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Determinants of Two-Wheeler Crash Severity at Intersections in Kathmandu Valley

by

Jeewan Kunwar

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ABSTRACT

Two-wheeler riders face a heightened risk of fatal and serious injuries due to their inherent lack of protection compared to occupants of other vehicles. Intersection-related crashes, in particular, have demonstrated a tendency to lead to more severe consequences. This study aims to investigate the determinants of two-wheeler crash severity at intersections in Kathmandu Valley, providing valuable insights into crucial aspects of two-wheeler safety at these locations.

Using a multinomial logit model, the analysis explores a range of contributing factors influencing the severity of two-wheeler crashes at intersections in Kathmandu Valley. Crash severity (minor injury, serious injury, and fatal injury) is used as the dependent variable while age, gender, driving under influence, over speeding, day and timing of crash, collision type, and intersection type are used as independent variables. The analysis employs coefficient estimates, significance levels, and Relative Risk Ratios (RRR) of the variables as the measure of comparisons, and uses "Fatal Injury" as the base category for comparison.

Collisions with trucks pose an alarming threat, with the likelihood of a fatal injury being 11 times higher compared to minor injuries and 9 times more likely compared to serious injuries. Similarly, impacting roadside objects elevates the risk of fatal injuries, with a 12-fold increase relative to minor injuries and a 5-fold increase compared to serious injuries. Early morning crashes have a three-fold higher risk of causing fatal injuries than minor injuries and five times higher risk than serious injuries. Conversely, crashes during non-rush hours show a reduced risk of fatal injuries compared to minor injuries but are three times more likely to result in fatal injuries than in cases involving serious injuries. These insights can have significant implications for two-wheeler safety and inform targeted interventions.

Keywords: Multinomial Logit Model, Injury Severity, Two-wheeler Crashes, Intersection, Risk Factors

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LIST OF SYMBOLS AND ABBREVATIONS

WHO	World Health Organization
MLR	Multinomial Logistic Regression
UK	United Kingdom
RRR	Relative Risk Ratio
SPSS	Statistical Package for the Social Sciences
DUI	Driving Under Influence
DOTM	Department of Transport and Management
IIA	Independence of Irrelevant Alternatives

CHAPTER 1: INTRODUCTION

1.1 Background

Traffic safety is a big worry all over the world, and it's an even bigger problem in places that are still developing. The heightened severity of issues in these areas can be attributed to insufficient measures taken to ensure the safety of people on the roads, whether they're driving, biking, taking buses, or simply walking.

A significant issue arises from the substantial difference in the quality of roads, the resources available, and the knowledge about road safety between more developed and less developed regions. In developed countries, the roads are usually well maintained, and are equipped with features like traffic lights and road signs, aiding individuals in understanding proper road behavior. Moreover, these countries prioritize road safety education and enforce regulations through vigilant law enforcement. In contrast, many developing nations struggle with poorly maintained roads, insufficient traffic control measures, lack of effective law enforcement.

Another issue is that the vehicles people use in these regions are often old and not taken care of very well. This makes crashes more likely. Also, there are more people using two wheelers (two-wheelers and scooters), and they do not always have the right safety gear, which can be dangerous. People who ride in cars and buses are at risk too because many of these vehicles also lack advanced safety features in developing countries. Crashes can cause a lot of injuries and even deaths. And sometimes, the buses and other public transport means are really crowded and not in great condition, which makes things riskier for passengers. Even people who simply walk encounter challenges in developing countries, as there are often insufficient pedestrian-friendly spaces such as sidewalks. Crossing roads safely becomes difficult because drivers may not consistently yield to pedestrians (Kadali & Vedagiri, 2016).

Globally, road traffic crashes stand as a prominent cause of death, particularly among the younger population. Annually, over 1.35 million individuals lose their lives on the world's roadways, with millions more enduring severe injuries, often resulting in long-term adverse health repercussions. At present, road traffic injuries rank as the eighth most common cause of death across all age groups worldwide. However, it is anticipated that by 2030, they will move up to become the seventh leading cause of death (World Health Organization, 2018). This shift is primarily due to the growing number of road fatalities, particularly in low- and middle-income countries. This trend is especially noticeable in developing economies, where rapid economic growth is accompanied by increased urbanization and more people owning and using vehicles.

The number of registered road-related fatalities has more than doubled between 2006 and 2016, increasing from approximately 1000 to more than 2000 registered fatalities (World Health Organization, 2018). However, considering potential underreporting, the WHO estimates that the true number of road related fatalities could be substantially higher, ranging from 3880 to 5546 traffic related deaths (World Health Organization, 2018). In the latest data reported by the Nepalese Police Force for the year 2021/22 A.D., there were a total of 9,697 road-related injuries recorded within the Kathmandu Valley. Among these incidents, 159 tragically resulted in fatal crashes (Nepal Police, 2022). Generally, an overall trend of rapidly rising road related fatalities can be observed in Nepal, with road traffic related injuries and fatalities representing one of the main causes for hospitalization in Nepal (Joshi & Banstola A, 2018; Joshi & Shrestha, 2009).

Riding a two-wheeler undoubtedly offers an exhilarating experience, but this excitement also comes with inherent risks. Two-wheelers lack the protective features found in other vehicles, such as seatbelts and structural enclosures, making riders more vulnerable. Additionally, two-wheelers' smaller size makes them less conspicuous on the road. As a result, two-wheeler riding poses a considerable risk to personal safety. According to the recent statistics of Department of Transport and Management (DOTM, 2018) more than 75% of registered vehicles in Bagmati zone is two-wheelers indicating a growing popularity of two-wheelers in Kathmandu, with more people opting for this mode of transportation than ever before.

Two-wheeler riders, particularly those riding motorcycles, face significantly higher risks of severe injury and fatalities compared to other vehicle drivers. This is primarily due to the lack of protection inherent in their mode of transportation (Lin & Kraus, 2009). The annual toll of road traffic fatalities stands at an alarming 1.2 million, with vulnerable users such as pedestrians, cyclists, and two-wheeler riders tragically accounting for nearly half of these deaths (World Health Organization, 2015). On a global scale, two-wheeler riders comprise almost 25% of all road traffic fatalities. Nevertheless, this statistic is not evenly distributed worldwide, with the South-East Asian Region and the Western Pacific Region jointly accounting for 34% of two-wheeler rider deaths worldwide. In contrast, the African Region represents a mere 7% of these fatalities. This discrepancy underscores the ongoing trend of significantly higher two-wheeler usage in Asian countries compared to other regions (World Health Organization, 2015).

Intersections represent a significant location for traffic crashes, with these crashes often experiencing increased severity compared to incidents occurring on other road sections (Abdel-Aty et al., 1908). Two-wheeler crashes at intersections exhibit distinct characteristics and severity levels compared to crashes involving other road users. This variance can be partially explained by the increased prevalence of certain injurious crashes, such as angle collisions, at intersections (Abdel-Aty et al., 1908). Additionally, the heightened complexity of conflicting movements between two-wheelers and other vehicles at intersections, characterized by overlapping trajectories and unpredictable maneuvers, significantly contributes to increased severity of injuries sustained by two-wheeler riders.

1.1.1 Road Crashes in Kathmandu Valley

Table 1.1 and Figure 1.1 present a decade-long overview of road safety metrics for Kathmandu Valley, with data spanning from the fiscal year 2068/069 to 2078/079 B.S. (2017/018 to 2021/022 A.D.). Notably, the total number of crashes exhibits a general increasing trend over the years, reaching a peak in 2075/076 with 8511 crashes. However, there is a slight decrease in the last two fiscal years, 2076/077 and 2077/078, suggesting a potential shift in the overall trend.

Fatal injuries, though fluctuating, show no consistent pattern of increase or decrease. The highest number of fatal injuries occurs in 2075/076, indicating a significant road safety concern during that period. Serious injuries also vary across fiscal years, with the highest count in 2075/076 and the lowest in 2070/071. Similar patterns are observed in the number of minor injuries, reflecting fluctuations without a clear upward or downward trajectory.

A noteworthy observation is the outlier year, 2075/076, where all categories—crashes, fatal injuries, serious injuries, and minor injuries—peak significantly. This year stands out as an anomaly compared to the surrounding years. In more recent fiscal years (2076/077 to 2078/079), there is a decline in the number of crashes and injuries compared to the peak year of 2075/076. While this decline is a positive sign, the absolute numbers remain substantial, emphasizing the need for continued attention to road safety measures.

Table 1.1 Yearly Road Crashes and Severity Levels in Kathmandu Valley

S.N.	**Fiscal Year**	**Crashes**	**Fatal Injury**	**Serious Injury**	**Minor Injury**
1	2068/069	5096	148	396	3317
2	2069/070	4770	148	246	3431
3	2070/071	4672	143	229	3481
4	2071/072	4999	133	233	3642
5	2072/073	5668	166	275	3901
6	2073/074	5530	182	201	3914
7	2074/075	6381	194	219	4333
8	2075/076	8511	254	317	5890
9	2076/077	10038	153	240	6680
10	2077/078	9545	166	229	7095
11	2078/079	9697	159	235	7437

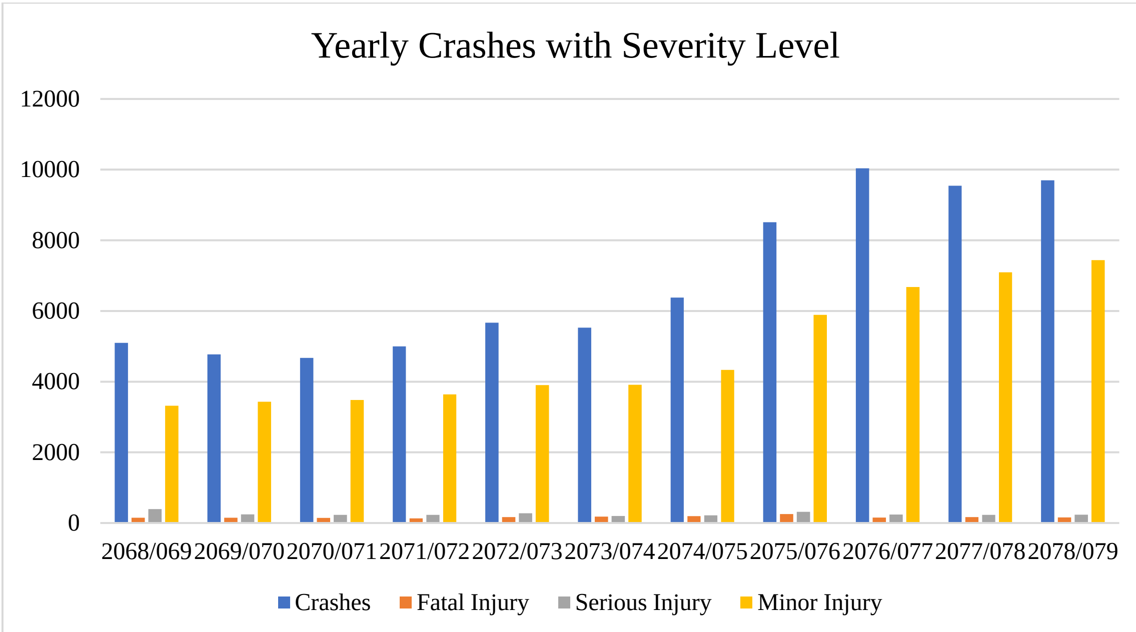

Figure 1.1 Yearly Road Crashes with Severity Level in Kathmandu Valley

The provided Table 1.2 and Figure 1.2 offer a comprehensive overview of vehicles involved in crashes over the past decade, segmented into various categories. Notably, the total number of vehicles engaged in crashes fluctuates across fiscal years, with a significant peak observed in 2075/076. This peak suggests a critical period in terms of road safety challenges, prompting the need for a closer examination of contributing factors.

Breaking down the categories, the involvement of trucks/tippers and JCBs generally increases until 2075/076, followed by a modest decline in subsequent years. Buses and micro-buses show similar patterns, with a notable surge in involvement in 2075/076 and a subsequent decrease. The category of car, van, and jeep involvement mirrors these trends, peaking in 2075/076 and subsequently diminishing. Of particular interest is the category of two-wheelers and scooters. Despite being one of the smaller vehicle types in terms of size, two-wheelers consistently contribute significantly to crashes. In each fiscal year, two-wheelers/scooters are among the highest contributors to accidents, underscoring the importance of targeted measures to enhance two-wheeler safety.

Examining the most recent fiscal years (2076/077 to 2078/079), there appears to be a decline in the involvement of various vehicle types compared to the peak year of 2075/076. However, the data highlights the ongoing need for proactive road safety initiatives, especially considering the sustained involvement of two-wheelers in crashes. Efforts to enhance two-wheeler safety, such as awareness campaigns, infrastructure improvements, and enforcement of safety regulations, could play a pivotal role in reducing overall crash rates and ensuring the well-being of road users.

Table 1.2 Vehicles Involved in Crashes

Fiscal Year	**Vehicles Involved in Crashes**						
	Truck/Tipper, JCB	**Bus**	**Micro-bus**	**Car, Van, Jeep**	**Two-wheeler/Scooter**	**Tempo/ Tractor**	**Non-motorized vehicle**
2068/069	730	990	578	2840	3417	211	180
2069/070	699	872	489	2653	3218	203	157
2070/071	892	962	538	2510	3024	141	136
2071/072	947	1006	565	2857	3252	193	138
2072/073	1210	1164	500	3231	3671	157	170
2073/074	1400	1168	413	3270	3349	130	100
2074/075	1580	1327	410	3890	4065	103	131
2075/076	1791	1951	365	5305	5511	138	129
2076/077	1731	2035	269	6564	7142	147	158
2077/078	1660	1174	105	5841	7945	123	215
2078/079	1641	1694	162	6163	7605	153	158

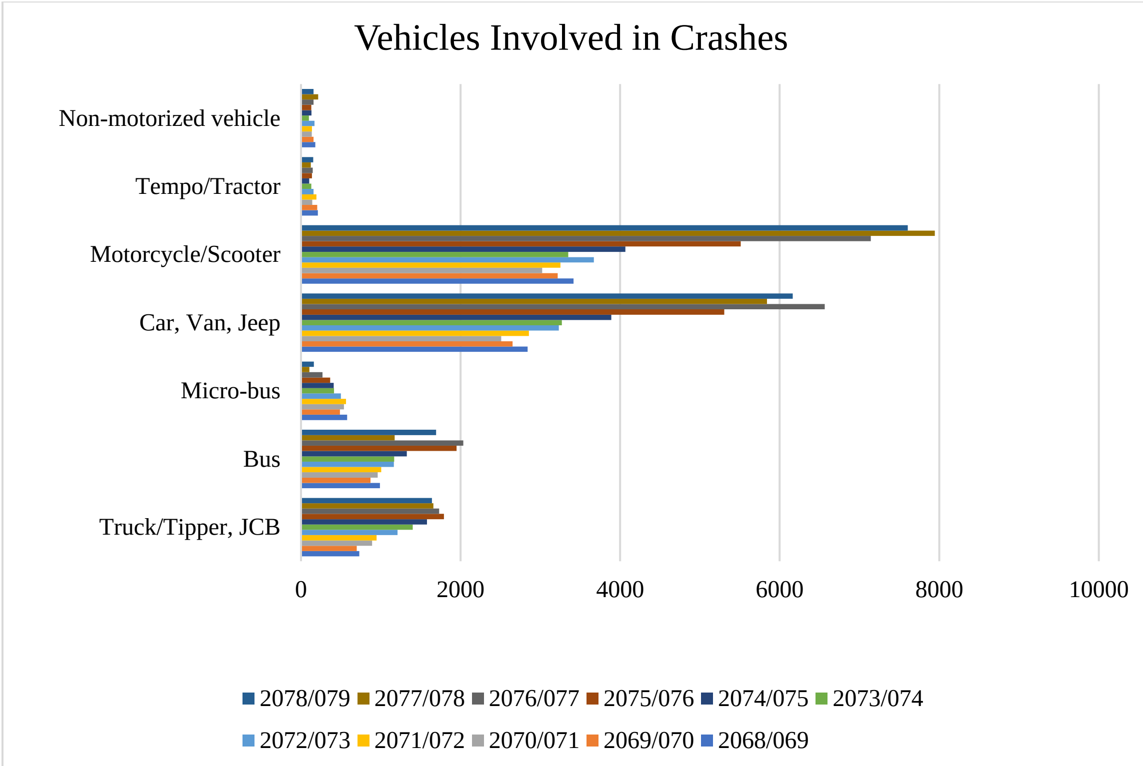

Figure 1.2 Vehicles Involved in Crashes

1.2 Problem Statement

In the scholarly field of road safety, extensive research has been conducted to understand the factors contributing to the severity of two-wheeler crashes. However, there is a noticeable gap in the literature in context of Nepal. Despite of high incidence of severe two-wheeler crashes at intersections in Kathmandu, there is a scarcity of scholarly investigations evaluating the contributing factors to crash severity at these specific locations.

This gap becomes more significant when considering the distinctive urban environment of Kathmandu. With two-wheelers being a prevalent mode of transportation and a disproportionately high rate of severe crashes at intersections, there is a need for focused scholarly inquiry. Existing research falls short in providing a comprehensive analysis of the factors influencing two-wheeler crash severity at intersections in Kathmandu.

Therefore, a thorough examination of these intersections is essential to unravel the complexities of the issue and establish a foundation for evidence-based interventions aimed at improving road safety for two-wheeler riders in Kathmandu.

1.3 Research Objectives

The primary objective of this study is to evaluate the risk factors that contribute to the severity of two-wheeler crashes at intersections in Kathmandu Valley. The specific objectives are:

i. To evaluate the risk factors that determines the two-wheeler crash severity at intersections in Kathmandu valley.
ii. To quantify the relative risk in the severity associated with the identified significant factors by employing multinomial logistic regression.

1.4 Scope and Limitations

This research paper focuses on investigating the determinants of two-wheeler crash severity at intersections, employing a multinomial logit model. The outcome that is two-wheeler crash severity has been categorized into minor, serious, and fatal injuries. The scope encompasses a comprehensive examination of factors, considering temporal patterns, collision partners, and specific risk associations, with the aim of providing valuable insights into intersection-related two-wheeler crashes. The study primarily centers on the urban context of Kathmandu and is carried out based on the crash data available for year 2074-075 to 2078-079 B.S. (2017/018 to 2021/022 A.D.).

Some limitations of this study are listed below:

- The study relies on available data, and limitations in data quality or completeness may impact the robustness of the analysis.

- The findings are tailored to the intersections of Kathmandu, and generalization to different locations may be limited.
- Although the findings offer insights, the paper does not extensively explore policy implications or specific interventions to mitigate crash severity.
- The chosen time groups may not fully capture the dynamic nature of traffic patterns i.e. traffic may vary with intersections.

1.5 Organization of Report

This thesis report contains five chapters. Chapter 1 is the **Introduction** of this thesis. It includes background, problem statement, research objective, scope and limitation of this research. Chapter 2 is a **Literature review** providing an overview of relevant research literatures globally and in context to Nepal.

Chapter 3 offers a **Methodology** adopted to carry out this research. It includes the description of study area, flowchart and description of methodological process adopted for carrying out analysis. Similarly, Chapter 4 includes **Result and Discussion** part. Chapter 5 includes **Conclusion and Recommendation** part which provides the concluded result and recommendations drawn from the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Studies on Two-wheeler Crashes

Numerous studies have been dedicated to the exploration of factors influencing the severity of two-wheeler crashes, employing various statistical models to unravel this complex phenomenon. Over the years, researchers have diligently delved into these aspects, with a focus on understanding the multifaceted determinants that contribute to the severity of two-wheeler accidents. This exploration has led to a more comprehensive comprehension of the underlying dynamics, providing invaluable insights for road safety measures and crash prevention strategies.

Indeed, a multitude of studies have delved into this intricate domain, each contributing valuable pieces to the puzzle. Researchers such as (Conrad' & Bradsiiaw~, 1996), (Kasantikul et al., 2005), (Majdzadeh et al., 2008), (Rifaat et al., 2011), and (Thurman et al., 1996) have diligently examined the contributing factors to two-wheeler crash severity, employing various statistical methodologies. Their research endeavors have encompassed a range of factors encompassing the road environment, traffic conditions, the surrounding environment, human characteristics, and vehicle-specific attributes, all of which play an instrumental role in shaping the outcomes of two-wheeler accidents.

Several pivotal findings have emerged from these comprehensive studies, underscoring the manifold factors that can exacerbate the severity of two-wheeler crashes. Among these determinants are the conspicuous absence of two-wheeler helmets, which has been identified as a significant risk factor as emphasized by (Shaheed & Gkritza, 2014). Likewise, excessive speed, as studied by Schneider IV and colleagues in 2012 (Schneider IV et al., 2012), is a prominent contributing factor to the severity of two-wheeler crashes. The displacement capacity of two-wheeler engines, as indicated by (Langley et al., 2000), has been linked to crash severity, with larger engines often associated with more severe outcomes.

Furthermore, the demographics of two-wheeler riders have also been a subject of investigation. The gender of the two-wheeler rider, as highlighted by (Waseem et al., 2019), and the age of the two-wheeler rider, as examined by (Rutter & Quine, 1996), have both been shown to have an impact on crash severity. Moreover, riding a two-wheeler without a proper license, an illegal practice that (Dandona et al., 2006) explored, has been identified as a significant risk factor.

The type of collision involved in a two-wheeler accident is also crucial in determining the outcome. Collisions with heavy vehicles, as researched by (Schneider IV et al., 2012), have been associated with heightened crash severity. The timing of two-wheeler rides, particularly during midnight or the early morning hours, as illuminated by (Abdul Manan et al., 2018), has been identified as a period of elevated risk. The location of the accident on the road, examined by (Çelik & Oktay, 2014), and the road geometry, as studied by (Abdul Manan et al., 2018), have also been identified as influential factors.

Furthermore, several other factors have been the focus of rigorous investigation, including traffic violations (as scrutinized by (Salum et al., 2019)), seasonal variations (as discussed by (Rifaat et al., 2011)), and high traffic density, an aspect considered by (Allen et al., 2017). These studies collectively contribute to a deeper understanding of the intricate web of variables that influence the severity of two-wheeler crashes.

Nonetheless, a significant observation in the realm of two-wheeler crash severity research is the prevalence of studies that predominantly concentrate on crashes occurring along roadway segments rather than specific locations such as intersections. Notably, works by (Haque et al., 2012) and (Pei & Fu, 2014) exemplify this trend, focusing primarily on two-wheeler crashes in the broader context of roadway segments. This approach, while valuable for understanding the general landscape of two-wheeler crashes, may not offer a comprehensive insight into the complex factors affecting crash severity at specific locations like intersections. It becomes imperative, therefore, to address this gap in the literature by delving deeper into the nuanced dynamics at these critical junctures.

In light of this, the study conducted by Shankar and Mannering assumes significant importance. Their investigation delved into injury severity in single-vehicle two-wheeler crashes, employing a Multinomial Logistic Regression Model as the analytical framework. The findings from this study, as documented by (Washington et al., 2003), reveal a rich tapestry of variables influencing the severity of two-wheeler riders' injuries in the aftermath of a crash.

Notably, a wide range of factors was found to influence the severity of two-wheeler crash injuries, including two-wheeler displacement, rider ejection, speed, rider attention, pavement surface, and type of highway. These variables each play a critical role in determining the extent of injury and underscore the complexity of factors affecting two-wheeler crash severity. By shedding light on these critical determinants, the study contributes significantly to our understanding of two-wheeler crash severity and provides valuable insights for enhancing road safety for two-wheeler riders.

In an insightful exploration of the factors influencing the severity of two-wheeler riders' crash injuries, Rutter and Quine undertook a comprehensive investigation that considered two critical aspects: operator age and riding experience. Drawing upon a substantial dataset derived from a national survey encompassing more than 4,000 riders within the United Kingdom, this empirical study offered a profound understanding of the intricate dynamics at play in two-wheeler accidents (Rutter & Quine, 1996). The central of their research was the discernment of how age and riding experience intersect to shape the outcomes of two-wheeler crashes. Through meticulous analysis, Rutter and Quine discerned that operator age bore a noteworthy influence on casualty rates, particularly among younger two-wheeler riders. The impact of age was found to be particularly pronounced, significantly contributing to the severity of injuries sustained in accidents. Notably, the study's findings highlighted that age exerted a more substantial effect on casualty rates among younger riders compared to driving experience. This pivotal observation underscores the vulnerability of younger two-wheeler riders, whose relative lack of experience can be further compounded by their age. It's a clear testament to the intricate interplay of factors that influence the outcomes of two-wheeler accidents, with age emerging as a significant determinant. Furthermore, Cheshman, Rutter and Quine delved into the behavioral patterns associated with two-wheeler crashes. Their research illuminated a connection between crashes and specific behavioral tendencies among two-wheeler riders. In particular, their study unveiled a propensity among some riders to disregard traffic laws and engage in unsafe riding practices. This connection between behavioral choices and crash involvement provides valuable insights into the complex factors contributing to the severity of injuries sustained in two-wheeler crashes (Chesham et al., 1993).

2.2 Multinomial Logit Model

The multinomial logistic model operates under the assumption that each case in the data has unique values for its independent variables. Additionally, it presupposes that perfect prediction of the dependent variable based on the independent variables is not possible for any case. Unlike some regression methods, there is no requirement for the independent variables to be statistically independent, although it is expected that collinearity is relatively low. High collinearity can pose challenges in distinguishing the individual impact of variables on the outcome.

Savolainen and Mannering created nested logit and standard multinomial logistic (MNL) models to examine two-wheeler crashes involving a single vehicle or multiple vehicles. They utilized police-reported crash data from Indiana in their analysis. The researchers found that various factors, such as age, crash type, characteristics of the roadway, alcohol consumption, helmet usage, and unsafe speed, had a notable impact on the severity of injuries sustained in two-wheeler crashes (Savolainen, 2007).

Rider-specific factors, particularly age and gender, significantly influence both the occurrence and seriousness of two-wheeler accidents. Earlier studies have indicated that the probability of fatal or disabling injuries in single-vehicle two-wheeler incidents rises with the advancing age of the rider. The increased likelihood of severe injuries among older two-wheeler riders may be explained by factors such as slower reaction times, diminished sensory and perceptual capabilities, and reduced physical resilience to two-wheeler crashes when compared to younger riders (Pai & Saleh, 2008).

2.3 Summary of Literature Review

Table 2.1 summarizes the key findings from the literature review on factors influencing motorcycle crash severity. Each factor is accompanied by a citation to the research study that identified the link between that factor and crash severity.

Table 2.1 Summary of Literature Review

Finding	Author(s)
Helmet absence increases severity	Shaheed & Gkritza (2014)
Excessive speed increases severity	Schneider IV et al. (2012)
Larger engine displacement increases severity	Langley et al. (2000)
Male riders have higher crash severity	Waseem et al. (2019)
Younger riders have higher crash severity	Rutter & Quine (1996)
Riding without a license increases severity	Dandona et al. (2006)
Collisions with heavy vehicles increase severity	Schneider IV et al. (2012)
Midnight to early morning riding increases severity	Abdul Manan et al. (2018)
Road location and geometry impact severity	Çelik & Oktay (2014)
Traffic violations increase severity	Salum et al. (2019)
Seasonal variations influence severity	Rifaat et al. (2011)
High traffic density increases severity	Allen et al. (2017)
Two-wheeler displacement affects injury severity	Shankar & Mannering (Washington et al., 2003)
Speed affects injury severity	Shankar & Mannering (Washington et al., 2003)
Rider attention affects injury severity	Shankar & Mannering (Washington et al., 2003)
Pavement surface affects injury severity	Shankar & Mannering (Washington et al., 2003)
Highway type affects injury severity	Shankar & Mannering (Washington et al., 2003)
Operator age influences casualty rates	Rutter & Quine (1996)
Young riders are more susceptible to severe injuries	Rutter & Quine (1996)
Specific riding behaviors contribute to crashes	Cheshman et al. (1993)

CHAPTER 3: METHODOLOGY

3.1 Research Framework

Figure 3.1 shows the flowchart of the research framework. It summarizes the methodological framework used in this study. The flowchart outlines a systematic process followed for the analysis of two-wheeler crash data of the study area. The first step involves defining the study area, which is crucial for the contextual relevance of the research. Once the study area is established, the focus shifts to data collection. The data encompass two-wheeler rider characteristics, intersection characteristics, and crash characteristics. These elements collectively form a comprehensive dataset that serves as the foundation for understanding the intricate dynamics of two-wheeler crashes at the intersections of the study area.

Following data collection, Multinomial Logistic Regression, a statistical approach is employed to analyze the relationships among variables. Multinomial Logistic Regression is a key step in uncovering patterns and dependencies within the collected data. Subsequently, the analysis phase involves processing the data through the Multinomial Logistic Regression, which allows for the identification of significant factors influencing two-wheeler crash severity at intersections. The interpretation of results is a critical step that follows the analysis, shedding light on the implications of the statistical findings.

The output phase of the flowchart involves presenting the results in a meaningful and actionable format. This includes risk ratios and a delineation of the relationships between various variables. The risk ratio provides a quantitative measure of the likelihood of specific outcomes, offering valuable insights into the relative impact of different factors on two-wheeler crash severity. By elucidating the relationships between variables, the output can provide insights to inform road safety measures and crash prevention strategies. In summary, this flowchart provides a structured and methodological approach to study and understand the complexities of two-wheeler crashes at intersections, from data collection to result interpretation and practical output.

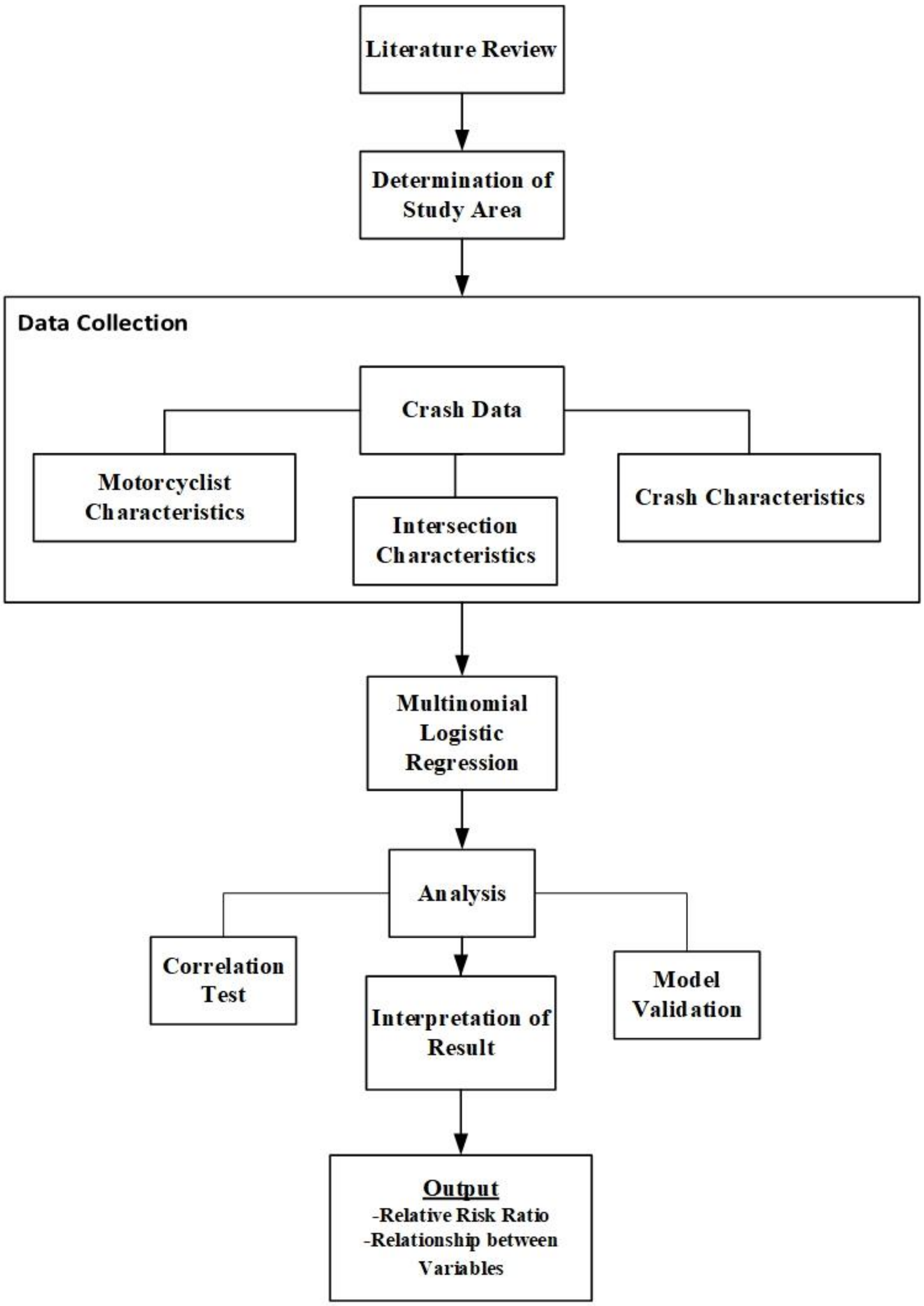

Figure 3.1 Flowchart of Methodology

3.2 Study Area

In pursuit of research objectives, the acquisition of two-wheeler crash data arising at intersections within the Kathmandu Valley constitutes a fundamental prerequisite. This study has identified and subsequently designated 286 intersections within the Kathmandu Valley as the focal points for our analytical investigation. Figure 3.2 shows the locations of these intersections along with its types. These intersections have been selected on the criterion that they have experienced at least one recorded two-wheeler crash.

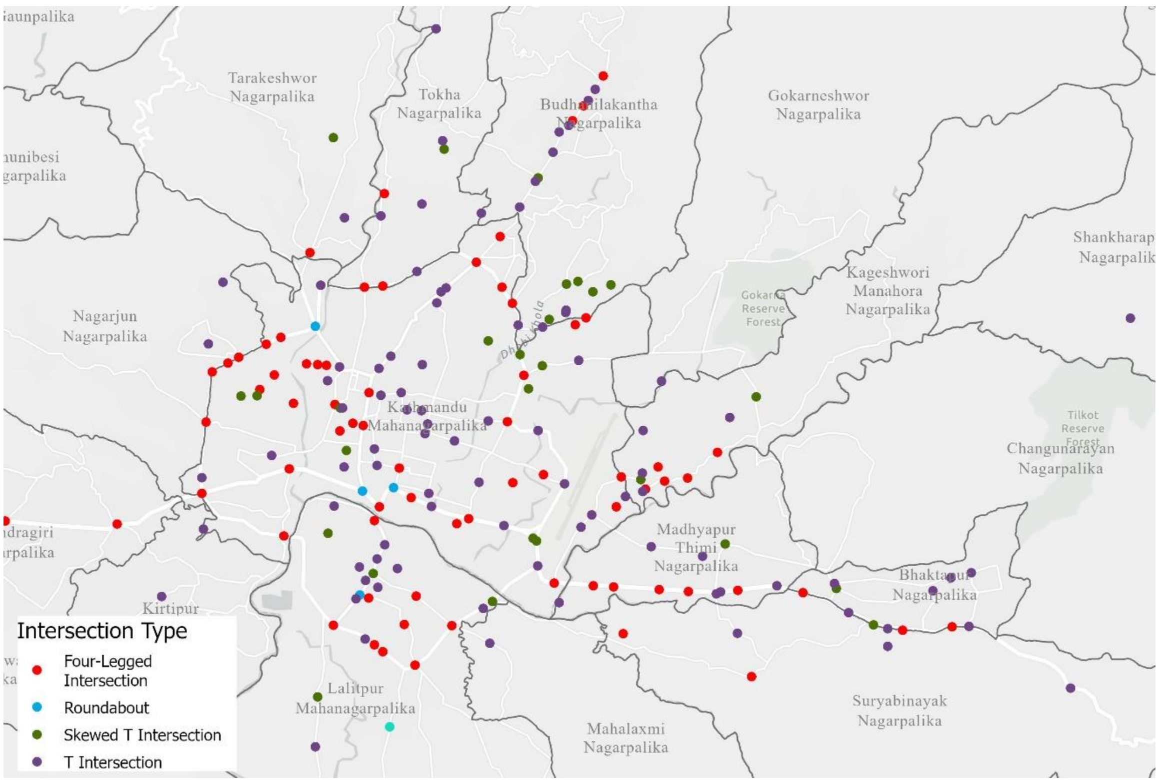

Figure 3.2 Locations of Intersections within Kathmandu Valley

3.3 Data Collection

The study is based on secondary data. For developing the model, the two-wheeler crash data recorded at Kathmandu Valley Traffic Police Office for the period of five years from the fiscal years 074-075 to 078-079 B.S. (2017/018 to 2021/022 A.D.) were used. For analysis purposes, 3086 two-wheeler intersection crash records were utilized, following data cleaning and merging to address missing information.

3.4 Data Extraction

Two-wheeler crashes were initially segregated from the comprehensive dataset. Among these, intersection crashes were isolated. All identifiable intersections were subsequently selected and processed in preparation for further analysis.

3.5 Risk Factors

The study employs multinomial logistic regression to identify the significant risk factors that associates to two-wheeler crash severity at intersections of Kathmandu and also quantifies the variation in the severity the risk factors can bring into. For this, based on the literature review and a pilot review of the crash statistics of Kathmandu, a list of potential risk factors that can influence the severity of the crashes are considered. Table 3.1 lists out the various risk factors considered in this study. The factors have classified into three broad categories as discussed below.

3.5.1 Two-wheeler rider Characteristics

This study explores the potential influence of two-wheeler rider age and gender on the severity of crashes at intersections. Previous research has identified different methods for classifying rider age, suggesting potentially important factors influencing crash outcomes (Çelik & Oktay, 2014; Pai & Saleh, 2008). The investigation incorporated a widely recognized three-tier age classification system (young: <26, middle-aged: 26-59, older: >59) to explore potential age-related differences in riding behavior.

Driving under the influence (DUI) and overspeeding are two significant factors that contribute to road crashes worldwide. These behaviors significantly increase the risk of accidents, injuries, and fatalities on the roads (Isong et al., 2017).

3.5.2 Crash Characteristics

The study also encompassed an analysis of both the day of the week and the time of two-wheeler crashes. The classification of days of the week followed the prevailing norm, delineating them into "weekday" and "weekend" categories.

Drawing upon prior literature, we further segmented the time of the crash into five distinct intervals contingent upon traffic volume (Çelik & Oktay, 2014): "mid-night/early morning" (00:00–6:29 a.m.), "morning rush hours" (6:30–8:59 a.m.), "non-rush hours" (9:00 a.m. to 14:59 p.m.), "evening rush hours" (15:00–18:29 p.m.), and "evening" (18:30–23:59 p.m.).

Furthermore, two-wheeler crashes were categorized into four distinct types, namely: "collision with a vehicle," "collision with a pedestrian," "collision with a roadside object," and "loss of control (no collision)" based on collision type. Experiences show collisions involving two-wheeler and truck in particular often lead to severe consequences for the two-wheeler rider. The vast difference in size and weight between the two vehicles, with trucks being significantly larger and heavier, increases the risk of serious injuries. These types of crashes are known for their potential to result in life-threatening injuries. Therefore, collisions involving trucks were considered as a separate additional category.

3.5.3 Intersection Characteristics

The intersections under consideration in this study are categorized into four distinct groups, namely: Four-legged intersections, T-type intersections, Skewed T-type intersections and Roundabout based on their layout.

Table 3.1 Risk factors considered in the study

Category	**Risk Factor**
Two-wheeler rider Characteristics	Age: - Young (less than 26 years old) - Middle-aged (26-59 years old) - Old (more than 59 years old)
	Gender: - Male - Female
	Driving Under Influence (DUI)
	Overspeeding
Crash Characteristics	Day of Crash: - Weekday - Weekend
	Time of Crash: - Mid-night/early morning (00:00-6:29) - Morning rush hours (6:30-8:59) - Non-rush hours (9:00-14:59) - Evening rush hours (15:00-18:29) - Evening (18:30-23:59)
	Collision Type: - Collision with vehicle - Collision with pedestrian - Collision with roadside object - No collision (loss of control)
	Collision with truck
Intersection Characteristics	Intersection Type: - Four-legged - T-type - Skewed T-type - Roundabout

3.3 Multinomial Logistic Regression

This study aims to understand how two-wheeler crashes severities (dependent variable) unfold and how they relate to different risk factors (independent variables) using Multinomial Logistic Regression (MLR) as the tool for analysis. The severity of crashes was classified into three distinct categories for analysis purposes: minor injuries requiring medical attention (e.g., bruises, pain), serious injuries necessitating hospitalization, and fatal injuries resulting in death within a 30-day period. Crashes that only involve property damage were intentionally excluded and focused on those where people are injured. This is because data on property-only crashes can be unreliable and often go unreported.

An unordered model, such as the MLR model, has been recommended for use in crash severity studies, even though crash severity inherently follows a natural order (Çelik & Oktay, 2014; Salum et al., 2019). According to Islam and Mannering (2006), the multinomial logit model is less affected when it comes to underreporting in the data. Additionally, this model offers a more adaptable and versatile functional approach (Malyshkina & Mannering, 2010).

The MLR in specific to this study can be presented as shown in Equation 3.1:

$$P_{ni} = \frac{e^{\beta_i X_{ni}}}{\sum_{i=1}^{I} e^{\beta_i X_{ni}}} \text{ , i = 1, 2, …, I} \tag{3.1}$$

Where,

P_{ni}: Probability of the two-wheeler rider in the crash n to suffer the output injury of i,

β_i: A vector of the calculative coefficient for the output severity i associated with X_n

X_n: Vector of the explanatory variables/risk factors

This research uses fatal crashes as the starting point for comparing other crash severity levels. While this choice may have some drawbacks, especially if fatal crashes are uncommon, recent studies suggest using fatalities as the baseline for the MLR model. This approach is recommended because it reduces bias and inconsistency in the model, resulting in more trustworthy findings (Çelik & Oktay, 2014; Salum et al., 2019; Ye et al., 2013). Additionally, it is worth mentioning that fatal injuries tend to be reported more consistently.

3.3.1 Odds Ratio and Relative Risk Ratio (RRR)

Due to the nonlinear attributes inherent in the MLR, the estimated coefficients associated with independent variables are incapable of directly signifying their impact on the dependent variable.

To address this limitation, this study has leveraged the Relative Risk Ratio (RRR) parameter for the purpose of risk assessment. It is noteworthy that the RRR parameter takes into account not only the influence of individual independent variables but also considers the collective effects of various factors. These encompass two-wheeler rider characteristics, intersection properties, and crash-related variables, in addition to accounting for the interrelationships and covariances among these independent variables.

Exp(β) is the exponential of the coefficient, β, in a logistic regression model. It is also known as the odds ratio. It is a measure of how much the odds of the outcome (e.g., a severe motorcycle crash) change for a one-unit increase in the predictor variable (e.g., collision with truck).

Relative Risk Ratio (RRR) can be calculated by 1/ Exp(β). The RRR parameter associated with each independent variable serves as an indicator of the risk pertaining to a specific crash severity in relation to the reference category. Specifically, when $RRR > 1$, it signifies an escalation in the risk, while $RRR < 1$ indicates a reduction in the risk (Washington et al., 2003). In this study, both the MLR and the RRR are estimated with a confidence level of 95% and the analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) software.

3.3.2 Correlation Test

In the context of MLR, the chi-square test and Cramer's V are valuable tools for assessing the correlation between categorical variables. These statistical tests play a crucial role in understanding the relationships among different factors and can help identify significant associations within the dataset.

The chi-square test is commonly employed to examine the independence of categorical variables by comparing observed frequencies with expected frequencies. In the context of multinomial logistic regression, the chi-square test serves as an initial step to determine whether there is a significant correlation between predictor variables. A low p-value from the chi-square test suggests that there is evidence of association, prompting further investigation into the specific nature and strength of these associations.

Following the chi-square test, Cramer's V becomes instrumental in gauging the strength of the identified correlations. Cramer's V is a measure of association between categorical variables, ranging from 0 (no association) to 1 (complete association). In the realm of multinomial logistic regression, Cramer's V provides insights into the degree of correlation among predictor variables. It is particularly useful in quantifying the strength of associations when dealing with nominal or ordinal variables.

Despite its utility, it is important to interpret Cramer's V judiciously, especially when assessing correlations in multinomial logistic regression. While a statistically significant chi-square test indicates the presence of an association, Cramer's V helps differentiate between weak and strong associations. However, it is crucial to note that Cramer's V has limitations and may not capture nuances in complex relationships, necessitating a comprehensive understanding of the variables under investigation.

In summary, the combination of the chi-square test and Cramer's V in the context of multinomial logistic regression provides a robust framework for assessing and understanding the correlations between categorical variables. These statistical tools help researchers identify significant associations and quantify the strength of these relationships, contributing to a more nuanced interpretation of the complex interplay among predictor variables in a multinomial logistic regression setting.

3.3.3 Validation

Model validation is an integral component in the process of evaluating the efficacy and reliability of a theoretical model. In the realm of MLR, validation involves assessing whether the model accurately represents and explains the observed phenomena, making it a fundamental step in the scientific method.

Model validation is a critical step in assessing the performance and reliability of predictive models. In the context of the presented confusion matrix, which depicts the observed and predicted crash severity categories, model validation involves evaluating how well the model’s predictions align with the actual outcomes.

Furthermore, the validation process involves checking assumptions inherent to multinomial logistic regression. These include the assumption of independence of irrelevant alternatives (IIA) and the assumption that the relationships between predictor variables and response categories are consistent across all levels of the dependent variable.

In summary, model validation in multinomial logistic regression encompasses a comprehensive evaluation of the model's performance through metrics like accuracy, precision, recall, and discrimination indices. Employing cross-validation techniques and ensuring adherence to underlying assumptions enhances the robustness and reliability of the model, making it a valuable tool for making predictions across multiple unordered categories.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Two-wheeler Crashes at Intersections in Kathmandu Valley

The two-wheeler crash data at intersections recorded from fiscal years 074-075 to 078-079 by the Kathmandu Metropolitan Traffic police are summarized in Table 4.1. The table concisely encapsulates the key insights from two-wheeler crash records. It classifies crashes into different severity levels, with minor incidents being the most prevalent, followed by serious and fatal cases. The data is further broken down by variables such as the day of the week (weekdays and weekends), types of intersections, factors like over-speeding and driving under the influence, the gender of those involved, collision types, age groups, and the time of day when crashes occurred. Notably, the largest number of crashes is associated with "non-Rush" times. With a total of 3,086 recorded crashes, this dataset serves as a valuable resource for comprehending crash patterns and were used for further analysis.

Table 4.1 Summary of Two-wheeler Crash Data at Intersections in Kathmandu Valley

Variables	**Categories**	**Number of crashes**
Crash severity level	Fatal	51
	Minor	2948
	Serious	87
Day	Weekday	2652
	Weekend	434
Intersection type	Four-legged	1905
	T-type	890
	Skewed T-type	225
	Roundabout	66
Overspeeding	Yes	337
Driving Under Influence	Yes	227
Collision with Truck	Yes	208
Gender	Male	2607
	Female	479
Collision	Collision with vehicle	2467
	Collision with pedestrian	339
	Collision with roadside object	40
	No collision (loss of control)	240
Age Group	Young (less than 26 years old)	1388
	Middle-aged (26-59 years old)	1677
	Old (more than 59 years old)	21
Time Group	Early Morning (00:00-6:29)	143
	Morning Rush (6:30-8:59)	260
	Non-Rush (9:00-14:59)	1135
	Evening Rush (15:00-18:29)	762
	Evening (18:30-23:59)	786
Total		3086

Table 4.2 shows the number of fatal crashes, with number of minor and serious crashes occurred in those intersections in Kathmandu valley. Nalin Chowk stands out as a dangerous intersection with a high number of fatal crashes, accounting for 4 out of the total 51 fatalities recorded at intersections. This represents a significant portion (nearly 8%) of

all intersection-related fatalities, highlighting the urgent need for thorough investigation and targeted interventions to prevent future tragedies.

Table 4.2 Number of Fatal Crashes at Intersections

Name of Intersection	Fatal Cases	Serious Cases	Minor Cases
Aadarsha Chowk	2	0	0
Ammar Singh Chowk	1	0	0
Babarmahal Chowk	2	0	2
Balaju Chowk	2	0	2
Banasthali Chowk	2	0	1
Baneshwor Chowk	1	0	1
Bijulibazar Chowk	1	0	1
Chaardobato	2	1	2
Dhumbarai Chowk	2	0	1
Gatthaghar Chowk	1	0	0
Ghalate Chowk	2	0	2
Gongabu Chowk	2	0	1
Gwarko Chowk	3	0	0
Hattigauda Chowk	1	1	1
Italitaar Chowk	1	0	0
Jadibuti Chowk	2	0	2
Jaulakhel Chowk	1	0	0
Kalanki Chowk	1	0	0
Koteshwor Chowk	2	0	1
Lahure Chowk	1	0	0
Lohtse Chowk	1	0	0
Manahara Chowk	1	0	1
Milan Chowk	1	0	0
Miteri Chowk	1	0	0
Nalin Chowk	4	0	1
Radhe Radhe Chowk	1	0	0
Sallaghari Chowk	2	0	2
Sanepa Chowk	1	0	0
Sanothimi Chowk	2	1	0
Singhdurbar Chowk	1	0	0
Soltidobaato Chowk	1	0	1
Ss Chowk	2	1	0
Suryabinayek Chowk	1	0	0
Grand Total	**51**	**4**	**22**

4.2 Results of Correlation Analysis

The results of the chi-square tests and the corresponding Cramer's V values for categorical variables are presented in Table 4.3. The p-values from the chi-square tests assessing the correlation between Age and Collision with Truck, Gender and Time, Gender and DUI, Time and Over-speeding, Time and Intersection Type, DUI and Intersection Type, and Intersection Type and Collision Type are all less than or equal to 0.05. As a result, these pairs are deemed statistically significant. However, upon examining the Cramer's V values for these significant pairs, it was observed that the relationships between them are weak. Nevertheless, all categorical variables were included in the subsequent analysis, recognizing the weak relationships (less than 0.3) indicated by the Cramer's V values for the significant pairs.

Table 4.3 Chi-Square and Cramer's V Value for the Categorical Variables

Correlation between Variables	Chi square(p-value)	Crammer's V
Age & Collision with Truck	0.003	0.062
Gender & Time	0.01	0.065
Gender & DUI	0.002	0.056
Time & Over-speeding	0.004	0.071
Time & Intersection Type	0.016	0.052
DUI & Intersection Type	0.048	0.051
Intersection Type & Collision Type	0.005	0.051

4.3 Multinomial Logistic Regression Modeling

Logistic regression was carried out using Statistical Package for the Social Sciences (SPSS) Version 25 software package to explore the relationship between crash severity and various risk factors day and time of crash occurrence, intersection type, over speeding and driving under influence or not, collision with truck, gender, collision type, and age. presents the results of the Multinomial Logistic Regression. Table 4.4 includes the coefficient estimates, significance, and odds ratio (e^{β}) for the significant independent variables for severity categories minor severity (MI) and serious severity (SI) respectively. The base category for the corresponding model is fatal injury, the coefficient estimates explain the differences compared to the fatal injury. The variables that are significant at the 95% confidence level are identified. The significant factors that influence the injury severity of two-wheeler crashes at a 95% confidence level were observed to be collision with truck, collision with roadside object and time at which the crash occurred.

Table 4.4 The Result of The MLR for Motorcyle Crashes at Intersections in Kathmandu Valley

Variable	**Estimated Coefficient**[a]	**P-value**	**Exp[β]**[b]
Intercept [MI]	2.493 (1.482)	0.093	-
Intercept [SI]	-0.699 (1.981)	0.724	-
Collision with truck [MI]	-2.393 (0.371)	<0.001	0.091 (0.044, 0.189)
Collision with truck [SI]	-2.236 (0.564)	<0.001	0.107 (0.035, 0.322)
Collision with roadside object [MI]	-3.973 (0.541)	<0.001	0.019 (0.007, 0.054)
Collision with roadside object [SI]	-2.511 (0.744)	0.001	0.081 (0.019, 0.349)
Time of crash, early morning [MI]	-1.198 (0.436)	0.006	0.302 (0.128, 0.709)
Time of crash, early morning [SI]	-1.594 (0.608)	0.009	0.203 (0.062, 0.669)
Time of crash, non-rush hours [MI]	1.296 (0.584)	0.026	3.656 (1.164, 11.481)
Time of crash, non-rush hours [SI]	-1.131 (0.511)	0.027	0.323 (0.119, 0.879)

[a]*Standard errors are in parentheses.*

[b]*Lower and upper limits at 95% confidence interval are in parentheses.*

[MI], minor injury; [SI], serious injury. The reference category is the fatal injury.

The total number of observations in the dataset is 3086. This represents the size of the sample or dataset on which the logistic regression model has been applied. The log-likelihood is a measure of how well the logistic regression model explains the observed data. It quantifies the likelihood of observing the given data under the estimated model. In this case, the log-likelihood is 614.816, and higher values generally indicate a better fit of the model to the data.

The McFadden Pseudo R-squared of 0.154, while relatively small, is consistent with typical findings in psychological studies where such values often fall below 0.5. It's important to note that psychological phenomena are often complex and influenced by numerous factors, making it challenging to explain a large proportion of the variability solely through the model variables considered.

Moreover, there is potential for improvement in the McFadden Pseudo R-squared with an increase in data quality. Introducing more detailed categories or factors could lead to a richer dataset, providing a more nuanced understanding of the psychological phenomena under investigation. The inclusion of additional variables may enhance the model's explanatory power by capturing subtleties and complexities inherent in psychological processes. Therefore, an expansion of the dataset in terms of both breadth and depth could contribute to a more comprehensive and refined logistic regression model, potentially resulting in a higher McFadden Pseudo R-squared.

4.4 Model Validation

The confusion matrix in Table 4.5 provides a snapshot of the model's performance across different severity levels. In this matrix, the diagonal elements represent the correctly predicted instances for each severity category, while off-diagonal elements indicate misclassifications. For instance, the "Fatal" severity level shows that only 2 out of 51 observations were correctly predicted, resulting in a low percentage accuracy of 3.90%. The "Minor" severity level, on the other hand, exhibits a high percentage of correct predictions (100.00%), indicating that the model accurately identified the majority of instances in this category. The "Serious" severity level presents a notable challenge, with the model failing to predict any instances correctly, resulting in an accuracy percentage of 0.00%. This discrepancy raises concerns about the model's ability to discern and appropriately classify the less frequent severity categories. The overall percentage correctly classified (95.60%) provides a summary measure of the model's accuracy across all severity levels.

Table 4.5 Validation Table

		Predicted			
		Crash Severity			
Observed		**Fatal**	**Minor**	**Serious**	**Percent Accuracy**
Crash Severity	Fatal	2	49	0	3.90%
	Minor	1	2947	0	100.00%
	Serious	0	87	0	0.00%
	Overall Percentage	0.10%	99.90%	0.00%	95.60%

4.5 Relative Risk Ratios for the Identified Risk Factors

In order to analyze major factors and delve into the relative risk ratio (RRR) of noteworthy variables, it is crucial to pinpoint the variables/risk factors that achieve statistical significance, often characterized by a p-value (Sig.) below a predetermined significance threshold, such as 0.05 as shown in Table 4.4. The analysis provides compelling insights into the disparities in injury severity outcomes resulting from collisions involving trucks, along with their Relative Risk Ratios (RRR). The data shows that when a collision involves a truck, the likelihood of a fatal injury is approximately 11 times higher (RRR=1/0.091) compared to cases that lead to minor injuries. This substantial RRR value underscores the significantly increased risk of severe outcomes associated with such collisions. Additionally, when contrasted with incidents that result in serious injuries, collisions with trucks are about 9 times more likely to lead to fatal injuries (RRR=1/0.107). These RRR values not only highlight the elevated risk of fatal injuries in truck-involved crashes but also underscore the importance of implementing targeted safety measures and crash prevention strategies to mitigate these risks and enhance overall road safety.

Collisions involving roadside objects exhibit a significantly elevated likelihood of resulting in fatal injuries when compared to minor injuries, as indicated by a Relative Risk Ratio (RRR) of approximately 1/0.019. In a similar vein, these collisions are approximately 12 times more inclined to lead to fatal injuries in comparison to cases involving serious injuries, emphasizing the substantial disparity in the risk of severe outcomes associated with such accidents (RRR=1/0.081). Collisions with roadside objects might involve a higher degree of impact or force, leading to more severe consequences. The nature of the collision, such as high-speed impacts or direct collisions with rigid objects, could contribute to an increased likelihood of fatal injuries.

According to the model's findings, it appears that two-wheeler crashes during the early morning hours have a significantly higher likelihood of resulting in fatal injuries when compared to minor injuries, with a Relative Risk Ratio (RRR) of approximately 1/0.302, indicating roughly three times higher risk. Similarly, these early morning crashes are about five times more prone to causing fatal injuries than cases involving serious injuries, emphasizing the substantial disparity in the risk of severe outcomes associated with crashes occurring during these hours (RRR=1/0.203).

Crashes occurring during non-rush hours exhibit a reduced likelihood of resulting in fatal injuries when compared to minor injuries, with a Relative Risk Ratio (RRR) of approximately 1/3.656, implying a lower risk. However, the data also indicates that during non-rush hours, crashes are about three times more inclined to result in fatal injuries than in cases involving serious injuries, highlighting a notable difference in the risk of severe outcomes during these time periods (RRR=1/0.323). During non-rush hours, traffic conditions are often less congested, which might reduce the overall risk of collisions. However, the lower volume of traffic could result in higher travel speeds, potentially increasing the severity of collisions when they do occur.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Two-wheeler riders confront an elevated susceptibility to experiencing fatal and serious injuries, primarily attributable to the inherent absence of protective features that shield them in comparison to occupants of other vehicles. Specifically, collisions occurring at intersections have exhibited a proclivity to result in more severe outcomes. The objective of this research is to scrutinize the factors influencing the severity of two-wheeler crashes at intersections within the Kathmandu Valley, offering essential perspectives on critical facets of two-wheeler safety at these specific locations.

Utilizing a multinomial logit model, this analysis thoroughly investigates the myriad factors influencing the severity of two-wheeler crashes at intersections in the Kathmandu Valley. The dependent variable is crash severity, categorized into minor injury, serious injury, and fatal injury, while independent variables encompass age, gender, driving under the influence, over speeding, day and timing of the crash, collision type, and intersection type. The evaluation relies on coefficient estimates, significance levels, and Relative Risk Ratios (RRR) as the metrics for comparisons, with "Fatal Injury" serving as the base category. Significantly, the analysis identifies collision with a truck, collision with a roadside object, and the timing of the crash as noteworthy factors, each achieving statistical significance at a 95% confidence level.

The key findings of numerical analysis are as follows:

- The correlation test of categorial variables shows there is weak correlation between variables with crammers v values less than 0.3 for all categorial variable pairs.
- Collision with Trucks:
    - 11 times more likely for fatal injuries vs. minor injuries.
    - 9 times more likely for fatal injuries vs. serious injuries.

- Collision with Roadside Objects:
    - 12 times more likely for fatal injuries vs. minor injuries.
    - 5 times more likely for fatal injuries vs. serious injuries.
- Time of the Crash (Early Morning):
    - 3 times higher risk of fatal injuries vs. minor injuries.
    - 5 times higher risk of fatal injuries vs. serious injuries.
- Time of the Crash (Non-Rush Hours):
    - Reduced risk of fatal injuries vs. minor injuries.
    - 3 times more likely for fatal injuries vs. serious injuries.

The findings of this study serve as a valuable asset for both road authorities and researchers, offering essential insights for the formulation of tailored road safety initiatives and strategies aimed at mitigating the fatality rate among two-wheeler riders involved in intersection-related crashes.

5.2 Recommendations and Future Works

Two-wheeler riders face a disproportionate risk of fatalities in collisions, particularly when they involve trucks or roadside objects. These crashes often involve significant force and lack the protective barriers present in cars, leading to higher fatality rates. Additionally, early morning hours, with their lower visibility and potential driver fatigue, are associated with an increased risk of two-wheeler accidents.

To address these risks, several safety measures are needed. Upgrades to truck safety features, such as collision avoidance systems and improved underride guards, can significantly impact outcomes. Additionally, improving road infrastructure by widening lanes, enhancing visibility, and creating safer intersections can play a crucial role in preventing crashes. Public awareness campaigns targeting safe driving practices around two-wheelers, especially near trucks and roadside objects, would further promote responsible behavior among all road users.

Furthermore, continuous monitoring and analysis of two-wheeler crash data are essential. This data allows for the identification of trends and emerging risk factors, enabling targeted interventions. Regular data collection and analysis can also assess the effectiveness of implemented safety measures, ensuring resources are used efficiently. Collaborative research efforts involving government agencies, law enforcement, and road safety organizations can leverage combined expertise to develop evidence-based solutions for reducing fatalities. Finally, sharing knowledge, resources, and best practices among stakeholders can create a more comprehensive and united approach to improving two-wheeler safety across the board.

REFERENCES

Abdel-Aty, M., Keller, J., Brady, P. A., Abdel-Aty, M., & Keller, J. (1908). Analysis of Types of Crashes at Signalized Intersections by Using Complete Crash Data and Tree-Based Regression. In *Transportation Research Record: Journal of the Transportation Research Board*.

Abdul Manan, M. M., Várhelyi, A., Çelik, A. K., & Hashim, H. H. (2018). Road characteristics and environment factors associated with two-wheeler fatal crashes in Malaysia. *IATSS Research*, *42*(4), 207–220. https://doi.org/10.1016/j.iatssr.2017.11.001

Allen, T., Newstead, S., Lenné, M. G., McClure, R., Hillard, P., Symmons, M., & Day, L. (2017). Contributing factors to two-wheeler injury crashes in Victoria, Australia. *Transportation Research Part F: Traffic Psychology and Behaviour*, *45*, 157–168. https://doi.org/10.1016/j.trf.2016.11.003

Çelik, A. K., & Oktay, E. (2014). A multinomial logit analysis of risk factors influencing road traffic injury severities in the Erzurum and Kars Provinces of Turkey. *Accident Analysis and Prevention*, *72*, 66–77. https://doi.org/10.1016/j.aap.2014.06.010

Chesham, D. J., Rutter, D. R., & Quine, L. (1993). MOTORCYCLING SAFETY RESEARCH: A REVIEW OF THE SOCIAL AND BEHAVIOURAL LITERATURE. In *Sm. Sci. Med* (Vol. 37, Issue 3).

Conrad', P., & Bradsiiaw~, Y. S. (1996). HELMETS, INJURIES AND CULTURAL DEFINITIONS: TWO-WHEELER INJURY IN URBAN INDONESIA. In *Accid. Anal. and Prev* (Vol. 28, Issue 2).

Dandona, R., Kumar, G. A., & Dandona, L. (2006). Risky behavior of drivers of motorized two wheeled vehicles in India. *Journal of Safety Research*, *37*(2), 149–158. https://doi.org/10.1016/j.jsr.2005.11.002

DOTM. (2018). *Vehicles Registered in Bagmati Zone*. Dotm. https://www.dotm.gov.np/

Haque, M. M., Chin, H. C., & Debnath, A. K. (2012). An investigation on multi-vehicle two-wheeler crashes using log-linear models. In *Safety Science* (Vol. 50, Issue 2).

Isong, B., Khutsoane, O., & Dladlu, N. (2017). Real-time Monitoring and Detection of Drinkdriving and Vehicle Over-speeding. *International Journal of Image, Graphics and Signal Processing*, *9*(11), 1–9. https://doi.org/10.5815/ijigsp.2017.11.01

Joshi, S., & Shrestha, S. (2009). A Study of Injuries and Violence Related Articles in Nepal. *J Nepal Med Association*.

Kadali, B. R., & Vedagiri, P. (2016). Review of pedestrian level of service: Perspective in developing countries. *Transportation Research Record*, *2581*, 37–47. https://doi.org/10.3141/2581-05

Kasantikul, V., Ouellet, J. V., Smith, T., Sirathranont, J., & Panichabhongse, V. (2005). The role of alcohol in Thailand two-wheeler crashes. *Accident Analysis and Prevention*, *37*(2), 357–366. https://doi.org/10.1016/j.aap.2004.07.006

Langley, J., Mullin, B., Jackson, R., & Norton, R. (2000). Two-wheeler engine size and risk of moderate to fatal injury from a two-wheeler crash. In *Accident Analysis and Prevention* (Vol. 32). www.elsevier.com/locate/aap

Lin, M. R., & Kraus, J. F. (2009). A review of risk factors and patterns of two-wheeler injuries. *Accident Analysis and Prevention*, *41*(4), 710–722. https://doi.org/10.1016/j.aap.2009.03.010

Majdzadeh, R., Khalagi, K., Naraghi, K., Motevalian, A., & Eshraghian, M. R. (2008). Determinants of traffic injuries in drivers and two-wheeler riders involved in an accident. *Accident Analysis and Prevention*, *40*(1), 17–23. https://doi.org/10.1016/j.aap.2007.03.019

Malyshkina, N. V., & Mannering, F. L. (2010). Zero-state Markov switching count-data models: An empirical assessment. *Accident Analysis and Prevention*, *42*(1), 122–130. https://doi.org/10.1016/j.aap.2009.07.012

Pai, C. W., & Saleh, W. (2008). Exploring two-wheeler rider injury severity in approach-turn collisions at T-junctions: Focusing on the effects of driver's failure to yield and junction control measures. *Accident Analysis and Prevention*, *40*(2), 479–486. https://doi.org/10.1016/j.aap.2007.08.003

Pei, Y., & Fu, C. (2014). Investigating crash injury severity at unsignalized intersections in Heilongjiang Province, China. *Journal of Traffic and Transportation Engineering (English Edition)*, *1*(4), 272–279. https://doi.org/10.1016/S2095-7564(15)30272-5

Rifaat, S. M., Tay, R., & De Barros, A. (2011). Effect of street pattern on the severity of crashes involving vulnerable road users. *Accident Analysis and Prevention*, *43*(1), 276–283. https://doi.org/10.1016/j.aap.2010.08.024

Rutter, D. R., & Quine, L. (1996). AGE AND EXPERIENCE IN MOTORCYCLING SAFETY. In *Accid. Anal. and Prev* (Vol. 28, Issue 1).

Salum, J. H., Kitali, A. E., Bwire, H., Sando, T., & Alluri, P. (2019). Severity of two-wheeler crashes in Dar es Salaam, Tanzania. *Traffic Injury Prevention*, *20*(2), 189–195. https://doi.org/10.1080/15389588.2018.1544706

Savolainen, P. (2007). Savolainen. *Transportation Research Record: Journal of the Transportation Research Board*, *2031*(07), 52–58.

Schneider IV, W. H., Savolainen, P. T., Van Boxel, D., & Beverley, R. (2012). Examination of factors determining fault in two-vehicle two-wheeler crashes. *Accident Analysis and Prevention*, *45*, 669–676. https://doi.org/10.1016/j.aap.2011.09.037

Shaheed, M. S., & Gkritza, K. (2014). A latent class analysis of single-vehicle two-wheeler crash severity outcomes. *Analytic Methods in Accident Research*, *2*, 30–38. https://doi.org/10.1016/j.amar.2014.03.002

Joshi, S., & Banstola A. (2018). *Editorial: Injuries in Nepal-A Neglected Public Health Burden and Ways Forward*.

Thurman, D. J., Jeppson, L., Burnett, C. L., Beaudoin, D. E., Rheinberger, M. M., & Sniezek, J. E. (1996). Surveillance of traumatic brain injuries in Utah. In *West J Med* (Vol. 165).

Waseem, M., Ahmed, A., & Saeed, T. U. (2019). Factors affecting two-wheeler riders' injury severities: An empirical assessment using random parameters logit model with heterogeneity in means and variances. *Accident Analysis and Prevention*, *123*, 12–19. https://doi.org/10.1016/j.aap.2018.10.022

Washington, Simon., Karlaftis, M. G., & Mannering, F. L. (2003). *Statistical and econometric methods for transportation data analysis*. Chapman & Hall/CRC.

World Health Organization. (2015). *Global status report on road safety 2015*.

World Health Organization. (2018). *GLOBAL STATUS REPORT ON ROAD SAFETY 2018*.

Ye, F., Lord, D., & Development, Z. (2013). *Comparing Three Commonly Used Crash Severity Models on Sample Size Requirements: Multinomial Logit, Ordered Probit and Mixed Logit Models*.