FACTORS AFFECTING SAFETY PERCEPTION OF HELMET AND SEAT BELT USE: A BAYESIAN NETWORK APPROACH

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Approval

The dissertation titled "FACTORS AFFECTING SAFETY PERCEPTION OF HELMET AND SEAT BELT USE: A BAYESIAN NETWORK APPROACH" submitted by Md. Rifat Hossain Bhuiyan, Md. Rwanakul Islam Chowdhury and Kashfia Nahrin Nokshi has been accepted as partial fulfillment of the requirement for the degree, Bachelor of Science in Civil Engineering.

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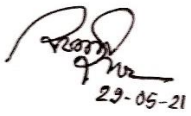
Declaration

It is hereby declared that this thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma.



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Dedication

To our beloved family members and the respected teachers

for

their advice, their patience, and importantly for believing in us.

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All the praises to Almighty Allah, by the grace of whom we were able to successfully finish our research work. Our heartfelt gratitude will always remain towards Allah, the most benevolent, the most merciful.

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List of Acronyms

AUC	Area Under the Curve
BBN	Bayesian Belief Network
CI	Conditional Independence
CPT	Conditional Probability Table
DAG	Directed Acyclic Graph
EM	Expectation Maximization
FGD	Focus Group Discussion
HBM	Health Belief Model
IUT	Islamic University of Technology
KAP	Knowledge, Attitude, and Personality
LOO	Leave One Out
PSM	Propensity Score Estimator
PC	Peter and Clark
RTA	Road Traffic Accident
ROC	Receiver Operating Characteristic
SDG	Sustainable Development Goals
SEM	Structural Equation Modelling
TPB	Theory of Planned Behavior
WHO	World Health Organization

Abstract

Major growth in economy over the last few years, alongside the increasing trend of ride sharing applications resulted in a significant increase of motorized vehicles in Bangladesh. With the increase of motorized vehicles in national and regional highways, there has been a spike in the number of road fatalities. Being one of the fastest growing economies, Bangladesh is still lagging behind in terms of ensuring road safety and awareness due to its poor law enforcement and improper management from the authorities. Safety restraints, particularly helmet and seatbelt, have been proven to be highly effective in reducing road fatality and accidents. But unfortunately, the number of applications of such safety restraints is not up to the mark compared to the number of motorized vehicles plying in the highways in this region.

Previous research on road accidents and application of safety restraints in Bangladesh mostly comprised of volumetric studies and statistical analysis of road fatalities and trends of road accidents in the region. There is a gap in research regarding the socio demographic factors that influenced one's perception of helmet or seat belt usage and the dependence of the factors among themselves, especially for the case developing nations such as Bangladesh. The following study seeks to establish a causal relationship among the factors that influence the rider or driver's usage of helmet and seatbelt respectively, in order to identify the variables that has the most impact on safety restraints application and their impact on other influencing factors.

In this study, a causal relationship was established among variables that represent both demographic and safety perception to identify the factors that influenced helmet and seat belt use on national and regional highways in Bangladesh. The network was established based on previous research findings and expert knowledge using Bayesian Belief Network. The Bayesian network was formed using PC algorithm that was based on conditional independence. Data were collected from 32 intersections from national and regional highways. The study was conducted on secondary data provided by Roads and Highways Department (RHD). The Bayesian network was used to find the posterior probability for all variables for the presence of helmet and seat belt respectively using the expectation-maximization algorithm and sensitivity analysis.

Results showed that effectiveness of helmet as safety restraint, motorbike ownership, and helmet avoidance are the major influential factors for helmet use, whereas education level, license type, perception of accident reduction, and perception of injury for not wearing helmet are the main factors behind seat belt usage. In both cases, police intervention did not have any significant effect on helmet and seat belt usage, indicating poor law enforcement in the region. Results from this study can be a useful resource for policy makers and law enforcement authorities to take necessary actions to encourage use of safety restraints among riders and drivers.

Keywords: Safety Restraint, Bayesian Network, Helmet and Seat belt, Safety Perception, Developing Country.

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The number of road traffic death is rising worldwide and has reached the height of 1.35 million in 2016. Road Traffic Accident (RTA) is now the eighth leading cause of death for all age groups and the leading cause of death for young adults aged between 5-29 years. Safety for road users has been deemed an immense challenge as increased population and rapid motorization have rendered the existing road safety efforts insufficient. Due to deficient progress on road safety, the Sustainable Development Goal (SDG) target to reduce road traffic death by 50% within 2020 is far from reality. The situation is even grimmer for middle and low-income countries where the average road traffic death is 27.5 per 100,000 which is three times higher than high-income countries. Despite having only 1% of the world's motor vehicles, 13% of deaths related to RTA occur in these countries. To ameliorate the current situation, proper road safety measures should be taken into hand and implemented with the utmost seriousness (WHO, 2018).

Bangladesh is a middle-income country in South Asia with a very high road fatality rate. The country is facing rapid motorization due to its recent economic development and introduction of rider sharing services. Particularly in Dhaka, the capital city of Bangladesh, the number of registered motorcycles stood at 616,641 in 2018, while it was only 210,000 in 2010. (Dhaka Tribune, 2020) Similarly, the number of four-wheel vehicles is also expanding. High-income countries' experience dictates a potential rise in deaths and injuries among car occupants in Bangladesh due to the increased car ownership. The estimated road traffic fatality is above 20,000 in Bangladesh considering under-reporting and other inconsistencies of which drivers and passengers of 4-wheeled cars account for 41%, and riders of two-wheelers account for 11% (WHO, 2015). Altogether, the fatality among motorbike riders and vehicle occupants constitutes more than 50% of total fatality, which is very alarming. The heavy road fatality among motorbike riders and car users is an integral representation of unplanned

motorization aggravated by the lack of safety measures. Given the situation, proper interventions by the authority to limit this number is nearly inexistent.

Injuries on head and neck for motorbike riders and frontal impact on vehicle occupant's sensitive organs is the leading cause of death and disability. Safety restraints such as helmet and seat belt have been proven effective in protecting the head and other sensitive body parts. Proper use of helmet can reduce fatal injury by 42% and reduce head injury by 69% (Liu et al., 2008). The use of seat belt can reduce the risk of fatal injury by 43% to 65% (WHO, 2004). Hence, best practices for helmet and seat belt law should include an obligation for drivers and passengers to wear safety restraints on all roads. Safety restraints are said to be one of the most effective road safety measures and proved to have saved more lives and money than any other intervention.

Seat belt plays an important role in saving casualty cost by reducing severity of the accident. Between 1975 and 2000, the saved casualty cost due to seat belt use in US was US$588 billion. However, road deaths and injuries of non-users still cost around US$26 billion every year due to medical cost, loss of productivity etc. in US (ACEP, 2002). A study in Norway shows that, 60% of all injuries suffered by vehicle occupants are head injuries and drivers and front seat passengers not using seat-belt suffer similar percentage of head injury as non-users in rear seats (Nordisk Trafiksikkerhedsrad, 1984). This study indicates the importance of seat belt use for both the front and rear seat occupants of vehicle. According to American College of Emergency Physicians, seat belt is the best protection against ejection in a crash. Ejection from a vehicle during crash is one of the most injurious incidents that can happen to a person and seat belt effectively prevents it from happening. It has been seen that, 44% of unrestrained vehicle occupants killed were ejected from the vehicle partially or completely compared to only 5% restrained occupants (National Highway Traffic Safety Administration, 2006). Seat belts do not prevent crashes from happening but definitely increases the chance of survival of the occupant. Seatbelts help in injury reduction in following ways:

- Reduce contact with the interior of the vehicle
- Distribute the force of crash to stronger parts of human body

- Prevents ejection of occupant from the vehicle
- Prevents injury to other occupants as there is a chance of rear seat passenger hitting the front seat passenger in case of a frontal crash.

Commonly used safety restraint by motorcycle riders is helmet. Motorcycle riders are at a higher risk of being involved in a crash as they share traffic space with fast moving vehicles and are hard to notice. For two-wheeler users, head injury generally contribute around 75% of deaths but in some middle and low income countries (Umar, 2002). Globally the use of motorcycle is increasing for both transportation and recreational purpose. To cope with this increasing trend, proper implementation of helmet use needs to be ensured on all roads. Motorcyclists not wearing helmet are at a greater risk of sustaining head injury and dying from it (WHO, 2006). A helmet can reduce the severity of injury in following ways:

- Helmet reduces deceleration of the skull and the brain movement. Soft materials present in helmet absorbs some of the impact force and head comes to halt more slowly.
- It spreads the force of impact more uniformly in a large area.
- It prevents direct contact between the skull and hitting object and function as a mechanical barrier.

Using helmet while riding is economically beneficial too. Researchers in Michigan found that helmet use led to 20% reduction of hospital cost compared to those who don't wear helmet (Brandt, Ahrns, Corpron, Franklin, & Wahl, 2002).

Road safety issue for Bangladesh is of paramount importance now more than ever before. Recently being established as a developing nation from least developed nation, the number of motorized vehicles running in the streets have increased significantly over the years, which resulted in higher casualties of road accidents. Lack of helmet and seatbelt using behavior can be attributed to higher casualty due to road accidents. Various studies were performed to analyze the road accidents and safety regulations for the streets of the capital city Dhaka and other major divisions. Conclusive study on risk

factors of Road Traffic Accidents (RTA) in Bangladesh revealed more than 50% of the accidents were attributed due to motorized vehicles and proved to have an association with high-speed driving (Jabbar, Islam, Sultana, & Akhter, 1970). Analysis of the variation in road accidents and determination of constraints were scrutinized in individual studies performed over the years (Mahmud & Hoque, n.d.; Maniruzzaman & Mitra, 2005). Insights of patterns in road accidents in rural areas were also analyzed due to higher chances of lack of law enforcement in such areas (Ul Baset et al., 2017). Despite of the extensive research on road accidents in Bangladesh, lack of study focusing particularly on helmet and seat belt use is observed within the region of the country. Studies include application of safer motorcycling and safer roads in the context of our country (Mahmud & Hoque, n.d.) and factors that influence non-compliance of helmet use among motorcycle riders in Bangladesh (Rahman, 2012). Other than few similar studies, extensive research on factors that influence use of seatbelt and helmet in context of Bangladesh is not observed. Motor vehicle ownership is about 2 to 10 vehicles per 1000 persons in Bangladesh nowadays and is increasing gradually. (Mahmud, Ahmed, & Hoque, 2014). These increased motor vehicles are directly contributing to increased road crashes. Whereas in developing countries road accidents are predicted to decrease by 30%, in developing countries it may increase up to 90 % in near future (Mahmud , Talukder, Ahmed, & Raihan, 2013). As a consequence, more research should be performed to reduce or control traffic accidents and one of the best ways to reduce it is to use safety restraints, typically helmet for motorcycle users and seat belt use for passengers. But unfortunately, studies performed in Bangladesh is lagging in terms of extensive research on safety restraints. One of the reasons might be the sudden outburst of vehicle ownership in recent years, something that was not that much of an issue for previous years. Lack of detailed research on safety restraints and its contribution to reduce fatality may also have discouraged researchers to explore the factors that influence the use of such safety restraints.

Issues related to safety restraints and consciousness about using helmet and seat belt is more acute in comparatively lower-income nations. Bangladesh, being a developing nation, has experienced an increased number of motorized vehicles, and private ownership of vehicles has increased manifolds. Sudden increase in motorized vehicles is also contributed by the recent rise in popularity of ride sharing platforms in

Bangladesh (Islam et al, 2019). Studies on safety restraints have been conducted on many developed countries around the world, but the methodology of those studies might not be applicable for a developing nation like Bangladesh. Lack of law enforcement is one of the major issues that causes the negligence towards safety restraints, but social factors play a greater role in terms of attitude towards safety restraints. A study conducted in USA incorporated variables like drug abuse and implications of universal helmet law (Lee, 2018a), while another study incorporated variables like rider age, gender, road type and tendency of illegal behavior of drivers(Chang et al , 2019). Such factors will not have the same impact for a developing country like Bangladesh, where social factors are more effective in terms of safety restraints usage, which are more often than not ignored in the available studies.

Research on behavioral attitude towards safety restraints is a topic that has been pondered upon by researchers globally. Different studies were conducted worldwide to identify the variables that directly or indirectly motivate helmet and seatbelt use (Cohen & Einav, 2003; Lee & Outlaw, 2018; Strine et al., 2010a). However, such factors are not always mutually independent, and more often, it is the integrated influence of multiple factors affecting one's perception about the effectiveness of safety restraints. That is why the causal relationship between such factors should be analyzed to establish a clear understanding of the matter. Perception towards safety restraint use might vary from person to person due to the combined influence of factors such as any past-history with road accidents, driving time, driving area, and road conditions. Since casual relationships are based on prior beliefs, Bayesian theory can be used to establish a relationship among the variables using conditional probability.

1.2 Purpose and Objectives

Identifying the factors that have a greater influence on helmet and seat belt usage can be valuable information for policymakers and transportation corporations to implement and execute measures that promote safety restraints and their usage. Our study attempts to determine the key factors influencing helmet and seat belt use as well as avoidance

in national and regional highways of a developing country, Bangladesh. The focal objectives of our study are:

- To identify the key factors that affect helmet and seat belt use on national and regional highways and help design fitted interventions from the standpoint of a developing country.
- To find out the causal relationship among demographic and safety perception factors of helmet and seatbelt use based on conditional dependency.

1.3 Scope of the Study

The study concerns about finding out important factors motivating safety restraint use among the drivers and establishing a causal relationship among those factors. The respondents and focus group attendees during the survey phase of this study consisted of people belonging to different districts (32 intersections on national and regional highways) of the country. Such diversity among survey participants ensured the most representative response.

1.4 Thesis Outline

The thesis has been organized into six chapters. The chapters are briefly introduced underneath:

Chapter 1: **Introduction**- This chapter explains the background, problem statement, purpose, and objective of the research.

Chapter 2: **Literature Review**- This chapter discusses the relevant pieces of literature that helped in gaining the most suitable work plan for the research.

Chapter 3: **Study Area and Data Collection**- This chapter sheds light on scoping, bounding and data acquiring techniques.

Chapter 4: **Methodology**- This chapter explains the gradual working process of the research and illustrates the method adapted to analyze acquired data.

Chapter 5**: Analysis and Results**- This chapter discusses the analysis of collected data and interprets the obtained results.

Chapter 6: **Conclusion and Recommendations**- This chapter presents the main findings of the research and suggests suitable policy implications.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Study on effectiveness and behavioral aspects of safety restraints is not yet a well-discussed topic among the transportation researchers of Bangladesh. The lack of locally conducted research motivated in considering regional studies with higher degree of importance for this research. This chapter starts by discussion on definition of safety restraints and its impact on road safety. Then the summary of existing relevant literatures conducted regionally and internationally along with their methodology and final finding is discussed in detail. Literatures concerning helmet and seat belt are reviewed separately in this chapter.

2.2 Safety Restraint in Transportation Engineering

Attaching the occupant to an object to prevent him/her from getting hurt is called safety restraint system. During collision, vehicle changes its direction rapidly and causes occupant to move in an uncontrolled way and sometimes eject from vehicle. Safety restraint systems prevent occupant from moving and being ejected from the vehicle. These systems also distribute the crash impact in a large area of occupant's body which otherwise could be lethal. Drivers and passengers of a car commonly use seat belt as safety restraint. Similarly, commonly used safety restraint by riders and pillion riders of a motorbike is helmet.

2.3 Previous Studies on Helmet Use

Comparing vulnerability towards accidents, it is evident that motorcycle users are more prone to face fatality due to road accidents than car users, due to lower safety precautions taken (Tarigan & Sukor, 2018). Previously conducted studies include

various types of helmet users, consistency of helmet use, factors that influence inconsistency of traffic law violation on helmet use, effectiveness of universal helmet laws to prevent fatalities and possible interventions and their application towards promoting helmet use. Global research also covered areas including influence of drug abuse on motorcycle fatality, socio demographic factors of motorcycle accident victims and factors that motivate their helmet usage and underlying factors that has correlation with intension of helmet usage for riders in order to create future policies and guidelines. In scrutinizing the reason for inconsistent helmet use among users, it was found that personal history of road accidents directly influenced use of regular helmet use (Tarigan & Sukor, 2018). Helmet has negative impact on possibility of fatal result and positive influence on less severe injury (Lee, 2018a). Results from these researches show clear indication of positive association of helmet use and reduced fatality from motor vehicle accidents.

2.3.1 Studies on Attitude and Behavior towards Helmet Use

Lee (2018) studied the antecedents of helmet use prior to the enforcement of helmet legislation. The author used the Propensity Score Estimator (PSM) to investigate helmet efficacy and found that, riders believing in the effectiveness of helmet against fatal accidents have higher abidance. 63% of the non-helmet users blame helmet for vision obstruction and neck pain.

Karuppanagounder & Vijayan (2016) did research on helmet use behavior, perception, and attitude among Indian motorist and extracted significant findings such as- helmet usage is maximum under law enforcement, most users feel discomfort, more than 50% of riders think driving slowly and carefully makes helmet wearing unnecessary, only 45% uses wore a standard helmet.

Ledesma, López, Tosi, & Poó (2015) used descriptive statistics to analyze the motorcycle helmet use associated factors. The considered variables were gender, climate condition, type of motorcycle, time of day, part of the week, helmet use among driver and passenger. They found that intercity travelers had higher helmet use and the presence of license plate resulted in greater compliance.

Wu & Loo (2016) investigated the behavior of occupational and non-occupational motorbike riders as ride sharing is commonly increasing. The results of chi-square tests showed that the behavior both the occupational and non-occupational riders were quite similar. Speeding late at night or early in the morning, not requiring passengers to wear helmets and running the red-light in a hurry are common behavior for occupational riders.

Roehler et al. (2013) attempted to identify the helmet-wearing barriers, attitude, behavior, and belief among Cambodian motorcyclists. The authors used various demographic variables such as age, education, occupation, gender and considered other variables like helmet ownership, the reason for not wearing a helmet, and source of road safety information. A Chi-square test was conducted to find statistically significant differences. Saving lives in the event of a crash was found impetus in 96% and 98% of cases for drivers and passengers respectively. The significant barriers to helmet use were 'driving area', 'forgetfulness', 'discomfort'.

Zamani-alavijeh, Bazargan, Shafiei, & Bazargan-hejazi (2011) tried to find out the barriers and facilitators of helmet use among Iranian motorcyclists. They ran a qualitative and quantitative analysis on the data and found that the major barriers to helmet use are trapping heat and lack of ventilation, heaviness, limitation to communication, disruption to cosmetic appearance, high cost of helmet, possible helmet theft, etc. The facilitators on the other hand were positive influence of the others, perception of vulnerability and accident severity, belief in helmet efficiency, previous traffic injury.

Hung, Stevenson, & Ivers (2008) recommended the length of the trip (greater than 10 km), travelling on a mandated road and having a university-level education are associated with the helmet use. Univariate analysis and multivariate logistic regression model were used to analyze the result. 95% of the registered vehicles in Vietnam are motorcycles and 77% of the road accidents are caused by them. Out of which 88% of the deaths are due to head injury. Due to a very low financial penalty and many roads with no compulsory helmet wearing law, the head injury is very high among riders.

Li, Li, & Cai (2008) examined the rate of correct helmet use among drivers in two cities. The rate was higher in Chaozhou (34.6%) than in Shantou (30.2%; $P < 0.001$). Correct helmet use was higher among drivers in main streets, during daytime hours,

and during weekdays ($P < 0.001$). The level of helmet knowledge of motorcycle drivers was high with most reporting that helmets prevent or reduce head injury (Shantou: 78.2%; Chaozhou 70.6%). Knowledge, Attitude, and Personality (KAP) Survey followed by chi-square test were used in the research work.

Pileggi, Bianco, Nobile, & Angelillo (2006) performed research on risky behavior among motorcycling Italian adolescents. They incorporated variables such as age, sex, education level, cigarette and drug use, previous traffic-related accident, tickets in the last one-year period riding a motorcycle, etc. into a multiple logistic regression model. The data used in the model were self-reported and it was found that helmet use is high among males, current smokers, alcohol drinkers who have at least one helmet user close friend. 25.7% of the riders experienced accidents in the last year and accident occurrence was higher among cell phone users while driving and new riders.

Kulanthayan, Radin Umar, Ahmad Hariza, & Nasir, Mohd, (2001) modeled the compliance behavior of motorcyclists in Malaysia. A logistic regression model was used to identify significant variables such as location, gender, age, distance, enforcement, and practice. It was also found that compliance to proper helmet use was higher among motorcyclists of 21 years or above.

Weiss (1992) studied motorbike accidents in the Los Angeles area to understand the effect of helmet on the severity of head injury. The author used a multivariate ordered probit model for analysis and concluded that helmet can increase safety against head injury by 40% and reduce individual rider's medical costs for treatment by $1700.

2.4 Previous Studies on Seat Belt Use

Seat belt use behavior among riders and passengers has been studied by researchers for many years. Studies include influence on driver's seatbelt use on use of seatbelt for passengers, effects of seat belt laws on traffic fatalities and driving behavior, urban and rural factors affecting seat belt use, effect of service learning on helmet use, perception and attitude of seatbelt use among different groups, effects of renewed law enforcement on volume of motor vehicle crash and identification of determinants of seat belt use. Further studies also covered areas such as behavioral intention of intercity bus

passengers, roles of both implicit attitudes and Theory of Planned Behavior (TPB) constructs in the prediction of seatbelt use, impact of the automated system in ensuring compliance with seatbelt and phone use laws, socio demographic factors of seatbelt use, investigation of seatbelt awareness and factors that predict rear seat belt use among adult back seat passengers. Studies revealed that higher seat belt usage decreases occupant fatalities with negative coefficient (Cohen & Einav, n.d.-a) and being female, having college education, having children, retirement, being homemaker had significant association with seat belt use (Strine et al., 2010).

2.4.1 Studies on Attitude and Behavior towards Helmet Use

Hezaveh & Cherry (2019) studied the neighborhood-level factors affecting seat belt use to unveil the socio-demographic factors involved. Higher seat belt use was found among females and people traveling in daylight. Driver and rear passenger seat belt use were found positively correlated. Vehicle ownership had a significant association whereas the percentage of bachelor-degree had a positive relationship with seat belt use.

Nambulee, Jomnonkwao, Siridhara, & Ratanavaraha (2019) aimed to model seat belt use intention for intercity buses using Structural Equation Modelling (SEM) and Health Belief Model (HBM). The authors incorporated both perceived benefit and perceived severity-related variables in the model found that perceived severity had the most positive influence on seat belt use among teenagers. On the other hand, perceived benefits had the most positive impact on adult people. Perceived barriers were a significant negative influence for both groups.

Taylor & Daily (2019) examined the data from the 2016 Motor Vehicle Occupant Safety Survey, conducted by the National Highway Traffic Safety Administration. The objective of this study was to predict the factors affecting the use of rear seat belts and other demographic factors related with seat belt usage. Different factors like Front seat belt use, support and belief of state seat belt laws, nighttime seat belt use, age, and education were found significantly associated with rear seat belt use.

Teye-Kwadjo, Salia, Mensah, & Ofori (2020) found that despite the mandatory law for seat belt use, only a few commercial drivers use seat belts in Ghana. The aim of the study was to understand the factors associated with the intention of seat belt use. The result showed that attitudes were significantly associated with seat belt use where subjective norms and perceived behavioral control were not the predictors. Based on the Theory of Planned Behavior, structural equation modelling was used for analysis. This result also suggested introducing intelligence seat belt reminders like loud sound or light display.

Dun & Ali (2018) targeted the young Arab males in Qatar to understand their attitude and behavior on seat belt wearing. They found that some men strongly believe, seat belt do more harm than good. Being a skillful driver reduces seat belt necessity, an accident is predetermined by God, etc. were observed among the respondents.

Booker & Sung (2017) observed that risky motor vehicle behaviors decreased with the increase of seat belt usage. Chi-square tests examined bivariate associations between regular seat belt use and demographic variables. Logistic regression assessed associations between regular seat belt use and other risky behaviors such as 'drink & drive', 'text & drive', and 'ride with the drunk driver.'

Han (2017) conducted Chi-square test to examine the association between the driver's seatbelt use and the passenger's seatbelt use. The logistic regression model showed that if a driver wore a seatbelt, 92.6% of his/her passengers also wore seatbelts while if a driver did not wear a seatbelt, only 19.1% of his/her passengers wore seatbelts. Seatbelt of drivers influences others.

Reagan, McClafferty, Berlin, & Hankey (2013) reported that people with higher education used seat belts more consistently. The study also showed that there were no statistical differences between infrequent, occasional, and consistent belt users' perceptions of driving if the driver felt drowsy or used a cell phone while driving. Moreover, a positive relationship between observed and self-reported seat belt use was noticed.

Şimşekoğlu & Lajunen (2008) did a study on the social psychology of seat belt used based on the theory of planned behavior and health belief model. Their objective was to identify the significant predictors of seat belt use and explain self-reported seat belt use on urban and rural roads. The authors found that seat belt wearing had no

relationship with an individual's belief in the effectiveness of seat belt. Gender and age were found insignificant variables whereas attitude and subjective norms were strong predictors of seat belt use intention.

Cohen & Einav (n.d.) examined the effects of seat belt laws on traffic fatalities and driving behavior. They found that a 1-percentage-point increase in usage saves 136 lives (using a linear specification), and that a 1% increase in usage reduces occupant fatalities by about 0.13% (using a log-log specification). This paper also put some interesting fact like seat belt may have insignificant or even positive effect on fatality rate. This argument was put forward by Peltzman (1975), who argued that seat belt use might produce careless driving and in turn greater risks for non-occupants. However, they did not find any evidence that higher seat belt usage has a significant effect on driving behavior. The result showed that for mandatory seat belt use, primary enforcement (i.e., allowing the police to stop and fine violators even if they do not engage in other offenses) is more important to have rather than secondary enforcement (i.e., allowing the police to fine violators only when they are stopped for some other offense).

The previous research works tried to explore the safety restraint use behavior among motor vehicle users applying qualitative, quantitative and social theory related approaches. However, the causal relationship among safety perception and other demographic and social factors was rarely addressed in these studies, especially from the perspective of a developing country.

CHAPTER 3

STUDY AREA AND DATA COLLECTION

3.1 Study Area

The survey data was collected from 32 intersections at both national and regional highways. The selection of intersection was done meticulously so that the survey data can represent the demographic and psychographic aspects of most of Bangladesh's population.

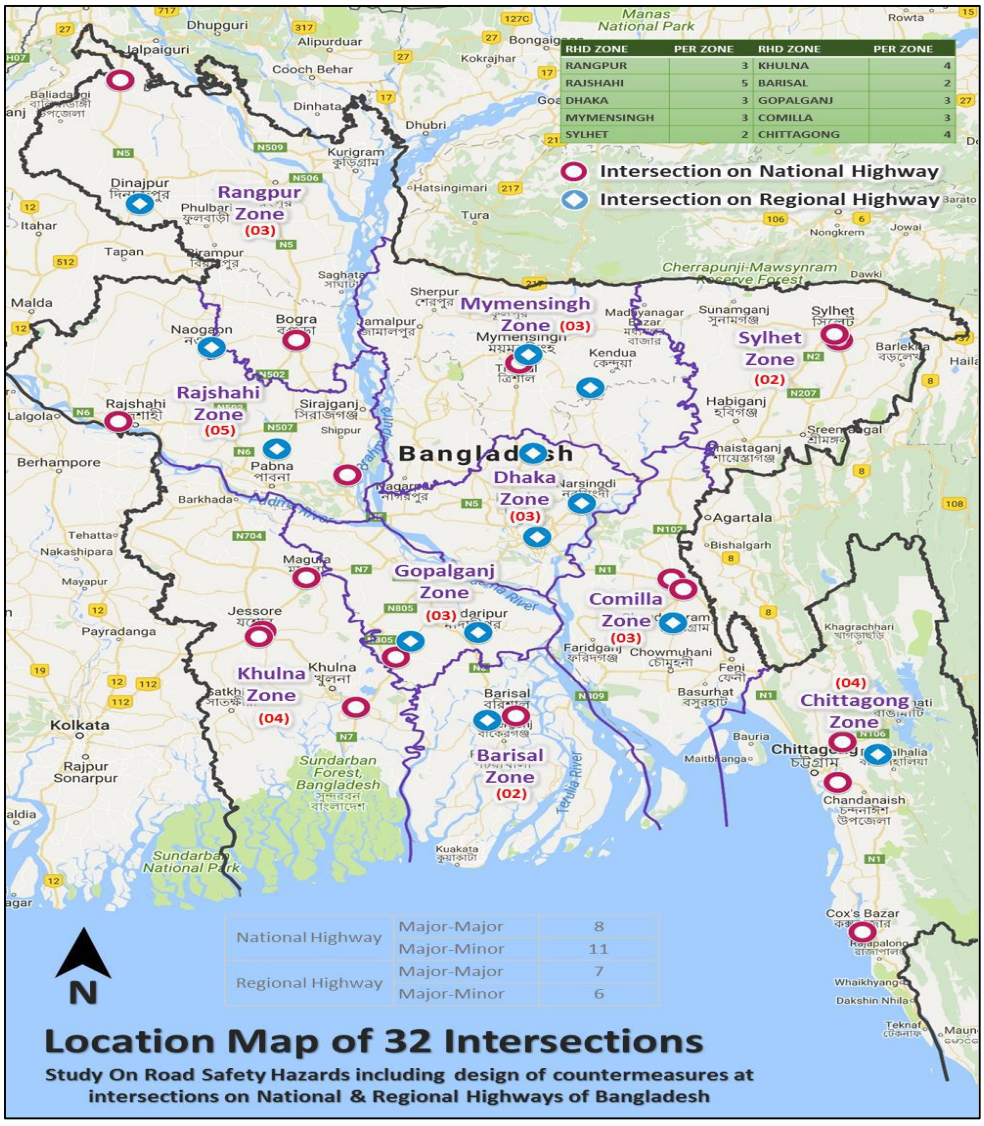

Figure 1: Study area of the survey

3.2 Data Collection

Motorcycle and motor vehicle users who were supposed to wear helmet or seat belt were interviewed with a set of well-prepared questions by the surveyors. The questionnaire included some demographic questions as well as vehicle user's perceptions about wearing safety restraints and how they can be encouraged to follow the rules. The questionnaire for helmet and seatbelt use was developed based on literature review and transportation expert judgment. Focus Group Discussion (FGD) was also conducted to understand the relevance of the survey form to local people. A pilot study was done in a single intersection by the survey team to assess the questionnaire's effectiveness and the method of conducting the interview. The survey respondents were classified into two categories named 'Helmet for Rider' and 'Seat belt for Driver'. Partial and unengaged responses were removed by data screening. After the screening process, a total of 898 responses under 'Helmet for Rider' category and 627 responses under 'Seat belt for Driver' category were acquired. Only motorcycles, private cars, SUVs, and other multipurpose vehicles were considered in this study. Bus and truck were excluded from the study as generally, there is no seat belt in this type of vehicle in Bangladesh. Alongside the questionnaire, two observation-based variables were created named 'Presence of Helmet for Rider' and 'Presence of Seat belt for Driver', which were answered by the surveyors. Table 1 and Table 2 below show the descriptive statistics of the responses collected from the survey.

Table 1: Statistics of questionnaire survey 'Helmet for Rider'

SI	Variable	Item	Frequency	Percentage
1	License status	Valid	675	75.17%
		Outdated	223	24.83%
2	Motorbike ownership	Personal	702	78.17%
		Official	118	13.14%
		Others	78	8.69%
3	Education level	Primary and Below	107	11.92%
		Secondary	439	48.89%
		Graduate and Above	352	39.20%

4	Feeling Enforced to Wear Helmet	Yes	300	33.41%
		No	584	65.03%
5	Wearing Helmet Should be Personal Preference	Yes	760	84.63%
		No	138	15.37%
6	Does Wearing Helmet Make You Feel Safer	Yes	721	80.29%
		No	177	19.71%
7	Perception of Injury for Not Wearing Helmet	Short Term Injury	140	15.59%
		Long Term Injury	128	14.25%
		Death	410	45.66%
		No Impact	220	24.50%
8	Suggestion to Promote Helmet Wearing	Promotional Campaign	395	43.99%
		Law Enforcement and Fine	503	56.01%
9	Previous motorcycle crash record	No Crashes	516	57.46%
		Injury and Death	293	32.63%
		Property Damage	89	9.91%
10	Helmet Avoidance	No	221	24.61%
		Yes Sometimes	586	65.26%
		Yes Often	91	10.13%
11	Stopped by Police	Never	376	41.87%
		Once or Twice	349	38.86%
		More than Twice	173	19.27%
12	Presence of Helmet for Rider	Yes	476	53.01%
		No	422	46.99%

Table 1 shows that 48.89% of the respondents under 'Helmet for Rider' category received secondary education whereas 39.2% of them were graduates and above. 11.92% of the respondents received primary education or below. The tendency of avoiding helmet wearing sometimes or often was seen among the major portion (75.39%) of the respondents. The presence of helmet during the survey was observed among 53.01% of the respondents. A total of 422 people were found not wearing helmet though 80.29% of the respondents are conscious about the safety benefits of wearing helmet.

Table 2: Statistics of questionnaire survey 'Seat Belt for Driver'

SI	Variable	Item	Frequency	Percentage
1	Road Condition	Damaged	319	50.88%
		Good	308	49.12%
2	License Type	Professional	532	84.85%
		Non-Professional	95	15.15%
3	Car Ownership	Personal	231	36.84%
		Official	396	63.16%
4	Age Group	Less than 20	49	7.81%
		From 20 to 40	470	74.96%
		Greater than 40	108	17.22%
5	Education level	Illiterate	79	12.60%
		Primary	131	20.89%
		Secondary	417	66.51%
6	Presence of Proper Seat Belt for Driver	Yes	569	90.75%
		No	58	9.25%
7	Wearing Seat Belt Should be Personal Preference	Yes	341	54.39%
		No	286	45.61%
8	Feel Safe After Wearing Seat Belt	Yes	388	61.88%
		No	239	38.12%
9	Feel Uncomfortable to Wear Seat Belt	Yes	295	47.05%
		No	332	52.95%
10	Seat Belt Use Can Reduce Accident	Yes	539	85.96%
		No	88	14.04%
11	Perception of Severity of Injury for not Wearing Seat Belt	Short Term Injury	321	51.20%
		Long Term Injury	184	29.35%
		Death	105	16.75%
		No Impact	17	2.71%
12	Suggestion to Promote Seat Belt Wearing	Promotional Campaign	320	51.04%
		Law Enforcement and Fine	307	48.96%
13	Previous Crash Record	No Crashes	485	77.35%
		Injury and Death	80	12.76%
		Property Damage	62	9.89%
14	Ever Ride Without Wearing Seat Belt	No	111	17.70%
		Yes	516	82.30%
15	Stopped by Police for not Wearing Seat Belt	No	601	95.85%
		Yes	26	4.15%

Table 2 shows that 66.51% of the respondents under ‘Seat Belt for Driver’ category received secondary education. No graduate or higher educated driver was found whereas 20.89% of them received primary education and 12.6% were illiterate. This statistics is not unusual in the perspective of Bangladesh as car owners prefer not to drive their cars and employ professional drivers in most cases, especially when traveling outside of the city. The tendency of not wearing seat belt was seen among 82.3% of the drivers. However, only 4.15% of them were ever stopped by police. Out of 627 respondents, a total of 569 drivers were found wearing seat belt.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This chapter presents the methodological approach followed in this research in a gradual organization. The concern of this study was to unveil the underlying factors affecting safety restraint use from the stand-point of a developing country and to establish a causal relationship among the factors. Since such factors are often mutually dependent and influenced by prior belief, Bayesian Belief Network (BBN) can be used to establish a causal relationship among them using conditional probability. In this chapter, a brief yet thorough introduction of Bayesian Belief Network (BBN) will be provided along with the depiction of applicability of this method for our research work.

4.2 Work Flow of the Research

The work flow of the research is outlined below in figure 2:

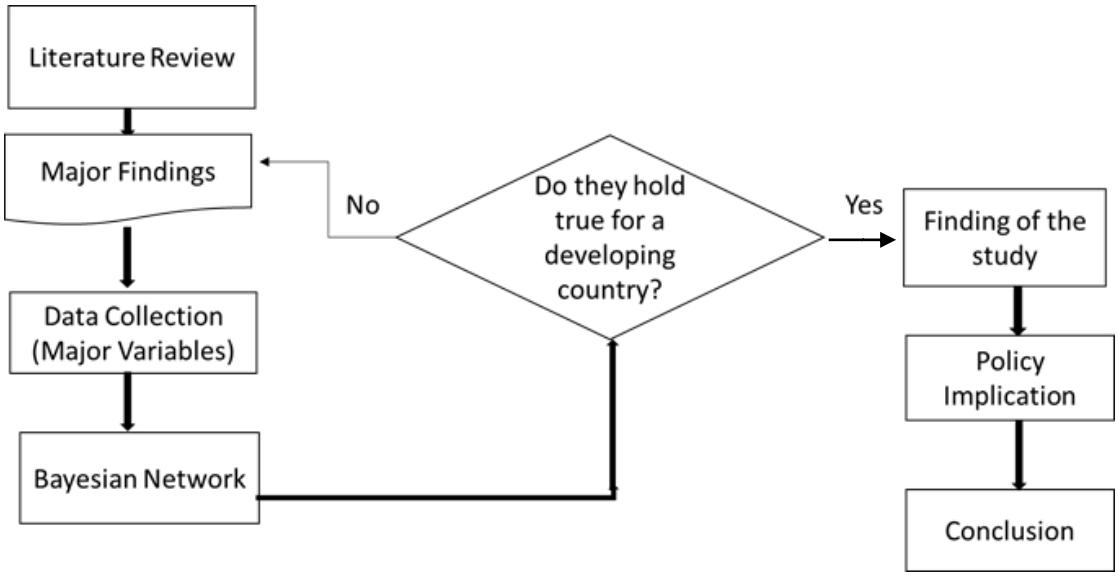

Figure 2: Work flow of the research

The research work began with comprehensive and thorough literature review based on which the questionnaire survey was prepared. Data were collected from a field survey where the relevance and effectiveness of the questionnaire were judged earlier by pilot study and FGD. The collected data was then fitted into Bayesian network in the form of DAG (Directed Acyclic Graph). The established model was pruned and optimized based on experts judgement and knowledge gained from thorough literature review. After all the mentioned steps were completed, the model became ready to be asked questions and receive outputs accordingly.

4.3 Bayesian Belief Network (BBN)

In this research, the Bayesian Belief Network (BBN) is implemented to understand the underlying relationship between variables such as safety perception, demographic characteristics and how they influence the use of safety restraints. Bayesian network is a graphical model that represents a set of variables and their conditional dependencies. The conditional dependencies are represented as Directed Acyclic Graph (DAG) which acts as a useful tool to visualize the probabilistic model, appraise the relationship between random variables and notice their posterior probability for given evidence. Each random variable in DAG is called a node and remains connected by arcs. The nodes on the origin side of an arc are called a mother node and the other ones are called child nodes. Besides DAG, the Bayesian network includes Conditional Probability Table (CPT) which shows the quantitative probability of one variable to another. The Bayesian framework is based on the Bayes hypothesis also known as the Bayes rule (Wang & Vassileva, 2005).

$$P(A|B) = \frac{P(B|A)\ P(A)}{P(B)} \qquad (1)$$

$P(A)$ is the probability of occurrence of A and $P(B)$ is the probability of occurrence of B. $P(A|B)$ indicates the probability of occurrence of A given that B has already occurred and $P(B|A)$ is the probability of B given that A has already occurred. A Bayesian network represents the joint probability distribution graphically and can be expressed as product rule-

$$P(X_1, X_2, \ldots . X_n) = \prod_{i=1}^{n} P(X_i | pa(X_i)) \quad (2)$$

The structure of the Bayesian network can be learned from data or can be a mixture of expert knowledge and structural learning technique. In this study, the mixture method was adopted for network building. The data obtained from the questionnaire was imported into GeNIe 2.5 Academic Version and the structural learning was completed using PC algorithm. PC algorithm is a popular constraint-based method used for causal discovery. This algorithm employs Conditional Independence (CI) test between pairs of variables to develop the structure of the network (Tsagris, 2019). To achieve the joint probability distribution through parameter learning, GeNIe applies the Expectation Maximization (EM) algorithm. The EM algorithm is an approach to perform maximum likelihood estimation in presence of latent variables. EM first estimates the values of latent variables and continues an iterative improvement process to maximize the estimation. The iteration process consists of two steps known as E-Step (Expectation Step) and M-Step (Maximization Step). The iteration continues until the two steps converge.

4.4 GeNIe Workspace

GeNIe (Graphical Network Interface) is a software tool developed at University of Pittsburgh. This software is useful for decision analysis and graphical representation of the union of probability and network occurrences. GeNIe can be used for analysis of Bayesian networks and is very handy for analyzing noisy data and uncertainty measures. The calculation of a Bayesian network with large number of inter-connected nodes can get very complex at times and GeNIe can easily handle the analysis of such type of problems.

In our research work, GeNIe 2.5 Academic Version was used for the purpose of structural learning (network formation) and parameter learning (preparation of CPT). After the completion of parameter learning, GeNIe provides different analysis options such as observing prior and posterior marginal probability, sensitivity analysis, tornedo diagram, strength of influence etc.

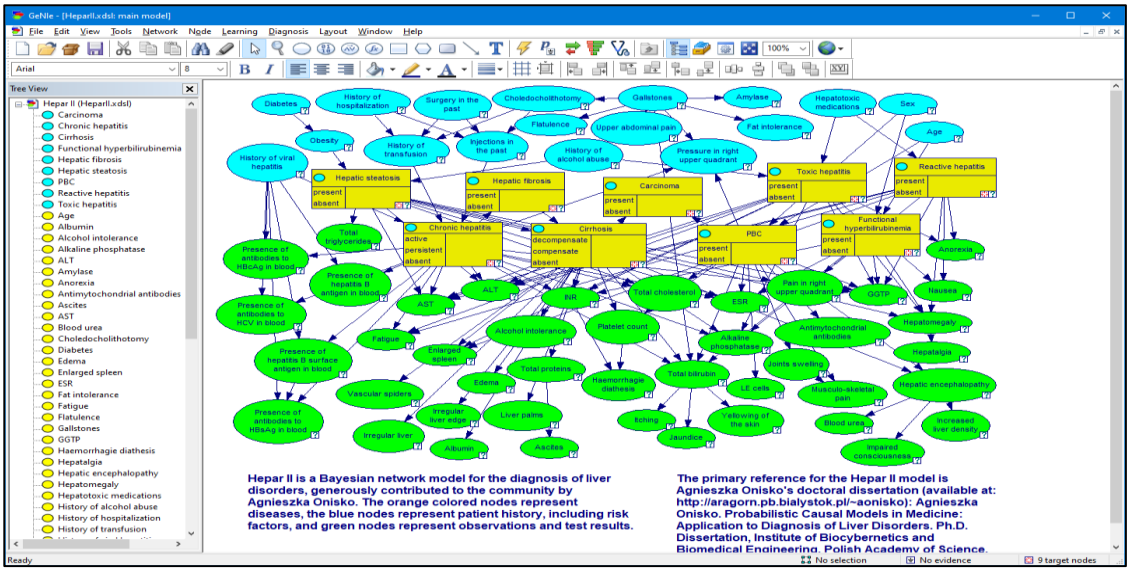

Figure 3: GeNIe workspace

4.5 Model Development

The initial Bayesian network was obtained from GeNIe by structural learning using PC algorithm. The network was then modified based on correlation analysis, literature review, and expert knowledge. Correlation analysis was done using IBM SPSS Statistics 26 to examine the significance of the relationship between two variables. The results of the correlation analysis are attached here.

Table 3: Result of correlation analysis 'Helmet for Rider'

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1		**			**							
X_2	**											**
X_3												**
X_4					**							
X_5	**			**								**
X_6												**
X_7									**			**
X_8										**		**
X_9							**					
X_{10}								**			**	**
X_{11}										**		
X_{12}		**	**		**	**	**	**		**		

**Significant at 0.01 level

Table 4: Result of correlation analysis 'Seat Belt for Driver'

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
X_1								**							
X_2			**												
X_3		**				**		**							
X_4							**	**							
X_5						**									
X_6			**		**			**	**	**	**				
X_7				**				**	**						
X_8	**		**	**		**	**								
X_9						**	**						**	**	
X_{10}						**						**			
X_{11}						**							*		
X_{12}										**					
X_{13}											*				
X_{14}									**						
X_{15}															

**Significant at 0.01 level and *Significant at 0.05 level

Table 5: Variable Definition 'Helmet for Rider'

x_1	License Status	x_4	Feeling Enforced	x_7	Injury Perception	x_{10}	Helmet Avoidance
x_2	Motorbike Ownership	x_5	Personal Preference	x_8	Promotional Suggestion	x_{11}	Stopped by Police
x_3	Education Level	x_6	Safety Perception	x_9	Crash Record	x_{12}	Presence of Helmet

Table 6: Variable Definition 'Seat Belt for Driver'

x_1	Road Condition	x_4	Age Group	x_7	Personal Preference	x_{10}	Perception of accident reduction by seat belt	x_{13}	Crash Record
x_2	License Type	x_5	Education Level	x_8	Safety Perception	x_{11}	Injury Perception	x_{14}	Seat Belt Avoidance
x_3	Car Ownership	x_6	Presence of Seat Belt	x_9	Perception of Discomfort	x_{12}	Promotional Suggestion	x_{15}	Stopped by Police

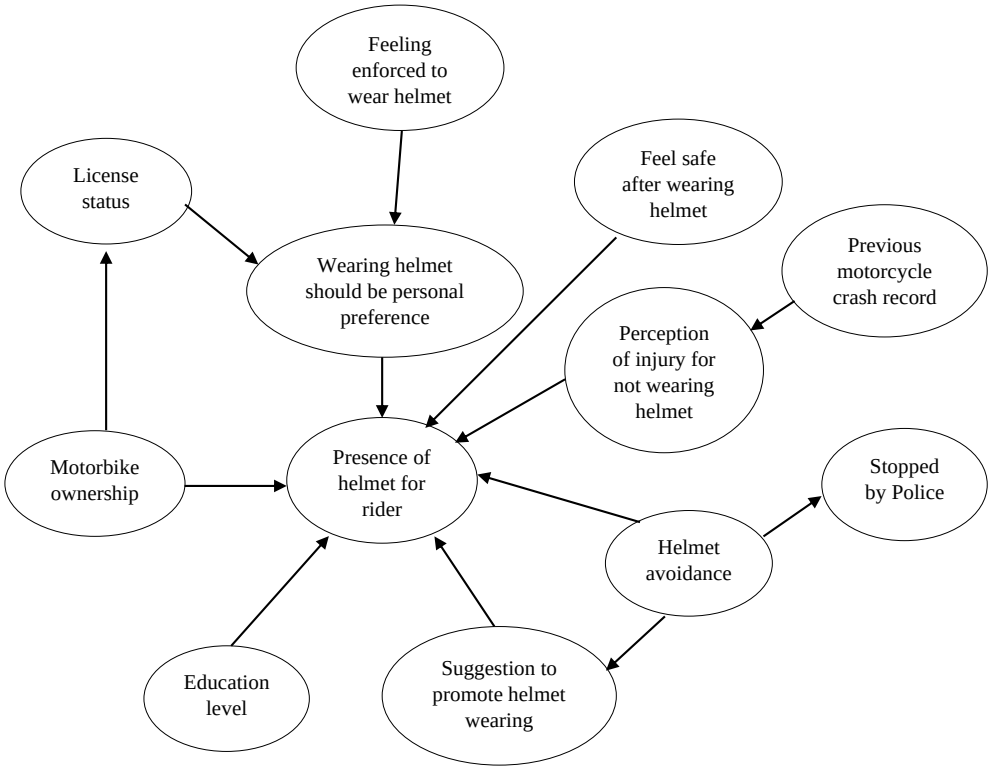

Figure 4: Bayesian network of 'Helmet for Rider'

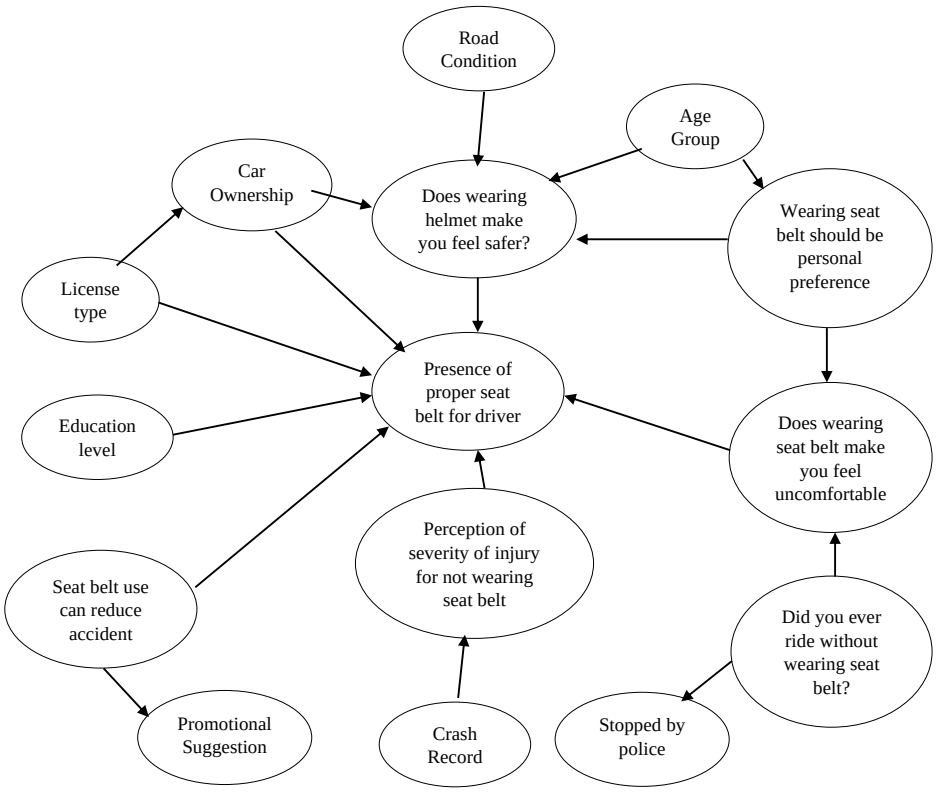

Figure 5: Bayesian network of 'Seat belt for Driver'

4.6 Model Validation

The accuracy of the models was evaluated using the default validation tool provided in GeNIe. Leave One Out (LOO) method was used for validation as it is the most efficient method with feasible computation time. LOO is a cross-validation method where the network is trained on all records within the data set except the target variable. The results obtained from the evaluation are expressed as Receiver Operating Characteristic (ROC) curve. The ROC curve represents a plot of sensitivity vs false positive rate, where the line along the diagonal represents a pure 50% chance of accurate prediction of a model, and Area Under the ROC Curve (AUC) represents a value between 0 and 1, where value closer to 1 suggests the better performance of the model (Park, Goo, & Jo, 2004). In general practice, an AUC value above 0.7 is considered an acceptable value for model validation. In our study, the helmet model achieved 0.74, and the seat belt model achieved a 0.83 AUC value, suggestive of a good functioning model.

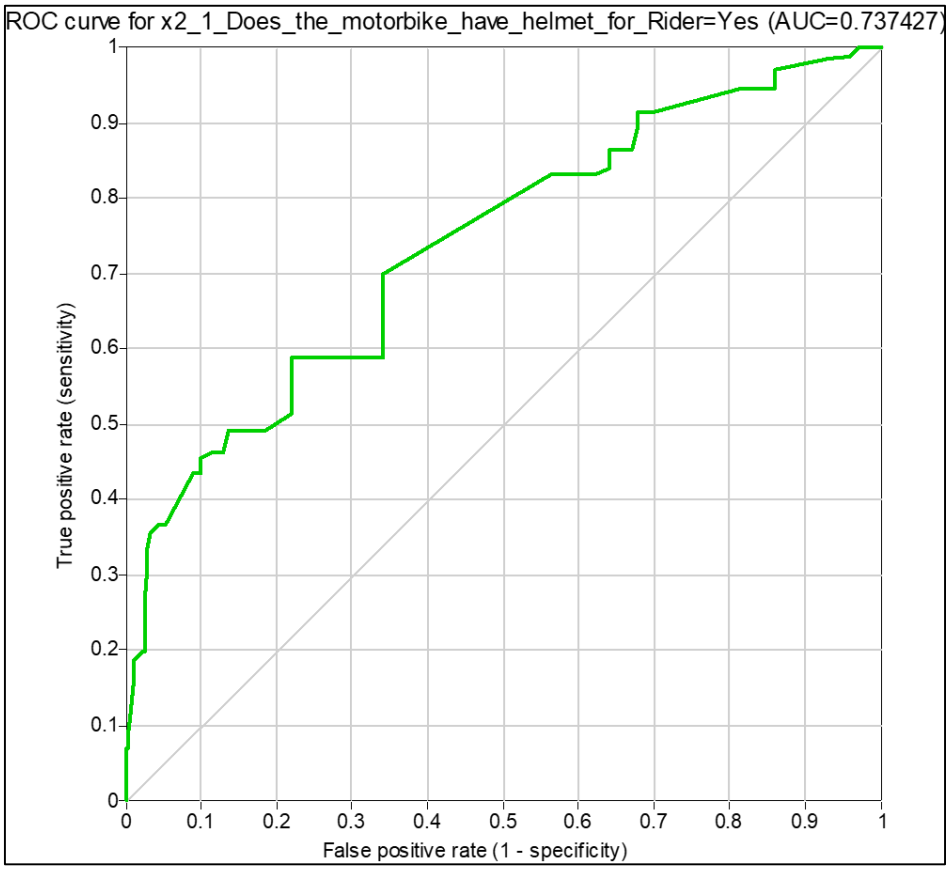

Figure 6: ROC curve for 'Helmet for rider' model

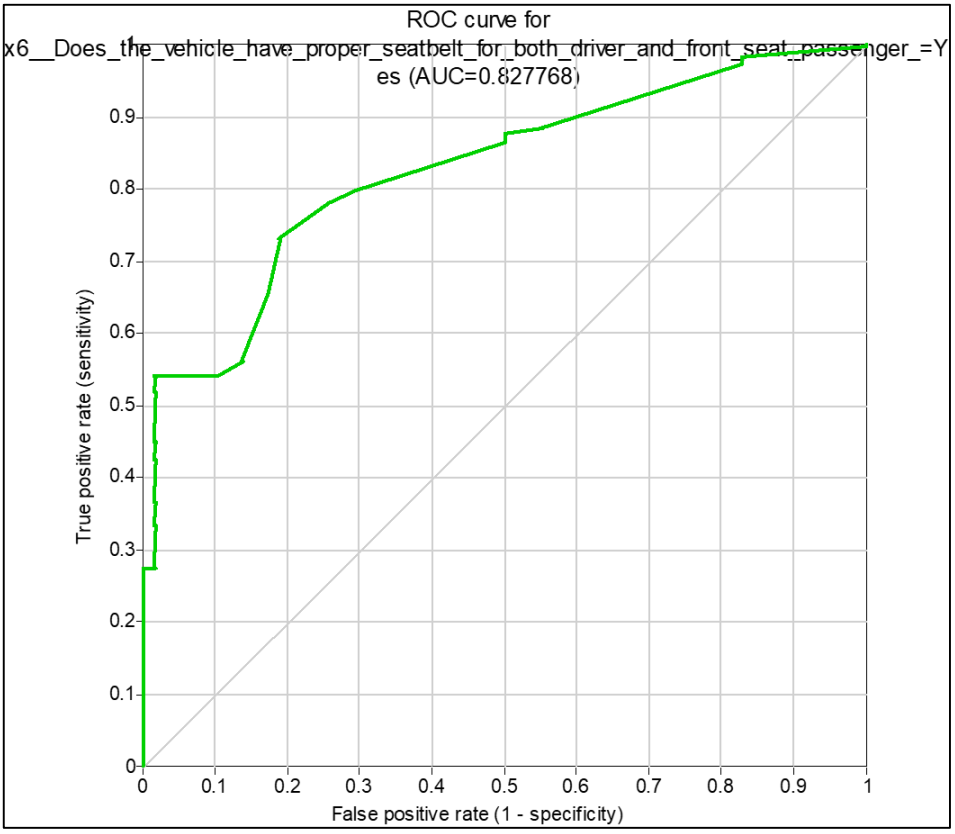

Figure 7: ROC curve for 'Seat belt for driver' model

Confusion matrix or error matrix is a table layout that helps in visualizing the performance of a model. In a confusion matrix, each column represents actual class and each row represents predicted class. The confusion matrix for helmet and seat belt model are attached here-

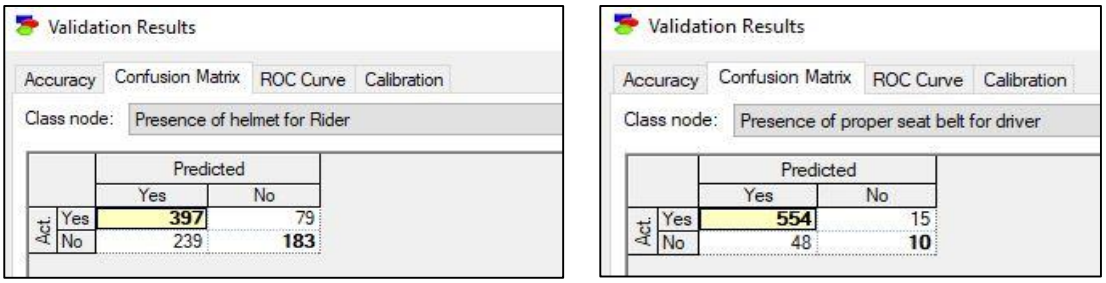

Figure 8: Confusion matrix of helmet and seat belt model

CHAPTER 5

ANALYSIS AND RESULTS

5.1 Introduction

This chapter presents the main findings of the study after completing data analysis using BBN model. The data collected from the survey was re-categorized and re-distributed initially based on descriptive statistics. The fine-tuned data was then fit into Bayesian network structure. The nodes of the network were tweaked and tested to understand each variable's impact on selected target variable. Several analysis works were carried out on the model such as- sensitivity analysis, tornedo diagram. The accuracy of the model was also tested using the built-in model validation feature of the GeNIe software. After the completion of analysis step, all the findings of the research were aggregated and presented in this chapter concisely.

5.2 Model Analysis

Parameter learning is the first step of the analysis process using GeNIe software. GeNIe uses the default EM (Expectation-Maximization) algorithm for parameter learning. The marginal probabilities of all nodes in the network were obtained after parameter learning. The marginal probability is the sum or union of all the probabilities of events of other variables for a given event of the target variable. In this study, the observation-based 'Presence of helmet for rider' and 'Presence of seat belt for rider' were set as target variables as they fortify the models by eliminating the social desirability bias of self-reported data.

In a Bayesian network structure, the prior marginal probabilities of variables are similar to the observed data as long as the dependent variable remains unchanged. However, using GeNIe, the posterior marginal probability can be observed for any change in the events of the dependent variable. The analysis has been divided into two segments

'Helmet for Rider' and 'Seat belt for Driver' and observed for the change in safety perception and socio-demographic factors due to the forced alteration in target variables.

5.3 Analysis of Helmet Model

Motorbike riders observed wearing helmet during the survey were put under 'Yes' and non-users were put under 'No'. Figure 9 shows the prior marginal probabilities of each node whereas Figure 10 shows the posterior marginal probabilities when the target variable's state 'Yes' is set as evidence. Similarly, Figure 11 shows the posterior marginal probabilities when 'No' is set as evidence in the target variable.

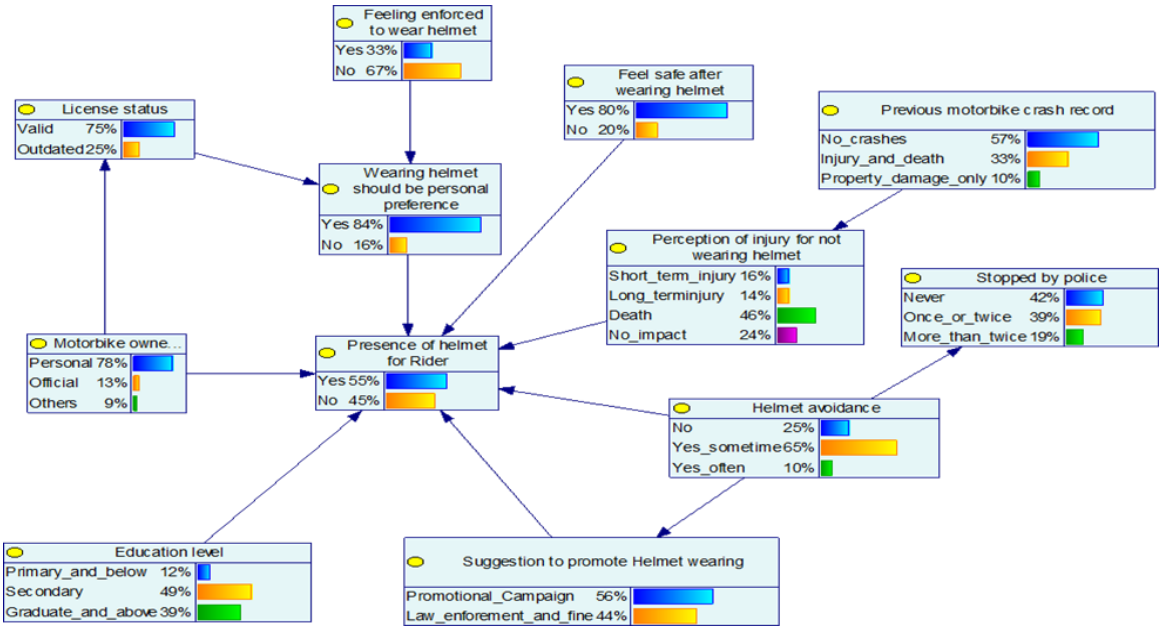

Figure 9: Prior marginal probability distribution diagram of 'Helmet for Rider'

Figure 10: Posterior marginal probability distribution diagram when the presence of helmet is 100%

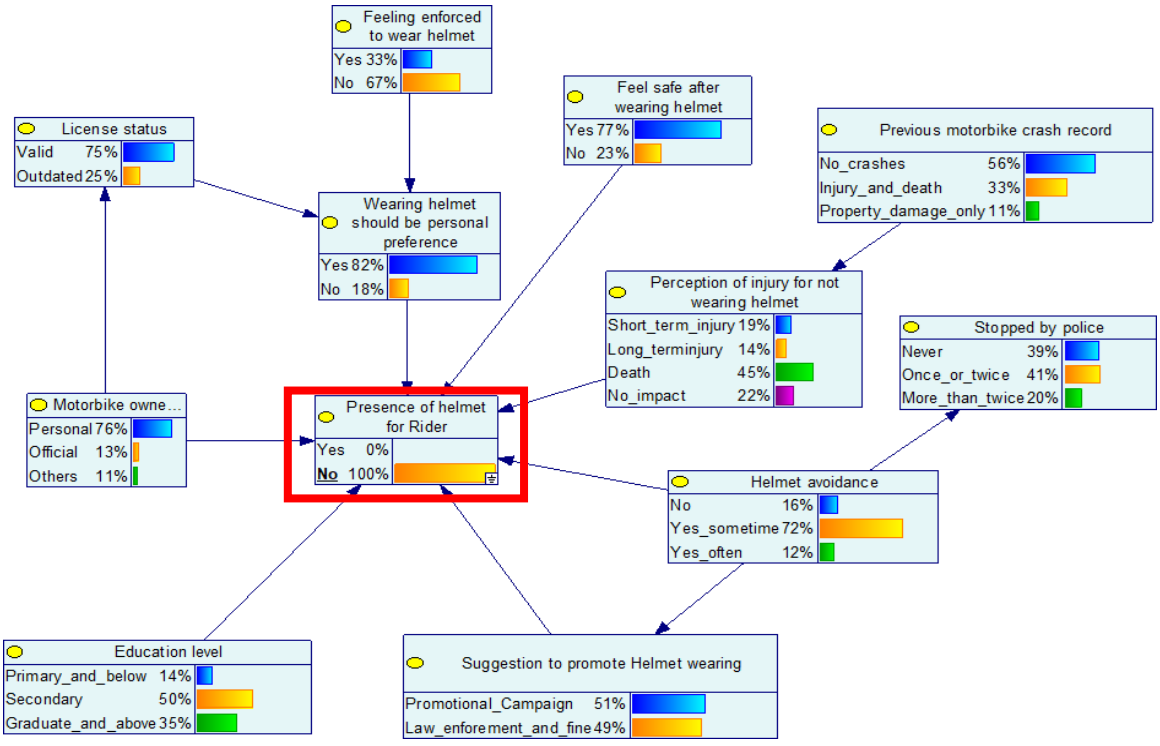

Figure 11: Posterior marginal probability distribution diagram when absence of helmet is 100%

The posterior marginal probabilities of each node were observed for both the evidence of target variable 'Presence of Helmet for Rider'. Table 7 illustrates the outcomes of the observation.

Table 7: All nodes marginal probabilities for 'Yes' and 'No' state of target variable 'Presence of Helmet for Rider'

Attribute	Attribute Category	Evidence (%)	
		Presence of helmet for rider	
		Yes	No
License status	Valid	75	75
	Outdated	25	25
Motorbike ownership	Personal	80	76
	Officials	13	13
	Others	7	11
Education level	Primary and below	10	14
	Secondary	48	50
	Graduate and above	42	35
Feeling enforced to wear helmet	Yes	34	33
	No	66	67
Wearing helmet should be personal preference	Yes	86	82
	No	14	18
Feel safe after wearing helmet	Yes	83	77
	No	17	23
Perception of injury for not wearing helmet	Short term injury	12	19
	Long term injury	14	14
	Death	47	45
	No impact	27	22
Suggestion to promote helmet wearing	Promotional campaign	60	51
	Law enforcement and fine	40	49
Previous motorbike crash record	No crash	59	56
	Injury and death	32	33
	Property damage only	9	11
Helmet avoidance	Never	32	16
	Yes, sometimes	60	72
	Yes, often	8	12
Stopped by police	Never	44	39
	Once/twice	37	41
	More than twice	19	20

The analysis showed a 6% increase in helmet avoidance for secondary or lower educated riders. Personal and official motorbike riders were seen using helmet whereas non-owners of the motorbike were not using helmet. Results also show that 84% of the riders not wearing helmet during the survey don't wear helmet 'sometimes' or 'often'

and 61% of them were stopped by police at least once in their life. The attitude of not wearing helmet despite being penalized by police refers to the weakness of existing laws and interventions in Bangladesh. Positive safety perception was 6% higher among helmet users compared to non-users. Non-users of helmet were found to have 3% higher previous crash experience as well. Variables such as feeling enforced to wear helmet and license status were found unaffected by helmet availability. Surprisingly, non-users of helmet were more supportive of introducing enforcement and punishment to ensure better helmet use.

5.3.1 Sensitivity Analysis of Helmet Model

Sensitivity analysis was conducted on the existing network to achieve a better understanding of the most significant variables. In a sensitivity analysis, GeNIe shows the effect of variation in the target variable. The variables with dark red color have the most impact on the target variable. With decreasing intensity of red color, the impact gradually decreases. The variables with white color have a very low impact on the target variable whereas grey color represents no impact at all.

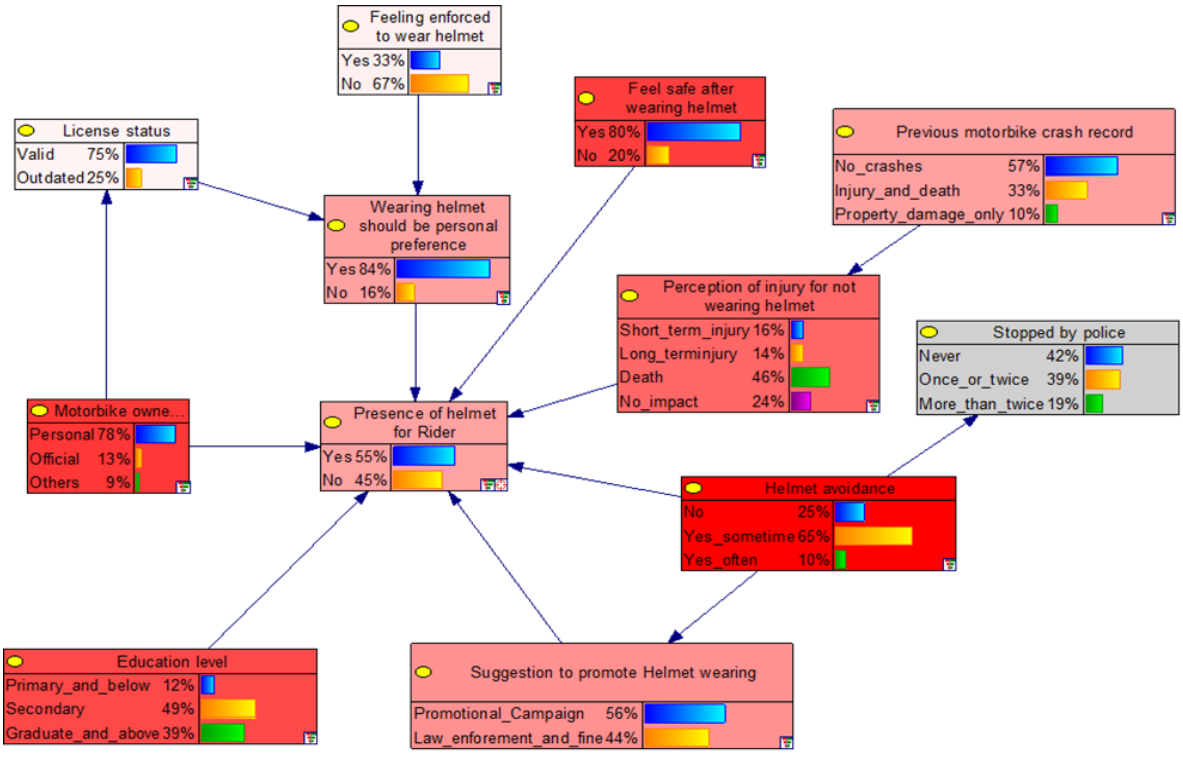

Figure 12: The BBN and key variables for 'Presence of helmet for rider'

The sensitivity analysis shows that ‘Feel safe after wearing helmet’, ‘Motorbike ownership’ and ‘Helmet avoidance’ are the most significant variables. ‘Education level’ and ‘Perception of injury’ were found second most important whereas ‘License status’ and ‘Feeling enforced to wear helmet’ had the least influence on the target. It was also found that previous experience of getting stopped by police doesn’t impact the helmet availability at all.

A tornado diagram in sensitivity analysis identifies the most significant state of a variable for a selected state of the target variable. For the helmet model, positive safety perception was found most significant on helmet availability. The result also dictates higher helmet prevalence among riders who avoid wearing helmet ‘never’ or ‘sometimes’.

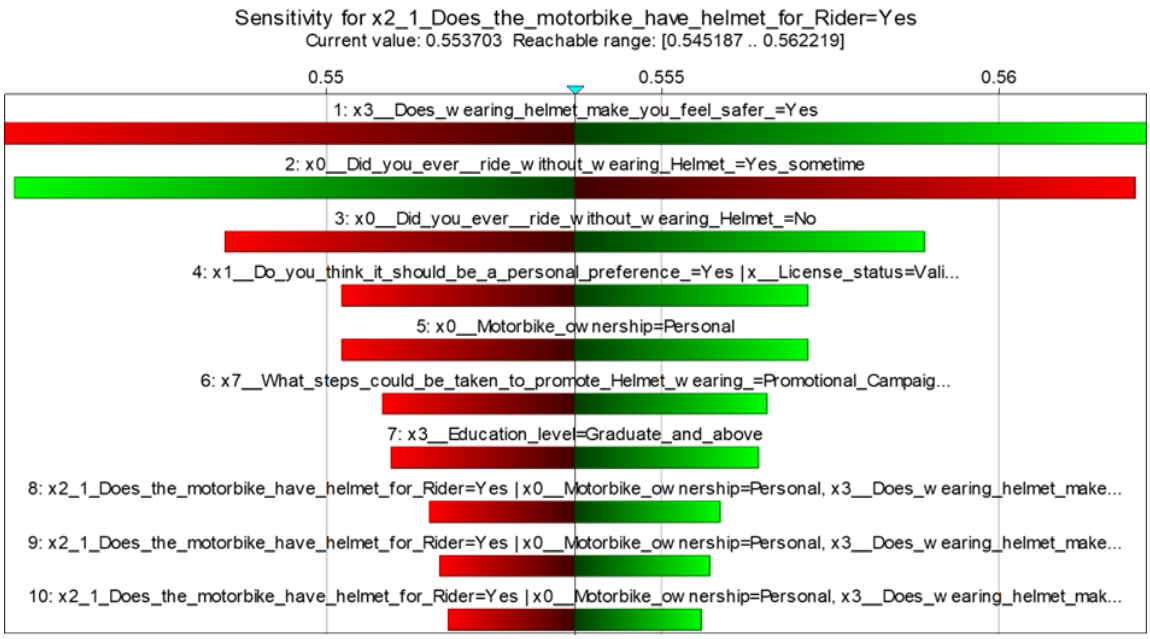

Figure 13: Tornado diagram in sensitivity analysis when the presence of helmet for rider is ‘Yes’

5.4 Analysis of Seat Belt Model

A similar analysis was done for the seat belt model as well. Figure 14 shows the marginal probabilities before updating belief and Figure 15 shows the posterior marginal probabilities when 'Yes' is set as evidence in the target variable 'Presence of proper seat belt for driver'. Figure 16 depicts the scenario where absence of seat belt is considered 100%.

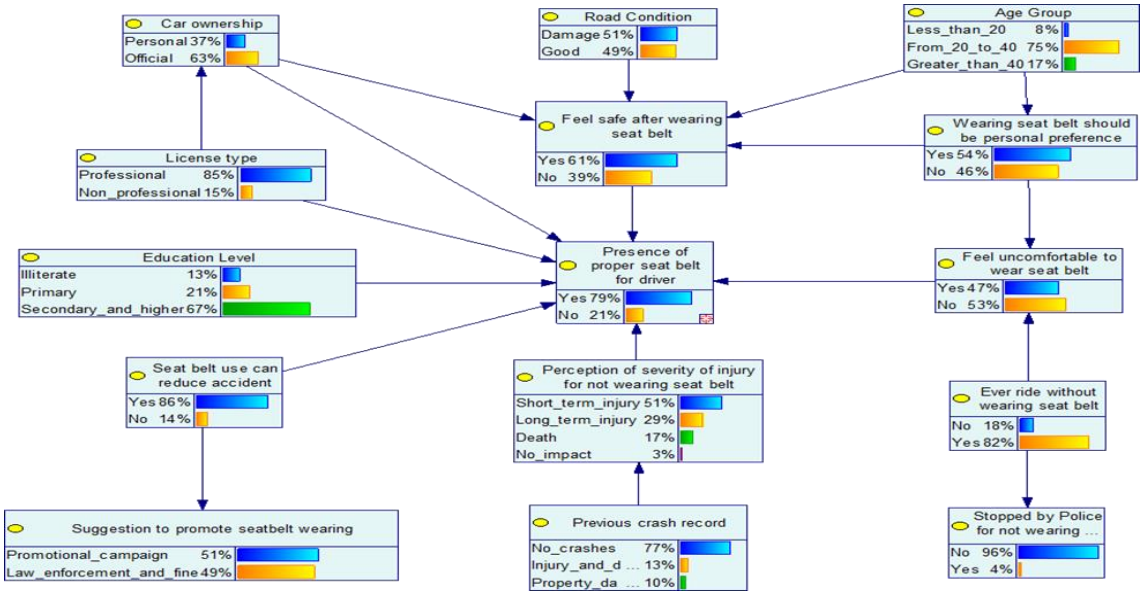

Figure 14: Prior marginal probability distribution diagram of 'Seat belt for Driver'

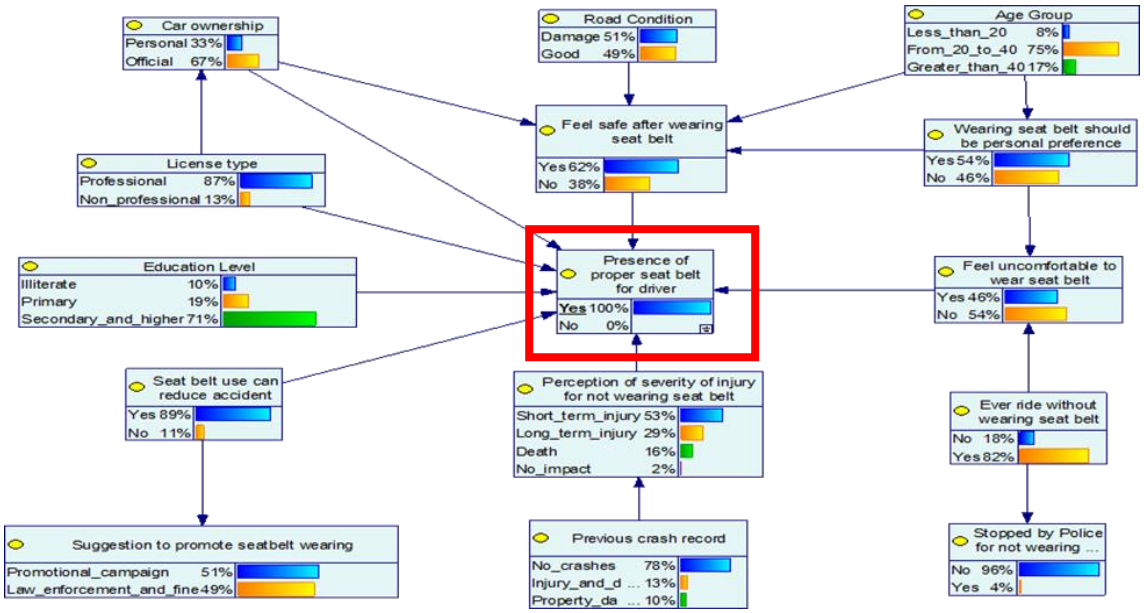

Figure 15: Posterior marginal probability distribution diagram when the presence of seat belt is 100%

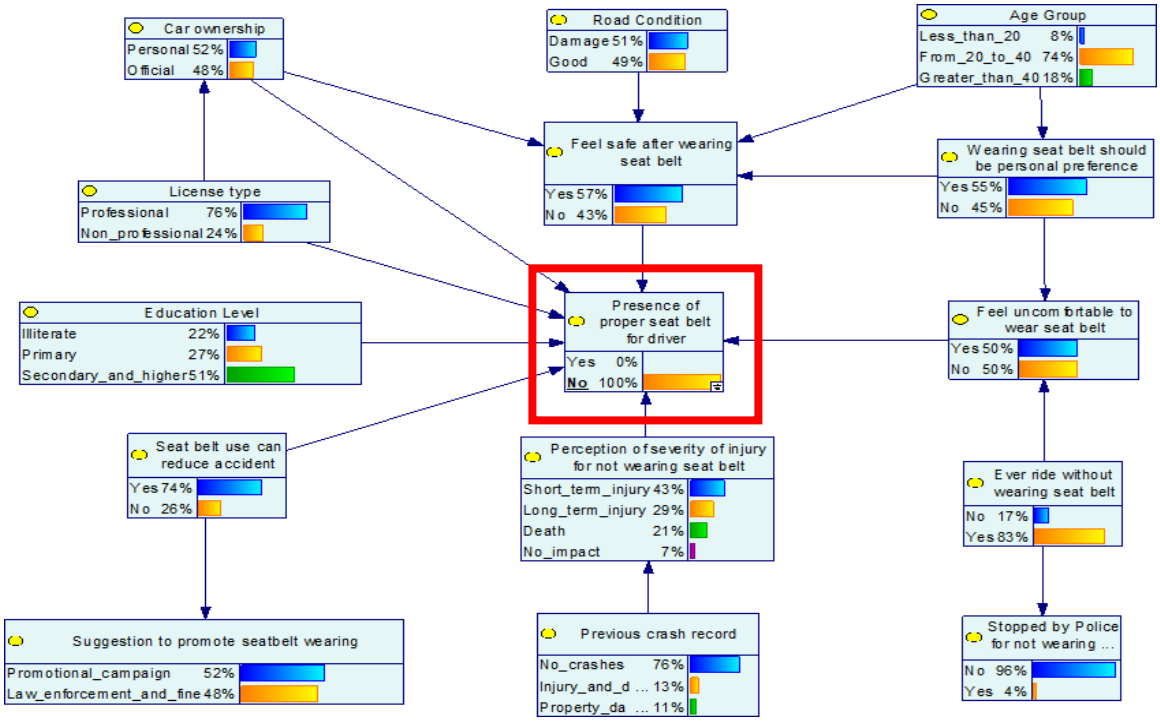

Figure 16: Posterior marginal probability distribution diagram when absence of seat belt is 100%

The posterior marginal probabilities for two pieces of evidence of node 'Presence of Seat belt for Driver' are shown side by side in table 8.

Table 8: All nodes marginal probabilities for 'Yes' and 'No' state of target variable 'Presence of proper seat belt for driver'

Attribute	Attribute Category	Evidence(%)	
		Presence of proper seat belt for driver	
		Yes	No
Road condition	Damage	51	51
	Good	49	49
License type	Professional	87	76
	Non-professional	13	24
Car ownership	Personal	33	52
	Official	67	48
Age Group	< 20	8	8
	20-40	75	74
	>40	17	18
Education Level	Illiterate	10	22
	Primary	19	27
	Secondary and higher	71	51
	Yes	54	55

Wearing seat belt should be a personal preference	No	46	45
Feel safe after wearing seat belt	Yes	62	57
	No	38	43
Feel uncomfortable after wearing seat belt	Yes	46	50
	No	54	50
Seat belt use can reduce accident	Yes	89	74
	No	11	26
Perception of severity of injury for not wearing seat belt	Short term injury	53	43
	Long term injury	29	29
	Death	16	21
	No impact	2	7
Suggestion to promote seatbelt wearing	Promotional campaign	51	52
	Law enforcement and fine	49	48
Previous crash record	No crash	78	76
	Injury and death	13	13
	Property damage only	10	11
Ever Ride without wearing seat belt	No	18	17
	Yes	82	83
Stopped by Police for not wearing seat belt	No	96	96
	Yes	4	4

Seat belt use was found dominant among secondary and higher educated people with professional driving licenses. Age group did not have a significant impact on seat belt wearing for drivers. Official cars had a significantly high use of seat belt compared to personal cars. Disapproval of safety importance of seat belt use was 5% higher among non-users. The previous crash experience was 2% higher among non-users. 50% of non-users and 46% of users were found uncomfortable wearing seat belt. Most of the users and non-users think seat belt wearing can't prevent death in a fatal accident. Road condition and previous experience of getting stopped by police were found unaffected by seat belt presence.

5.4.1 Sensitivity Analysis of Seat Belt Model

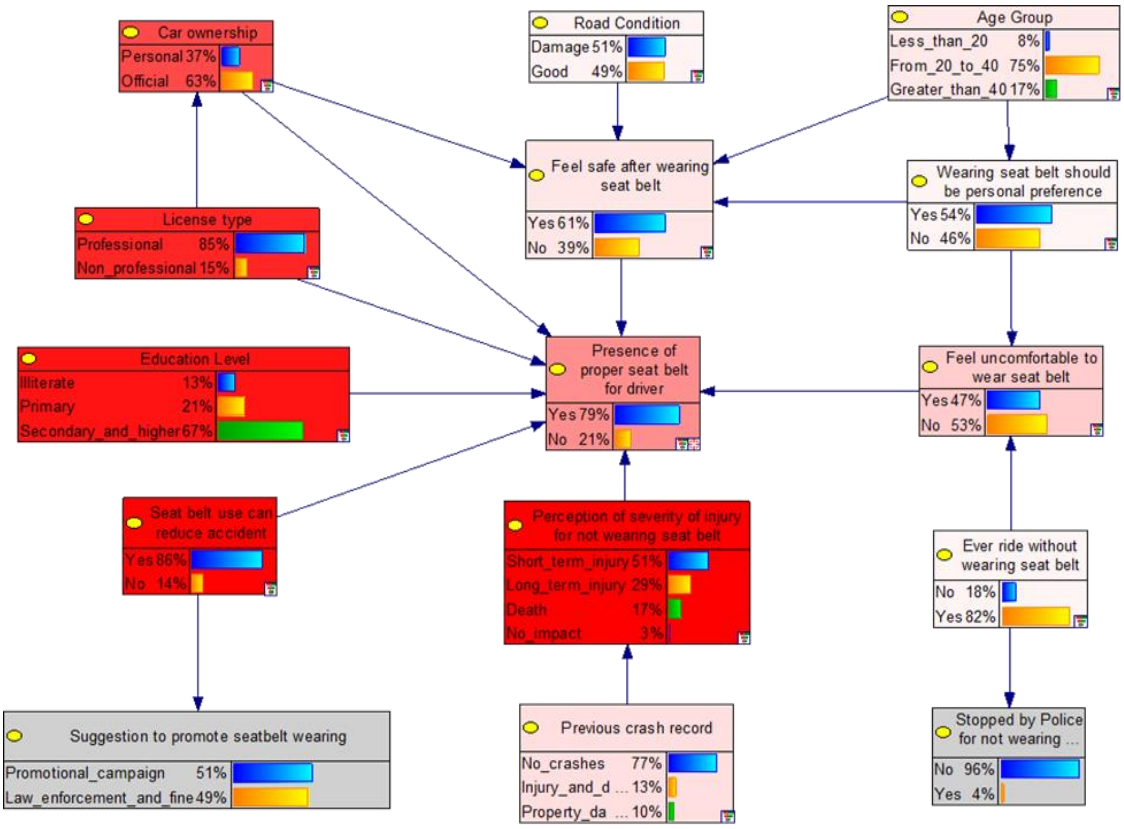

Figure 17: The BBN and key variables for 'Presence of seat belt for driver'

The sensitivity analysis on seat belt model revealed that 'Education level', 'License type', 'Seat belt use can reduce accident', 'Perception of injury for not wearing seat belt' were the key variables. 'Car ownership' was observed as the second most significant variable. Most other variables had a little impact on the target whereas 'Stopped by police for not wearing seat belt' and 'Suggestion to promote seat belt wearing' had zero impact.

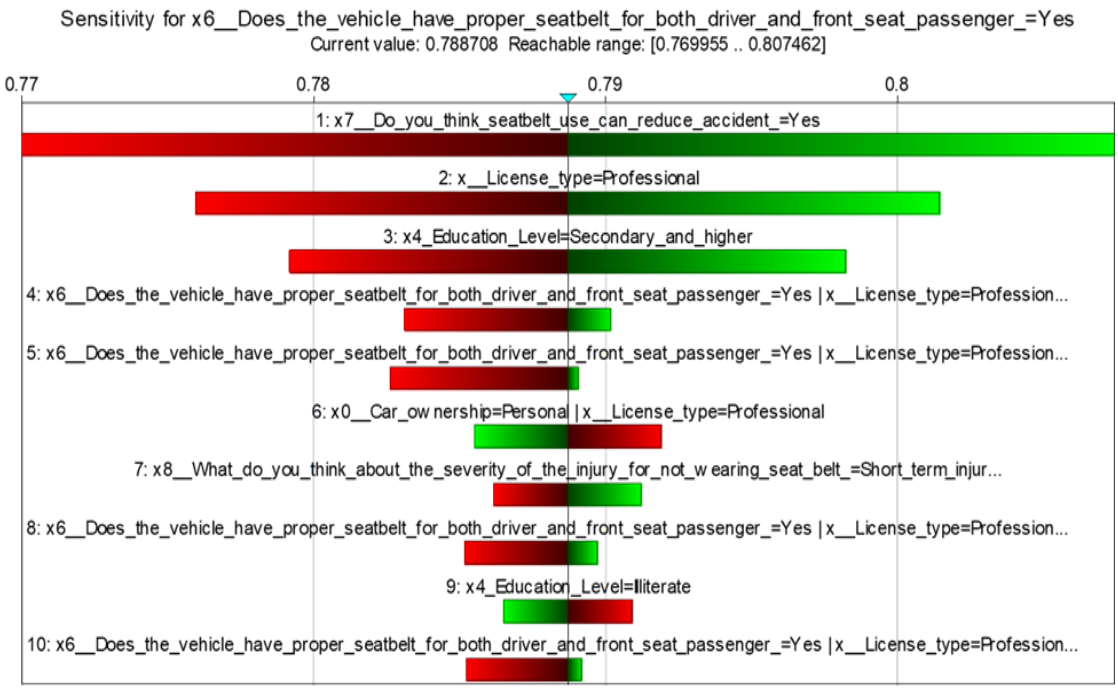

Figure 18: Tornado diagram in sensitivity analysis when the presence of seat belt for driver is 'Yes'

A tornado diagram was also developed for the seat belt model to deeply inspect the significant variables. Positive accident reduction perception of seat belt use was found the most significant parameter for the availability of seat belt among drivers. Professional license status, secondary and higher education level were also found notably significant.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Introduction

The major findings of this study are summarized in this chapter and plausible recommendations have been made based on the outcomes. The delineated recommendations and implications might be helpful for policy makers, transport planners, vehicle users and all other relevant personnel. In the concluding remark, the limitations and future scopes of our study has been outlined.

6.2 Key Findings (Helmet for Rider)

6.2.1 Safety Perception Related Findings

Understanding whether safety perception motivates helmet wearing among motorbike riders was a key objective of our study. The participants of the survey were asked about various safety perception and safety importance of helmet use related questions such as ‘feeling safe after wearing helmet’, ‘perception of injury due to helmet avoidance’, ‘helmet wearing should be personal preference’ etc. It was found that, positive safety perception was 6% higher among helmet users compared to non-users. The sensitivity analysis showed that ‘Feel safe after wearing helmet’ and ‘Helmet avoidance’ are the most significant variables effecting presence of helmet. Besides, ‘Perception of injury’ was found the second most important variable.

6.2.2 Law Enforcement Related Findings

Results show that 84% of the riders not wearing helmet during the survey don’t wear helmet ‘sometimes’ or ‘often’ and 61% of them were stopped by police at least once in

their life. The attitude of not wearing helmet despite being penalized by police refers to the weakness of existing laws and interventions in Bangladesh. From sensitivity analysis, it was also found that previous experience of getting stopped by police doesn't impact the helmet availability at all.

6.2.3 Other Important Findings

The analysis showed a 6% increase in helmet avoidance for secondary or lower educated riders. On the other hand, personal and official motorbike riders were seen using helmet whereas non-owners of the motorbike were not using helmet. This information dictates the importance of education and motorbike ownership in helmet wearing attitude. Variables such as feeling enforced to wear helmet and license status were found unaffected by helmet availability. Surprisingly, non-users of helmet were more supportive of introducing enforcement and punishment to ensure better helmet use. The similar idea emerged from sensitivity analysis as well. 'Education level' was found the second most significant variable and 'License status' was found having very low influence on helmet wearing.

6.3 Key Findings (Seat Belt for Driver)

6.3.1 Safety Perception Related Findings

It was found that, disapproval of safety importance of seat belt use was 5% higher among non-users. The previous crash experience was 2% higher among non-users. 50% of non-users and 46% of users were found uncomfortable wearing seat belt. Most of the users and non-users think seat belt wearing can't prevent death in a fatal accident. Result from sensitivity analysis revealed that safety perception related variables such as 'Seat belt use can reduce accident', 'Perception of injury for not wearing seat belt' were the key variables in terms of presence of seat belt for driver.

6.3.2 Law Enforcement Related Findings

From the analysis, variable referring to previous experience of getting stopped by police was found unaffected by seat belt presence. Sensitivity analysis also showed that, 'Stopped by police for not wearing seat belt' had zero impact on the target variable.

6.3.3 Other Important Findings

Seat belt use was found dominant among secondary and higher educated people with professional driving licenses. Age group did not have a significant impact on seat belt wearing for drivers. Official cars had a significantly high use of seat belt compared to personal cars. The sensitivity analysis on seat belt model revealed that 'Education level', 'License type', 'Seat belt use can reduce accident', 'Perception of injury for not wearing seat belt' were the key variables. 'Car ownership' was observed as the second most significant variable. Most other variables had a little impact on the target whereas 'Suggestion to promote seat belt wearing' had no impact.

6.4 Recommendation and Policy Implication

This study aimed to unveil the underlying determinants of safety restraint use from the standpoint of a developing country. For this purpose, a survey was conducted in 32 national and regional highway intersections and motorists were asked about socio-demographic and safety perception-related information. The collected data was fit into a Bayesian network and through rigorous analysis, key indicators such as safety perception, education, injury perception, and vehicle ownership were identified. The findings of the research were able to shed light on aspects that are to be brought under government policy to achieve higher safety among motor vehicle users. Such findings call for strong policy implications as it was able to unveil the significant determinants of safety restraint use. Findings on the positive association of efficiency of safety restraints, severity, and safety perception with proper use of safety restraint support existing regional studies(Nambulee et al., 2019; Zamani-alavijeh, Bazargan, Shafiei, &

Bazargan-hejazi, 2011b). Another similar finding was, non-users are likely to comply if law enforcement is strengthened (Karuppanagounder & Vijayan, 2016b; Kulanthayan, Radin Umar, Ahmad Hariza, & Nasir, Mohd, 2001b). Rider's faith in the effectiveness of safety restraint against fatal accidents was found positively associated with helmet and seat belt use, falling in line with other related studies (Lee, 2018b). The key factors identified from the research were safety perception, education, injury perception, and vehicle ownership. Government agencies can run campaigns and promotions to grow positive safety perception and strengthen law enforcement to exacerbate proper helmet and seat belt use. People should be made aware of the severity of injury faced due to avoidance of safety restraints. Moreover, the safety consciousness gap among educated and less educated motorists should be lessened through proper measures.

6.5 Limitation and Future Scope

This research can be considered novel from many different aspects. This study identified factors that affect safety perception of people regarding the use of safety restraints, which has not been addressed by researchers locally. Besides, a causal relationship among the identified factors was established from which affect of one variable to another can be observed very easily. This study can be considered one of the first of it’s kind where such factors have been explored in this way. However, there are still some limitations in this study which require addressing.

The major limitation of the study was survey location. The picked locations of the survey were at national and regional highway intersections only. To achieve more representative data, study area can be extended to city centers and sub-urban regions in future. Factors related to discomfort of using safety restraint has been considered in this study but Bangladesh being situated in humid temperate zone, seasonal variability of this discomfort can also be introduced into the model. Besides, the data collected from road-side survey may have considerable social desirability bias being self-reported in nature. Hence, incorporation of video surveillance and car-recording techniques into

the survey can improve the quality of data by many folds. The policy implications and recommendations suggested in this study requires active participation of stakeholders, policy makers and related authorities, which can be a big challenge. Finally, the recommendations formulated through this study must be economically and financially viable in order to reach the implementation phase.

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APPENDIX

Sample of the questionnaire survey form:

CONSULTANCY SERVICES FOR STUDY ON ROAD SAFETY HAZARDS INCLUDING DESIGN OF COUNTERMEASURES AT INTERSECTIONS ON NATIONAL AND REGIONAL HIGHWAYS OF BANGLADESH

An observational study of seatbelt and helmet wearing behavior in Bangladesh – (Helmet for Driver)

Date: **Time:** **Survey no.:**
Serial No.: **Location Name:** **Intersection ID:**

1. Driving time	2. Driving area	3. Road conditions	4. Helmet Model	5. Helmet Strap	6. Riding frequency (In a day)
a. Day	a. Urban	a. Severely damaged	a. Full Face	a. Fasten	a. 2 trips
b. Night	b. Rural	b. Moderate	b. Open Face	b. Loose	b. 3- 6 trips
		c. Good		c. Open	c. More than 6 trips

7. Helmet ownership	8. License status	9. Driving license starting year	10. Motorbike ownership
a. Owned still not wearing	a. Valid		a. Personal
b. Does not have helmet while riding	b. Outdated		b. Official
			c. Others

11. Age group	12. Gender	13. Education level	14. Income level	
a. >18	a. Male	a. Illiterate	a. <5000	b. 5000-10000
b. 20-40	b. Female	b. Primary	c. 10000-25000	d. 25000-40000
c. >40		c. Secondary	e. >40000	
		d. Graduate		

15. Driving duration for the last trip	16. Is this area familiar to you	17. What is your attitude towards using seat belt	
a. Short time (45 minutes or less)	a. I am a Local	a. Good	b. Embarrassing
b. Long time (More than 45 minutes)	b. First time came here	c. Safe	d. Reasonable
	c. I visit this place at times	e. Indifferent	

18. Do you approve the importance of using Helmet?	**19. Do you feel any social pressure to use Helmet?**	**20. Do you think you're being enforced to wear Helmet?**	**21. Do you think it should be a personal preference?**	**22. Do you think wearing Helmet reduces injury?**	**23. Does wearing Helmet make you feel safer?**	**24. Do you think it is uncomfortable to wear Helmet?**	**25. Do you think Helmet usecan reduce accident?**
a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes
b. No	b. No	b. No	b. No	b. No	b. No	b. No	b. No
c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent

26. What do you think about the severity of the injury for not wearing Helmet?	**27. What steps couldbe taken to promoteHelmet wearing? (Please provide a ranking about the importance of the following processes)**	**28. Did youface any previous motorcy clecrash in the past?**	**29. What typeof injury occurred in your previous motorcycle crash?**	**30. Did you ever ride without wearing Helmet?**	**31. Did you ever get stopped by police for not wearing Helmet?**
a. Short term injury	a. Promotional campaign	a. No	a. Normal injury	a. No	a. Never
b. Long term injury	b. Law enforcement		b. Severe injury	b. Yes, sometimes	b. Once / twice
c. Death	c. Fine/ Penalty	b. Yes (If yes,follow question 29)	c. Fatal death	c. Yes, many times	
d. Does not haveimpact on death/injury	d. Others		d. Property damage only	d. Yes, often	c. More than twice

32. Does the motorbike have helmet for both driver and front seat passenger?	32.1 Driver		32.2 Passenger	
	a. Yes	b. No	a. Yes	b. No
33. How many passengers (including driver) were riding the bike in the last trip?				

Respondent Name: **Contact:** **Surveyor:**

Supervisor:

An observational study of seatbelt and helmet wearing behavior in Bangladesh – (Seatbelt for Driver)

Date: **Time:** **Survey no.:**
Serial No.: **Location Name:** **Intersection ID:**

1. Driving time	2. Driving area	3. Road conditions	4. Seating position	5. Riding frequency (In a day)	6. No. of persons sittingon front seat (excludingdriver)
a. Day	a. Urban	a. Severely damaged	a. Driver	a. 2 trips	
b. Night	b. Rural	b. Moderate	b. Front seat passenger	b. 3- 6 trips	
		c. Good		c. More than 6 trips	

7. License status	8. License type	9. Driving license starting year	10. Car ownership	11. Vehicle registration
a. Valid	a. Professional		a. Personal	a. Registered
b. Outdated	b. Non-professional		b. Official	b. Not registered

12. Age group	13. Gender	14. Education level	15. Income level	16. Does the vehicle have proper seatbelt for both driver and front seat passenger?	
a. >18 b. >20 c. 20-40 d. >40	a. Male b. Female	a. Illiterate b. Primary c. Secondary d. Graduate	a. <5000 b. 5000-10000 c. 10000-25000 d. 25000-40000 e. >40000	**16.1 Driver**	**16.2 Front Seat Passenger**
				a. Yes	a. Yes
				b. No	b. No

17. Driving duration for the last trip	18. Is this area familiar to you	19. What is your attitude towards using seat belt	
a. Short time (45 minutes or less)	a. I am a Local	a. Good	b. Embarrassing
b. Long time (More than 45 minutes)	b. First time came here	c. Safe	d. Reasonable
	c. I visit this place at times	e. Indifferent	

20. Do you approve the importance of using seatbelt?	21. Do you feel any social pressure touse seat belt?	22. Do you think you're being enforced to wear seat belt?	23. Do you think it should be a personal preference?	24. Do you think wearing seatbelt reduces injury?	25. Does wearing seatbelt make you feel safer?	26. Do you think it is uncomfor table to wear seatbelt?	27. Do you think seatbelt usecan reduce accident?
a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes	a. Yes
b. No	b. No	b. No	b. No	b. No	b. No	b. No	b. No

c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent	c. Indifferent

28. What do you think about the severity of the injury for not wearing seat belt?	**29. What steps couldbe taken to promoteseatbelt wearing? (Please provide a ranking about the importance of the following processes)**	**30. Did youface any previous crash in thepast?**	**31. What type of injury occurred in your previous crash?**	**32. Did you ever ride without wearing seatbelt?**	**33. Did you ever get stopped by police for not wearing seatbelt?**
a. Short term injury	a. Promotional campaign	a. No	a. Normal injury	a. No	a. Never
b. Long term injury	b. Law enforcement		b. Severe injury	b. Yes, sometimes	b. Once / twice
c. Death	c. Fine/ Penalty	b. Yes (If yes,follow question 31)	c. Fatal death	c. Yes, many times	
d. Does not haveimpact on death/injury	d. Others		d. Property damageonly	d. Yes, often	c. More thantwice

Respondent Name: **Contact:** **Surveyor:**
Supervisor: