLE	458	42.21%	32.10%	147	31.75%
HEAD_ON_COLLISION	38	3.50%	52.63%	20	4.32%
NO_COLLISION	160	14.75%	36.88%	59	12.74%
REAR_END	227	20.92%	59.47%	135	29.16%
SIDESWIPE_OPPOSITE_D	50	4.61%	58.00%	29	6.26%
SIDESWIPE_SAME_D	142	13.09%	49.30%	70	15.12%
UNKNOWN	10	0.92%	30.00%	3	0.65%
In Madison					
Total	251	100.00%	36.65%	92	100.00%
ANGLE	103	41.04%	26.21%	27	29.35%
HEAD_ON_COLLISION	7	2.79%	42.86%	3	3.26%
NO_COLLISION	24	9.56%	25.00%	6	6.52%
REAR_END	51	20.32%	64.71%	33	35.87%
SIDESWIPE_OPPOSITE_D	9	3.59%	22.22%	2	2.17%
SIDESWIPE_SAME_D	52	20.72%	38.46%	20	21.74%
UNKNOWN	5	1.99%	20.00%	1	1.09%

From this table, the rear end collision is the scene that riders are more likely to be involved as at-fault. It implies that the situation that mopeds follow too closely and are unprepared to stop when a motor vehicle stops is more likely to be happened that moped riders failed to stop. Riders are found to be involved in angle crashes for more than 40 percent of the total crashes. Furthermore, in this situation, riders are much less likely to be identified as the at-fault party (ten percent less than average percent of moped riders' at-fault number to total number). This is probably due to drivers failing to see moped before they can make any action to avoid the crash in time.

Figure 16 Manner Distribution



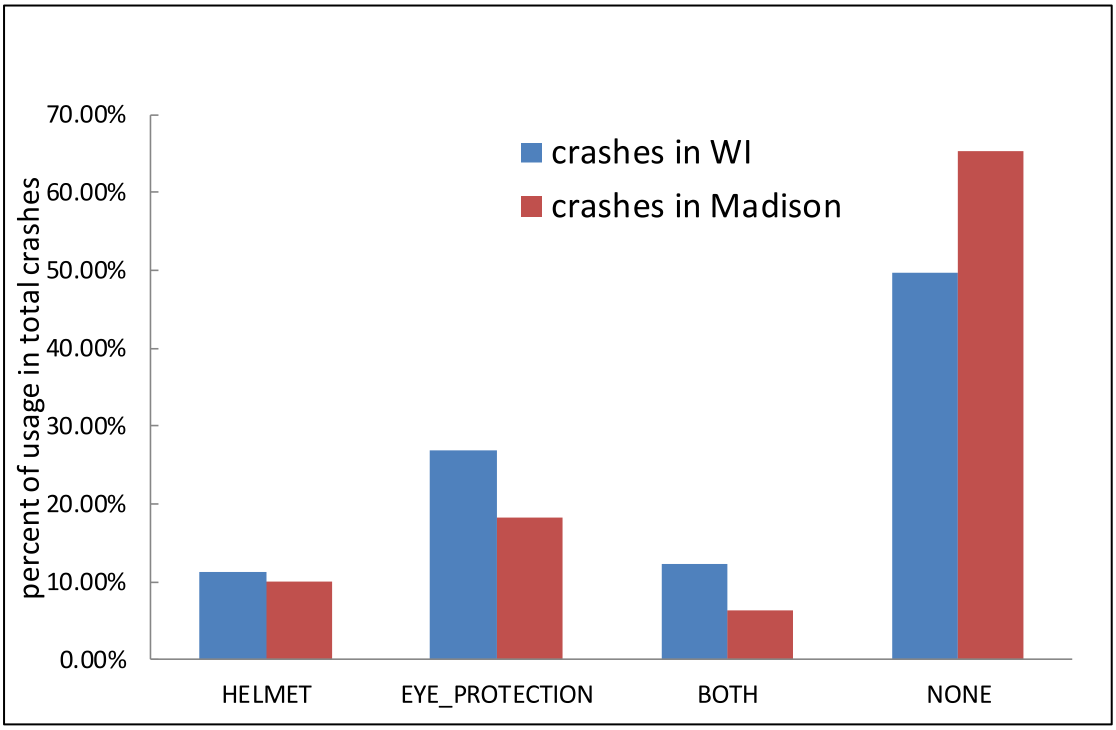
4.5.3 Safety Equipment Used by Moped Rider

Table 17 Safety Equipment Use

Safety Equipment	Moped-Motor Vehicle Crashes					Single Moped Crashes	
	Frequency	% of total	% of MOP at-fault # to total	# of MOP at-fault	% of MOP at-fault	Frequency	% of total
In Wisconsin							
Total	1085	100.00%	42.67%	463	100.00%	990	100.00%
HELMET	123	11.34%	37.40%	46	9.94%	113	11.41%
EYE_PROTECTION	291	26.82%	41.24%	120	25.92%	289	29.19%
BOTH	133	12.26%	36.09%	48	10.37%	113	11.41%
NONE	538	49.59%	46.28%	249	53.78%	475	47.98%
In Madison							
Total	251	100.00%	36.65%	92	100.00%	74	100.00%
HELMET	25	9.96%	40.00%	10	10.87%	8	10.81%
EYE_PROTECTION	46	18.33%	34.78%	16	17.39%	10	13.51%
BOTH	16	6.37%	37.50%	6	6.52%	4	5.41%
NONE	164	65.34%	36.59%	60	65.22%	52	70.27%

In terms of safety equipment use, it seems that the riders in Madison are less likely to wear that gear. Less than 35 percent of them prefer wear any protection equipment on their mopeds. The probability of moped riders being at-fault is higher under those situations. It may imply that if the riders are willing to drive safely and put effort to achieve that, their at-fault involvement can be decreased. Furthermore, it means that if more instructions are available for people to easily learn how to put them in a better safety condition, they could benefit from that by decreasing the probability of being identified at-fault.

Figure 17 Safety Equipment Use



Chapter 5: Fault Investigation in the Logistic Regression Model

The logistic regression model is applied to analyze the relationship between fault and other crash factors. The relationship is assessed by computing the exponential of coefficient estimate, which means the odds change in particular variable while its value changes from 0 to 1 and other variables hold at their mean.

5.1 Model Fitting Process

In this chapter, the data from Chapter 4 was used. A total of 35 explanatory variables assumed to influence the moped rider's fault are investigated in a logistic regression model. As shown in table 18, roadway factors, moped rider human factors, environmental factors and demographic factors are included. After the fitting process, 21 significant factors are identified, which is shown in table 18.

Steps of fitting logistic regression model are shown below:

1. Preliminary data analysis. Pick out variables for logistic model. The base variable in each category belongs to the group with the highest number of crashes [44]. 35 variables are chosen.
2. Calculate the correlation coefficients among all chosen variables, then drop one variable in each paired variables that have correlation of 0.75 or more. The one to be dropped needs to be chosen based on empiricism and preliminary data analysis. In this study, no correlation value is more than 0.7. Correlation coefficient represents the

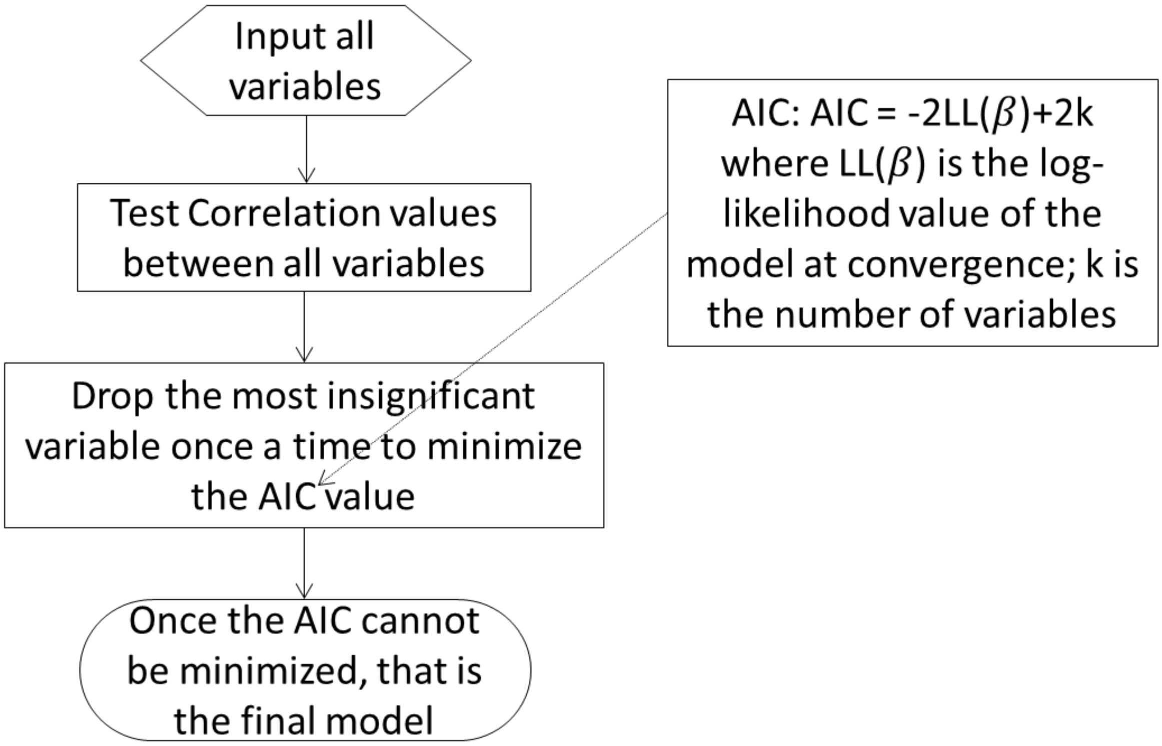
strength of the linear association between two variables.

3. Input qualified variables into a logistic regression model. Drop one non-significant variable after each run. This method is introduced as backward elimination fitting method in [44].
4. Use chi-square value to tell if the model as a whole fits significantly better than an empty model. Record Akaike information criterion (AIC) value. Chi-square value is the null deviance that shows how well the response is predicted by a model with nothing but an intercept. The AIC can provide a means for model selection, as it is a measure of the relative quality of a statistic model.
5. Run remaining variables in logistic regression model and drop one non-significant variable. The new model is supposed to have smaller current AIC value than former ones. If not, the current model is worse than the former one and maybe another variable needs to be dropped. If all remaining variables are significant or no better model can be found by minimizing the AIC, choose several models from former runs and go to step 6, otherwise go to step 4.
6. Use chi-square test p-value to tell if the model as a whole fits significantly better than an empty model. Record this AIC value and compare it with other recorded AIC values. By doing this, the difference in the information loss between this and other models can be explained
7. Among all these candidate models, the preferred model is the one with the minimum AIC value.

Results from six candidate models are chosen to show the process of fitting the model.

The reason why specific variables are dropped and others are kept is explained. The exponential of the parameter estimates is calculated and meanings of significant variables are discussed at the end of this chapter.

Figure 18 Basic Steps of Fitting Logistic Model



5.2 Results of Six Candidate Models

Results from six candidate models are chosen to show the process of fitting the model. The reason why specific variables are dropped and others are kept is explained. The exponential of the parameter estimates is calculated and meanings of significant variables are discussed at the end of this chapter.

5.2.1 Result of the First Model

Table 18 Result of First Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.00	0.19	-5.41	<0.001
FEMALE	0.19	0.17	1.14	0.26
KILLED	-0.78	0.70	-1.11	0.27
INCAPACITATING	0.34	0.20	0.20	0.10
POSSIBLE	-0.37	0.18	-2.04	0.04
UNREPORTED	0.02	0.23	0.08	0.93
PEAKHOUR	0.18	0.17	1.07	0.28
WEEKEND	0.43	0.17	2.48	0.01
WINTER	0.10	0.34	0.30	0.77
TOWN	0.03	0.27	0.10	0.92
VILLAGE	0.04	0.25	0.17	0.86
CURVE	-0.59	0.33	-1.78	0.08
HILL	-0.26	0.24	0.24	0.27
NOT_DRY	-0.21	0.31	-0.69	0.49
NOT_AT_INTERSECTION	0.40	0.15	2.70	0.01
NOT_CLEAR	0.04	0.17	0.24	0.81
DAWN_DUSK	-0.99	0.52	-1.90	0.06
DARK	-0.92	0.45	-2.03	0.04
LIGHT	-0.05	0.21	-0.22	0.83
CHANGING_LANES	1.39	0.75	1.87	0.06
MAKING_LEFT_TURN	0.96	0.23	4.11	<0.001
NEGOTIATING_CURVE	2.75	0.76	3.63	<0.001
OVERTAKING_ON_THE_LEFT	2.64	1.10	2.39	0.02
OVERTAKING_ON_THE_RIGHT	2.47	1.11	2.24	0.03
RIGHT_TURN	2.24	0.39	5.74	<0.001
SLOWING_OR_STOPPED	0.58	0.43	1.33	0.18
STOPPED_IN_TRAFFIC	-2.62	0.64	-4.11	<0.001

HEAD_ON_COLLISION	0.79	0.38	2.08	0.04
NO_COLLISION	0.18	0.21	0.86	0.39
REAR_END	1.47	0.21	7.07	<0.001
SIDESWIPE_OPPOSITE_D	0.32	0.37	0.87	0.38
SIDESWIPE_SAME_D	0.63	0.22	2.81	0.00
UNKNOWN	-0.78	0.83	-0.95	0.34
HELMET	-0.48	0.24	-2.03	0.04
EYE_PROTECTION	-0.26	0.17	-1.53	0.12
BOTH	-0.51	0.23	-2.20	0.03

Null deviance: 1480.7 on 1084 degrees of freedom

Residual deviance: 1240.3 on 1049 degrees of freedom

The AIC value is 1312.3.

From the null and residual deviance, it can be known that all predictors decreased the deviance by 240.4 on 35 degrees of freedom, which means that this model is statistically better than no input. In terms of variables' p-value, unreported, town and village are three variables with the highest value. These three variables are the ones that have least likelihood of significant effects on rider fault involvement. In this case, they are dropped one by one, while the AIC value is being monitored to keep decreasing. Then, the second round results are gotten.

5.2.2 Result of the Second Model

Table 19 Result of Second Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.00	0.18	-5.56	<0.001
FEMALE	0.19	0.16	1.13	0.26
KILLED	-0.78	0.70	-1.11	0.27
INCAPACITATING	0.34	0.20	1.69	0.09
POSSIBLE	-0.37	0.17	-2.12	0.03
PEAKHOUR	0.18	0.17	1.07	0.28
WEEKEND	0.43	0.17	2.52	0.01
WINTER	0.10	0.34	0.30	0.77
CURVE	-0.59	0.33	-1.78	0.08
HILL	-0.26	0.24	-1.08	0.28
NOT_DRY	-0.21	0.31	-0.69	0.49
NOT_AT_INTERSECTION	0.40	0.15	2.75	0.01
NOT_CLEAR	0.04	0.17	0.23	0.82
DAWN_DUSK	-0.99	0.52	-1.89	0.06
DARK	-0.91	0.44	-2.04	0.04
LIGHT	-0.05	0.21	-0.23	0.82
CHANGING_LANES	1.40	0.75	1.87	0.06
MAKING_LEFT_TURN	0.97	0.23	4.24	<0.001
NEGOTIATING_CURVE	2.76	0.75	3.68	<0.001
OVERTAKING_ON_THE_LEFT	2.64	1.10	2.40	0.02
OVERTAKING_ON_THE_RIGHT	2.47	1.11	2.24	0.03
RIGHT_TURN	2.24	0.39	5.77	<0.001
SLOWING_OR_STOPPED	0.58	0.43	1.34	0.18
STOPPED_IN_TRAFFIC	-2.61	0.63	-4.13	<0.001
HEAD_ON_COLLISION	0.79	0.38	2.10	0.04
NO_COLLISION	0.18	0.21	0.87	0.39
REAR_END	1.46	0.21	7.08	<0.001
SIDESWIPE_OPPOSITE_D	0.32	0.37	0.88	0.38
SIDESWIPE_SAME_D	0.62	0.22	2.81	0.01
UNKNOWN	-0.79	0.82	-0.95	0.34
HELMET	-0.48	0.24	-2.04	0.04
EYE_PROTECTION	-0.26	0.17	-1.53	0.13
BOTH	-0.51	0.23	-2.20	0.03

Null deviance: 1480.7 on 1084 degrees of freedom

Residual deviance: 1240.4 on 1052 degrees of freedom

AIC: 1306.4

Non-significant variables “UNREPORTED”, “TOWN” and “VILLAGE” are deleted from the first candidate model. It means that the unreported injury severity, town and village are situations that have no strong associations with rider fault involvement.

5.2.3 Result of the Third Model

Table 20 Result of Third Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.99	0.17	-5.91	<0.001
FEMALE	0.19	0.16	1.15	0.25
KILLED	-0.79	0.70	-1.14	0.26
INCAPACITATING	0.34	0.20	1.71	0.09
POSSIBLE	-0.37	0.17	-2.11	0.03
PEAKHOUR	0.18	0.16	1.10	0.27
WEEKEND	0.43	0.17	2.50	0.01
CURVE	-0.59	0.33	-1.79	0.07
HILL	-0.26	0.24	-1.07	0.28
NOT_DRY	-0.18	0.29	-0.64	0.52
NOT_AT_INTERSECTION	0.41	0.15	2.76	0.01
DAWN_DUSK	-0.97	0.52	-1.87	0.06
DARK	-0.89	0.44	-2.02	0.04
CHANGING_LANES	1.41	0.75	1.89	0.06
MAKING_LEFT_TURN	0.97	0.23	4.27	<0.001
NEGOTIATING_CURVE	2.75	0.75	3.67	<0.001
OVERTAKING_ON_THE_LEFT	2.63	1.10	2.39	0.02
OVERTAKING_ON_THE_RIGHT	2.47	1.11	2.23	0.03
RIGHT_TURN	2.25	0.39	5.80	<0.001
SLOWING_OR_STOPPED	0.58	0.43	1.36	0.18
STOPPED_IN_TRAFFIC	-2.60	0.63	-4.12	<0.001
HEAD_ON_COLLISION	0.80	0.38	2.12	0.03
NO_COLLISION	0.18	0.21	0.85	0.40
REAR_END	1.46	0.21	7.09	<0.001
SIDESWIPE_OPPOSITE_D	0.32	0.37	0.88	0.38
SIDESWIPE_SAME_D	0.62	0.22	2.79	0.01
UNKNOWN	-0.78	0.83	-0.94	0.35
HELMET	-0.47	0.23	-2.02	0.04
EYE_PROTECTION	-0.25	0.17	-1.53	0.13
BOTH	-0.51	0.23	-2.19	0.03

Null deviance: 1480.7 on 1084 degrees of freedom; Residual deviance: 1240.6 on 1055 degrees of freedom; AIC: 1300.6

Non-significant variables “WINTER”, “NOT_CLEAR” and “LIGHT” are deleted from the second candidate model. It means that the winter weather and light condition are situations that have no strong associations with rider fault involvement.

5.2.4 Result of the Fourth Model

Table 21 Result of Fourth Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.95	0.16	-6.03	<0.001
FEMALE	0.19	0.16	1.18	0.24
KILLED	-0.84	0.70	-1.22	0.22
INCAPACITATING	0.33	0.20	1.64	0.10
POSSIBLE	-0.38	0.17	-2.21	0.03
PEAKHOUR	0.17	0.16	1.01	0.31
WEEKEND	0.44	0.17	2.55	0.01
CURVE	-0.57	0.33	-1.73	0.08
HILL	-0.26	0.24	-1.08	0.28
NOT_AT_INTERSECTION	0.43	0.15	2.93	0.00
DAWN_DUSK	-0.96	0.52	-1.85	0.06
DARK	-0.88	0.44	-2.01	0.04
CHANGING_LANES	1.42	0.75	1.90	0.06
MAKING_LEFT_TURN	0.98	0.23	4.33	<0.001
NEGOTIATING_CURVE	2.86	0.74	3.84	<0.001
OVERTAKING_ON_THE_LEFT	2.62	1.10	2.38	0.02
OVERTAKING_ON_THE_RIGHT	2.48	1.11	2.25	0.02
RIGHT_TURN	2.31	0.38	6.15	<0.001
SLOWING_OR_STOPPED	0.57	0.43	1.33	0.18
STOPPED_IN_TRAFFIC	-2.62	0.63	-4.15	<0.001
HEAD_ON_COLLISION	0.73	0.37	1.96	0.05
REAR_END	1.40	0.20	7.16	<0.001
SIDESWIPE_SAME_D	0.55	0.21	2.60	0.01
UNKNOWN	-0.86	0.83	-1.03	0.30
HELMET	-0.47	0.23	-2.00	0.05
EYE_PROTECTION	-0.26	0.17	-1.56	0.12
BOTH	-0.50	0.23	-2.15	0.03

Null deviance: 1480.7 on 1084 degrees of freedom; Residual deviance: 1242.1 on 1058 degrees of freedom; AIC: 1296.1

Non-significant variables “NOT_DRY”, “NO COLLISION”, “SIDESWIPE_OPPOSITE_D” are deleted from the third candidate model. It means that the roadway surface and no collision type of crash have no strong associations with rider fault involvement.

5.2.5 Result of the Fifth Model

Table 22 Result of Fifth Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.91	0.15	-6.07	<0.001
FEMALE	0.19	0.16	1.18	0.24
KILLED	-0.86	0.70	-1.24	0.21
INCAPACITATING	0.32	0.20	1.63	0.10
POSSIBLE	-0.40	0.17	-2.29	0.02
WEEKEND	0.42	0.17	2.45	0.01
CURVE	-0.55	0.33	-1.68	0.09
HILL	-0.27	0.24	-1.11	0.27
NOT_AT_INTERSECTION	0.43	0.15	2.93	0.00
DAWN_DUSK	-0.97	0.52	-1.87	0.06
DARK	-0.91	0.44	-2.09	0.04
CHANGING_LANES	1.32	0.72	1.83	0.07
MAKING_LEFT_TURN	0.98	0.23	4.33	<0.001
NEGOTIATING_CURVE	2.77	0.74	3.76	<0.001
OVERTAKING_ON_THE_LEFT	2.61	1.10	2.37	0.02
OVERTAKING_ON_THE_RIGHT	2.49	1.10	2.25	0.02
RIGHT_TURN	2.32	0.38	6.16	<0.001
SLOWING_OR_STOPPED	0.57	0.43	1.32	0.19
STOPPED_IN_TRAFFIC	-2.61	0.63	-4.14	<0.001
HEAD_ON_COLLISION	0.73	0.37	1.97	0.05
REAR_END	1.41	0.20	7.22	<0.001
SIDESWIPE_SAME_D	0.56	0.21	2.64	0.01
HELMET	-0.45	0.23	-1.93	0.05
EYE_PROTECTION	-0.26	0.17	-1.60	0.11
BOTH	-0.48	0.23	-2.08	0.04

Null deviance: 1480.7 on 1084 degrees of freedom

Residual deviance: 1244.3 on 1060 degrees of freedom

AIC: 1294.3

Non-significant variables “PEAKHOUR” and “UNKNOWN” are deleted from the third candidate model. It means that the peak hour and unknown type of crash have no strong associations with rider fault involvement.

5.2.6 Result of the Final Model

Table 23 Coefficients of Final Candidate Model

COEFFICIENTS:	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.90	0.14	-6.35	<0.001
INCAPACITATING	0.33	0.20	1.68	0.09
POSSIBLE	-0.36	0.17	-2.09	0.04
WEEKEND	0.39	0.17	2.31	0.02
CURVE	-0.60	0.32	-1.85	0.06
NOT_AT_INTERSECTION	0.43	0.14	3.00	0.00
DAWN_DUSK	-0.92	0.52	-1.78	0.08
DARK	-0.88	0.44	-2.01	0.04
CHANGING_LANES	1.38	0.72	1.93	0.05
MAKING_LEFT_TURN	1.00	0.23	4.44	<0.001
NEGOTIATING_CURVE	2.77	0.74	3.77	<0.001
OVERTAKING_ON_THE_LEFT	2.58	1.10	2.36	0.02
OVERTAKING_ON_THE_RIGHT	2.51	1.10	2.28	0.02
RIGHT_TURN	2.33	0.37	6.26	<0.001
SLOWING_OR_STOPPED	0.61	0.43	1.42	0.15
STOPPED_IN_TRAFFIC	-2.58	0.63	-4.10	<0.001
HEAD_ON_COLLISION	0.69	0.37	1.87	0.06
REAR_END	1.38	0.19	7.13	<0.001
SIDESWIPE_SAME_D	0.55	0.21	2.61	0.01
HELMET	-0.42	0.23	-1.83	0.07
EYE_PROTECTION	-0.27	0.17	-1.63	0.10
BOTH	-0.49	0.23	-2.14	0.03

Null deviance: 1480.7 on 1084 degrees of freedom

Residual deviance: 1248.8 on 1063 degrees of freedom

AIC: 1292.8

Non-significant variables “FEMALE”, “KILLED” and “HILL” are deleted from the third candidate model. It means that the rider’s gender, crash severity of killed and the hill (horizontal terrace) have no strong associations with rider fault involvement.

5.3 Coefficient Analysis

The Odds ratio of riders being at-fault over not at-fault shows the effect of value changing from 0 to 1 in each variable ($e^{a_{i1}-a_{i0}}$). If the value of odds ratio is greater than 1, the variable is positively related to fault, which means that riders are more likely to be identified at-fault under particular situation. If the value of odds ratio is less than 1, the variable is negatively related to fault, which means that riders are less likely to be identified at-fault under particular situation. Factors that significantly associated with fault means that they are in the significance level of 0.05.

Table 24 The Odds Ratio of Riders Being At-fault Over Not At-fault

Var. positively related to fault		Var. Negatively related to fault	
WEEKEND	1.47	POSSIBLE	0.70
NOT_AT_INTERSECTION	1.55	DARK	0.42
MAKING_LEFT_TURN	2.73	STOPPED_IN_TRAFFIC	0.08
NEGOTIATING_CURVE	16.01	BOTH	0.61
OVERTAKING_ON_THE_LEFT	13.26		
OVERTAKING_ON_THE_RIGHT	12.35		
RIGHT_TURN	10.27		
REAR_END	3.99		
SIDESWIPE_SAME_D	1.74		

According to the AIC theory, the current model is the best one that can be gotten by dropping variables, since the AIC value cannot be minimized any more.

From the table above, it is shown that the vehicle maneuver prior to the crash and the manner of the first harmful event have the most significant influence on the fault of moped riders involved in crashes. Except for stopped in traffic where riders are 13.2 times less likely to be the at-fault party, any other factors in these two categories is positively related with the at-fault crash involvement of moped riders. It means that under those situations, moped riders are more likely to be identified at-fault. When the riders are negotiating a curve, the odds of being identified at-fault increase by 16.01 times. When the riders are overtaking on the left or right, the odds of the moped drivers involved being at-fault are 12.26 and 11.35 times higher than when not overtaking. The odds of increases due to right turn are also very high, which are 10.27 times of not making right turn.

However, making a left turn is not contributing to at-fault as much as these other three situations. The odds of being at-fault under this situation are only 2.73 times higher than not making a left turn. It reveals that riders are much more careful when making a left turn, since people are so easy to be identified at-fault, if they made left turn inappropriately.

Rear end collisions show the highest odds among three significant crash types, which is 2.99 times higher than if the situation is not a rear end collision. The other type significantly associated with fault is sideswipe same direction, under which situations moped riders are 1.74 times, respectively, more likely to be involved as the at-fault party.

The use of protection gear is found to significantly influence the riders' fault involvement. When riders wear both helmet and eye protection, they are less likely to be found at-fault. This is perhaps due to the fact that they care about their own safety and have better knowledge to identify dangerous situations.

In terms of injury severity, "possible" are found to be significant associated with fault in moped crashes. The more severe the injury the greater the likelihood of an at-fault crash involvement, which is consistent with the crash characteristics analysis. If the injury severity type is "possible", which means the injury severity is more likely to be minor than the other possibilities, the riders are less involved as at-fault. The odds are 0.699 times of not "possible".

When the crashes occurred during the weekend, the odds of riders being at-fault are 1.47 times of the odds when the crashes occurred during a weekday.

When the crashes did not happen at an intersection, the odds of the riders' being at-fault increased by 1.55 times.

When the crashes happened when it was dark, the odds are 0.42 times of happening at the situation of not dark.

Chapter 6: Conclusion and Future work

6.1 Conclusions

In the data collection section, moped-motor and single moped crashes are gathered. Whether moped riders are at-fault or not is identified. In both characteristics analysis and logistic model analysis, factors which are strongly associated with riders' being at-fault are analyzed. Several key points and findings are summarized below:

1. The situations that moped riders are more likely to be identified at-fault are at non-intersection or during the weekend.
2. The situations that moped riders are less likely to be identified at-fault are when they suffered minor injury or ride under bad light condition.
3. The inappropriate curve negotiating, overtaking and right turn could increase the probability of riders' fault greatly. Making a left turn has a lesser but still positive effect on increasing riders fault involvement.
4. Under the crash type of rear end or sideswipe in the same direction, riders are more likely to be the at-fault party.
5. If the riders use protection gear, they are less likely to be involved in a rider at-fault crash.
6. Moped crashes are likely uncorrelated with adverse weather, bad road condition.
7. The most moped crashes happened while riders were going straight.

6.2 Future work

Future work on this topic is discussed in this paragraph.

More analysis can be conducted by using cross table to investigate the coefficient among several factors. For example the age group being identified as at-fault under particular situations.

Besides, moped-motor and single moped crashes, the crashes between moped and pedestrian/bicyclist can be analyzed. Their fault can be investigated. Another study might be a comparison of motorcycle to moped crashes and fault conditions to determine what things are more or less common between the two classes of vehicles – such information could help modify motorcycle safety classes to be given to moped riders.

The findings of this study will help to develop more targeted countermeasures to improve moped safety and develop safety awareness program aiming at helping moped riders better know the situations where they are very likely to be identified at fault and the hot spots of moped crashes.

Moped riders can have a better understanding of how to avoid these situations. Law enforcement agencies can evaluate their policies and standards of identifying fault and identify their bias. Insurance companies can use our results to investigate rider characteristics and develop rates based on their vulnerability in being considered at-fault in traffic accidents. This quantitative study can also be used as the support of other qualitative study on moped safety problems.

Reference

1. *Traffic Safety Facts 2011 Data*, U.S. Department of Transportation, 2013
2. David F.Preusser, Allan F.Williams and Robert G.Ulmer. *Analysis of fatal motorcycle crashes: crash typing*, Accident Analysis & Prevention, 1995
3. *2012 Wisconsin Motorcycle Safety Facts Book*, Wisconsin Department of Transportation
4. Using your moped on campus, Transportation Services at University of Wisconsin-Madison
5. Karl Kim. *Crash- and Injury-Outcome Multipliers*, Transportation Research Record, 2000
6. Karl Kim, David Takeyama and Lawrence Nitz. *Moped Safety in Honolulu, Hawaii*, Journal of Safety Research, 1995
7. Karl Kim and Joseph Boski. *Finding Fault in Motorcycle Crashes in Hawaii Environmental, Temporal, Spatial, and Human Factors*, Transportation Research Record, 2001
8. Karl Kim and Lei Li. *Modeling Fault Among Bicyclists and Drivers Involved in Collisions in Hawaii, 1986-1991*, Transportation Research Record, 1996
9. Xuedong Yan, Essam Radwan and Mohamed Abdel-Aty. *Characteristics of rear-end accidents at signalized intersections using multiple logistic regression model*, Accident Analysis & Prevention, 2005
10. Identify Who Is at Fault in a Car Accident: http://www.wikihow.com/Identify-Who-Is-at-Fault-in-a-Car-Accident

11. Karl Kim, Sungyop Kim and Eric Yamashita. *Alcohol-Impaired Motorcycle Crashes in Hawaii*, Transportation Research Record, 2000

12. Narelle Haworth and Kristi Greig, Angela Nielson. *Comparison of Risk Taking in Moped and Motorcycle Crashes*, Transportation Research Record: Journal of the Transportation Research Board, 2009

13. William H.Schneider and Peter T.Savolainen. *Comparison of Severity of Motorcyclist Injury by Crash Types*, Transportation Research Record: Journal of the Transportation Research Board, 2011

14. Andreas Muller. *Daytime headlight operation and motorcyclist fatalities*, Accident Analysis & Prevention, 1984

15. Kim, K., L. Li, J. Richardson, and L. Nitz. *Drivers at Fault: Influences of Age, Sex, and Vehicle Type*. Journal of Safety Research, Vol. 29, No. 3, 1998.

16. Liz DeRome and Teresa Senserrick. *Factors Associated with Motorcycle Crashes in New South Wales, Australia, 2004 to 2008*, Transportation Research Record: Journal of the Transportation Research Board, 2011.

17. Karl Kim, Pradip Pant and Eric Y.Yamashita. *Hit-and-Run Crashes Use of Rough Set Analysis with Logistic Regression to Capture Critical Attributes and Determinants*, Transportation Research Record: Journal of the Transportation Research Board, 2008.

18. In-Kyu Lim and Young-Jun Kweon, *Identifying High-Crash-Risk Intersections*, Transportation Research Record: Journal of the Transportation Research Board, 2013.

19. Xuesong Wang, Yilun Xu, Paul J.Tremont and Dongyuan Yang. *Moped Rider Violation Behavior and Moped Safety at Intersections in China*, Transportation Research Record:

Journal of the Transportation Research Board, 2012.

20. M.j. Williams and E.r. Hoffmann, *Motorcycle Conspicuity and Traffic accidents*, Accident Analysis & Prevention, 1979.

21. D.j. Chesham, D.r. Rutter and Lyn Quine, *Motorcycling Safety research: A review of the social and behavioural literature,* Social Science & Medicine, 1993.

22. Ross Alexander Blackman. *The increased popularity of mopeds and motor scooters exploring usage patterns and safety outcomes,* Centre for Accident Research & Road Safety, Queensland.

23. How fault is determined after a car accident. http://www.esurance.com/claims-info/accident-info/determining-accident-fault

24. How to identify car accident fault. http://www.autos.com/auto-insurance/how-to-identify-car-accident-fault

25. *Fault Determination Rules,* Regulation 668 under the Insurance Act, ONTARIO 1990.

26. Carlos Nava Fonseca and Makoto Okumura. *Research Review about Moped Accidents and the Necessity of Time Dimensional Management in University Campus Traffic*, Traffic and Transportation Studies ASCE, 2010.

27. Md. MazharulHaque, Hoong ChorChin and Helai Huang. *Modeling fault among motorcyclists involved in crashes,* Accident Analysis & Prevention, 2009.

28. Guoping Sun. *Study on Identification Method of Road Hazardous Locations* (Master Thesis).

29. Wen Yao. *Prevalence of Traffic Accident*, Disease Burden and the Personality Proness of Drivers in Hongkou District of Shanghai (Doctor of Philosophy Thesis).

30. Yanzhang Li. *Characters of Motorcycle Crashes and Psychological Factors Influencing Motorcyclists in Chongqing City* (Doctor of Philosophy Thesis).

31. Wen Shen. *Researches in Highway Black-Spots* (Doctor of Philosophy Thesis).

32. Yang Li. *Characteristics of Motorcycle Traffic Crashes and Injury* (Master Thesis).

33. Kan Tao. *A Geospatial Analysis of the Accessibility Characteristics of Transit Transfers* (Master Thesis).

34. Lang Yu, *Analysis of On-Duty Struck-By Crashes on Wisconsin Highways* (Master Thesis), University of Wisconsin-Madison.

35. Crash Data Query Tool. WisTransPortal University of Wisconsin-Madison. http://transportal.cee.wisc.edu/.

36. John A. Deacon, Charles V. Zegeer and Robert C. Deen. *Identification of Hazardous Rural Highway Locations*, Transportation Research Board, 1974.

37. Peter Savolainen and Fred Mannering. *Probabilistic Models of Motorcyclists' Injury Severities in Single- and Multi-Vehicle Crashes*, Accident Analysis & Prevention, 2007.

38. Wendy Weijermars and Fred Wegman. *Ten Years of Sustainable Safety in the Netherlands*, Transportation Research Record: Journal of the Transportation Research Board, 2011.

39. Sheng-nian Zhang, Wei Lu, Shunfu Zhou and Shaoming Chen. *Epidemiological study on traffic accident in Shanghai from 2000 to 2002,* Chin J Epidemiol, 2004.

40. Savolainen, P., Mannering, F. *Additional evidence on the effectiveness of motorcycle training and motorcyclists' risk taking behavior,* Transportation Research Record, 2007b.

41. Gregersen, N., & Berg, H. *Lifestyle and accidents among young drivers*. Accident Analysis and Prevention, 1994.

42. Elander, J., West, R., & French, D. *Behavioral correlates of individual differences in road-traffic crash risk: An examination method and findings*. Psychological Bulletin, 113(2), 279-294, 1993.

43. Feinberg, S. *The Analysis of Cross Classified Categorical Data*. The MIT Press, Cambridge, Mass., 1980.

44. Wisconsin State Climatology Office, *Monthly Historical State Climate Summaries*, Statewide Average Temperature (degrees Fahrenheit).

45. Ross A.Blackman and Narelle L.Haworth. *Comparison of moped, scooter and motorcycle crash risk and crash severity*, Accident Analysis & Prevention, 2013.