An Exploratory Empirical Analysis of Injury Severity of Motorcycle Crashes in Pakistan

By

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THESIS ACCEPTANCE CERTIFICATE

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Signature (Dean/Principal): ______________________________

Date: ______________________________

"Dedicated to my exceptional parents, adored siblings and uncles whose tremendous support and cooperation led me to this wonderful accomplishment and specially dedicated to my Grand Mother who always encouraged me to fly towards my dream"

ACKNOWLEDGMENTS

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RTI	Road Traffic Injuries
RTCs	Road Traffic Crashes
IIA	Independence of Irrelevant Alternative
MNL	Multinomial Logit
PBS	Pakistan Bureau of Statistics
PAMA	Pakistan Automotive Manufacturers Association
NHA	National Highways Authority
RDA	Rawalpindi Development Authority
WHO	World Health Organization
NHSTA	National Highway Traffic Safety Administration

ABSTARCT

Among motorized road users motorcyclists are more vulnerable to road traffic fatalities and injuries due to least protection offered. Motorcyclists are victim of one quarter of global road crash fatalities. In Pakistan there has been a disproportionate growth in vehicle population over last one decade particularly the vulnerable means of transport (motorcycles and auto rickshaw). In Pakistan motorcycles constitutes 61% of total registered vehicles and there has been a 371% growth in motorcycles in last on decade (2005-2015). In a single year (2015), 6,074 crashes involving motorcycles have been reported by Rescue 1122, a National Emergency Response Unit. Using motorcycle crash data for one year (July 2014 to June 2015) for Rawalpindi city, present study estimated a mixed logit model to investigate the factors influencing motorcycle cash injury severity. No injury, minor injury, major injury and fatal injury are used as four categories of motorcyclist injury to calibrate the model. Major factors that were considered for analysis include crash-specific factors, roadway geometric characteristics, and environmental conditions. It was revealed that probability of fatal/ major injury increases for crashes: involving middle age riders (25-50 years) and riders with no education, occurring on major arterial roads and road with posted speed limit of 70 kilometer per hour, involving a motorcycle and a heavy vehicle, involving collision with a fixed object, occurring during dry weather conditions, in the early morning hours, late afternoon and early evening hours. Also, probability of minor injury increases for crashes occurring on roads with posted speed limit of less than 50 kilometer per hour, crashes involving registered motorcycle, crashes involving

cheaper bikes (China manufactured), crashes on divided streets, crashes where at least one motorcycle and auto rickshaw was involved. The research findings suggest that besides measures to control/ reduce the risky behavior from motorcyclists (speeding, not using helmet and improper lane changes etc.), there is a need to lower speed limits on road with high motorcycle proportion, separation of motorcyclist from heavy vehicles and by removing dangerous fixed objects such as poles and trees from roadside. Besides data limitations this is the pioneer study on motorcycle crash injury severity in the country. Results are expected to generate more interest and discussion on motorcycle safety in the country and can be used by Rawalpindi Development Authority to enhance road safety in the city.

Chapter 1

INTRODUCTION

1.1 Background

Road users without a protective shield are called "Vulnerable Road User". This includes pedestrians, cycle and motorcycle users. Motorcycle being one of the most vulnerable road users, have the highest number of road traffic casualties. Approximately half of the fatalities on world’s roads are contributed by the ones with the least protection including motorcyclists (23%), pedestrians (22%) and cyclists (4%) (WHO, 2015). In particular, motorcyclists account for 34% of road fatalities in western Pacific and Southeast Asian countries, 20% in America and 9% in Europe, (WHO, 2015). Low and middle income countries like Pakistan have high road crash injuries and fatalities. In Pakistan about 79% of road traffic accidents involve motorcycles (Rescue1122, 2016). Low-powered vehicles have become the apex priority of Pakistanis due to poor economy, higher inflation and lack of adequate transportation infrastructure. In Pakistan there has been a disproportionate growth in vehicle population over last one decade particularly the vulnerable means of transport (motorcycles and auto rickshaw). In Pakistan motorcycles constitutes 61% of total registered vehicles and there has been a 371% growth in motorcycles in last on decade (2005-2015) (PBS, 2015). Annual motorcycle production in country has increased form eighty nine thousand in 1998 to 1.36 million in 2016 (PAMA, 2016). Rapid motorcycle growth combined with general disregard of traffic rules and safety has resulted in 137% increase in motorcycle crashes in last 7 years in Rawalpindi city (Rescue1122, 2016).

1.2 Motorcycle Injuries in Developing Countries

Motorcycle crash victims are higher in developing and low income countries as compared to developed countries (Ameratunga et al., 2006). It is extremely important and necessary to transfer effective counter measure strategies adopted by developed countries in order to reduce the rate of motorcycle injuries in developing countries (Lin and Kraus, 2009). However the interventions can be transferred successfully if the potential barriers, ground scenarios and causation to the problems are first thoroughly explored. There are significant differences in the traffic condition, usability and type of motorcycles between developed and developing countries (Lin and Kraus, 2009).

In developing countries motorcycles are extensively used as compared to other vehicular modes of transportation. Its rapid growth is attributed to its low cast, convenience in congestion and parking (Lin and Kraus, 2009). Registered motorcycles are also significantly higher in Asian countries particularly in Vietnam (95%), Taiwan (67%), China (63%) and Malaysia (60%) and are considered an essential mode of transportation (Radin et al., 1996; Zhang et al., 2004; Hung et al., 2006). Furthermore motorcycle crash injuries and fatalities are worth alarming in these countries (Thailand (80%), Malaysia (50%), Taiwan (50%) and Singapore (42%) (Wong et al., 1990; Radin et al., 1996; Ichikawa et al., 2003). In developed countries like Europe and America motorcycles are only 2% of the registered vehicles with high engine capacities and are generally used for leisure riding (Haworth, 2012; NHTSA, 2014).

In developing countries more congested and mixed traffic conditions including passenger cars, heavy vehicles, bikes, rickshaws and animal drawn carriages/carts are observed. Also, careless driving due to lack of training and education, low rate of using safety gadgets particularly helmets because of low policing are common issues in developing countries (Mohan, 1984; Sahdev et al., 1994; Li et al., 2008). The kind of motorcycle crashes and the type of injuries sustained by motorcycle riders in developing countries are in contrast to the developed countries due to potential differences in roadway environments. Therefore before implementing some expensive interventions like costly road projects, it is necessary to examine and analyze the conditions through empirical evidences as they might not be valid and feasible to the situation in developing countries (Forjuoh, 2003; Lin and Kraus, 2009). However some universally successful and widely effective interventions might be adopted directly like reducing and regulating the safe speed limits, enforcement of helmet use and licensing in order to reduce road traffic crashes involving motorcyclists (Forjuoh, 2003; Hyder et al., 2007; Lin and Kraus, 2009).

1.3 Problem Statement

Effective road safety measures can only be introduced if the extent of the problem and its underlying factors are thoroughly explored. Despite high motorcycle crash fatalities and injuries in Pakistan, very limited studies have focused on motorcycle safety. Significant research has been made on motorcycle safety in developed countries but there is significant difference in the level of exposure, motorcycle type and road environment. In US, Canada and Europe motorcycles with higher engine capacity are preferred and are occasionally used for leisure tours (Haworth, 2012), while in Pakistan low capacity motorcycles are extensively used for daily commuting by low and middle income families. Safety being the highest priority for all road users, such high percentage of motorcycle crashes is a major concern and requires the attention to explore risk factors contributing to motorcycle crash severity.

1.4 Research Objectives

The main objective of the study includes:

- To develop a mixed logit model for the injury severity analysis of motorcycle crashes in Pakistan
- To identify key factors responsible for motorcycle crashes in Pakistan.

1.5 Overview of the Study Approach

A detailed methodology was developed to successfully achieve the desired objectives (Figure 1.1). Major tasks included:

- A comprehensive study of previous studies on motorcycle crashes around the globe.
- Collection and collation of data.
- Study of various statistical approaches and selection of appropriate modeling framework.
- Estimation of mixed logit model for injury severity analysis.
- Analysis of results and discussion.
- Conclusions and recommendations.

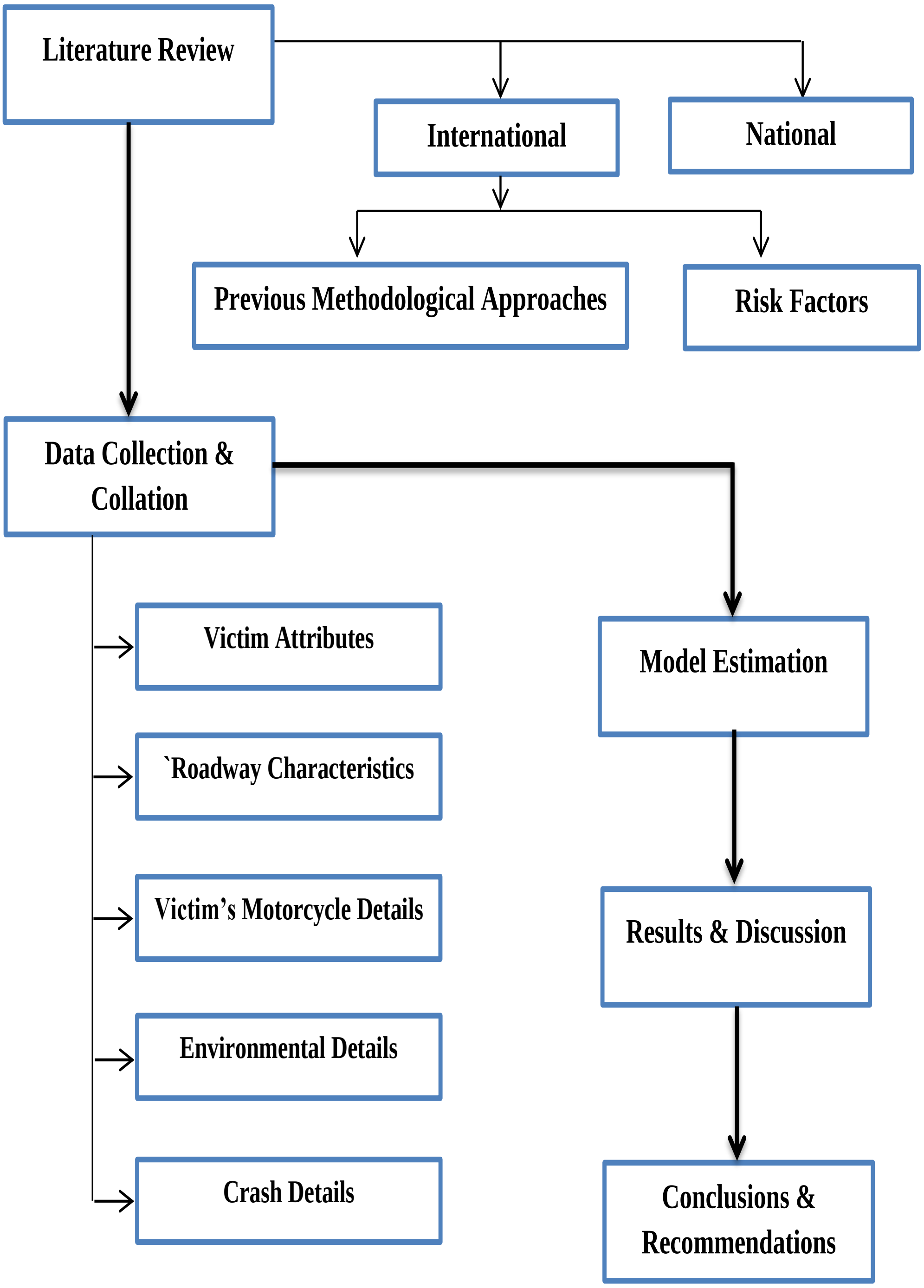

Figure 1.1: Overview of Study Approach

1.6 Organization of the Thesis

The thesis includes five chapters in which chapter 1 provides contextual information for the requirement to establish a framework for injury severity analysis followed by the problem statement and objectives of the research. Chapter 2 includes a comprehensive review of the past literature regarding injury severity analysis via econometric approaches and to understand the association of various parameters with the injury severity of the road crashes. Chapter 3 discusses the collection and collation of data used in present study. Chapter 4 discusses modeling framework, model estimation results and discussion. In the end, Chapter 5 presents research summary, conclusions and recommendations.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a brief review of methodological approaches and contributory risk factors to motorcyclist injury severities. Different analysis techniques adopted in the traffic safety research were found to have certain limitations and advantages which are discussed here. Choosing the right analysis approach to find determinants of crash severity outcomes based upon the data availability and the desired outputs can be a complex task.

2.2 Previous Methodological Approaches

Several modeling procedures have been applied in past to estimate motorcyclist's injury severity. Shankar and Mannering, (1996) utilized multinomial logit model and stated that MNL is a promising approach to study factors contributing to motorcycle injury severity. Quddus et al., (2002) used ordered probit approach to investigate injury severity and motorcycle damage severity in motorcycle crashes in-order to incorporate the ordinal nature of the severity outcomes. Savolainen and Mannering, (2007) identified potential drawbacks in applying ordered probability and multinomial logit models to injury severity analysis. The ordered probability approaches impose restrictions on extreme outcomes and influence outcome probabilities. On the other hand, multinomial logit model is susceptible to violate independence of irrelevant alternative (IIA) property. To overcome these limitations they estimated nested logit model to analyze injury severities in single and multi-vehicle motorcycle crashes. Rifaat et al., (2012) carried out motorcycle crash severity analysis in Calgary using ordered logit model, a heterogeneous choice model and a partially constrained generalized ordered logit model.

These traditional crash severity models do not allow explanatory variables to vary across individual outcomes. In reality, each individual outcome responds differently to explanatory variables and thus cannot be considered fixed. Also there are some unobserved factors affecting severity of crashes which are difficult to collect in a comprehensive manner. Ignoring these unobserved factors (referred as unobserved heterogeneity) could lead to biased parameter estimates and erroneous inferences (Mannering et al., 2016). To address the problem of unobserved heterogeneity, Shaheed et al., (2013); Shaheed and Gkritza, (2014) developed mixed logit model and latent class models to analyze motorcycle severity outcomes in two vehicle crashes and single vehicle crashes. Considering the strength and weaknesses of different methodological techniques and limitations in the available data for motorcycle crashes in Pakistan, mixed logit model was adopted to investigate determinants of motorcycle crashes.

2.3 Risk Factors

Researchers have identified various contributing risk factors that could possibility enhance severity of motorcycle crashes using predictive models. F These factors include: no-helmet use (Shankar and Mannering, 1996; Savolainen and Mannering, 2007; Schneider IV and Savolainen, 2011; Shaheed et al., 2013; Shaheed and Gkritza, 2014), high travelling speed (Shankar and Mannering, 1996; Savolainen and Mannering, 2007; Shaheed et al., 2013; Shaheed and Gkritza, 2014), motorcycles with larger engine capacity (Quddus et al., 2002; De Lapparent, 2006; Pai, 2009), increase in rider age (Savolainen and Mannering, 2007; Schneider IV and Savolainen, 2011), motorcyclist without valid driving license (Dandona et al., 2006), collision with heavy vehicle and stationary objects (Savolainen and Mannering, 2007; Schneider IV and Savolainen, 2011; Shaheed and Gkritza, 2014), riding in dark lighting condition (De Lapparent, 2006; Savolainen and Mannering, 2007; Shaheed et al., 2013; Chung et al., 2014), alcohol-impaired riding (Savolainen and Mannering, 2007; Schneider IV and Savolainen, 2011; Shaheed and Gkritza, 2014) and roads of higher functional classification (Quddus et al., 2002; Savolainen and Mannering, 2007; Eustace et al., 2011).

2.3.1 Speeding

Prior studies have identified speeding as the leading cause of motorcycle crashes that greatly increase the risk of severe injuries and fatalities. High speed at the time of crash was found more likely to cause serious motorcycle crash injuries (Shankar and Mannering, 1996; Quddus et al., 2002; Savolainen and Mannering, 2007). In single vehicle motorcycle crashes two-third of fatalities were related to speeding (Shankar, 2001). Helmet was found to be less effective in reducing fatal injuries with crash speed exceeding 50 kilometer per hour (Shibata and Fukuda, 1994).

2.3.2 Engine Size

Past studies have determined significant relationship between crash risk and motorcycle engine capacit. It was found that motorcycles with higher engine capacity were associated with sever crash injuries (Langley et al., 2000; Quddus et al., 2002; De Lapparent, 2006).

2.3.3 Age and Gender

Observable rider attributes such as age and gender were considered in several studies and were found to have major influence on crash injury severity and crash frequency. Past studies have identified that crash injury severity increases with increase in rider’s age ("Pai and Saleh, 2007; Savolainen and Mannering, 2007"). Quddus et al., (2002) found that older riders were more likely to be involved in fatal and severe injury crashes. This is attributed to deterioration in physical, audio-visual and mental capabilities of old riders. However younger motorcycle riders (below 25 years) had less probability of severe injuries in single vehicle motorcycle crashes (Shaheed and Gkritza, 2014). Similarly studies have also identified that female riders are more exposed to serious RTCs and were involved in severe motorcycle injuries compared to male riders due difference in driving behavior and riding experience (Savolainen and Mannering, 2007; Jones et al., 2013; Shaheed and Gkritza, 2014).

2.3.4 Roadway Type and Geometry

Roadway functional class and its associated road side objects have a major effect on motorcycle crash injuries. Roadways with higher fictional class and greater speed limits pose serious risks leading to severe motorcycle crash injuries (Quddus et al., 2002). Past studies showed that crashes on highways with posted speed limit above 55mph, collision with fixed road side objects and crashes on horizontal and vertical curvatures were more likely to result into major injuries (Savolainen and Mannering, 2007; Shaheed and Gkritza, 2014).

2.3.5 Helmet Use

No helmet use is a key risk factor that influences motorcyclist crash severity. A number of past studies have shown significant role of helmet use in reducing head injuries and fatalities (Shankar and Mannering, 1996; Shaheed et al., 2013; Shaheed and Gkritza, 2014). Helmet was found to reduce fatal injuries by 29 percent in the United States and increases the probability of no injuries by 50 percent (Savolainen and Mannering, 2007; Lin and Kraus, 2009).

2.4 National Research Studies on Motorcycle Crashes

Khan et al., (2008) investigated the use of helmet among motorcycle riders in Karachi using survey based data. “Study results showed that 56 percent of the respondents were using helmets in order to prevent their-self from injuries. Non-helmet users pointed out physical discomfort (44%) and limited vision (25%) as the major reasons of not wearing a helmet.

Ali et al., (2010) carried out a questionnaire based study using motorcycle crash victims presented in emergency department of three government hospitals in Karachi. Purpose of the study was to determine frequencies of corresponding risk factors to motorcycle crashes in Karachi. Frequencies of different risk factors found in the study were: riders younger than 33 years (76%), riders without valid driving license (49%), crash on major roads (71%), crash on working days (72%), crash speed greater than 50 km/hour (43%) and crash during evening time (61%).

Hashmi et al., (2012) assessed motorcyclist’s helmet use and safety awareness through a population based survey in Multan. Out of the total 1748 participants, 44 percent of the riders were without driving license and 83.3 percent had never used a helmet.

Yousaf et al., (2013) used hospital data to examine the pattern of orthopedic injuries in motorcycle crash victims in Faisalabad. It was found that majority of the victims were 21-30 years of age (31.7%), rate of no helmet use was 93.4 percent and head injuries were the most common along with orthopedic injuries.

Khan et al., (2015) and Ahmed et al., (2016) carried out two independent studies in Karachi and Lahore to analyze cloth related motorcycle injuries. It was found that majority of the victims were females (73.9%) and pillion riders (80.3%). Ahmed et al., (2016) also studied post-crash behavior of the victims after one month using phone call and found that 50.6 percent victims were using helmets.

Tahir et al., (2016) conducted a retrospective analysis on motorcycle one-wheeling using three years (2011-2013) crash data from Rescue 1122. Study result revealed that almost 70 percent of the victims were critically injured and none of the victim was wearing helmet. Study results showed that majority of the fatal injured victims were 16-25 years of age.

Chapter 3

DATA COLLECTION AND COLLATION

3.1 Crash Data

The study setting was Rawalpindi city, a predominantly urban district situated in the north of the province of Punjab, Pakistan. According to the 2017 census, the district had a population of 5.4 million. The crash data for current study were obtained from Rescue 1122 Headquarters Rawalpindi, a leading emergency response unit in the country. The reason behind obtaining data from Rescue 1122 was the underreporting of lower severity injuries in the police reported data, which leads to inconsistent coefficient estimates and biased parameters (Yamamoto et al., 2008). Around 30,000 emergency response forms were sorted out to extract the road traffic injuries (RTI) involving a motorcycle victim. The form included the demographic information of the victim such as age, gender, location, date and time of the crash, type of vehicle involved in the crash and motorcycle details. Weather data were obtained from Pakistan Meteorological Department, Islamabad and geometric information of the road segments were obtained from Rawalpindi Development Authority. Further missing geometric details were obtained by visiting individual road segments. Data were collected for a period of one year (July 2014 to June 2015). The final data set contained 5,311 observations after omitting records with missing details.

3.2 Data Description

Victim's actual injury at the scene of crash was noted in the emergency response form by the ambulance staff of rescue 1122, who are qualified emergency medical technicians having diploma in paramedics. Actual injuries are then categorized into 4 injury severity levels (no injury, minor injury, major injury and fatal injury) which are coded with the following options. The description of 4 levels of injury severity is given in Table 3.1

Table 3.1: Description of Crash Injury Severity Levels

Level	Definition	Description
1	No Injury	No harm to the body of the occupants occurred or just minor pain
2	Minor Injury	It extends no risk to the life of the affected person (i.e. abrasions, lacerations or minor cuts etc.)
3	Major Injury	It extends risk to the life of the affected person (i.e. neck, head, spinal injury and single or multiple fractures etc.)
4	Fatal Injury	It results in immediate fatality of the affected person.

Out of 5,311 observations there were 179 (3.37%) cases having no injuries, 3848 (72.45%) victims with minor injuries, 1234 (23.23%) victims with major injuries and 50 (0.94%) fatal injuries (Figure 3.1).

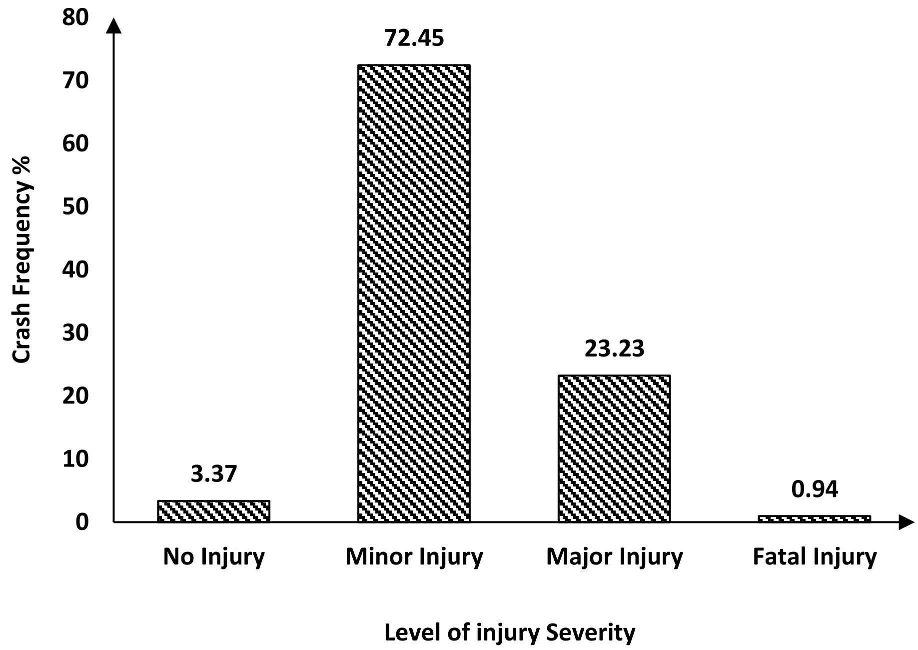

Figure 3.1: Injury Severity Distribution of Motorcycle Crashes in Rawalpindi

3.3 Data Attributes

Major factors that were considered for analysis include rider attributes, temporal details, motorcycle characteristics, environmental conditions, roadway characteristics and crash specific factors. Each of the mentioned characteristics contained certain variables which were included in the final dataset are presented in (Table 3.2). Crash injury severity was taken as the response variable whereas 74 explanatory variables were included in the final data set. All the variables (except roadway characteristics and environmental conditions) were extracted from emergency response form that contains 23 crash relevant queries.

Table 3.2: Classifications of Independent Variables

Variables Category	Explanatory Variables with Description
Rider Attributes	a) Rider type
	b) Gender
	c) Age
	d) Education level
Temporal Details	a) Crash month
	b) Crash Season
	c) Day type
	d) Time of the day
	e) Traffic hours
Environmental Conditions	a) Weather forecast
	b) Light condition
Motorcycle Characteristics	a) Manufacturing company
	b) Registration
	c) Engine CC
Roadway Characteristics	a) Roadway class
	b) Lanes per direction
	c) Presence of median
	d) Posted speed limit
Crash Specifications	a) Single vehicle crashes
	b) Collision with passenger car
	c) Collision with a motorcycle-rickshaw
	d) Collision with a heavy vehicle
	e) Hit to a fixed object
	f) Hit to an animal
	g) Hit to a pedestrian
	h) Collision at Intersection
Others	a) Presence of Pillion Rider
	b) Cloth stuck in wheel

3.4 Rider Attributes

3.4.1 Rider Type

Victims were categorized as drivers and pillion riders. Among total victim's 78.35 percent were motorcycle drivers while 21.65 percent were pillion riders (Figure 3.2). Out of total major and fatal injured victims, motorcycle drivers have the highest share of major (83.2%) and fatal injuries (84%) compared to pillion riders (Figure 3.4).

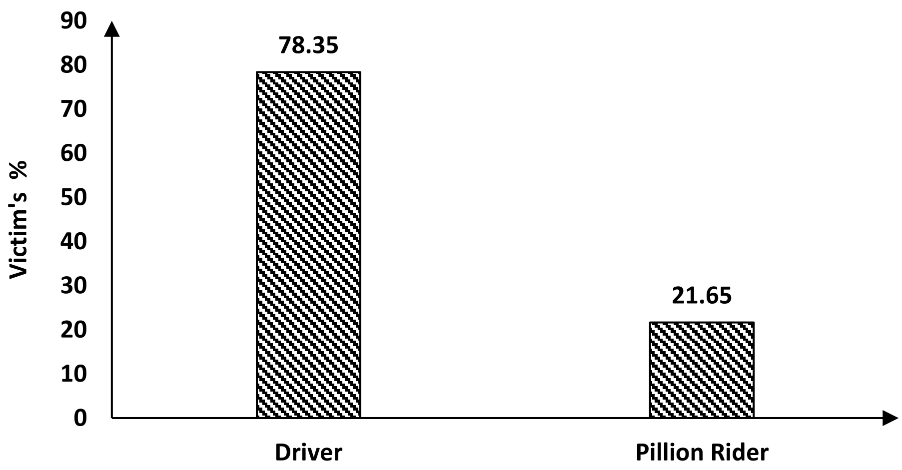

Figure 3.2: Frequency Distribution of Victims (type) Involved in Crash

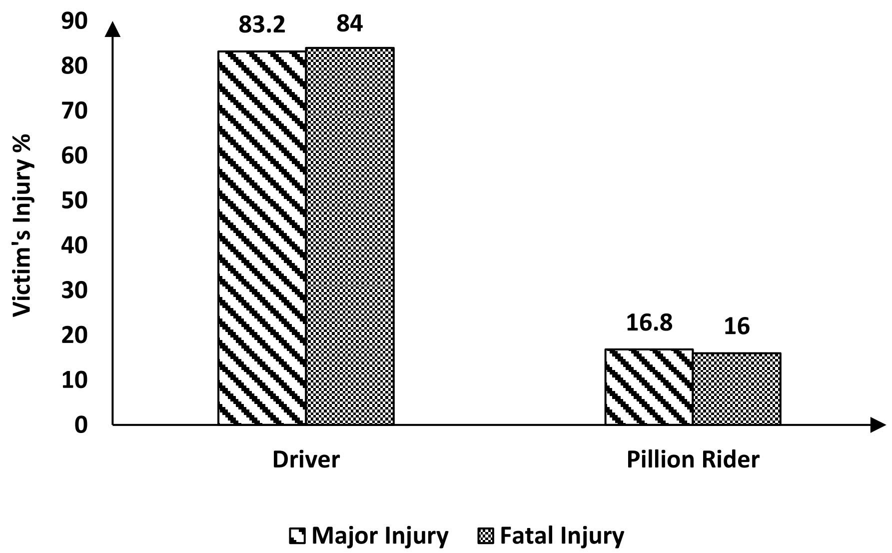

Figure 3.3: Comparative Injury Severity Distributions of Victims

3.4.2 Gender

Due to cultural and social constraints female motorcycle drivers are very few in Pakistan. In majority of the cases male ride motorcycle as driver while female as pillion rider, so female victim's here are primarily pillion rides. Due to excessive use of motorcycles, male victims are higher in percentage (90.83%) as shown in (Figure 3.4) with higher fatalities (96%) compared to female riders (Figure 3.5).

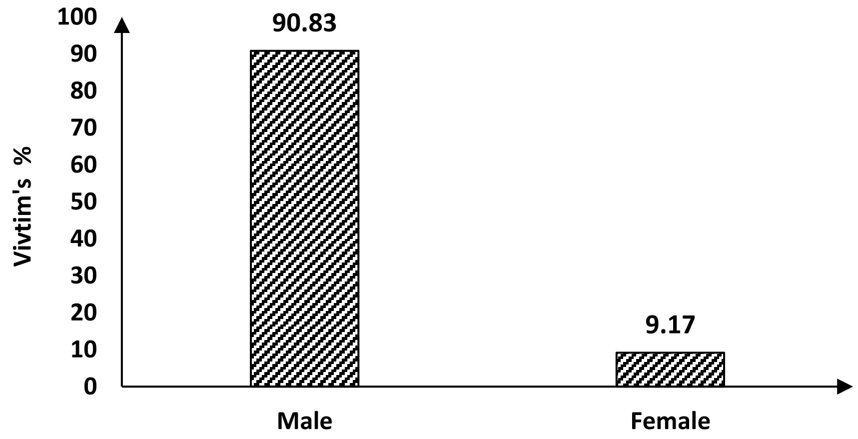

Figure 3.4: Gender-Wise Frequencies of Motorcycle Crash Victims

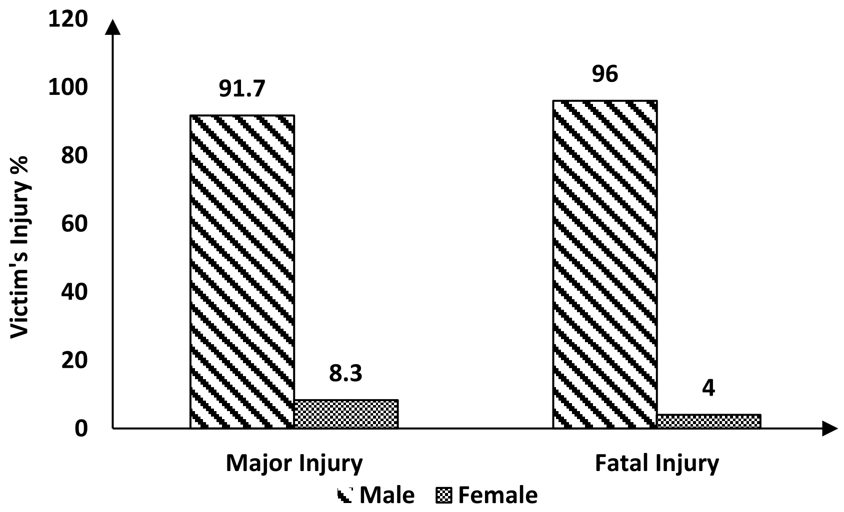

Figure 3.5: Gender-Wise Injury Severity Distributions of Victims

3.4.3 Age

Rider's age ware categorized into groups as: younger riders (below 25), middle age riders (25-50), and older riders (above 50). As per data majority of the riders were below the age of 50 years (93.9%) (Figure 3.6). Fatal and major injuries are also higher in younger and middle age riders (Figure 3.7).

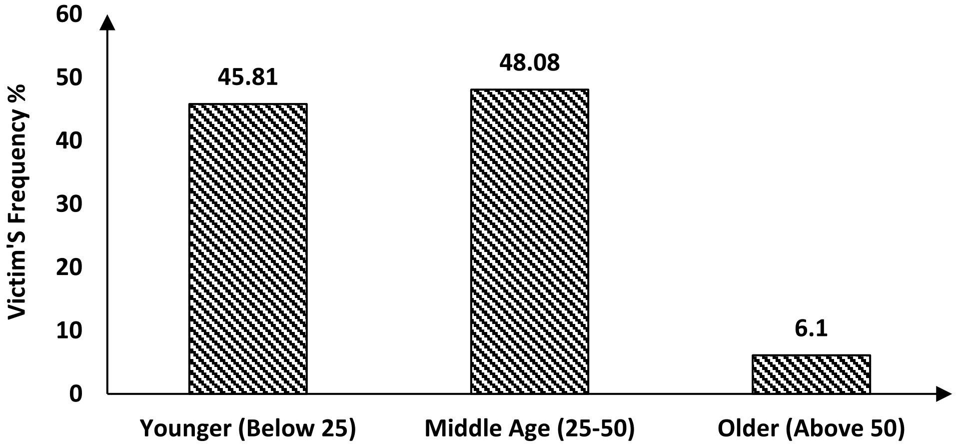

Figure 3.6: Age-Wise Frequency Distributions of the Victims

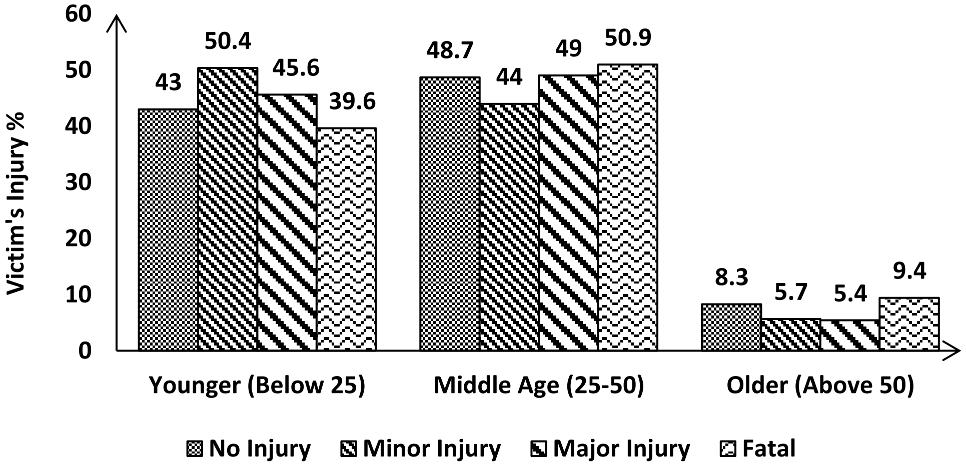

Figure 3.7: Age-Wise Injury Severity Distributions of the Victims

3.4.4 Education

Motorcycle is one of the affordable means of transport in Pakistan. It is used by people belonging to different educational backgrounds. Rider's education level includes; no education, middle (grade 8), matric (grade 10), intermediate (grade 12) and higher (grade 14 and above). Majority of the motorcycle crash victims were less educated (grade 10 and below) (Figure 3.8).

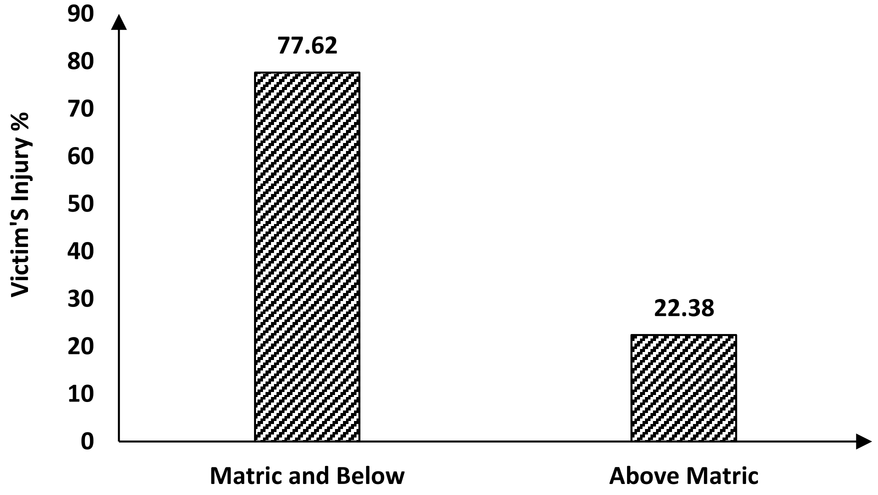

Figure 3.8: Victims Crash Frequencies on the Basis of Education Level

3.5 Temporal Details

Data were collected for a period of one year (July 2014 to June 2015). Temporal details of the data includes: crash month, crash season, day type, crash time and Traffic hours. As per the data fatalities were higher during the months of May (20%) and November (18%) (Figure 3.9). It was observed that crash rates were significantly higher on weekdays (71.91%) (Figure 3.10). In order to understand the seasonal variation of the crashes, data were classified into four seasons, summer and spring. Majority of the crashes occurred during summer season (35.91%) (Figure 3.12). Peak and off peak hours were defined based upon rush hours in the city as Morning Peak 7:30am to 10am, Evening Peak 4:30pm to 7pm. It was observed that crash frequency, major and fatal injuries were higher during off-peak hours (Figure 3.15).

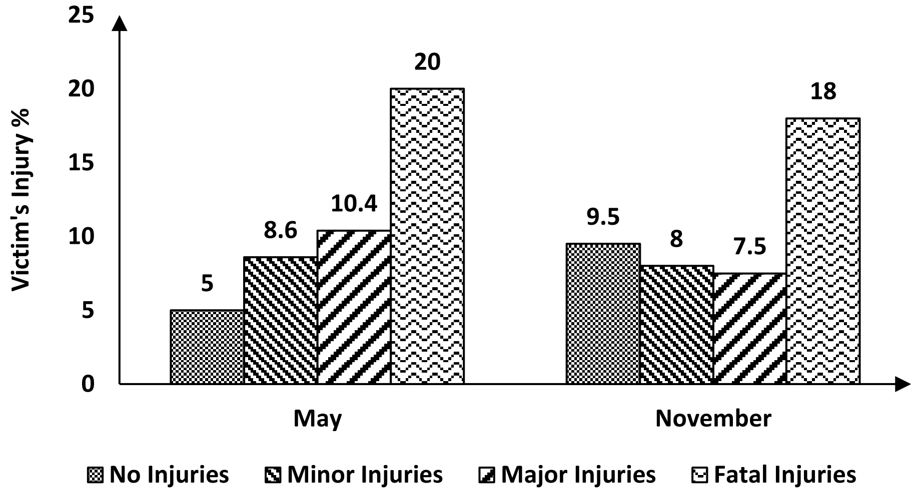

Figure 3.9: Comparative Injury Severity Distributions of May and November

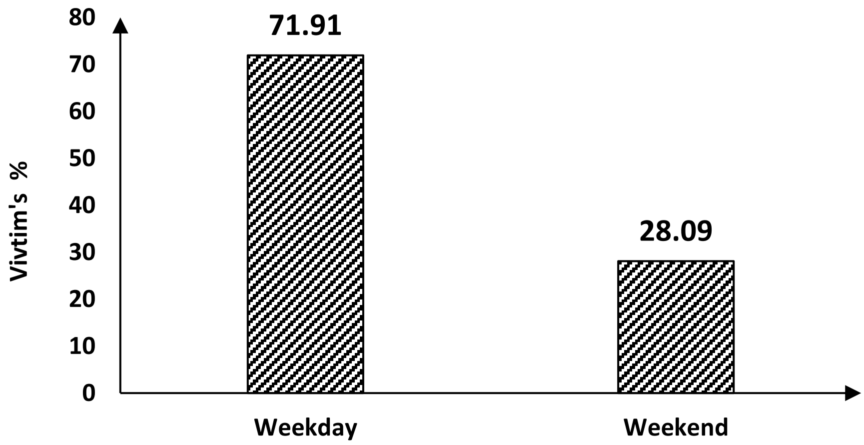

Figure 3.10: Crash Frequency Distribution of Victims on the Basis of Day Type

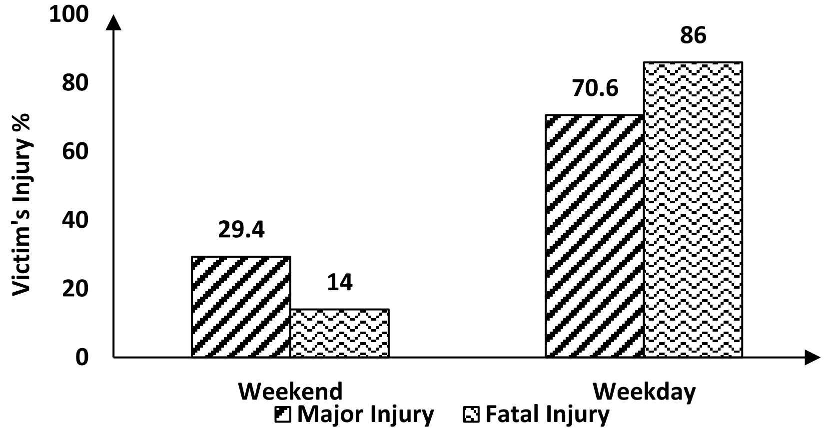

Figure 3.11: Victim’s Injury Severity Distribution on the Basis of Day Type

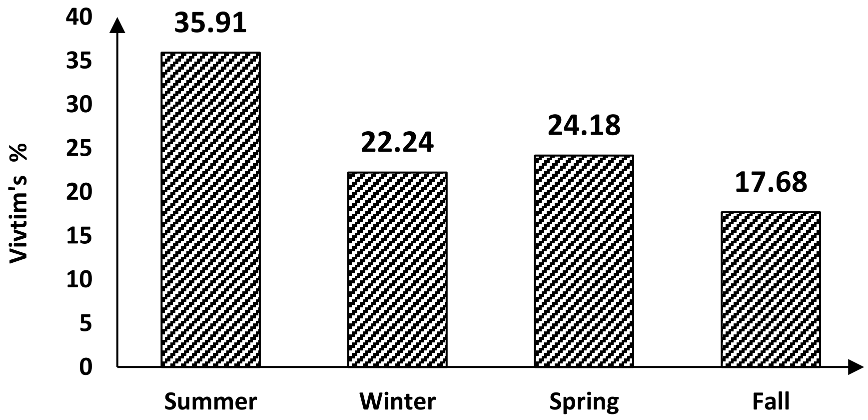

Figure 3.12: Season of the Year-Wise Crash Frequency Distribution of Victims

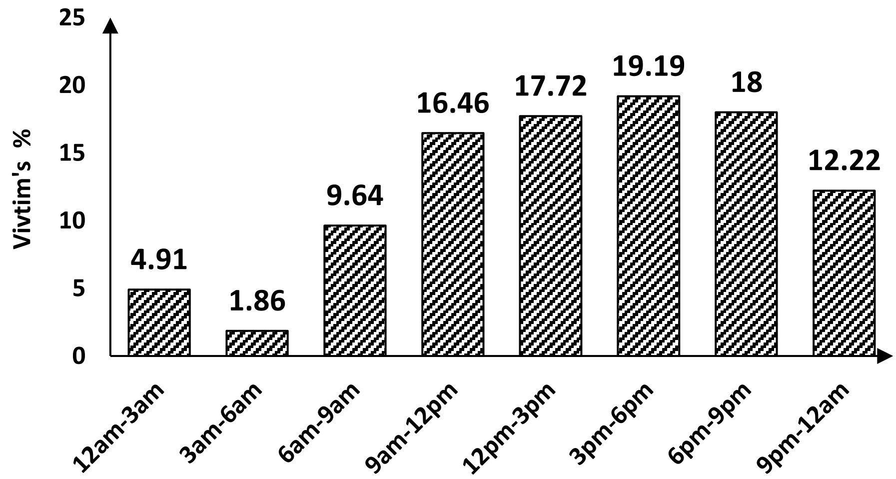

Figure 3.13: Crash Frequency Distribution of Victims on the Basis of Day Time

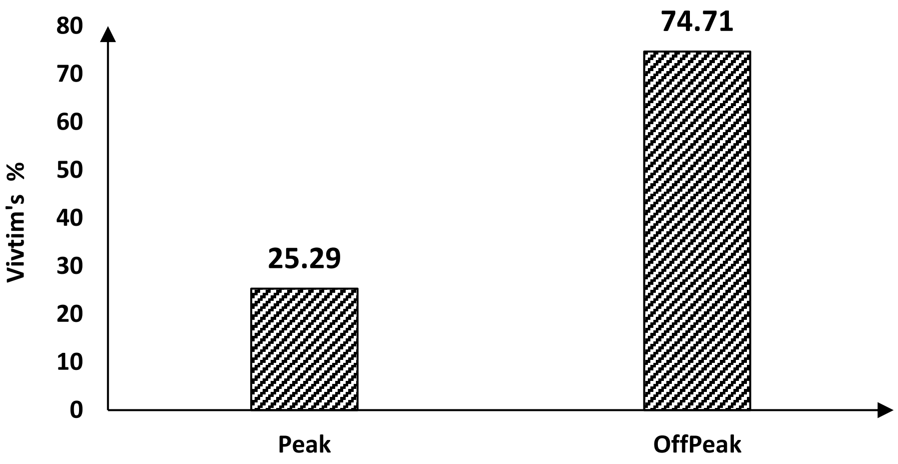

Figure 3.14: Crash Frequency Distribution of Victims on the Basis of Traffic Hours

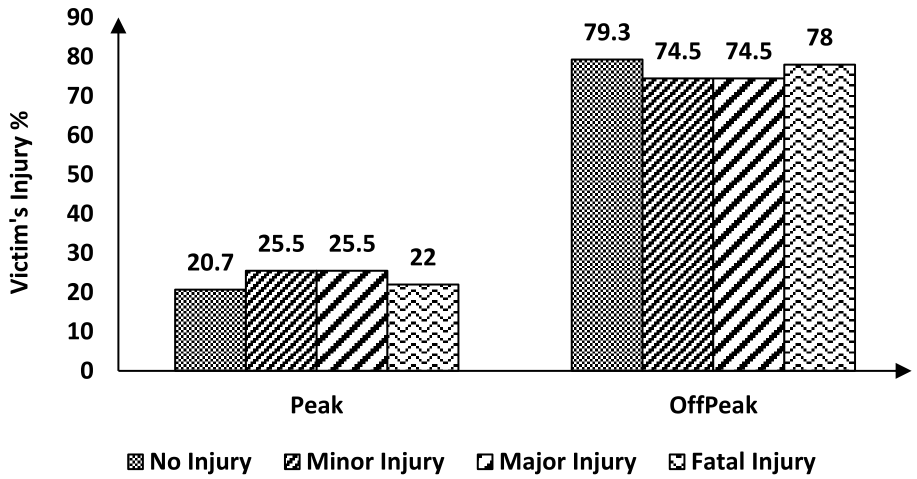

Figure 3.15: Victim’s Injury Severity Distribution on the Basis of Traffic Hours

3.6 Environmental Condition

Environmental conditions also affect driver capabilities and have a major influence on RTIs. The environmental factors included in the data were weather and light conditions at the time of crash. Weather data were categorized as “Dry” and “Rainy” weather, whereas light conditions were categorized into “Day light” and “Dark night” condition, keeping in view the sun rise and sunset timings around the year. As per the data crash frequency, major injuries and fatalities were higher during dry weather and day light conditions as shown in (Figure 3.16) and (Figure3.17).

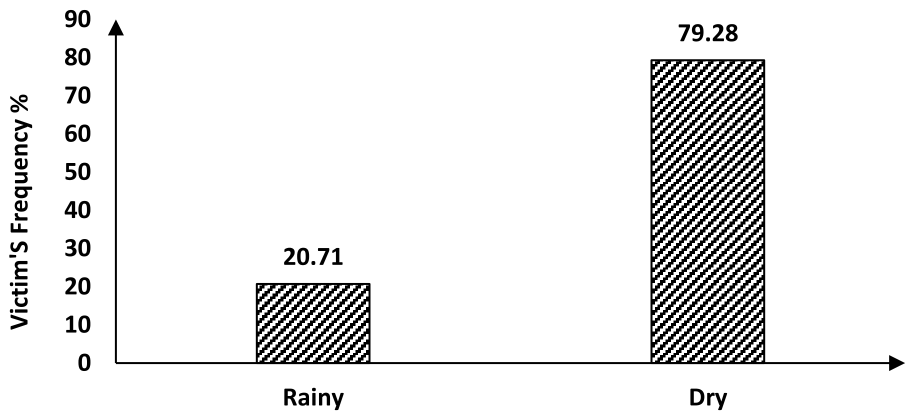

Figure 3.16: Crash Frequency Distribution of Victims on the Basis of Weather Condition

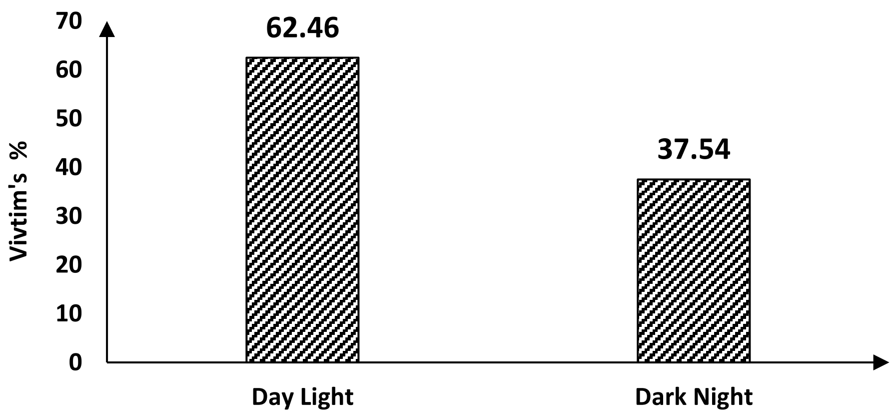

Figure 3.17: Frequency Distribution of Victims on the Basis of Light Conditions

3.7 Motorcycle Vehicle Details

The data also contained information regarding motorcycle manufacturing company, engine capacity and registration details of the motorcycle. There are more than 50 motorcycle manufacturing/ assembling companies in Pakistan. They were categorized into: 1) Chinese/Pakistani manufactured and/or assembled companies like united, union star, hi speed, hero etc. 2) Japanese manufactured companies like Honda, Yamaha, Suzuki and Kawasaki. In some of the observations victim's motorcycle information was unknown, they were categorized as "unknown motorcycle info". It was observed that crash distribution among Japanese manufactured and Chinese/Pakistani assembled motorcycles were almost similar. Victims with unknown motorcycle information were mostly involved in fatal crashes (38%) whereas Japanese manufactured motorcycles were mostly involved in major injury crashes (38.3%). As per the data low engine capacity motorcycles (70cc) were mostly involved in crashes (73%). In Pakistan 70cc have dominated the country roads due its high affordability in terms of its lower price, better fuel efficiency and low maintenance costs. It was reported that production of 70cc was more than 80% of the total market share that's why its involvement in crashes and fatalities are also higher (66%). Motorcycle Registration details were categorized into; 1) registered 2) un-registered. Registration details were obtained from the motorcycle registration number mentioned in the emergency response form. Victim's motorcycle was categorized as unregistered when motorcycle was either applied for registration or have no number plate. The data set revealed that (72.6%) registered motorcycles were involved in crashes.

3.8 Roadway Characteristics

Roadway characteristics included in the data were roadway functional class, number of lanes per direction, presence of median and posted speed limit. All relevant roadway details were obtained from the location information mentioned on the emergency response from. Roadway classifications on the basis of functional classes were: major arterials, minor arterials, collectors and local street roads. Major arterials included Grand Trunk road and Islamabad

Highway/Expressway whereas; minor arterial included IJP road, Murree road Airport road, Rawal road and Adyala road. Roads categorized as collectors were Misrial road, Dhamial road, Abid Majeed road, Stadium double road, Chakri road, Tulsa road, Kashmir road, Kahuta road, PWD double road, Saidpur road, 6th Road, 4th road, Khanna road, Kurri road, Chaklala road, Tipu road and Kallar Syedan road. Local Street roads were Shelly Valley road, Range road, Westridge road, Harley street road, service roads and roads running through residential areas. According to the data crash rate, fatalities and major injuries were higher on major arterials (Figure 3.18). The geometric information (i.e. the number of lanes, presence of median and posted speed limit) were obtained from RDA (Rawalpindi Development Authority) whereas roads with missing geometric information were visited to collect the necessary details. According to the data, roads with three lanes per direction had maximum number of motorcycle crashes (44.62%) (Figure 3.20). Speed limit has also a major contribution in road safety. Posted speed limit details for all roads were obtained by visiting those roads and were confirmed from RDA. It was observed that majority of the crashes occurred on roads with posted speed limit 70 kilometer per hour (Figure 3.22). They are also the leading contributor to fatal (58%) and major injured crashes (47.4%) (Figure 3.23). Most of the roads running through the city of Rawalpindi are median separated that’s why these roads accounts for the highest number of motorcycle crashes (80%).

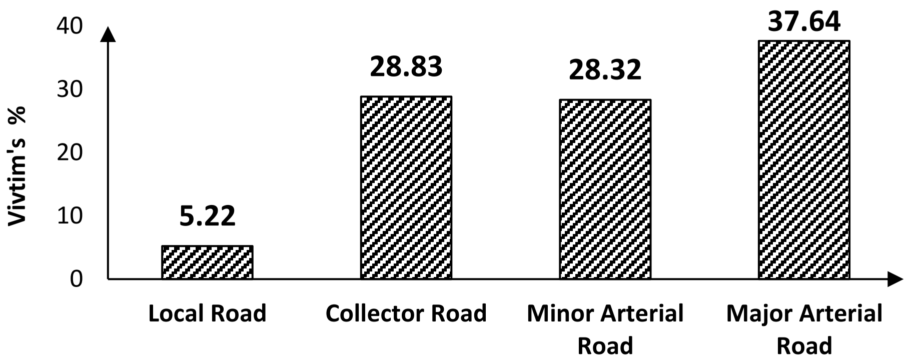

Figure 3.18: Motorcycle Crash Frequency Distribution on Roadway Class

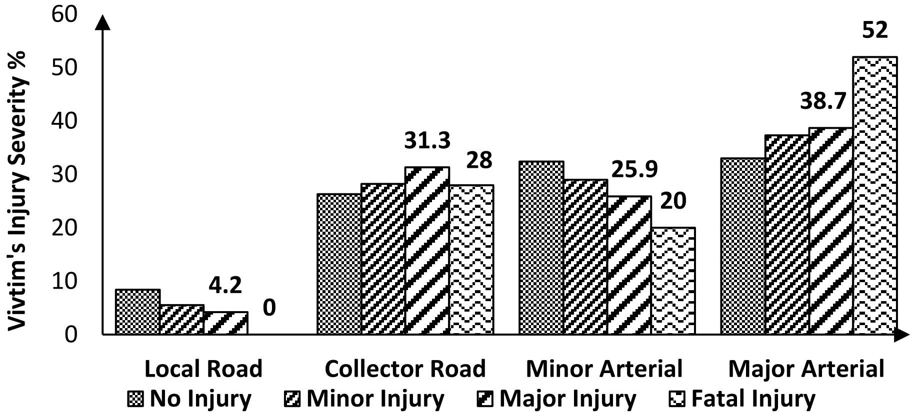

Figure 3.19: Crash Injury Severity Distribution of Victims on Roadway Class

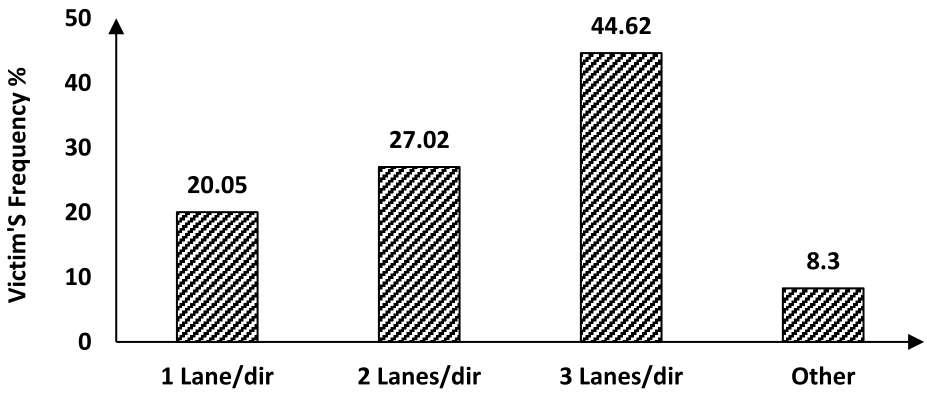

Figure 3.20: Number of Lanes per Direction vs Motorcycle Crash Frequency

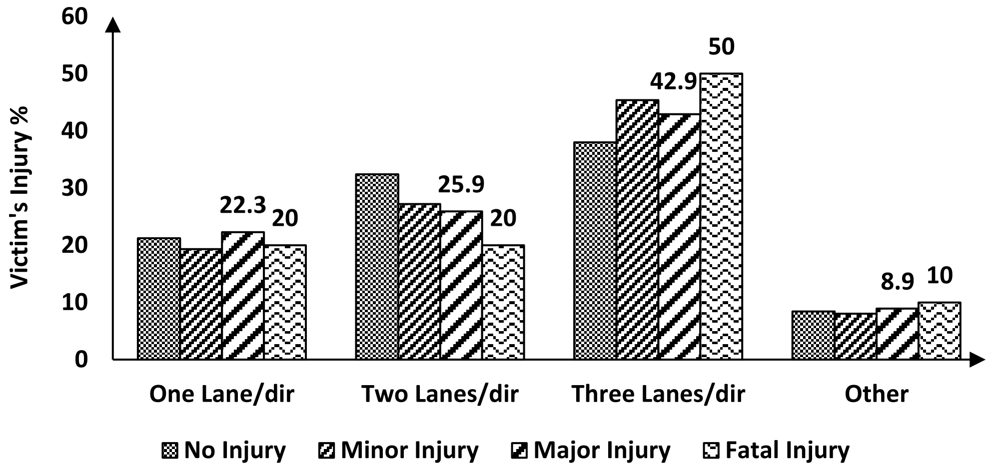

Figure 3.21: Injury Severity Distribution vs Number of Lanes per Direction on Road

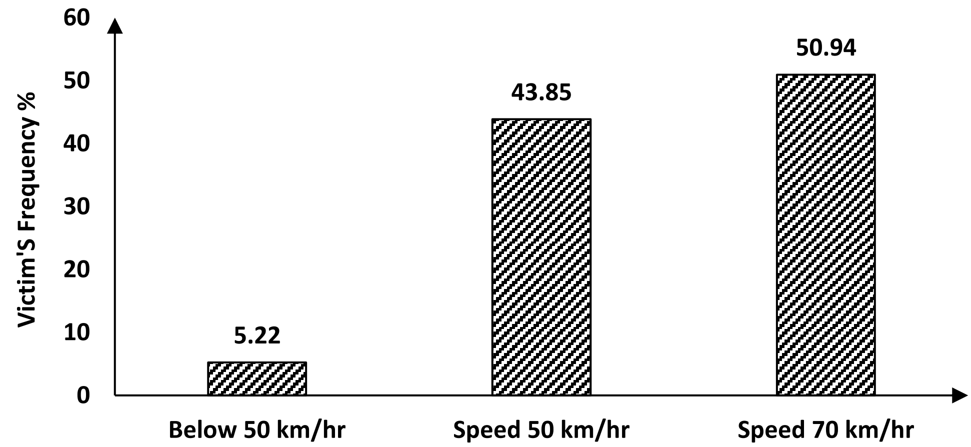

Figure 3.22: Crash Frequency vs Posted Speed Limit

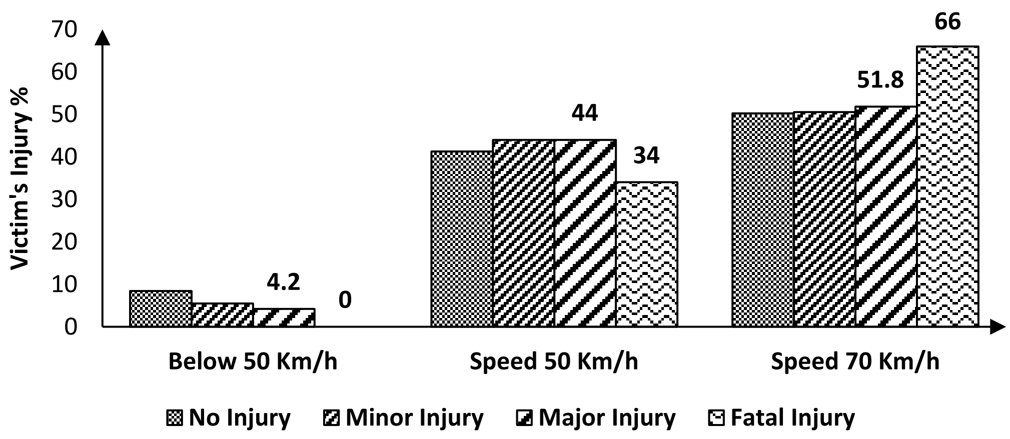

Figure 3.23: Injury Severity Distribution vs Posted Speed Limit

3.9 Crash Characteristics

Crash characteristics include: (1) the type of vehicle involved in crash (2) crash at intersection. On the basis of collision type crashes were classified into two broader categories such as single vehicle crashes, in which the motorcycle crash occurred with no other vehicle involved in collision. Single vehicle crashes included accidents like losing control over vehicle and falling, slipping of the motorcycle due to sudden application of breaks, running over debris or hitting to a median curb stone, and pillion passenger clothes stuck in wheel of the motorcycle etc. All other crashes involving any other vehicle like passenger car, truck or motorcycle were categorized into multi-vehicle crashes. According to the data multi-vehicle crashes accounted 56.8 percent of all crashes with maximum rate of fatal (78%) and major injuries (63.5%) (Figure 3.25). There are various types of vehicles operating on the roads, involving each one in an accident leads to different outcomes. In order to catch the effect of each collision vehicle, they were categorized as passenger cars (car, jeep, and van), heavy vehicles (bus, truck, tractor trolley, and trailer), motorcycles and rickshaws. Categorization was made for other types like motorcycle hit an object (wall, pole, and barrier), motorcycle hit a pedestrian. The data reveled that passenger car to motorcycle crashes were higher (31.48%) followed by motorcycle-rickshaw to motorcycle crashes (20.22%) (Figure 3.26). The passenger car to motorcycle crashes resulted into 36.8% of major injuries (Figure 3.27). Out of the total fatal injuries, 56% were when a motorcycle hit a heavy vehicle and 14% were when motorcycle hit an object (Figure 3.27). Cloth related crashes in motorcycles were also found in the data. It is one of the growing concerns in motorcycle safety particularly in Muslim populated countries like Pakistan. Following the religious guidelines and cultural norms females cover themselves with a chador or abaya. Females who are mostly riding motorcycles as pillion passengers, their clothes usually stuck in rear wheel of motorcycle. As a result the motorcyclist loses control and fell over causing serious injuries to the rider. As per data 76 percent of total cloth related victims were females.

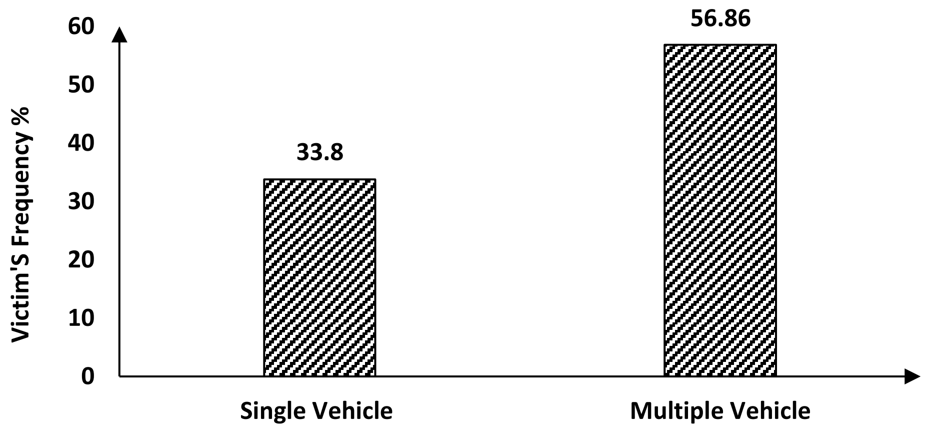

Figure 3.24: Frequency Distribution of Single Vehicle vs Multiple Vehicle Crashes

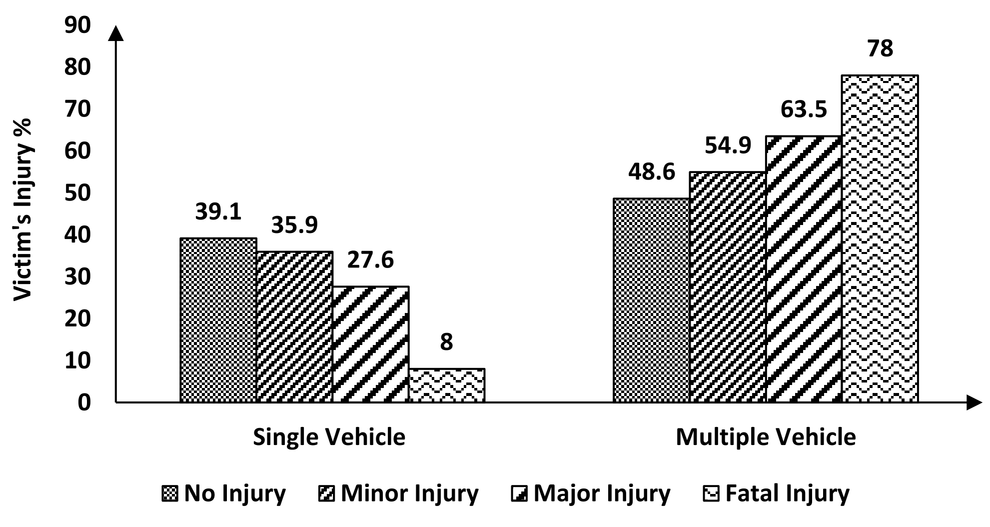

Figure 3.25: Injury Severity Distribution of Single Vehicle vs Multiple Vehicle Crashes

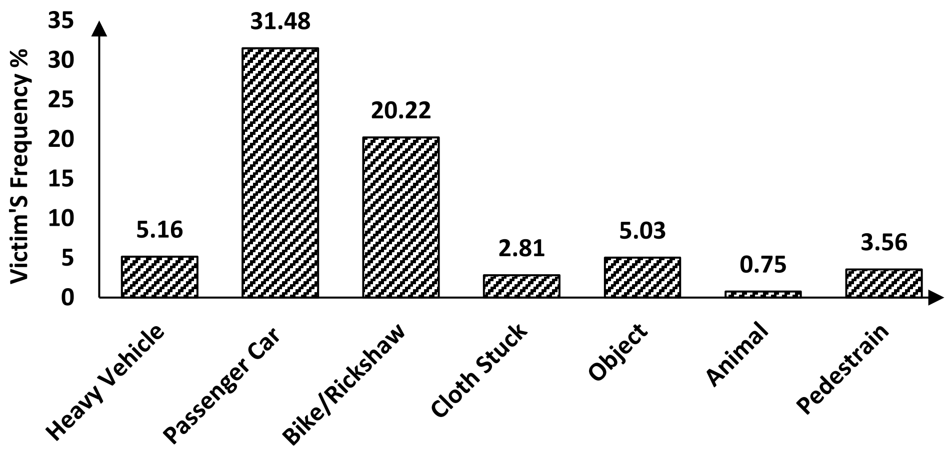

Figure 3.26: Frequency Distribution of Victims on the Basis of Collision Party

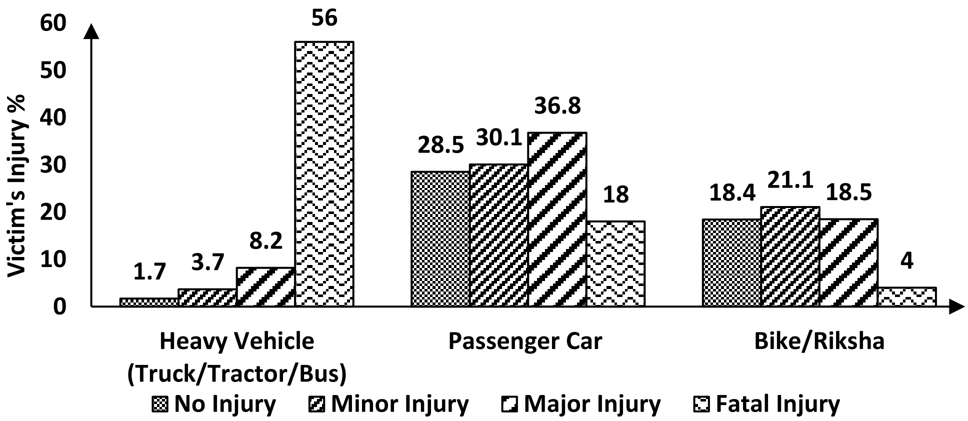

Figure 3.27: Injury Severity Distribution of Victims on the Basis of Collision Vehicle

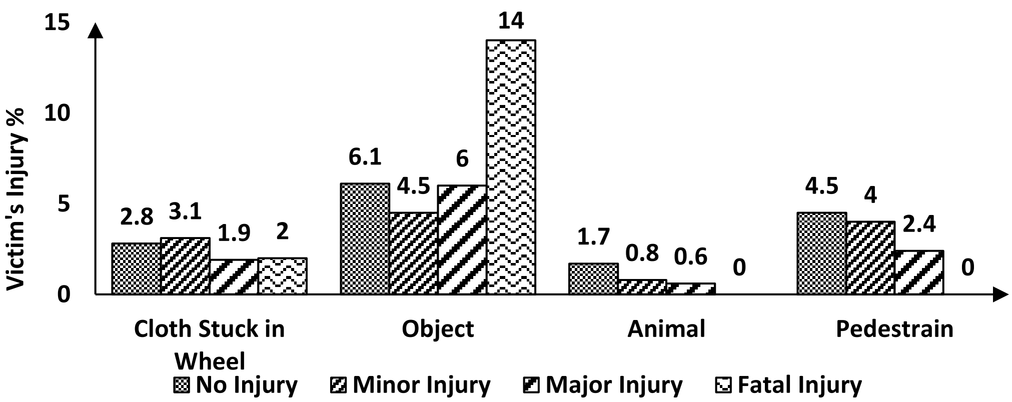

Figure 3.28: Injury Severity Distribution of Victims on the Basis of Collision Party

Table 3.3: Descriptions of Response and Explanatory Variables

Sr. No	Selected variables description
1.	**Crash injury severity**: 1) no injury 2) minor injury 3) major injury 4) fatal injury
2.	**Rider type indicator**: 1 if rider is driver, 0 otherwise
3.	**January indicator**: 1 if crash month is January, 0 otherwise
4.	**February indicator**: 1 if crash month is February, 0 otherwise
5.	**March indicator**: 1 if crash month is March, 0 otherwise
6.	**April indicator**: 1 if crash month is April, 0 otherwise
7.	**May indicator**: 1 if crash month is May, 0 otherwise
8.	**June indicator**: 1 if crash month is June, 0 otherwise
9.	**July indicator**: 1 if crash month is July, 0 otherwise
10.	**August indicator**: 1 if crash month is August, 0 otherwise
11.	**September indicator**: 1 if crash month is September, 0 otherwise
12.	**October indicator**: 1 if crash month is October, 0 otherwise
13.	**November indicator**: 1 if crash month is November, 0 otherwise
14.	**December indicator**: 1 if crash month is December, 0 otherwise
15.	**Weekday indicator**: 1 If crash occurs on weekdays, 0 otherwise
16.	**Summer indicator**: 1 if crash occurs in summer season, 0 otherwise
17.	**Winter indicator**: 1 if crash occurs in winter season, 0 otherwise
18.	**Spring indicator**: 1 if crash occurs in spring season, 0 otherwise
19.	**Fall indicator**: 1 if crash occurs in fall season, 0 otherwise
20.	**Dry Indicator**: 1 if crash occurs in dry weather condition, 0 otherwise
21.	**Rainy Indicator**: 1 if crash occurs in rainy weather condition, 0 otherwise
22.	**Light condition indicator**: 1 if crash occurs at dark night condition,0 otherwise
23.	**12am-3am indicator**: 1 if crash occurs between 12am to 3am, 0 otherwise
24.	**3am-6am indicator**: 1 if crash occurs between 3am to 6am, 0 otherwise
25.	**6am-9am indicator**: 1 if crash occurs between 6am to 9am, 0 otherwise
26.	**9am-12pm indicator**: 1 if crash occurs between 9am to 12pm, 0 otherwise
27.	**12pm-3pm indicator**: 1 if crash occurs between 12pm to 3pm, 0 otherwise
28.	**3pm-6pm indicator**: 1 if crash occurs between 3pm to 6pm, 0 otherwise
29.	**6pm-9pm indicator**: 1 if crash occurs between 6pm to 9pm, 0 otherwise
30.	**9pm-12am indicator**: 1if crash occurs between 9pm to 12am, 0 otherwise
31.	**Peak hours indicator**: 1 if crash occurs during peak hours, 0 otherwise
32.	**Single lane indicator**: 1 if crash occurs on two lane two way road , 0 otherwise
33.	**Two lanes indicator**: 1 if crash occurs on roads with two lanes per direction, 0 otherwise

Sr. No	Selected variables description
34.	**Three lanes indicator**: 1 if crash occurs on roads with three lanes per direction, 0 otherwise
35.	**Four lanes indicator**: 1 if crash occurs on roads with four lanes per direction, 0 otherwise
36.	**Five lanes indicator**: 1 if crash occurs on roads with five lanes per direction, 0 otherwise
37.	**Intersection indicator**: 1 if crash occurs at intersection/u turn, 0 otherwise
38.	**Major arterial indicator**: 1 if crash occurs on major arterials, 0 otherwise
39.	**Minor arterial indicator**: 1 if crash occurs on minor arterials, 0 otherwise
40.	**Collector indicator**: 1 if crash occurs on collector roads, 0 otherwise
41.	**Local indicator**: 1 if crash occurs on local street road, 0 otherwise
42.	**Below 50kmph indicator**: 1 if crash occurs on road with posted speed limit < 50kmph, 0 other wise
43.	**50kmph indicator**: 1 if crash occurs on road with posted speed limit 50kmph, 0 other wise
44.	**70kmph indicator**: 1 if crash occurs on road with posted speed limit 70kmph, 0 other wise
45.	**Below 25 indicator**: 1 if victim's age is below 25 years, 0 otherwise
46.	**25-50 indicator**: 1 if victim's age is between 25-50 years, 0 otherwise
47.	**26-45 indicator**: 1 if victim's age is between 26-45 years, 0 otherwise
48.	**Above 45 indicator**: 1 if victim's age is above 45 years, 0 otherwise
49.	**Gender indicator**: 1 if gender is male , 0 otherwise
50.	**No education indicator**: 1 if victim has no education, 0 otherwise
51.	**Primary indicator**: 1 if victim's education is primary (grade 6), 0 otherwise
52.	**Middle indicator**:1 if victim's education is middle (grade 8), 0 otherwise
53.	**Matric indicator**: 1 if victim's education is matric (grade 10), 0 otherwise
54.	**Intermediate indicator**: 1 if victim's education is intermediate (grade 12), 0 otherwise
55.	**Higher indicator**: 1 if victim's education is higher (grade 14 and above), 0 otherwise
56.	**Registration indicator**: 1 if victim's motorcycle is registered,0 otherwise
57.	**Japanese manufactured indicator**: if victim's motorcycle is Honda/ Yamaha/ Suzuki/ Kawasaki, 0 otherwise
58.	**Chinese manufactured indicator**: 1 if victim's motorcycle is Hero /United /Union star/ Zxmco etc, 0 otherwise
59.	**Unknown motorcycle indicator**: 1 if motorcycle's manufacturing company is unknown, 0 otherwise
60.	**70CC indicator**: 1 if victim's motorcycle engine is 70cc, 0 otherwise
61.	**High Engine indicator**: 1 if victim's motorcycle engine is more than 70cc, 0 otherwise
62.	**Unknown engine indicator**: 1 if victim's motorcycle engine is unknown,0 otherwise

Sr. No	Selected variables description
63.	**Single vehicle indicator**: 1 if crash occurred with no other vehicle involved, 0 otherwise
64.	**Multi-vehicle Indicator** : 1 if other vehicle was involved in crash, 0 otherwise
65.	**Heavy vehicle indicator**: 1 if collision with a heavy vehicle (Truck/Tractor/Bus) occurs, 0 otherwise.
66.	**Passenger car indicator**: 1 if collision with a passenger car occurs, 0 otherwise
67.	**Motorcycle-Rickshaw indicator:** 1 collision with a motorcycle-rickshaw occurs, 0 otherwise
68.	**Cloth related indicator**: 1 if crash was due to pillion clothes stuck in rear wheel of the motorcycle, 0 otherwise
69.	**Object indicator**: 1 if motorcycle hit an object, 0 otherwise
70.	**Animal indicator**:1 if motorcycle hit an animal, 0 otherwise
71.	**Pedestrian indicator**: 1 if motorcycle hit a pedestrian, 0 otherwise
72.	**Pillion indicator**: 1 if pillion rider was present, 0 otherwise

Table 3.4: Descriptive Statistics of Significant Independent Variables

Variable	**Mean**	**Std. Dev.**
Dry weather Indicator	0.624	0.484
Speed below 50 indicator	0.049	0.212
Pillion rider indicator	0.364	0.481
December indicator	0.076	0.265
Motorcycle-Rickshaw indicator	0.202	0.402
Chinese motorcycle indicator	0.356	0.479
Registration indicator	0.726	0.446
70kmph indicator	0.462	0.499
6am-9am indicator	0.096	0.295
Median indicator	0.800	0.399
May indicator	0.090	0.286
August indicator	0.083	0.276
3pm-6pm indicator	0.192	0.394
Heavy vehicle indicator	0.052	0.221
25-50 indicator	0.481	0.499
Object collision indicator	0.050	0.219
Passenger car indicator	0.315	0.464
Weekday indicator	0.719	0.449
No education indicator	0.131	0.337
November indicator	0.080	0.271
Major arterial indicator	0.038	0.484
Local Road indicator	0.052	0.222

Table 3.5: Descriptions of Data Variables

Variables	**Percentage**
Crash Severity	
No injury/Minor injury/Major injury/Fatal	3.37/72.45/23.23/0.94
Month of Year	
Jan/Feb/Mar/Apr/May/Jun/Jul/Aug/Sep/Oct/Nov/Dec	7.72/6.89/6.83/8.36/8.98/9.94/9.62/ 8.28/8.06/9.68/8/7.63
Day of Week	
Mon/Tue/Wed/Thu/Fri/Sat/Sun	13.29/14.61/14.65/13.37/15.99/ 14.12/13.97
Weekday/Weekend	71.91/28.09
Weather Forecast	
Dry/Cloudy/Rainy	62.49/16.79/20.71
Season of the Year	
Summer (June, July, August)/Winter (September, October, November)/Spring (December, January, February)/Fall (March, April, May)	35.91/22.24/24.18/17.68
Time of the Day	
12am-3am/3am-6am/6am-9am/9am-12pm/12pm-3pm/3pm-6pm/6pm-9pm9pm-12am	4.91/1.86/9.64/16.46/17.72/19.19/1 8/12.22
Peak(7am to 10am, 4pm to 7pm)/off-peak hours	25.29/74.71
Roadway Type	
Major Arterial /Minor Arterial /Collector /Local	37.64/28.32/28.83/5.22
Posted Speed Limits	
70kmph/50kmph/below 50kmph	50.94/43.85/5.22
Rider Details	
Driver/Pillion Rider	78.35/ 21.65
Age: Below 25yrs/25-50yrs/Above 50yrs	45.81/48.08/6.1
Gender: Male/Female	90.83/9.17
Education	
Below Matric/Matric/Above Matric	37.89/39.73/22.39
Motorcycle Information	
Registered/unregister or unknown	72.6/27.4
Manufacturing Company	
Japanese (Honda, Yamaha, Suzuki) /Chinese Bike (Hero, United/ Union Star. Etc.) /Unknown	37.9/35.7/26.4
Engine CC	
70CC/Above 70CC/Unknown	73.06/14.71/12.24
Crash Characteristics	
Single vehicle /Multi-vehicle Crash	43.14/56.86
Heavy Vehicle/Passenger Car /Bike & Rickshaw/Cloth Stuck in Wheel/Object/Animal/Pedestrian	5.16/31.48/20.22/2.81/5.03/0.75 /3.56
Pillion Rider: Present/Not Present	36.41/63.59

Chapter 4

STUDY METHODOLOGY AND MODEL ESTIMATION RESULTS

4.1 Introduction

The statistical analysis of crash data typically addresses the likelihood of a crash and its resulting injury severity. The likelihood of a crash is often analyzed by considering the number of observed crashes occurring at a definite time period. Once a crash is observed, the injury severities of involved individuals are often modeled as discrete outcomes, for example, no injury, minor injury, major injury, and fatality (Savolainen et al., 2011; Mannering and Bhat, 2014).

4.2 Mixed Logit Model

Considering the strengths and weaknesses of different methodological approaches adopted in crash severity analysis, we applied mixed logit model to estimate significant contributory factors to injury severity of motorcycle crashes. Due to unavailability of certain variables that could affect motorcyclist's severity outcome like helmet use, driving license, motorcycle mechanical condition, reason of crash, type of crash, road and traffic condition at the time of crash, speed of colliding vehicles and driving behavior (physiological differences, reaction time and level of aggression). These factors constituting unobserved heterogeneity can affect the impact of observed variables on injury severity and can lead to biased parameter estimates and erroneous inferences (Mannering et al., 2016). Mixed logit model can accommodate the problem relevant to unobserved heterogeneity.

The parameters values are allowed to vary across observations in mixed logit model. Following Milton et al., (2008) the severity function determining motorcycle injury severity outcome is defines as:

$$M_{in} = \beta_i X_{in} + \varepsilon_{in} \qquad (1)$$

M_{in} is a motorcyclist crash severity function determining severity for category i (no injury, minor injury, major injury, fatality) for crash n; X_{in} is a vector of measurable explanatory characteristics (rider/ collision/ vehicle/ weather/ temporal-specific variables); β_i is a vector of estimable parameter for discrete outcome i; and ε_{in} is an error term (generalized extreme value distributed) (McFadden, 1981). Following McFadden, (1981) ε_{in} are assumed to be extreme value distributed, then standard multinomial logit model results such that:

$$P_n(i) = \frac{EXP[\beta_i X_{in}]}{\sum EXP[\beta_I X_{in}]} \qquad (2)$$

Where $P_n(i)$ is the probability of crash severity outcome i for crash n and I denoting a set of all crash severity outcomes. A mixing distribution is introduced in the multinomial logit model to allow parameter variation across individual crashes. The outcome specific constants and the elements of β_i may be either fixed or randomly distributed over all parameters with fixed means. This will allow for the unobserved heterogeneity in the crash data. The model formulation (with a mixing distribution) giving crash severity outcome probabilities are as follows (McFadden and Train, 2000):

$$P_{in} = \int_x P_n(i) f(\beta/\varphi) d\beta \qquad (3)$$

Where $f\ (\beta/\varphi)$ is the density function of β with φ referring to a vector of parameters of the density function (mean and variance), and all other terms as previously defined. Eq. (3) represents the mixed logit model formulation. The density function $f\ (\beta/\varphi)$ is utilized to determine β, which can account for the unobserved heterogeneity (Milton et al., 2008). The probabilities are approximated by drawing values of β from $f\ (\beta/\varphi)$ for given values of φ. Simulated maximum likelihood approach is employed to estimate mixed logit model in Eq. (3) using Halton draws (Train, 2009). Previous studies have identified that Halton draws are more effective than random draws. We used 200 Halton draws for our model estimation which are sufficient for accurate parameter estimation as per prier studies (Milton et al., 2008; Anastasopoulos and Mannering, 2009; Savolainen, 2016). Among several other distributions for the random parameters normal distribution offer the best statistical fit for functional form of parameter density function which is consistent with past studies (Shaheed et al., 2013; Behnood and Mannering, 2016).

4.3 Model Estimation Results

Discrete choice probability models (ordered and unordered) are well suited for such categorical dependent variable. However ordered probability models impose restrictions on extreme outcomes of the response variables which can potentially leads to biased parameter estimates (Savolainen et al., 2011). Furthermore conventional probability models assume coefficients to be fixed across all outcomes of the response variables which seem arbitrary. These conventional models i.e. (ordered probit, multinomial logit) require a detailed data for predicting the contributing factors to the injury severity. Pakistan like other low and middle income countries have poor data collection and management system regarding road crashes that is considered a leading barrier in precise estimation of the models to predict the root cause to the scenario therefore in the present study mixed logit model technique have been adopted, which have the ability to reduce the problems relevant to limited data resources and most importantly can account for the unobserved heterogeneity.

Mixed logit model estimation results are shown in Table 5.1. Whereas direct and cross marginal effects of corresponding mixed logit model for injury severity of motorcycle crashes are shown in Table 5.2. All parameters were statistically significant at a 90% confidence level and higher. If the standard errors of the parameters under the assumed distribution were statistically significant, the parameters were considered random. Parameters were found fixed across observations if the standard errors of the parameter estimates were not statistically different from zero. Normal distribution appeared to provide the best statistical fit for these random parameters. Parameter found to be random were: 1) Constant for fatal injury outcome 2) registered motorcycle indicator 3) Chinese manufactured motorcycle indicator 4) motorcycle / rickshaw collision indicator. All the parameters found significant are discussed below.

Table 4.1: Mixed Logit Model Estimation Results for Motorcycle Crash Severity Outcomes

Variable	Parameter Estimate	t-Stat
Fatal Injury		
Constant (Standard error of parameter distribution)	-11.57 (4.050)	-3.071 (2.572)
Weekday indicator (1 If crash occurred on weekdays, 0 otherwise)	1.832	2.177
No education indicator (1 if rider has no education, 0 otherwise)	2.745	2.960
May indicator (1 if crash occurred in the month of May , 0 otherwise)	2.369	2.646
November indicator (1 if crash occurred in the month of November , 0 otherwise)	1.985	2.242
Major arterial indicator (1 if crash occurred on major arterials, 0 otherwise)	1.211	1.907
Motorcycle-Rickshaw collision indicator (1 if crash included a motorcycle and rickshaw, 0 otherwise)	-3.013	-2.315
Motorcycle registered indicator (1 if victim's motorcycle is registered,0 otherwise) (Standard error of parameter distribution)	-2.192 (1.524)	-2.932 (2.849)
Major Injury		
Constant	-0.870	-6.645
70kmph indicator (1 if crash occurred on road with posted speed limit of 70 kilometer per hour, 0 otherwise)	0.191	1.895
Passenger car indicator (1 if motorcyclist collided with a passenger car, 0 otherwise)	0.606	5.858
25-50 years indicator (1 if age of the rider is between 25-50 years, 0 otherwise)	0.246	2.821
6am-9am indicator (1 if crash occurred between 6am to 9am, 0 otherwise)	0.262	1.817
3pm-6pm indicator (1 if crash occurred between 3pm to 6pm, 0 otherwise)	0.350	3.079
May indicator (1 if crash occurred in the month of May, 0 otherwise)	0.426	2.830
August indicator (1 if crash occurred in the month of August, 0 otherwise)	0.391	2.635
Median indicator (1 if crash occurred on median divided road, 0 otherwise)	-0.508	-3.799

Variable	Parameter Estimate	t-Stat
Object collision indicator (1 if motorcyclist collided with an object (pole, barrier, tree, wall), 0 otherwise)	0.631	3.351
Heavy vehicle collision indicator (1 if motorcyclist collided with bus, tractor or truck, 0 otherwise)	1.276	5.582
Motorcycle registration indicator (1 if victim's motorcycle is registered,0 otherwise)	-0.840	- 2.891
(Standard error of parameter distribution)	(1.524)	(2.849)
Minor Injury		
Local road indicator (1 if crash occurred on local road,0 otherwise)	0.643	2.850
Pillion rider indicator (1 if pillion rider was present, 0 otherwise)	0.608	6.249
December indicator (1 if crash occurred in the month of December , 0 otherwise)	-0.255	-1.770
Chines motorcycle indicator (1 if victim's motorcycle is manufactured by a Chinese company (Hero, United, Union star etc.), 0 otherwise)	0.469	1.988
(Standard error of parameter distribution)	(1.107)	(1.829)
No Injury		
Constant	-2.651	-21.30
Dry weather indicator (1 if crash occurred in dry weather, 0 otherwise)	-0.360	-2.312
Speed limit below 50kmph indicator (1 if crash occurred on road with posted speed limit below 50 kilometer per hour, 0 otherwise)	1.002	2.935
Model Statistical Fitness		
McFadden Pseudo R-squared 0.493		
Restricted log likelihood -7362.609		
Log likelihood at convergence -3735.528		

Table 4.2: Estimated Marginal Effects of the Mixed Logit Model

Variable	Fatal	Major	Minor	No Injury
Fatal Injury				
Weekday Indicator	0.7659	-0.1971	-0.5411	-0.0277
No education Indicator	0.4660	-0.1210	-0.3292	-0.0158
May Indicator	0.1986	-0.0562	-0.1362	-0.0062
November Indicator	0.1492	-0.0373	-0.1068	-0.0051
Major Arterial Indicator	0.3131	-0.0821	-0.2202	-0.0108
Motorcycle-Rickshaw Collision	-0.0766	0.0171	0.0564	0.0031
Motorcycle Registration Indicator *	-0.2885	0.0610	0.2157	0.0117
Major Injury				
70kmph speed limit Indicator	-0.0143	1.2151	-1.1390	-0.0618
Passenger car Indicator	-0.0295	2.8205	-2.6479	-0.1431
25-50 years Indicator	-0.0156	1.6654	-1.5620	-0.0878
6am-9am Indicator	-0.0039	0.3661	-0.3427	-0.0195
3pm-6pm Indicator	-0.0097	0.9875	-0.9278	-0.0501
May Indicator	-0.0101	0.5546	-0.5189	-0.0256
August Indicator	-0.0037	0.4900	-0.4583	-0.0280
Median Indicator	0.0536	-5.4027	5.0680	0.2812
Object Collision Indicator	-0.0057	0.4840	-0.4530	-0.0253
Heavy Vehicle Collision Indicator	-0.0185	1.1239	-1.0538	-0.0516
Motorcycle Registration Indicator*	-0.0030	-0.5874	0.4962	0.0941
Minor Injury				
Local Road Indicator	-0.0065	-0.3607	0.5006	-0.1334
Pillion rider Indicator	-0.0830	-2.520	3.0204	-0.4174
December Indicator	0.0058	0.2632	-0.3236	0.0545
Chines motorcycle Indicator*	-0.0374	-0.4693	0.3941	0.1126
No Injury				
Dry Weather Indicator	0.0037	0.1413	0.4821	-0.6271
Below 50kmph Speed limit Indicator	-0.0008	-0.0494	-0.2082	0.2584

4.4 Result Discussion

Model estimation results (Table 5.1), weekday indicator was significant fixed parameter for fatal injury outcome. It was observed that crashes on weekdays increases the likelihood of fatal injuries compared to minor injuries. It might be attributed to excessive use of motorcycles on weekdays by middle and lower class citizens for daily commute to work/jobs and schools.

Crash involving victims with no education are more likely to result in fatal outcome. Our results are consistent with past findings (Borrell et al., 2005; Heydari et al., 2012; Sehat et al., 2012).With increase in the education level, the motorcyclists became more cautious about the safety precautions. Educated road users often wear helmets and follow traffic regulations, therefore are less involved in severe traffic crashes (Kulanthayan et al., 2000; Houston and Richardson, 2008; Hung et al., 2008)

Crashes occurring during the month of May and August increase the probability of fatal and major injuries respectively. It may be attributed to riders travelling at higher speeds during warm weather conditions (Lee and Mannering, 2002). Also low helmet rates are observed during warm days as the driver might feel potential thermal discomfort which leads to sever injuries (Gkritza, 2009; Shaheed et al., 2013). Also during August the monsoon season is at its peak in Rawalpindi city which can result in slippery and deteriorated road surfaces, thus leads to severe injury crashes. It was also found that winter months (November and December) are more likely to result in severe injuries. The positive coefficient of November in fatal injury outcome and negative coefficient of December in minor injury outcome suggest that probability of victims involving in fatal and major injuries increases during these months. This might be attributed to smoggy conditions in urban areas during winter season which leads to poor visibility (Singh and Suman, 2012).

Crashes occurring on major arterial roads are more probable to be fatal. It is intuitive as drivers might achieve high travelling speeds on major arterial roads. Also presence of heavy vehicles on these roads increases the probability of fatal injuries (Quddus et al., 2002; Savolainen and Mannering, 2007). Motorcyclist was more likely to be killed or severely injured in a traffic crash the occurred on major road as compared with a local road (Eustace et al., 2011).

Crashes occurring on local roads increase the likelihood of minor injuries which is also intuitive. On local roads due to limited number of lanes, low travelling speeds, crashes are more likely to result into minor injuries as compared to major or fatal injuries (Shankar and Mannering, 1996; Savolainen and Mannering, 2007; Li et al., 2009; Pai, 2009).

Motorcycle-rickshaw indicator was found to be significant fixed parameter in fatal crash function. It was found that collision of motorcycle with another motorcycle-rickshaw is less likely to cause a fatal injury which is in-agreement with previous findings (Savolainen and Mannering, 2007) as well as intuitive due to low momentum of the collision bodies.

The parameter for motorcycle registration indicator was found to be normally distributed for fatal injury (with mean -2.19 and standard deviation of 1.52) and major injury (with mean -0.84 and standard deviation of 1.52) outcomes. For fatal outcome the parameter is less than zero for 92.5% of the crashes and greater than zero for 7.5% of the crashes. This indicates that majority of the crashes involving registered motorcycles are less likely to result in fatal crashes. Similarly for major injury outcome the parameter is less than zero for 71% of the crashes and greater than zero for 29% of the crashes. This implies that registered motorcycles are less likely to get involved in major injured crashes. The net effect of the variable (Table 5.2) suggests a lower probability of fatal compared to major crashes. This randomness of the parameter is due to unobserved heterogeneity in the data. The unobserved heterogeneity may include important details such as manufacturing year of the motorcycle/age of the motorcycle, motorcycle fitness/mechanical condition, motorcycle conspicuity, self-owned/borrowed motorcycle, helmet use and motorcycle speed at the time of collision which were missing and were not accounted in the model estimation. This might be attributed to cautious rider attitude by registered motorcycle users and careless and/or risky behavior by unregistered motorcycle owners. These results are consistent with previous research findings. The motorcyclists riding an unregistered motorcycle are a specific high risk group (Haworth et al., 1994). It is likely that new motorcycles are unregistered and mostly operated by less skilled drivers which could be a greater threat to rider’s safety (Lin et al., 2003; Sexton et al., 2004; Harrison and Christie, 2005).

Passenger car collision indicator was found significant in major injury outcome. It was found that collision of motorcycle with a passenger car is more likely to result in major injuries. This is intuitive as passenger car are more likely to operate at higher speeds therefore if involved in crash with a motorcyclists can potentially lead to sever injuries.

The positive significance of heavy vehicle indicator in the major injury outcome indicates that crashes involving heavy vehicles (bus, tractor, truck) are more likely to result in major injuries compared to minor injuries. The results are intuitive and consistent with past findings. Savolainen and Mannering, (2007) found that collision with tractor-trailers greatly increases the probability of severe and fatal injuries.

Object collision indicator was significant fixed parameter in major injury outcome. It was observed that collision of motorcyclists with a stationery object i.e. barrier, curb stone, pole etc. increases the probability of major injuries. Synonymous results were obtained by (Quddus et al., 2002; Savolainen and Mannering, 2007).

Motorcycle crashes on roads with posted speed limit of 70kmph increases the likelihood of fatal injuries compared to minor injuries. It is intuitive as higher speeds are the major contributing factor in causing severe road crashes. This is consistent with past findings. (Shankar and Mannering, (1996) and Savolainen and Mannering, (2007) found that speeding increases the likelihood of major and fatal injury crashes. Motorcyclist wearing helmet were less effective in reducing fatalities if the crash speed were more than 50kmph (Shibata and Fukuda, 1994). The helmet may also be lost by the motorcyclist if the chin strip is not properly fastened during high speed crashes (Richter et al., 2001). Chances of brain injuries were more due to differential movements of head and brain in high speed crashes (Lin and Kraus, 2009). Similarly crashes on roads with posted speed limits below 50kmph are more likely to result in no injuries, which is also intuitive. All roads with speed limits below 50kmph are mostly running through market places or residential streets. Therefore they are less contributing to severe crashes.

Median indicator was found significant in the major injury outcome. It was observed that crashes if occurs on median divided roads are less probable to result in major injuries. This is intuitive as presence of median is considered a significant roadway safety enhancing parameter. A divided road reduces the probabilities of head on collisions with opposite traffic thus less likely to result into major injury crashes.

Turning to motorcycle rider age, it was found that middle age riders (25-50years) are more likely to be involved in major injury crashes. It might be attributed to excessive utilization of motorcycles by middle age riders as they are primarily the working age group. This is consistent with past findings. Riders aged between 26 to 39 are prone to medium risk injuries (Mannering and Grodsky, 1995). Middle age riders were associated with higher rate of casualties (Rutter and Quine, 1996).

The next finding relates to the time of crash, which is defined for major injury severity level. Results suggest that injury severity of motorcycle are more if the crash occurred during early morning hours (6am-9am) and late afternoon/early evening time (3pm-6pm). It might be due to aggressive driving behavior during these hours as people are in hurry either leaving for jobs/work or schools during early morning hours and returning back home during late afternoon hours. Comparatively the probability of motorcyclist being major injured is more at late afternoon hours than early morning time (Table 5.2). It might be due to lack of concentration as a result of mental and physical tiredness of riders along with aggressive driving behavior during these hours. It is also one of the reasons to higher percentage (19.2%) of riders involved in crashes during late afternoon hours (Table 3.5). Results are consistent with (Ahmed, 2013) for Karachi Pakistan, mentioning late afternoon/evening were the most frequent time of crash involvement of motorcyclists.

Pillion rider indicator was found significant in the minor injury outcome. It was observed that crashes in which pillion rider was present increases the likelihood of minor injuries and decreases the probability of major and fatal injuries. This might be attributed to reduction in speed due increase in mass of the motorcycle with pillion rider. This may also be attributed to increased vigilance and reduce risky behavior with presence of pillion rider. This finding is consistent with past studies. Presence of pillion passenger can lower the probability of fatalities (Cooper et al., 2005; Jou et al., 2012).

Chinese motorcycle indicator (Hero, United, Union star, hi speed etc.) appears to be random in the minor injury outcome. The parameter is normally distributed with mean 0.47 and standard deviation 1.11. It shows that the distribution is below zero for 33.6% of the crashes and above zero for 66.4% of the crashes. It means Chinese motorcycles are more likely to be involved in crashes resulting into minor injuries (less likely to be involved in major or fatal crashes). Most of the Chinese manufactured motorcycles having an engine capacity of 70cc are popular in Pakistan due its low price. Among other engine capacities 70cc motorcycles have a market share of about 88% (Khan, 2015). People prefer Japanese manufactured companies (Honda, Yamaha, and Suzuki) for high engine capacity motorcycles. Due to low engine power of these motorcycles, they cannot be operated at higher speeds. Therefore they are mostly involved in low injury crashes. The variation found here reflects unobserved heterogeneity that may be related with manufacturing year of the motorcycle/age of the motorcycle, collision speed, driving license/experience of the rider and helmet worn by the rider which were not included in the model estimation.

Dry weather indicator was a significant fixed parameter in no injury outcome. The negative coefficient of the parameter indicates that crashes occurred in dry weather are less likely to cause no injuries and more probable to result in injury crashes (minor, major and fatal). It is consistent with past findings. Crashes during dry weather result into severe casualties due to risk compensating behavior (Quddus et al., 2002; Savolainen and Mannering, 2007; Shaheed et al., 2013; Shaheed and Gkritza, 2014).

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Synopsis of the Research

This research is focused on the identification of contributory risk factors to motorcyclist's injury severity in Pakistan which is expected to enhance traffic safety environment for the vulnerable road users (motorcyclists). A systematic study of the relevant literature was done which provided in depth understanding of the injury severity analysis of RTCs involving motorcycles on international level. Various approaches have been applied in past for modeling crash injury severity including ordered probit, multinomial logit, nested logit, mixed logit and latent class models. Due to high flexibility, better goodness of fit and endorsement in recent studies for crash injury severity analysis mixed logit model was estimated. Crash data were obtained from Rescue 1122 headquarters Rawalpindi for a period of one year (July 2014 to June 2015). Major factors that were considered for analysis include crash-specific factors, roadway geometric characteristics, and environmental conditions. A number of trails were made via NLOGIT to estimate mixed logit model in order to investigate the association of crash injury severity with certain independent variables. Initially model was estimated using 40 Halton draws for the selection of random variables and its distribution as it's a time consuming task. The final model was revised using 200 Halton draws to identify significant factors at 90% confidence level (P-value = 0.10). Model with highest number of significant factors and better model statistical fitness parameters i.e. McFadden Pseudo R-squared (0.493), Restricted log likelihood (-7362.609) and Log likelihood at convergence (-3735.528) validates and justifies the selection of final model.

5.2 Conclusions and Recommendations

The crash injury severity injury analysis in our study revealed several problem areas leading to more severe injuries. It was revealed that probability of fatal/ major injury increases for crashes: involving middle age riders (25-50 years) and riders with no education, occurring on major arterial roads and road with posted speed limit of 70 kilometer per hour, involving a motorcycle and a heavy vehicle, involving collision with a fixed object, occurring during dry weather conditions, in the early morning hours, late afternoon and early evening hours. Also, probability of minor injury increases for crashes occurring on roads with posted speed limit of less than 50 kilometer per hour, crashes involving registered motorcycle, crashes involving cheaper bikes (China manufactured), crashes on divided streets, crashes where at least one motorcycle and auto rickshaw was involved. All the above parameters were statistically significant at a 0.1 significance level and with plausible signs.

The study findings through exploratory are expected to provide guidelines for different organizations concerned with road safety such as National highways authority (NHA), Rawalpindi development authority (RDA), and city traffic police to initiate appropriate counter measures for enhancing traffic safety for vulnerable road users like motorcycle riders. The research findings suggest that besides measures to control/ reduce the risky behavior from motorcyclists (speeding, not using helmet and improper lane changes etc.), there is a need to lower speed limits on road with high motorcycle proportion, separation of motorcyclist from heavy vehicles and by removing dangerous fixed objects such as poles and trees from roadside. Educating and making the riders aware of the factors found to increase the injury severity such as helmet use and safe speed, enforcement and regulation of the traffic laws particularly on motorcycle registration and driving licensing might be useful in minimizing the traffic safety risks and reduce the number of road crash injuries and fatalities involving motorcycles.

Besides data limitations this is the pioneer study on motorcycle crash injury severity in the country. Results are expected to generate more interest and discussion on motorcycle safety in the country and can be used by City Traffic Police and Rawalpindi Development Authority to enhance road safety in the city. It is expected that with availability of quality data and support of national organizations in future the motorcycle safety result is going to improve probability benefiting the society.

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Appendix Sample Crash Report Form (1)

EMERGENCY CALL FORM

Emergency Call #: .... Sr. # .... Date: .... Call Time: ....

Caller's Detail: ....

Nature of Emergency: ....

Place of Incident: ....

....

Name of CTWO: .... Sign: ....

Sign of Control Room Incharge: ....

Ambulance #: ....

Time out: ....

Response Time: ....

Shifted to: ....

Time in: ....

Meter out: .... Meter in: .... Total Mileage: ....

Name of WO: .... Sign: ....

EMT: .... EMT: .... Driver: ....

Remarks & Action Proposed by EO (Operations)

....

....

....

....

....

Sign of EO (Operations) ....

Districts Emergency Officer

Appendix Sample Crash Report Form (2)

RESCUE 1122 EMERGENCY RESPONSE FORM

Form # 606054 ________ EC # ____________ COD # __________ EV # _____________ Date __________

Time out: ____________________ In ____________________ Kms Covered ____________________

Mileage out: __________________ In ____________________ Response Time ____________________

Name: ____ Sex: F ☐ M☐ Age __________

Address: ____ Contact No. ____________________

Emergency Area: ____

Cause of Emergency: R.TA. ☐ Fire ☐ Fall ☐ Violence ☐ Explosion ☐ Building Collapse ☐

Suicide: Poisoning ☐ Strangulation☐ Medical Emergencies ☐ Train Accident ☐ Other (s) __________

No. of Victims: One ☐ Two ☐ More ☐ None ☐

Place of Emgergency: Road ☐ Work ☐ Home ☐ School ☐ Other (s) ☐

Time since onset of Emergency: ________ Education: Illiterate ☐ Primary ☐ Matric ☐ Higher ☐ P.G. ☐ Other (s)

Severity of injury sustained & outcom: Only First Aid → (Mild) Hospitalized → Moderate ☐ Critical ☐ Dead ☐

Type of Vehicle invloved: Motor Cycle ☐ Bicycle ☐ Rickshaw ☐ M/Rickshaw ☐ Car ☐ Bus ☐ Truck ☐

Driver of victim vehicle / Age: __________ Education: ____________________ Licenced Yes ☐ No ☐

Other (s): ______________________________ Accident with Vehicle / Object (Clarity) ____________________

HOW / WHY Emergency took place? ____

____

DETAIL OF FIRST TREATMENT

VITALS		TREATMENT	MEDICINES	QTY.
Pulse				
BP				
Temp.				
R.R.				
Conscious Level				

Type of Injury: S.T. Inj. Cut Fracture Single Multiple Head Spinal Chest Abdominal

Burn: Others: ____

Shifted to: ______________________________ CMO (Emergency Deptt.) ____________________

____

EMTs ________________________ Driver ________________________ CWO ________________

Station House Incharge / Station Co-ordinator ____

Emergency Officer (Operations) ____

____

(i) Items received from victim: ____

____

(ii) Victim / Attendent, suggestions & comments: ________________________________

____ *if requred P.T.O.*