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-PhD Thesis-

Determinants of Road Accidents in Low- and Middle-Income Countries

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Abbreviations and Acronyms

AIDS	Acquired Immunodeficiency Syndrome
BUET	Bangladesh University of Engineering and Technology
DCs	Developing Countries
GDP	Gross Domestic Product
GoB	Government of Bangladesh
HIV	Human Immunodeficiency Virus
LTI	Long-Term Injuries
NGOs	Non-Government Organisations
PI	Permanent Injuries
RTAs	Road Traffic Accidents
RTDs	Road Traffic Deaths
RTIs	Road Traffic Injuries
WHO	World Health Organization

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Thesis Summary

Determinants of Road Accidents in Low- and Middle-Income Countries

Introduction

The road transportation system is one of the central transportation systems and an accelerator of economic development in most low- and middle-income countries (LMICs). Although road transport has become the main mode of transport for most people, it has numerous drawbacks which directly and indirectly impact human life in these countries. According to the World Health Organization (WHO) reports published in 2013, 2015, 2018, and 2020, the problem of road traffic accidents (RTAs) in LMICs is getting worse than in developed countries. The reports show that deaths from RTAs have increased from 1.25 million in 2013 (WHO, 2015) to 1.35 million in 2016 (WHO, 2018), of which 93% were recorded in LMICs, although these countries have been found to have only 60% of the world's vehicles. Another 20–50 million people are injured or disabled every year. The WHO (2018) report estimates that 3700 people die every day due to road accidents worldwide and most of the victims are aged 5–29 years. The report also confirms that, between 2013 and 2016, no decline in the number of road traffic deaths was observed in low-income countries. Rather, road traffic deaths are one of the common problems in these countries. Unless immediate action is taken, this problem will continue to grow in most LMICs. Therefore, the aim of this dissertation is to provide a better understanding of the determinants of road accidents in LMICs. I believe that, by studying road accident statistics in detail, a clear understanding could be obtained on questions such as: 'What are the main reasons behind motor vehicle crashes in LMICs? What can be done to reduce Road traffic accidents RTAs and prevent injuries and deaths in these countries?'. The current

thesis contains three essays to examine theoretically and empirically the factors influencing RTAs.

Chapter 1: Factors Influencing the Severity of Road Accidents in Low- and Middle-I come Countries: A Systematic Review

The first essay is based on a systematic literature review. The purpose of this review is to investigate and document the factors contributing to RTAs, especially those relating to victims' socioeconomic and demographic characteristics, road and environmental characteristics, and driver behaviours. This study also focuses on some research gaps in the existing literature. A literature review was conducted for the period from 2003 to 2020. Searched terms included combinations of the following sentences: 'road traffic accidents', 'road traffic injury', 'road traffic fatality', 'road traffic mortality', 'road traffic death', 'place of road accident' and 'sociodemographic and economic factors relating to road traffic accidents'. Selected countries were identified in different regions (Asia, Africa, Middle East, South America, and Europe). This systematic review also searched for relevant articles describing the epidemiology of RTAs. The final review process consisted of 89 studies, most of which were empirically analysed. The review found that the majority of victims belonged to economically productive age groups, were male, pedestrians, and poor people without or with little education. Thus, it is necessary to find out what can be done to make these people more aware about RTAs to decrease the likelihood of becoming victims. This review also highlights that high driving speed, not using seat-belts and helmets, two-way roads without dividers, lack of traffic control systems, unplanned intersection areas on the road, absence of street lights, highways, poor road infrastructure, driver negligence, risk-taking attitudes (aggressiveness, improper overtaking, and reckless driving), having no driving license, and unawareness of road traffic agendas are the main causes of road crashes and severe injuries in most LMICs. In addition, further efforts should be made to investigate the factors that influence individuals' awareness level regarding RTAs and how severely this awareness level impacts on RTAs. It is important to note that road

infrastructures and reckless driving affects RTAs differently in many LMICs. Therefore, future research should focus on different road areas and road categories in LMICs to identify the most hazardous factors and to help governments on how to intervene to improve road infrastructure to prevent RTAs. Future research also needs to study how a driver's behaviour changes over time depending on the road types and road characteristics, by analyzing how different vehicle types influence drivers' attitude or behaviour while driving. Furthermore, the review indicates that the underreporting of both deaths and injuries is a major problem in LMICs. In these countries, systematic methods to collect road traffic data are not well developed. Without complete data on some key variables, it is impossible to find all the contributing factors affecting RTAs and to provide reliable results for policymakers. Future research should focus mainly on improving the data quality and carrying out more detailed studies on all the factors that contribute to RTAs in LMICs.

In the second and third essays, I selected Bangladesh, a middle-income country in South Asia, to implement some of the above-mentioned ideas. I chose Bangladesh because, in line with the global trend, road accidents are a major problem there. In fact, RTAs have become more severe in Bangladesh than in other LMICs (WHO, 2018). The most recent report published by WHO in 2018 estimated that, in 2016, 24,954 people lost their lives in road accidents in Bangladesh. However, only a few studies have focused on Bangladesh, mainly due to data limitations, for examining the factors contributing to RTAs, their severity level, victims' awareness of RTAs and knowledge of traffic rules (Baset *et al*., 2017). Most of the previous research descriptively analysed the relationship between rural road infrastructure and accidents, specific risk factors of fatal accidents in different areas, factors influencing pedestrian-vehicle crash severity, people's knowledge of road traffic rules and focused on the determinants of severe accidents in different age groups (Baset *et al*., 2017; Chowdhury, 2018; Islam *et al*., 2018; Kamruzzaman *et al*., 2013; Kamruzzaman, Haque, & Washington, 2014; Rifaat *et al*., 2014; Zafri *et al*., 2020).

Chapter 2: Determinants of Awareness About Road Accidents and Knowledge of Traffic Rules: Empirical Evidence from Khulna City in Bangladesh

Main Objectives and methodologies

The second essay empirically examines how victims' awareness of RTAs and knowledge of traffic rules depend on their social, demographic, economic, and other characteristics. The study uses primary data collected by Islam *et al*. (2018) for the period from January to February 2017. Data collection involved face-to-face interviews with 200 respondents admitted to hospitals in Khulna city after RTA.

Based on the available data, this study hypothesizes that the victims' awareness of RTAs and knowledge of traffic rules is significantly affected by their age, gender, marital status, place of residence, occupation, income, educational qualification, previous road accident experience, former training on traffic rules, and media access. In this study, I estimated two separate, independent probit models to empirically investigate what social, demographic, and economic factors affect the victims' awareness of RTAs and increase their knowledge about traffic rules. As robustness check, I estimated a simultaneous bivariate probit model to take into account of the high correlation between the two dependent variables.

Results and conclusions

The results from Chapter 2 found that several factors are significantly correlated with victims' awareness of RTAs and knowledge of traffic rules. These factors are: gender, training experience, education, access to media, previous involvement in road accidents, residence in urban areas, and high-skilled jobs. The government of Bangladesh (GoB) should take initiatives to provide training to people about RTAs. It is essential to provide hands-on training conducted by experienced trainers for long durations. Training manuals about RTAs should be updated and provided to trainees for free or at a low cost. Essential steps should be taken to

conduct mass media campaigns to build awareness of the risks and dangers of RTAs. It is also important for governments and non-government organisations (NGOs) to provide the necessary support to produce high-quality public information announcements, documentaries, dramas, and so on. The GoB should take initiatives to include introductory courses on road traffic systems in the education curriculum, in order to help people gaining knowledge about traffic rules and being aware of RTAs. The main takeaway of this study is that these results provide new empirical evidence in support of government and NGO policies to reduce RTA-related injuries and fatalities, by analyzing the factors that drive people to be aware of RTAs and increase their knowledge of traffic rules. Furthermore, the results of this study were compared to previous findings that have analyzed the correlation between road accidents and victims' awareness of RTAs. Further research is required to extend the data collection to other cities in Bangladesh to increase the sample size and to assess the external validity of this study.

Chapter 3: Identification of Factors Associated with Crash Severity on Roadways in Bangladesh: Empirical Evidence from Dhaka City

Main Objectives and methodologies

The third essay examines the road crash factors and injury severity levels, taking into consideration the victims' socioeconomic and demographic characteristics, their knowledge of road traffic systems and rules, and the conditions related to road infrastructure. The reference population in this study includes only people currently living in Dhaka City, Bangladesh. The survey was administered in different areas and at several universities and major hospitals in Dhaka. The survey was restricted to the metropolitan area of Dhaka because, according to the accident statistics from police records, it had the highest accident rate in the recent past (Ahmed, Ahmed, & Hainin, 2013, 2014; Chowdhury, 2018). A sample of 786 individuals was surveyed for the period from June 2019 to January 2020. Before sending the questionnaires or

scheduling face-to-face interviews, these sampled individuals were asked whether they were willing to participate in the survey and only those who consented were included in the final sample. Of these, individuals who had been directly involved in road accidents in the last two years (525) were asked to answer the full questionnaire for collecting information on some personal characteristics of the victims and other information concerning the main RTA experienced (e.g. the level of injuries, location of the accident, type of vehicles involved, etc.). The remaining 261 individuals, without direct involvement in road accidents, were asked to respond only to a shorter questionnaire to collect a set of demographic characteristics. During the interview, at least one interviewer was present, who could clarify the questions if required. For hospital victims, only those with normal conditions and being able to answer the questions were interviewed.

As our dependent variables were dichotomous, probit and Heckman probit models were estimated to take into account of the different factors associated with road accidents and their injury severity. The probit model was used to estimate the injury severity level only for those (525) individuals who have been directly involved in road accidents. The dependent variable of the probit model was a dummy variable coded as 'one' if the victim suffered long-term or permanent injury, otherwise the variable was coded 'zero' (i.e. if the victim suffered from only minor/temporary injuries/disabilities). As robustness check, I used a set of Heckman (1979) selection probit models. This model is estimated to explore the factors which significantly and simultaneously influence the likelihood of RTAs and the level of crash severity (conditional on having experienced an accident). The Heckman probit model was estimated using maximum likelihood methods with correction for sample selection bias in order to provide consistent and asymptotically efficient estimates for all parameters in the model. The dependent variable of the selection equation was a dummy variable coded as 'one' if the respondent experienced at least one RTA over the last two years, otherwise the variable was coded 'zero'. The dependent

variable of the outcome equation was a dummy variable coded as ‘one’ if the victim of the RTA (i.e. the respondent faced at least one RTA over the last two years) suffered from long term (LT)/permanent injury (PI), otherwise the variable was coded ‘zero’ (i.e. if the victim suffered from only minor/temporary injuries/disabilities). The explanatory variables used in the probit and Heckman probit models were: respondents’ age, gender, marital status, residence, educational qualification, employment status, family income, and other characteristics such as place of accident (highways, and rural and city areas), accident vehicle type, presence of manual traffic control system, no speed limit sign, not enough street lights, no divider to separate the road, unplanned intersection, no parking rules, competition among drivers, wrong-way driving, lack of awareness of road accidents, and not receiving training related to road traffic rules and regulations.

Results and conclusions

The results from Chapter 3 identified certain factors related to RTAs and their injury severity, such as wrong-way driving, no speed limit sings, and lack of adequate street lights on roads. Accidents occurring at city roads and highways, accidents caused by four-wheeler vehicles, victims’ lack of education, and victims’ marital status were significantly associated with LT/PI. Furthermore, the results of the selection equation in the Heckman probit model showed that lack of awareness of road accidents, residence in rural areas, and family income are significantly associated with RTAs. Therefore, the government should take necessary steps to introduce speed limit signs on streets and increase road safety awareness campaigns to prevent wrong-way driving and competition between drivers. This can play a pivotal role in ensuring road safety and decreasing LT/PI. In addition, strict law enforcement and proper road traffic legislations are important to stop reckless driving. It is also necessary to make efforts to monitor road infrastructure, such as providing enough light on the streets to improve visibility and ensure road safety.

Efforts are also needed to ensure and establish pedestrian rights, monitor city and highway traffic systems such as speed limit signs, build well-planned intersections, develop road crossing systems with digital traffic control systems, and implement laws to punish those who break traffic laws, such as violating the traffic lights and crossing the road not using the designated crossing points. Moreover, special road safety awareness campaigns need to be conducted for four-wheeler vehicle drivers. This will increase awareness about RTAs among drivers and the general public, which might help to decrease severe road accidents and unnecessary loss of lives. The results are compared to those of earlier studies conducted in Bangladesh and elsewhere, which confirms the reliability of the original findings. The results of this study may help government and NGOs in reducing the RTAs and the resulting injuries and fatalities by focusing on the above-mentioned factors. The government agencies and authorities play a pivotal role in the reduction of RTAs. The attention towards road safety management by authorities should be strengthened, so that they can regularly monitor road safety aspects. However, the following key limitations should be considered while interpreting the findings of the study. First, this study considers survey data collected only in some specific places, universities, public and private hospitals in Dhaka City. Second, since the sample is limited to 786 respondents, the findings may not be generalised to all the road traffic victims. Further research is required to extend the data collection to other cities in Bangladesh and to increase the number of respondents. Future studies should also try to address the problem of the so-called ‘survivorship bias’ that usually affects these types of analysis and, in our case, is due to the difficulty to collect survey data on RTAs that caused the death of the victims.

Chapter 1

Factors influencing the Severity of Road Accidents in Low and Middle-Income Countries: A Systematic Review

1.1 Introduction

Road traffic accidents (RTAs) have become one of the leading causes of death worldwide and have been increasing every year in most countries (World Health Organization, 2013; 2015; 2018). Over the last decade, RTAs have not only caused huge loss of life among adolescents and young people, but as a cause of death, they rank higher than deaths from dangerous diseases such as human immunodeficiency virus (HIV)/Acquired immunodeficiency syndrome (AIDS), tuberculosis, and diarrheal diseases (World Health Organization, 2018). The World Health Organization (WHO) estimated that 1.35 million people die annually and another 50 million are injured every year because of RTAs worldwide (World Health Organization, 2020). Low - and middle-income countries (LMICs) bear a disproportionate burden of the deaths and disabilities caused by road crashes (Anwaar *et al*., 2012) and account for 93% of all accidents, although these countries have been found to have only 60% of the world's vehicles (World Health Organization, 2020). Dramatic increases in the population, rapid economic growth, motorization, and urbanisation are the central causes of rising RTAs in LMICs (Bishai, *et al.*, 2006; Rifaat *et al.*, 2014; Staton, *et al.*, 2016; Wiebe *et al.*, 2016; Peden *et al*, 2004; World Health Organization, 2018). Another reason is that LMICs show less progress in reducing the number of road traffic deaths (RTDs) compared to high-income countries (World Health Organization, 2015; 2018). Recent statistics by WHO (2018) show that, between 2013 and 2016, there has been no reduction of RTAs in low-income countries. African and Asian countries experience substantially higher fatality rates than European, North American, and other developed countries (Boniface *et al.*, 2016; Manan *et al*., 2017; Ding *et al.*, 2017; Waseela

& Laosee, 2015; Manan *et al.*, 2017)**.** Traffic crashes also impact the economy of LMICs at an estimated cost of 2 to 5% of a country's gross domestic product (GDP) per year (World Health Organization, 2015; World Health Organization, 2018; Baru, Azazh, & Beza, 2019). According to pre-crash scenarios from the past, the prime reasons for motor vehicle crashes are a composite of of human interaction, vehicle condition, road characteristics, and environmental factors (Kamruzzaman *et al.*, 2013; Sarkar, Tay & Hunt, 2011). Nevertheless, several initiatives have been enacted by national and international leaders in the recent past to reduce the severity of the problem. One example is the set of Sustainable Development Goals adopted by world leaders in September 2015 to reduce RTAs by 50% by 2020. So far, little progress has been made towards this goal, and the number of deaths fuelled by transport has increased, becoming the eighth leading cause of death globally from being ninth before 2015 (Karkee, & Lee, 2016; Bonnet, Lechat & Ridde, 2018; Wangdi *et al.*, 2018). Therefore, it is expected that the situation will become much more complex by 2030, where road traffic injuries (RTIs) are expected to be the seventh leading cause of death worldwide (World Health Organization, 2015). Another report conducted by the WHO (2013) estimated that unless immediate action is taken, the global trends of RTDs will rise to 2.4 million per year, and RTAs will become the fifth leading cause of death and third leading cause of disability throughout the world by 2030 (Boniface *et al.*, 2016; Shrestha *et al.*, 2017; Mekonnen, Quezon & Mohammed, 2018). As such, improving road safety is a major concern in transport policy. Therefore, this review will focus on the factors analysed in the recent research undertaken on RTAs and try to identify the relevant research gaps for LMICs. The main objective is to obtain a better understanding of road accidents and to develop suitable methods and policies for safety improvement. I believe that, by studying road accident statistics in detail, a clear understanding could be obtained on questions such as: 'What are the main reasons behind motor vehicle crashes in LMICs? What can be done to reduce Road traffic accidents RTAs and prevent injuries and deaths in these

countries?' and then suggest future research directions and draw conclusions that need attention.

1.2. Materials and methods

1.2.1 Criteria for inclusion

Many publications, including government and institutional reports and studies providing quantitative data on motor vehicle crashes in LMICs, were selected. The literature search was conducted only for those study published in the time period between 2003 and 2020. The following search engines were queried for relevant online articles: Google, Google Scholar, and PubMed. Searched terms included combinations of the following sentences: 'road traffic

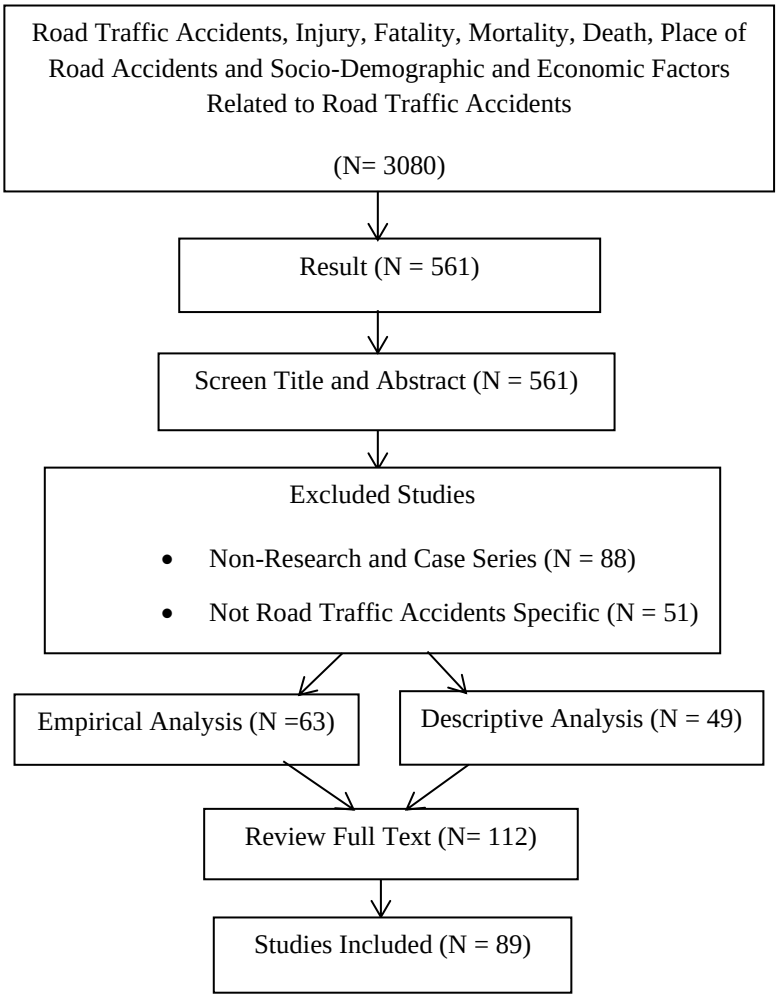

Figure 1.a. Summarizing the literature review process for LMICs.

accidents', 'road traffic injury', 'road traffic fatality', 'road traffic mortality', 'road traffic death', 'place of road accident' and 'socio-demographic and economic factors related to road traffic accidents'. Selected countries were identified in different regions (Asia, Africa, Middle East, South America, and Europe). This systematic review also searched for relevant articles describing the epidemiology of RTIs. All primarily identified articles were selected by scanning the title and abstract from the above-mentioned search engine (Google, Google Scholar, and PubMed) by using the key phrases. Articles that did not meet the research criteria (non-research and case series, non-RTA-specific articles and articles that did not fit the research topic), especially after checking the full text, were discarded from the inclusion criteria. Full text copies of the remaining 89 articles were downloaded. Full articles that were not available in the above-mentioned search engine had been collected from Sci-hab. We may have missed a limited number of articles appearing in other databases that were not searched, such as the Transport Research Information Systems maintained by individual governments.

1.2.2 Included studies

Eighty-nine studies were included in the final review process. The majority of these studies were empirically analysed to explore road and driver characteristics and environmental conditions as risk factors of morbidity and fatality in RTAs. These papers also demonstrated which segments of the population were mostly affected by RTAs by showing victims' socio-demographic and economic factors.

1.2.3 Sources of data collection and journals

Data sources analysed in these studies were diverse and broadly collected from hospital and traffic police records. Some studies used data from a population-based survey considering socio-demographic and economic factors. Numerous databases were used in different papers. Some of these are primary and secondary level data from medical records, the International Road Traffic and Accident Database, the International Road Federation - World Road

Statistics, the WHO Database, World Bank Database, , National Institute of Traumatology and Orthopaedic in different countries, cross-sectional survey on Socio-demographic and Economic information, and so on. To select the most relevant studies, some attempts were made to pick from the best journals. However, due to the lack of literature on LMICs, in some cases the selected journals were not high ranking.

1.2.4 Data quality

In LMICs, under-reporting and incomplete recording of RTDs were widespread. The estimation data used by researchers in some countries were taken from several studies/organizations rather than only one study/organization (Pebalus *et al.*, 2012; Ruikar, 2013; Patel *et al.*, 2016; Ubeda *et al.*, 2012; Sango *et al.*, 2016; Ding *et al.*, 2016). Some data were incomplete or unreliable, while others were only available on a monthly basis. Indeed, the number of fatalities recorded by official traffic safety statistics is underestimated. The police-derived statistics in most LMICs were limited to motor vehicle crashes and, in the majority of cases, lacked detailed demographic information on casualties (Staton *et al.*, 2016; Patel *et al.*, 2016; Sango *et al.*, 2016; Nagata *et al.*, 2012; Fisa *et al.*, 2019). Furthermore, it is apparent that, in most of the police records, the shares of fatal outcomes were relatively much higher than non-fatal accidents and contradicted by non-government sources (Kisitu *et al.*, 2016; Kazmi & Zubair, 2014; Kamruzzaman Haque & Washington, 2014). In LMICs, many poor and vulnerable road users were not treated properly after their accidents and, if they died for the consequences of RTAs, they remained unreported in the police records. In most cases, seriously injured patients are immediately transferred to local pharmacies or clinics, and very few seriously injured patients receive higher-level treatments in hospitals. Moreover, the largest share of hospital-based studies represents a small number of samples involved in RTAs (Majdzadeh *et al.*, 2008; Staton *et al.*, 2016; Misker *et al.*, 2017; Degais *et al.*, 2018; Baru, Azazh & Beza, 2019). Because of thus, their findings can hardly be generalised for the whole

population of reference. Despite these shortcomings, some studies classified casualties by uniformed categories of road users. For instance, in some studies, casualties were classified according to the victims' socio-demographic and economic factors, vehicle occupants, road characteristics, driver attitudes, and vulnerable road users who were not aware of RTAs (Almeida *et al.*, 2013; Asefa, Assefa & Tesfaye, 2014; Zhang, Yau & Gong, 2014; Liu *et al.*, 2018). Such aggregated groupings allow for an accurate identification of road-user profiles and specific factors that cause road accidents.

1.2.5 Methodology

The majority of studies used different types of regression analysis for estimating the relationships among the variables. Researchers often exploited characteristics and features related to road accidents and tried to clarify and understand the impact of RTAs. The variety of approaches helped researchers to measure how RTAs affect human life and understand the most relevant factors that cause them. These methods include, logistic regression models, ordered probit models, multiple regression analyses, generalised linear models, bivariable binary logistic regressions, multivariate logistic regressions, univariate crash severity models, negative binomial and multinomial logit models, autoregressive integrated moving average models, qualitative and quantitative research methods, and so on.

1.3. Results

The review identified 89 studies on LMICs (Table 1.a). Among the countries analysed, 52 were Asian, 24 were African, 8 were from the Middle East, 2 were from South America, and the remaining studies jointly took place in different LMICs. Of these, 17 were conducted in Bangladesh, followed by Ethiopia (7), Nepal (6), China (6),Taiwan (5), India (4), Nigeria (3), Ghana (3), Vietnam (3), Malaysia (3), Kenya (3), Iran (2), Tanzania (2), Zambia (2), Pakistan (2), Indonesia (2), Egypt (2), Brazil (1), Hong Kong (1), Swaziland (1), Libya (1), Oman (1),

Table 1.a. Summary of previous research analysing factors related to road accidents.

Study	Data and research objectives	Summary of key findings
Afukaar, Antwi& Ofosu-Amaah (2003)	Police reported accident data from National Building and Road Research Institute between 1994 and 1998 to highlight the magnitude of the road traffic safety problem, the pattern and distribution of RTIs in Ghana.	The working age is 26–60 years old (50.4%) and males (73.1%) represented the majority fatalities and overall casualties (60.3%) in Ghana. Pedestrians and children had among the highest fatality rates and urban areas were the most hazardous place of accidents.
Odero, Khayesi & Heda (2003)	Data collected from police records, medical records, research reports and articles and national newspaper in Kenya between 1965 and 2001 to analyse the RTA scenario.	Economically productive young adults were the largest group among road traffic casualties (75%) and most vulnerable groups were pedestrians and passengers (combinedly 80%). Among vehicles, buses were the most frequently involved in fatal crashes in both in highway and urban areas.
Shinar & Compton (2004)	Data collected during the months of April–June in 2002 were used to evaluate how several situational and individual factors interact to affect different over-aggressive driving behaviours.	Road congestion was associated with more aggressive driving. Males were more aggressive than women, young drivers were more aggressive than older drivers and the presence of passengers were associated with lower rates of aggressive driving.
Yau (2004)	Data collected from the traffic accident statistical system in Hong Kong were used to determine risk factors affecting the severity of single vehicle traffic accidents for 1999–2000.	Male drivers, older vehicles, lack of seat belt use, night-time driving and low visibility in the street were the significant factors associated with injury severity.
Rezaur (2005)	Data collected from the Khulna Metropolitan Police for five police stations in Khulna city, Bangladesh for 2001-2002 were used to provide information related to the characteristics of RTAs.	59% of victims were aged between 20-39 years, while 71% of fatalities were for those aged 30-49. RTAs happened most often in the morning and evening, and at intersection areas and in mid-blocks. Pedestrians are the worst victims. Trucks (26%) and buses (23%) and non-motor vehicles (40%) were the most hazardous mode in total accidents and fatalities.
Chang & Wang (2006)	Data collected from National Traffic Accident Investigation Reports supplied by the Taiwan Ministry of Transportation and Communications in 2001 were used to establish the relationship between injury severity and agendas related to RTAs.	Two and four-wheeled vehicles, vehicle collision with fixed objects, runoff-roadway and driver aggressiveness and unawareness were the main causes of accidents and severe injuries. Motorcycle, bicycle, pedestrian and passenger face severe injury.
Anjuman *et al.* (2007)	Data from Dhaka Metropolitan police in Bangladesh for the period of 1998-2005 were used to depict the scenario of RTAs in Bangladesh.	People aged between 15–44 years, male, pedestrian, and the poor were among the most frequent victims. Accident occurred by bus and truck) causes of majority of road traffic deaths. Over 100 deaths per 10,000 motor vehicles were recorded. Lack of speed control signs, no lane seperation on the road, excessive speeding, aggressiveness of drivers, defects in vehicles, unawareness, unsatisfactory education and lower safety rules and regulations were the main causes of RTAs.
Chang & Yeh (2007)	Data obtained from police records of injuries or fatalities in 2001 to investigate the relationship between age, gender, and risky behaviours of motorcyclists and their involvement in accidents in Taiwan.	Being young and male, disobeying traffic regulations, higher tendency towards negligence, violation behaviours, poor driving skills and less experience and slack motorcycle licensing system increased the likelihood of an accident.
Ipingbemi (2008)	Data collected from public and private hospitals in south-western Nigeria were used to assess the pattern and socio-economic burden of road crashes.	Those between the ages of 15 and 45 suffer the most from RTAs, Over 60% of them living below the poverty threshold. Motorcycles and buses accounted for 70% of the vehicles while about 40% of the victims were pedestrians.
Majdzadeh *et al.* (2008)	Data collected in 2005 were used to determine the association of potential risk factors with the incidence of injury among motor vehicle drivers and motorcyclists on Qazvin-Loshan Road in Iran.	Drivers aged 25-34, lack of use of safety equipment, motorcycle driver, man-made objective (unplanned road signs and intersections) and rainy weather condition were significantly associated with RTAs and severe injuries.

Table 1.a. Continued.

Chen (2009)	Data collected from the National Cheng Kung University in Taiwan were used to explore risky driving behaviours among young Taiwanese motorcyclists in December 2007.	Traffic safety is directly associated with risky driving behaviours, unsafe driving, driver risk-taking attitude and anxiety.
Li *et al.* (2009)	Data from different governmental departments in Taiwan from 2000 to 2002 were used to examine the road environmental factors and survival threat of crash injuries.	Non-straight or unpaved roadway sections, local roads, intersections, speeding and hazardous roadways are the main causes of motor-vehicle and motorcycle crashes.
Barua & Tay (2010)	Data collected from 1998 to 2005 by the police Micro-computer Accident Analysis Package database in Bangladesh were used to identify the factors that contribute to the severity of transit bus crashes.	The severity of bus transit crashes increased, and crashes frequently happened on weekends, off-peak periods and two-way streets (without dividers), high speed, with no police control area and the diver with less education. Severity increased for collisions involving only one vehicle, a pedestrian, or other vulnerable road users.
Mashreky *et al.* (2010)	Data collected from medical records in Bangladesh by interviewed patients to assess the burden and its economic impact for the period between February and March 2001.	People aged 18–45 years and male were the major victims of RTIs. Around 70% of the total road accident patients were admitted in primary and secondary level hospitals with an average cost of US$86 per victim.
Banik *et al.* (2011)	Data collected by interview drivers, pedestrians, traffic police and from a popular and reliable divisional newspaper in Bangladesh between 2005 and 2007 were used to present an overview of the RTAs.	Bus and truck contribute to 65.50% of total accidents and the highway was the most vulnerable area, where 34.33% of accidents took place. Causes of road accidents included: no institutional formal training for driving, pedestrians and passengers' unawareness, losing control of vehicles, overtaking attitude, collusion between vehicles, overloading, high speed, competitions, unplanned intersection and limited traffic police in highway.
Dinu & Veeraraga van (2011)	Data collected from 2001 to 2003 in the Indian state of Tamil Nadu to employ random parameter modelling for accident prediction on two-lane undivided rural highways in India.	Excess traffic volume, proportion of cars, motorised two-wheelers and trucks in traffic, driveway density and horizontal and vertical curvatures are randomly distributed across locations are the most common causes of accident prediction on two-lane undivided rural highways.
Dong *et al.* (2011)	Data collected from school-aged children in Guangzhou, China to examine the effects of road safety knowledge and risk behaviours on RTIs in April 2009.	Bicycle riders were mostly affected by road accidents and face severe injuries (46.0%). Lower levels of road safety knowledge and students with high risky road behaviour were significantly associated with accidents.
Karim, Khan & Farah (2011)	Data collected from National institute of traumatology and orthopaedic Dhaka, Bangladesh in 2010 to determine the economic impact of RTAs on families.	Patients age 10-30 years (73%) highest among the victims and other 18.1% belongs to 30-40 years of age. Buses and motorcycles were the main mode of transports that conducted highest RTAs. The result also indicates that RTAs are strongly linked with economic and family losses and increase the social burden.
Sarkar, Tay & Hunt (2011)	Crashes reported by the police in the Micro-computer Accident Analysis Package database in Bangladesh to identify the factors associated with the probability of a fatal outcome on the national highway system from 1998 to 2006.	Individuals aged 15-55 years were the most vulnerable group. The larger risk of fatalities with association of four and two wheelers vehicles. Walking on the edge of the road, poor braking, no traffic control system, new roads without plans for pedestrian safety, human activities near highways and rainy season were the main causes of fatalities.
Aderamo, (2012)	Data collected from Nigerian states of Police Force headquarters, the Federal Road Safety Commission, National Bureau of Statistics and National Population Commission for 2007-2008 were used to assess the effect of RTIs and productivity.	There exists a clear relationship between RTA injuries and productivity in Nigeria. Drivers error, not enough speed control signs and streetlight and no lane separations, bad vehicle condition and inadequate safety measures were found to be the main causes of RTAs.

Table 1.a. Continued.

Ali, & Tayfour (2012)	Historical data on population, number of registered cars and other related factors from 1991 to 2009 were used to present accident characteristics and considers road safety management in Sudan.	The major causes of accidents were aggressive driver behaviour, vehicle conditions, road network defects, speed-limit violations, negligence of seat-belt usage and lack of traffic-law enforcement in the streets.
Bachani *et al.* (2012)	Data collected from the Kenya Traffic Police, the National Vital Registration System of RTIs and Thika and Naivasha districts in Kenya for 2004-2009 were used to present the status of road accidents.	Highest proportion of RTIs occurred among individuals aged between 25 and 34 years and 75% of the victims were male. Motorcyclists and passengers were among the highest in facing injuries and fatalities. Annual fatalities steadily increased by 7%.
Bodalal, Bendardaf & Ambare-k (2012)	Data collected from Biostatistics Department of the Al-Jalaa hospital in Benghazi – Libya for 2001-2010 were used to observe and study the trends of RTAs.	The younger age group (10–29 years) and males had the most accidents. Drivers (23.1%) and passengers (35.5%) and pedestrians (38.4%) were in majority of RTA injuries. Pedestrians have the greatest risk for fatal injuries and nearly 45.9% were underage.
Haadi (2012)	Traffic-police records data collected from the motor transport and traffic unit Northern Region in Ghana to identify the variables that mainly contributed to accident severity between 2007-2009.	98.7% were considered as accidents with fatal injuries. Over loading and obstruction were both significant variables for regression coefficients related to fatal injuries.
Kashani, Shariat-Mo haymany & Ranjbari (2012)	Data obtained from the Department of Iranian Traffic Police from 2006 to 2008 were used to identify the significant factors influencing injury severity among drivers involved in crashes.	Improper overtaking, speeding, inattention to traffic ahead, vehicle defects, movement of pedestrians' livestock and unauthorised vehicles on freeways are the most serious causes of increasing injury severity.
Ahmed, Ahmed & Hainin (2013)	Data collected from Dhaka Metropolitan Police in Dhaka, Bangladesh from 2007-2011 were to identify high-risk road corridors of Dhaka city and accident frequencies.	Dhaka-Mymensing Road was the most accident-prone road in Dhaka followed by Airport Road and Mirpur Road, respectively, due to the high speed of vehicles, unplanned intersections, unawareness of drivers and pedestrians and not having strict regulations. The highest number of victims were pedestrians.
Almeida *et al.* (2013)	Data collected from Fortaleza Northeastern Brazil from January 2004 to December 2008 were used to describe the risk factors involved in RTAs and accidents resulting in death.	Two-wheeler vehicles, running over pedestrians and collision with fixed obstacles were the main causes of road traffic deaths. The main contributing factors of RTAs were unskilled drivers, single vehicle accidents, being male, traffic on roads under federal jurisdiction, early morning hours, on weekends and higher speeds.
Al Reesi *et al.* (2013)	Survey data from the Medical Research and Ethics Committee at Sultan Qaboos University in 2010 in Oman were used to investigate driving behaviour on RTAs.	Driver aggressiveness, unawareness of pedestrian while walk or crossing the roads, history of traffic offences and speeding were major risk factors for RTAs among the sample. Males, driving light vehicles, cell phone use while driving and having less driving experience are the main causes of RTAs.
Chiou *et al.* (2013)	Data collected from signalised intersections area during 2006–2007 in Taipei City, Taiwan were used to find out crash severity of two-vehicle accidents at signalised intersections.	Key risk factors of RTAs were driver age > 65, motorcyclists, alcohol use, intersection type (three-leg and multiple-leg), rear ended collisions, and lack of lighting at night.
Kumar & Srinivasan (2013)	Data collected from the RTA victims admitted in district hospital, Karimnagar in Nepal were used to evaluate socio demographic characteristics, among the RTA victims from September 2011 to August 2012.	Age group 21- 40 years (78.7%) and male (98.9%) were most vulnerable as victims. The majority of them (69.1%) were married. 39.3% victims were highly educated followed by 31.1% with intermediate education and 11.5% were illiterate. Around 28% were unemployed, and by 19.7% of the victims were shop-owners and farmers.
Kamruzza man *et al.* (2013)	Road collision data from Dhaka Metropolitan Police from 2007 to 2011 to identify the significant factors contributing to traffic injury severity in Dhaka, Bangladesh.	Single vehicle crashes, highway section, high speed, night-time crashes, no traffic police enforcements or other traffic controls, roadway without any divider, one-way traffic with higher lane indiscipline were found to be significantly associated with higher injury severities in RTAs.

Table 1.a. Continued.

La *et al.* (2013)	Survey data collected from 2006–2009 were used to understand the factors associated with RTAs among taxi drivers in Hanoi, Vietnam.	Age of the driver, higher level of commercial driving licence, working part-time and perceived insufficient income, not using a seatbelt, and traffic violation while driving a taxi tended to be significantly associated with the crash risk.
Lin at el. (2013)	Data collected from China National Sample Survey on Disability conducted in 2006 to estimate what are the socio- demographic and economic factors relate to RTD.	Results found that male, residence in rural area, less education, lacking employment or family income and low home ownership and increasing age in children, these are the odds that highly associated with RTD of an individual.
Nguyen *et al.* (2013)	RTIs data were from the Thai Binh General Hospital in Vietnam for the period from January 2010 to 31 August 2010 were used to examine the riskiest group and the costs of RTIs in Vietnam.	Male (75%), young people 18-29 years (36%) and motorcyclists (75%) represented the largest proportion in total accidents. Farmers represented 50% of the total sample and farmers represented as pedestrians 57%; bicyclists 43%; and motorcyclists 46%.
Osayomi (2013)	Annual Abstract of Statistics and United Nations Development Programme report data for 2009 in Nigeria were to analyse regional variations in RTAs and find out the determinants of RTAs.	Rural area and length of the concrete roads were significant and appeared to be dominant factors in road accidents at the national and rural scales in Nigeria.
Rubayat & Sultana (2013)	Data from the Accident Research Institute of Bangladesh University of Engineering and Technology, Bangladesh Road Transport Authority and other government bodies were used to explore the current traffic accident scenario in Dhaka City and identify the reasons behind RTAs.	Peoples' recklessness and unawareness were the main cause of road accidents. Causes of pedestrian facilities were reckless behaviour, poorly managed intersections, not using Zebra crossings, footpaths and bridges over roads, one-way roads, talking on the phone while crossing, crossing through moving traffic and poor management by government.
Ruikar (2013)	Data collected from Ministry of Road Transport and Highways, Government of India for 2002-2011 were used to highlight trends, indicators, and the characteristics of RTAs.	Between 2001 and 2011, fatalities and injuries increased. The majority of RTIs happened among males in the age group 15–24 years and in rural areas. Human factors like drunk drivers, indecisiveness, fatigue, distraction, and confusion contributed to RTAs. Inexperience, risk taking, impulsiveness, aggression, and unawareness of the road signals causes 77.5% of total accidents.
Zhang, Yau & Chen (2013)	RTAs data collected from 2006-2010 in Guangdong Province, China were used to find out the traffic violations and accident severity.	Male driver, not follow traffic rules, unfit safety status, overloading and commercial vehicles, lack of street-light, bad visibility, and weekends and public holidays were significantly associated with higher risk of severe accidents.
Ahmed, Ahmed & Hainin (2014)	Data collected from the Dhaka Metropolitan Police in 2007-2011 in Bangladesh to determine the characteristics of the RTAs.	Accidents took place where no there was traffic control system, intersection areas, T-junctions, one-way traffic movement and on straight road sections.
Abegaz *et al.* (2014)	Survey conducted in Addis Ababa on Hawassa road from June 2012 to July 2013 in Ethiopia were used to assess factors that contribute to crash injury severity in Ethiopia.	Alcohol use, speeding, falling asleep while driving, absence of streetlights at night, rainfall and four wheelers (tracks, buses and cars) vehicles were found to increase crash injury severity.
Asefa, Assefa & Tesfaye (2014)	Data obtained from eight police stations in central Ethiopia for the period of July 2007 to June 2012 were used to assess the magnitude and factors associated with RTAs in central Ethiopia.	Road location, time of collision (day and night), driving above speed limit, careless driving, type of vehicle, and failing to give priority to other vehicles and pedestrians found to have significant association with RTAs and fatality.

Table 1.a. Continued.

Coleman (2014)	Data collected from statutory bodies, media and past academic papers report on country RTA information in Ghana to highlight the increasing problem of RTA related morbidity and mortality.	The mortality trend from RTAs has been rising consistently in Ghana. From 2000 to 2012, people aged 1-40 years were the major victims of RTI with pedestrians and males being among the highest. Over speeding, illiteracy or poor understanding of the road code, not using seat belts, drinking alcohol, four wheelers vehicles, overloading, unlicensed drivers and lower enforcement in road area increase the rate of RTAs in Ghana.
Hosseinpour,Yahaya & Sadullah (2014)	Data collected from the Malaysia Institute of Road Safety Research, Highway Planning Unit, and Royal Malaysia Police in 2007 were used to identify the factors affecting both the frequency and severity of head-on crashes.	Horizontal curvature, terrain type, heavy-vehicle traffic, lack of speed limits, stopping in the outside of the lane, intending to turn opposing lane (road with no divider) and access points were found to be positively related to the frequency of head-on crashes.
Kamruzzaman Haque & Washington (2014)	Accident data from Dhaka Metropolitan Police for 2007- 2011 to identify roadway, traffic, and environmental factors that influence the injury severity of RTAs in Bangladesh.	The probabilities of fatal injuries increase with highways crashes (65%), absence of a road divider (80%), crashes during night-time (54%), vehicle–pedestrian collisions and lack of police control (41%).
Rifaat *et al*. (2014)	Data collected from Roads & Highways Department, Bangladesh Statistical bureau, Bangladesh Road Transport Authority and Local Government Engineering Department to identify significant factors contributing to traffic injury severity in Dhaka between 2004-2010.	National paved and unpaved roads, Regional and Union paved roads, increase in household population, being male, and low economic class increase the likelihood of road crashes at district level.
Zhang, Yau & Gong (2014)	Data collected from 2006–2010 in Guangdong Province, China to identify significant risk factors associated with RTAs and traffic violations.	Traffic rules violations, speeding, drunk driving, male drivers, novice drivers, private vehicles, lack of street lighting at night and poor visibility were significantly associated with RTAs.
Biemba *et al*. (2015)	Data collected from Hospital and Zambia Police Service for all the seven districts for the period from 2008 to 2013 were used to find out the factors associated with RTAs.	RTAs rates per 100,000 population have been increasing from 156/100,000 in 2008 to 205/100,000 in 2013. Crashes per 100,000 people increased at annual rate of 6% with the highest increase of 22% between 2011 and 2013, and fatal RTAs increased from 1,238 to 1,851 for same period. Those aged 16-45 years and male were the most vulnerable group. Poor road infrastructure, inadequate transport, speeding, inadequate manpower, not wearing seat belts and using mobile phones while driving were the main causes of accidents.
Choulagai *et al.* (2015)	Data collected from Nagdhunga to Narayangadh road segment of Prithvi Highway in Nepal for 2011-2012 were used to describe RTAs and reasons for delayed post-crash.	Truck, motorcycle and scooter (52%) cause majority of the RTAs. Most of the accidents occurred in daytime between 8:00 and 20:00.
Joewono, Vandebona & Susilo (2015)	Data collected in 2010 from motorcyclists in three metropolitan areas in Indonesia were used to evaluate the factors influencing RTAs and motorcyclists' violation behaviour.	Positive connection found between rider's violation behaviour and RTAs. Disobeying traffic rules (not wearing helmet, illegally crossing traffic signals, stopping beyond stop lines and sudden turning without signalling, and using illegal short cuts) poor road design, poor road quality, reckless driving (speeding and street racing), and overtaking on the wrong side were significantly associated with RTAs.
Mamun, Miah & Islam (2015)	Data collected from four Police Stations in Rajshahi city, Bangladesh from 2011 to 2013 were used to analyse the loss of human life and identify the road mid-blocks and intersection accident areas.	People aged from 20 to 35 years are most susceptible to accidents (42%) and trucks involved in 26% of total accidents and other major vehicles such as buses 23%, bike 14% and Auto-rickshaw 9%. Most accidents occurred in city areas and intersections in Rajshahi city.

Table 1.a. Continued.

Renuraj, Varathan & Satku-nanantha n (2015)	Data collected from the records of Jaffna police station in Sri Lanka for the period of 2010-2013 were used to identify the most influential factors involved in accident severity.	Type of vehicle (two, three and four wheeled) and age were identified as the most influential variables for accident severity.
Rodrígue , Peñaloza & Montoya (2015)	Data collected from Colombian National Legal Medicine and Forensic Sciences Institute regional office in Valledupar between 2008 to 2012 were used to analyse the occurrence of RTIs.	The average victim age was 35.4 years and the vast majority were male. Motorcyclists contributed to RTAs by 69%, followed by pedestrians at 12%. More than 72% had less than higher secondary education. 93% of the total events occurred in urban areas. Violation of traffic rules (70.5%), exceeding the speed limit (10.5%), drunk driving (2.5%), poor road conditions (0.7%), running traffic lights (0.6%) and driving the wrong way on one-way streets (0.6%) were the main causes of RTAs.
Waseela & Laosee (2015)	Data collected from the committee for Research Ethics (Social Sciences), Mahidol University, and the National Health Research Committee in Malé in Maldives to identify risk factors associated with RTIs between December 2012 and January 2013.	The younger age group (18 and 44) and male (96.6%) were the main victims. 53.1% completed higher secondary school, 53.8% worked in the private sector, 75.9% were categorised as having a poor level of knowledge, 57.9% had a negative attitude toward road safety and 60.5% had poor riding behaviours. Negative attitude (driving with excessive speed, traffic violations, and taking illegal drugs before riding) were identified as risk factors associated with RTIs.
Zimmer man *et al.* (2015)	Data obtained from two rural roads in the Bagamoyo District of Tanzania for 2012-2013 were used to quantify the scope of RTIs along 2 low-volume roads.	The average age of the victims was 27 and majority of victims were male (82%). Motorcyclists represented 71% of all injuries.
Adeloye *et al.* (2016)	Data collected from 15 African countries on RTAs between 1980 and 2015 were used to estimate the burden of RTIs and deaths for all road users.	From all registry-based studies, Nigeria recorded the highest (716.57) total crash rate. Ethiopia recorded the highest death rate at 81.6 in 2011 and lowest recorded in Nigeria at 1.64 in 2007. Algeria and Ghana also reported high road traffic injury rates at 700 and 938 accordingly. From 1990 to 2015, the overall road traffic injury rates increased from 40.7 to 92.9 and death rates decreased from 19.9 to 9.27. All result estimated per 100,000 population and measured by pooled estimated rates of road traffic crashes, injuries and deaths.
Adhikari (2016)	Police records of accidents from July 2009 to June 2012 for Kathmandu-Bhaktapur road in Nepal were used to identify locations with high accident numbers and investigate possible causes of accidents.	Age group from 15 to 45 were most involved in accidents. Motorbikes were frequently involved in accidents (45.5%) followed by car van and jeep (23%) and buses (16.5%) respectively. Human, vehicle and environment factors caused of 95% accidents. The dominant causes of accidents were carelessness (83%) and speeding (10%) followed by vehicular defects, overtaking and drunk driving (7%).
Huang *et al.* (2016)	Data were collected from post-mortem department and nine hospitals in Kathmandu Valley in Nepal to find out the characteristics of RTAs between August 2014 and July 2015.	Around 75% of victims were between 15-49 years old and majority of the victims were male. Pedestrians (51.8%) were the most vulnerable. Two and four-wheeled motorised vehicles were most frequently involved in RTAs.
Karkee, & Lee (2016)	Data collected from traffic police record for 2001–2013 in Nepal were used to investigate the RTIs.	The death rate increased from 4/100,000 to 7/100,000 between 2001-2013. The majority of RTIs were reported to occur among motorcyclists and pedestrians, males, and those aged group 20–40 years. Pedestrians' reckless behaviour, alcohol consumption and improper bus driving were the main causes of accidents.
Kumar & Toshniw al (2016)	Data collected from various attributes paper by applied k-means algorithm were used to identify high-frequency accident locations and identify various factors that affect RTAs at those locations.	Intersections on highways and intersections on highways which come across market locations were found more dangerous for every type of accidents. People living near to local roads were found to be more prone for pedestrian hit. Two-wheeler vehicles were responsible for most RTAs.

Table 1.a. Continued.

Nangana *et al*. (2016)	Data collected between April 1 and May 31, 2015 from the School of Public Health, University of Lubumbashi were used to determine the frequency, causes and human impact of motor vehicle-related RTA in Lubumbashi, Democratic Republic of Congo.	Absence of a valid driving license and unfastened seat belts were associated with the occurrence of RTA related fatalities. Speeding, distracted driving (text messaging, calling on phone, chatting), overtaking, careless driving and driving under the influence of alcohol were most prevalent causes of RTA occurrence.
Saeed *et al.* (2016)	Data collected from the patients coming to emergency in provincial hospitals between June and December 2013 in Afghanistan were used to estimate the burden and epidemiologic pattern of RTAs.	The age of 10–30 years accounted for 60% of RTIs, 85% of patients were male and the majority of them do smoke. Four (56.4%) and two (28.3%) wheelers were most likely to commit accident. Pedestrians (45.3%), passengers (25.7%) most vulnerable group. Speeding, poor driving skills, bad roads, pedestrians on the street, overloading, not following traffic signs, bad weather, poor vehicle and not using seat belts or helmets were the reasons of RTAs and severe injuries.
Singh *et al.* (2016)	Data collected from Chandigarh zone, undertaken at Post Graduate Institute of Medical Education and Research between 1974 and 2013 in India to provide a RTAs scenario.	The highest number of fatalities was observed in the 6–18 age group. Male, rural residents, accident occurred during daylight, pedestrians and two-wheeler occupants found to be the significant factors related to severe accident and fatality.
Anarkooli, Hosseinpour & Kardar (2017)	Crash data obtained from Royal Malaysian Police crash records between 2007 and 2012 were used to investigate the effects of various factors related to injury severities of single-vehicle rollover crashes.	Four-wheeled vehicles were responsible for most RTAs. Results shows that 'dark-ness and road side without light, rainy weather condition, improper overtaking, old age car, traffic volume and composition, number of travel lanes, no speed limits, undulating terrains, no presence of central median and unsafe roadside conditions were positively associated with more severe single-vehicle rollover crashes'.
Baset *et al.* (2017)	Data collected from households in rural areas in Bangladesh were used to examine the current magnitude and risk factors of RTIs for different age groups between June–November 2013.	The mortality rate due to RTIs was 6.8 per 100,000 people per year. Being male, being aged between 25–64 years and increasing socioeconomic status was significantly associated with increasing risk of non-fatal RTIs.
Boniface *et al.* (2017)	Data collected from different hospitals in Tanzania were used to determine the associated factors and management of RTI patients from April to September 2014.	Two and four-wheeled vehicles responsible for the majority of RTAs and driver, passengers, and pedestrians are most vulnerable groups affected by RTAs. Result shows reckless/dangerous driving, careless motorcyclists, bad roads, defective motor vehicles, driver age from 18 to 45 years and not using helmet causes of RTAs and severe injuries.
Cioca&Ivascu (2017)	Data collected from Romanian Police, the National Institute of Statistics and the European Commission were used to assess the RTAs for the period from 2012 to 2016.	Collisions between vehicles account for 40% of the total number of accidents. The largest increase is recorded between 2015 and 2016, an increase of 11.3% and 12% respectively due to the increase in the number of vehicles by 12%. Accidents mainly occurred on road alignment (71%), curves (18%), and intersections (9%). Highest accidents occurred in daylight with less experienced drivers.
Demissie (2017)	Data collected from RTA records at Manzini Traffic Police Station were used to determine the risk factors associated with serious and fatal RTAs in Manzini city, Swaziland for the period from July 2013 to June 2015.	Male drivers, drivers not wearing a seatbelt, pedestrian error, weekend accidents and accidents occurring at night were found to be associated with serious or fatal RTAs.
Fouda *et al.* (2017)	Data collected from Mansoura University Emergency Hospital in Egypt from August 2014 to April 2015 were used to measure the magnitude of motorcycle accidents.	Patients aged 20–40 years (67%) and males (90.5%) were predominantly involved in RTAs. Motorcycle collisions with cars (47.6%), speeding (17.5%), obstacles in road (27%) and collisions between two motorcycles (7.9%) were the main causes of accident, and none of the motorcyclists were wearing helmets.
Gebru (2017)	Data collected from academic literature, reports and research documents in 2004 were used to find out the contributed factors of RTAs in Ethiopia.	Driving under influence of alcohol and/or drugs, driving recklessly, lack of driving experience, speeding, failing to observe traffic signs, negligent pedestrians crossing on the wrong side of the road and rushing into the roadway, dangerous curves, poor visibility, lack of proper signs, signals and markings, intersection area and defects of vehicles were the main causes of RTAs.

Table 1.a. Continued.

Manan *et al.* (2017)	Data were obtained from Royal Police by the Malaysian Institute of Road Safety Research to determine risk factors contributing to traffic crashes involving motorcycle in Malaysia between 2010 and 2012.	Expressway, primary and secondary roads, overspeeding, roads with non-permissible markings and daylight condition increased the probability of motorcycle single-vehicle occurrences and fatal crashes.
Mutune, Mang'uriu & Diang'a (2017)	Primary data collected from the respondents along the Mombasa-Malaba road in Kenya were used to find the factors that influence road accidents.	Drivers errors, drivers' personal characteristics, driving behaviours such as speeding and less experience, highways, T-access junctions and drunkenness were the major reasons associated with incidence of RTAs.
Shrestha *et al.* (2017)	Data collected from United Mission Hospital and Lumbini Medical College & Research Centre in Nepal were used to assess the factors and pattern of injuries.	Being in the younger age group, being male, morning driving, driving speed, driving experiences, and driving hours on the road were positively associated with RTAs. The passengers (55.4%) and bike riders (29.5%) were the main victims of RTAs. Negligence of driver (42%) and poor vehicle condition (24.1%) were the major causes of the accident.
Tulu *et al.* (2017)	Data collected from Addis Ababa Police Commission and ten sub-city police departments were used to examine the influence of road, traffic and other characteristics on driver/pedestrian injury severities between 2009 to 2012.	High speed roads, intersection areas, darkness and less educated drivers were the main factors related to vehicle-pedestrian fatal crashes. Male drivers and pedestrians were found to be associated with serious or fatal accident than female.
Ahmad *et al.* (2018)	Survey data from three tertiary level referral hospital in Dhaka from December 2015 to September 2016 in Bangladesh were used to find out the factors related to RTAs.	The age group from 21 to 30 years and males had the greatest number of accidents. Maximum accidents occurred at daytime (41.45%), on city main roads (44%). Main causes of RTAs: hit and run injuries, not use foot over bridge and using mobile phone while crossing the road.
Alfalahi, Assabri & Khader (2018)	Data collected from Aljomhoury General Hospital and 24th Science and Technology Private Hospital for 2015 in Yemen were used to describe the pattern of RTAs and injuries associated factors.	On average, victims were 23 years old. People aged less than 30 years and male (82%) were the major victims. Children comprised of 39% of casualties. Poor driving skills caused 85% casualties and all the victims did not use seat belts or helmets.
Islam *et al.* (2018)	Accident data from Khulna Medical College Hospital and Satkhira Sadar Hospital and several private clinics between January and February 2017 in Bangladesh were used to identify the role of various factors regarding the knowledge and awareness about RTIs.	Accident rates are highest among those aged 15–44 years and males were the highest risk group for RTAs. Education (primary to higher secondary school), occupation as low-class workers, vehicle type, breaking traffic rules and prior road accident experience have significant relationships with individual's knowledge about traffic rules.
Liu *et al.* (2018)	Data collected from the Road Accident Statistical Annual Report issued by China's Traffic Management Bureau of the Public Security Ministry from 2004-2015 were used to investigate risk factors contributing to extremely serious RTAs.	The study identified professional drivers, fatigue, four-wheeled vehicles, overloading, and terrain road condition as significant risk factors of extremely serious road accidents.
Mekonnen (2018)	Data collected from North Shewa Zone Police station from February 2013 – September 2016 in Ethiopia were used to identify the major factors related to RTAs and their severity.	Drivers aged 18-30, employed drivers, driving above the speed limit, alcohol use, low level education and less than 5 years driving experience are more likely to attain severe outcome.
Wangdi *et al.* (2018)	Police records of RTAs in Bhutan during the period between 2013 and 2014 were used to estimate the burden and characteristics of RTAs.	People aged 25–44 years and males were most likely to be killed or injured. Drivers and passengers were more likely to be killed or injured rather than pedestrians and motorcyclists. The main causes of accidents were poor road condition, careless and reckless driving, drunk driving and over speeding.

Table 1.a. Continued.

Abegaz, & Gebremedhin (2019)	Data collected from Ethiopian Demographic and Health Survey conducted in 2016 were used to determine the rates of injuries and fatalities associated with RTAs in Ethiopia.	RTA related injuries and fatalities per 100,000 motor vehicles were 21,681 and 4,922 respectively. Among RTA causalities: 21.9% drivers, 35.0% passengers and 36.0% were vulnerable road users (motorcyclists 21.0%, pedestrians 12.1% and cyclists 2.9%). Approximately half (47.1%) of the causalities were between 15–29 years of age. Urban residence, young age group, male and household wealth gets statistically significant with RTAs.
Ahmad *et al.* (2019)	Data obtained from 2009–2015 on motorway crashes, collected by the National Highway and Motorway Police in Pakistan were used to explore empirically the impact of RTAs crash severity.	Speeding, drowsiness, head-on collisions due to driving the wrong way, illegal pedestrian crossing and increasing age of drivers found to be major risk factors that increase the propensity for severe injury.
Arafa, El-Setouhy & Hirshon (2019)	Data collected from hospital-based and the official data published by the Central Agency for Public Mobilization and Statistics from 1 September 2017 to 30 March 2018 to investigate the correlation between driving behaviours and RTAs in Egypt.	Driver age < 30 years, illiteracy and driver errors (eating while driving, not using seatbelts and traffic violations) were associated with RTA involvement.
Balasubramanian & Sivas-ankaran (2019)	Accident data from the Government of Tamil Nadu database (Road Accident Data Management System) in India for 2015–2016 were used to identify significant risk factors associated with this traffic violation.	Male drivers, drivers without valid driving licence, single-lane roads, uncontrolled junction roads, all type of vehicles, presence of central dividers and daylight were associated with speeding-related accidents.
Baru, Azazh & Beza (2019)	Data collected from several public hospitals in Addis Ababa, Ethiopia in 2017 were used to assess the factors affecting injury severity levels of road traffic collision victims.	Motorbike riders or passengers without helmets, driving under the influence of alcohol, large heavy vehicle, collisions occurring due to two-vehicular crash, and collision in dark lighting conditions were significantly associated with severe injuries.
Fisa *et al*., 2019	Data collected from Zambia Police, Traffic Division on accidents that occurred on the Great North Road highway in Zambia from 2010 to 2016 were used to estimate the incidence rate of death from RTAs, to determine factors associated with serious and fatal RTAs.	Pedestrians crossing the road, excessive speed and driving in the early hours of the day were the main causes of crashes and fatalities. Results further showed that public transport increased death from RTAs as compared to private transport.
Nguyen-Phuoc *et al.* (2019)	Survey data from three largest cities in Vietnam were used to investigate the prevalence and factors associated with RTAs among app-based motorcycle taxi riders in May and June 2018.	Traffic crashes were associated with non-students, low education levels, high daily travel distances, regular smoking, and using a mobile phone while driving.
Waseem, Ahmed & Saeed (2019)	Motorcycle crash data of Rawalpindi city collected by the Provincial Emergency Response Service from July 2014 to June 2015 in Pakistan were used to investigate the factors influencing the motorcycle injury severity.	Probability of fatal/severe injury increases for crashes with middle-aged riders (25–50 years), riders with no education, high speed roads, non-divided streets, unregistered motorcycles, crashes involving heavy vehicle and fixed object and occurring during dry weather conditions.
Zhang *et al.* (2019)	Data obtained from Traffic Management Bureau in Guangdong province in China from 2006–2010 were used to identify risk factors for overloading in crash-involved vehicles and contributing to greater crash severity.	Males from rural households, drivers aged under 25 years, speeding, unsafe condition and overload were the main factors related to higher severity overloaded vehicle crashes.
Satria *et al.* (2020)	Data collected from the Departments of Transportation and Traffic Police crash information in Indonesia between 2012 and 2015 were used to address RTAs.	Unawareness, larger traffic volume, most densely populated areas, higher number of intersections area in the road and lack of road design were found to be the main factors of RTAs.

Maldives (1), Sri Lanka (1), Sudan (1), Colombia (1), Yemen (1), Democratic Republic of Congo (1) Bhutan (1), Afghanistan (1), and Romania (1).

1.3.1 Reported rate

The relationship between fatality rates, population, and vehicle ownership came up in many countries in this review (Table 1.a). The majority of the studies took into consideration casualty rates per 100,000 people and 10,000 vehicles. The review shows that Iran recorded the highest rate at 44 per 100,000 (Bhalla *et al.*, 2009) who died due to RTAs in 2002, while the lowest death rate was recorded in Bangladesh at 6.8 per 100,000 in 2013 (Baset *et al.*, 2017). On the other hand, the rate of injuries was highest in Bangladesh at 889 per 100,000 in 2013 (Baset *et al.*, 2017), and the lowest was recorded in Kenya at 59.96 per 100,000 in 2009 (Bachani *et al*., 2012). Moreover, the World Health Organization (2015) estimated that in 2013, Libya had the highest number of road accident fatalities, with 73.4 per 100,000, and the lowest was found in Maldives at 3.5 per 100,000. In a study related to vehicle-based crashes, Bangladesh reported the highest number of RTDs at 100 per 10,000 vehicles in 2005 (Anjuman *et al.*, 2007), and the lowest was recorded in Bhutan at 10.9 per 10,000 (Wangdi *et al.*, 2018). However, the highest RTI per 100,000 and fatality rates were recorded in Ethiopia in 2016, which were 21,681 and 4,922, respectively (Abegaz & Gebremedhin, 2019). Moreover, the World Health Organization (2018) revealed that in 2016, on average, the mortality rates in terms of population and vehicles were highest in Africa (26.6 per 100,000 people and 64 per 100,000 vehicles) and South-East Asia (20.7 per 100,000 people and 64 per 100,000 vehicles).

1.3.2 Socio-demographic and economic factors related to RTAs.

Age group differences were significant in the majority of the studies. Over 90% of the studies demonstrated that the most economically productive age group (those aged 15-45) comprised between 48 and 78% (mean 69%) of all traffic casualties. These studies also showed that males were predominantly associated with RTAs over females and comprised nearly 80% of total

casualties. Even when examined by the type of road-users, drivers, and other aspects considering road traffic, males were still over-represented in every category. This can be explained by the greater exposure to roads for men than women, and also because the involvement of males is higher in the formal workforce than for females. Moreover, individuals education, occupation, level of income, and residence in rural areas were found to be the most relevant factors related to RTAs in this literature review.

1.3.3 Characteristics of cars and road users.

In more than two-thirds of the countries, buses, trucks, motorcycles, and bicycles are the main types of vehicles with the highest risks of injury and fatality from traffic crashes. The majority of the victims were also counted as lower socio-economic groups within these countries. Eleven studies showed that four-wheeled motorised vehicles, especially truck and bus are the main mode of transport responsible for most of the fatalities and injuries that have happened over time in different countries. On average, four-wheeled vehicles were involved in RTAs in 64% of the cases in LMICs (Naci & Chisholm, 2009), while 17 studies revealed that two-wheeled vehicles were the most vulnerable group in terms of both death and injury in LMICs. Over 90% of the studies described that pedestrians and passengers had higher injury and fatality rates than drivers and children.

1.3.4 Road characteristics and traffic rules violations.

Evidence from the studies in this review highlighted that high driving speed, not using seatbelts and helmets, wrong-way driving, two-way roads without dividers, lack of traffic control systems, intersection areas on the road, lack of speed control signs, dark streets or lack of adequate street lights, highways, city roads and poor road infrastructure were observed as the main causes of crashes in 23, 23, 5, 12, 7, 5, 4, 7, 8, 6 and 5 studies, respectively. Driver negligence, characterised by disregarding traffic control systems (not following traffic signals, carelessness, breaking traffic rules, and overloading vehicles), risk-taking attitudes

(aggressiveness, improper overtaking, and reckless driving), poor or less experienced driving skills, driving while intoxicated (drunk), having no driving license, unawareness of traffic systems, and fatigue were found to be the main causal factors of RTAs and severe injuries in 15, 11, 12, 9, 6, and 4 studies, respectively. Subsequently, pedestrian and passenger unawareness (running red lights, not obeying traffic signals and not knowing traffic rules) was also found to be one of the main reasons for severe injuries and fatalities in most LMICs.

1.3.5 Crash days and time.

The findings revealed that RTAs occurred more frequently during the morning (3), night-time (3), public holidays (3), and rainy seasons (3). The findings also demonstrated that morning, night-time, and public holidays are the times when drivers tend to drive faster than at other times. The findings also pointed out that the most severe accidents occurred at night, with the highest mortality rates compared to daytime (Kamruzzaman, Haque & Washington, 2014; Almeida *et al.*, 2013; Zhang, Yau & Chen, 2013).

1.4. Discussion

This review strengthens the understanding of the existing scenario of RTAs in LMICs by examining fatality rates, risk groups, and their associations, and highlights the problems with data collection. As can be seen from the detailed results provided in this review, socio-demographic and economic factors of drivers and victims, environmental conditions, time of the accidents, weather, and road-surface conditions together with a number of other variables were found to be significant factors related to RTAs.

There are wide variations in the characteristics of motor vehicle crashes between countries and regions in developing areas. Adolescents and young adults are at high risk of traffic injury, which has been well documented in many studies (Shinar & Compton, 2004; Majdzadeh *et al.*, 2008; La *et al.*, 2013; Abegaz *et al.*, 2014; Waseem *et al.*, 2019; Arafa *et al.*, 2019). Because many of these people were in their most economically productive years, road accidents hugely

impacted the economies of affected countries. The data in most studies show that males are more at risk than females of being injured in crashes (Abegaz *et al.*, 2014; Tulu *et al*. 2017; Waseem *et al.,* 2019). The higher likelihood for males may be attributed to their larger exposure to traffic and other associated factors such as working on roads under maintenance. The highest proportion of males involved in RTAs were drivers, pedestrians, passengers, motorcyclists and cyclists (Chang & Wang, 2006; Bodalal *et al.,* 2012; Chiou *et al.*, 2013; Boniface *et al.,* 2016; Shrestha *et al.*, 2017; Tulu *et al*. 2017; Wangdi *et al.*, 2018; Abegaz and Gebremedhin, 2019). Among these studies it is worth mentioning that pedestrians and passengers were the most vulnerable to injury and death, followed by drivers (Bodalal *et al.,* 2012; Chiou *et al.,* 2013). This may be due to several factors, including lack of proper pedestrian facilities in road design (Mutune *et al*, 2017), poor knowledge, and poor practice of road safety measures by pedestrians (Adhikari, 2016; Nangana *et al*., 2016), vehicle drivers, and riders (Joewono *et al.*, 2015). Other studies also reported that, in LMICs, drivers and motorcyclists (generally having low knowledge about road signs, not wearing seat belts or helmets, and driving or riding without licences) were also responsible for vulnerable injuries and deaths of pedestrians and passengers (Yongchaitrakul *et al.*, 2012; Joewono *et al.*, 2015; Sadeghi-Bazargani *et al.*, 2016). Based on this evidence, further research should more focus on these two groups to find out what are the main factors that influence or affect them to be the victims of RTAs. After that policymakers should take prompt and significant steps to reply the new evidence and fostering effective plans regarding pedestrians and passengers safety management. Subsequently, RTA victims were often people with lower socioeconomic status. This review found that the incidence of RTAs is quite high among those with low economic status, the unemployed, lower class workers, many of whom have limited or no literacy skills (Ipingbemi, 2008; Yongchaitrakul *et al.*, 2012; Kumar & Srinivasan, 2013; La *et al*. 2013; Lin *et al*., 2013; Coleman, 2014; Rifaat *et al.*, 2014; Raina *et al.,* 2016; Mekonnen, 2018; Islam *et al.*, 2018; Nguyen-Phuoc *et al*., 2019; Arafa *et*

al., 2019). Among these studies, it is worth mentioning that significant proportion of RTAs occurred with those who have a residence in the rural area (Lin *et al*., 2013) or live outside of cities and towns (Rifaat *et al.*, 2014). Therefore, based on this literature evidence, it is necessary to adopt immediate and effective safety strategies by researching on this particular group of population and road characteristics in rural areas.

Although four-wheeled vehicle accidents were the most frequent (Abegaz *et al.*, 2014; Anarkooli *et al.*, 2017), two-wheeled vehicle accidents were quite similar in proportion for that of four wheeled vehicles (Chang & Wang, 2006; Sarkar *et al.*, 2011; Almeida *et al.*, 2013; Banik *et al.*, 2011; Boniface *et al.*, 2016; Wangdi *et al.*, 2018). In LMICs, the death tolls due to RTAs mainly occurred on highways and district roads, which mostly belong to rural and underdeveloped areas (Odero *et al.*, 2003; Garg & Hyder, 2006; Ruikar, 2013) and injuries occurred due to RTAs largely occurred on city areas (Odero *et al*., 2003; Mamun *et al*.,2015; Rodrígue *et al*., 2015; Ahmad *et al*., 2018). As four-wheeled vehicles are the main mode of transport on highways, most of such crashes concern vehicle passengers (Wangdi *et al.*, 2018). Some studies done in LMICs also state that, on highways, motorised two-wheelers' occupants were highest in number (Li *et al.*, 2009; Yongchaitrakul *et al.*, 2012). Similar results have been reported by several studies in other settings that measured or investigated extreme severe accidents. Studies conducted by Majdzadeh *et al.* (2008), Chiou *et al.* (2013), Fouda *et al.* (2017), Choulagai *et al.* (2015), and Zimmerman *et al.* (2015) also showed that motorised two-wheeled vehicles were involved in most severe RTAs than other vehicles. This could happen due to road characteristics (roads without dividers (Kamruzzaman *et al.*, 2013; Hosseinpour *et al*., 2014; Waseem *et al.*, 2019), no traffic control signs (Sarkar *et al.*, 2011) , unplanned intersections in the road (Li *et al.*, 2009), lack of speed control signs (Hosseinpour *et al*., 2014; Anarkooli *et al.*, 2017), lack of adequate street lights at night (Chiou *et al.*, 2013; Baru *et al*., 2019), poor road infrastructure (Joewono *et al*., 2015; Rodrígue *et al*., 2015; Wangdi *et al.*,

2018), and lack of police control systems (Ali & Tayfour, 2012)), and driver attitudes (higher speed and acceleration (Waseela & Laosee, 2015; Waseem *et al.*, 2019), wrong way driving, fatigue (Ahmad *et al.*, 2019), drinking alcohol (Karkee, & Lee, 2016; Baru *et al.*, 2019), overtaking intention or tendencies (Boniface *et al.*, 2016), aggressiveness (Chang & Yeh, 2007), and unawareness of traffic rules and regulations (Waseela & Laosee, 2015)). These causes are common in most LMICs because of the lack of strict regulations, lack of a proper punishment system for rule breaking, and lack of adequate commitment by the government and traffic police also due to corruption (Anjuman *et al.*, 2007; Rubayat & Sultana, 2013). Despite this finding, yet many LMICs are facing a significant number of RTAs occurred on highways by these modes of transport, and the number of deaths occurred by these vehicles increases (WHO, 2018). Therefore, future research needs to focus deeply on drivers behavior and highways road characteristics to adopt effective safety strategies.

Based on this review, it can be said that roads themselves play an important role in RTAs. By improving road designs and infrastructure, RTAs can be significantly reduced worldwide. Most LMICs understand the association between road conditions and traffic accidents. Two-way roads without dividers or one-way roads (without lane separation) with no traffic control signs have been common and important factors of road crashes in many studies (Barua & Tay, 2010; Rubayat & Sultana, 2013; Kamruzzaman *et al.*, 2013; Ahmed *et al.*, 2014; Kamruzzaman *et al.*, 2014; Hosseinpour *et al.*, 2014; Rodrígue *et al.*, 2015). Experience in several countries demonstrated that roads without dividers and lack of strict enforcement of speed regulations were found to be the main determinants of serious injuries and fatalities in motor vehicle crashes (Ali & Tayfour, 2012; Coleman, 2014; Kamruzzaman *et al.*, 2014; Hosseinpour *et al.*, 2014; Asefa *et al.*, 2014; Rodrígue *et al.*, 2015; Anarkooli *et al.*, 2017; Mekonnen, 2018; Ahmad *et al.*, 2019). Some studies also reported that two-way roads without dividers increase the chances of a head-on collision, which tends to cause more severe fatalities and injuries

(Hosseinpour *et al.*, 2014; Ahmad *et al.*, 2019). However, a recent study conducted in Tamil Nadu, India, by using road accident survey data from the Government of Tamil Nadu dataset and demonstrates that road with the presence of a central divider is positively associated with speeding-related accidents (Balasubramanian & Sivas-ankaran, 2019).

The various traffic control structures at intersections also affect the fatality and injury severity (Satria *et al*., 2020). In the majority of LMICs, severe accidents occurred at the intersection point, rather than in other road areas (Banik *et al.*, 2011; Chiou *et al.*, 2013; Rubayat & Sultana, 2013; Ahmed *et al.*, 2014; Mamun *et al.*, 2015; Kumar & Toshniwal, 2016; Gebru, 2017). In these countries, crashes occurring at intersections without traffic signals are more severe than at intersections with traffic signals (Li *et al.*, 2009). Similarly, studies on developed countries have shown that signalised intersections with pedestrian crossing signal facilities decrease the chances of severe injuries from RTAs (Haque *et al.*, 2010; Yasmin & Eluru, 2013; Haleem & Abdel-Aty, 2010; Agbelie & Roshandeh, 2015). However, it is worth mentioning that few studies showed different contributions in terms of findings. For instance, Chiou *et al*. (2013) demonstrate that the geometric design of intersections on the road plays a key role in injury severity. They showed that accident occurs in three-leg and multiple-leg intersections increase injury severity than other intersections areas. A study conducted in India shows that intersections on the highway and across market locations increase pedestrian hit accidents (Kumar & Toshniwal, 2016). Moreover, studies conducted in Ethiopia and Malaysia illustrate that intersections with poor visibility at night (Gebru, 2017) and intersections at rural roads (Manan *et al.*, 2017) increase the RTAs severity.

Therefore, to resolve the controversy about the effectiveness of the presence of central dividers on the road in reducing the occurrence of RTAs and the impact of intersection road areas on RTAs, further research is required to implement an effective and reliable dataset and new methodology.

There is sufficient evidence to support the high incidence of RTAs in the morning and at night (Rezaur, 2005; Almeida *et al.*, 2013; Asefa *et al.*, 2014; Shrestha *et al.*, 2017; Manan *et al.*, 2017; Demissie, 2017). This can be explained by lower traffic volumes and high speeds during the night and early in the morning, which results in a greater risk of road accident involvement (Kamruzzaman *et al.*, 2014; Barua, & Tay, 2010; Patel *et al.*, 2016; Kisitu *et al.*, 2016; Fisa *et al.*, 2019; Zhang *et al.*, 2019). The relative decline in traffic casualties in the daytime may be explained by higher traffic volumes and lower speed due to congestion. Consequently, in most of the LMICs, the fatality rate is higher for night-time crashes than for those occurring during the day (Asefa *et al.*, 2014; Tulu *et al.*, 2017). Darkness, reduced visibility, and alcohol intoxication have been suggested as the other main factors contributing to RTAs at night and early in the morning (Abegaz *et al.*, 2014; Chiou *et al.*, 2013; Zhang *et al.*, 2014; Baru *et al.*, 2019; Gebru, 2017; Mutune *et al*, 2017). On the other hand, other studies also found statistically significant higher rates of RTAs during the day than at night (Choulagai *et al.*, 2015; Cioca & Ivascu, 2017; Ahmad *et al.*, 2018; Balasubramanian & Sivasankaran, 2019). The review showed that road accidents and their severity increased significantly on weekends and in rainy seasons, as compared to weekdays and other seasons (Majdzadeh *et al.*, 2008; Sarkar *et al.*, 2011; Almeida *et al.*, 2013; Zhang *et al.*, 2013; Choulagai *et al.*, 2015; Demissie, 2017; Anarkooli *et al.*, 2017). One of the reasons is that the traffic volume on weekends is comparatively lower than on weekdays (Barua & Tay, 2010; Kamruzzaman *et al.*, 2014). In developing countries, weekend crashes have long been associated with drunk driving and high speed on the street because during these days people are, in general, moving frequently from one place to another (Almeida *et al.*, 2013; Zhang *et al.*, 2019; Saeed *et al.*, 2016; Nangana *et al.*, 2016). A study conducted in Namibia demonstrated that 60% of weekly traffic injuries reported occurred during the weekend (Amweelo, 2016). Another study conducted in Colombia revealed that the increase in injuries on weekends was associated with fewer control measures

on holidays and the lack of clear regulations for punishing drunken drivers (Sadeghi-Bazargani *et al.*, 2016).

1.5. Conclusions and future investigations

LMICs suffer a heavy burden of RTIs and fatalities, which mainly occur on highways, roads without dividers, high-speed roads, areas with unplanned intersections, and with insufficient traffic signs on the street. The majority of accidents are caused by four and two-wheeled vehicles. Most published studies on RTAs in LMICs suggested that people of the age group of 15–45 years, males, poor pedestrians, passengers, and drivers are most commonly injured and killed in accidents. Despite these results existed over the decade, it is still unknown why RTAs have been increasing in most of the LMICs, and why the age group of 15–45 years (males, poor pedestrians, passengers, and drivers) are the fastest-growing group experiencing RTAs and commonly injured and killed by its consequences. Therefore, recent trends of RTAs may have changed in LMICs, if new prevention programs are identified and developed.

Throughout the review, we have found that people's awareness level is significantly and positively correlated with RTAs, but, so far, no particular research or empirical evidence exists on what are the factors that make people more aware about RTAs and how the people awareness level regarding road accidents can be enhanced. Hence, it is necessary to find out what can be done to make these people more aware about RTAs and help them to avoid being victims. In addition, further efforts should be made to investigate how severely their awareness level impacts RTAs and the factors that influence their awareness level regarding RTAs.

This review also highlighted that there is a higher correlation between road accidents and ‘road infrastructures and reckless driving’ in many LMICs. Despite this result, little progress has been made towards the goal of a reduction of road accidents in these countries, as the number of deaths and injuries caused by RTAs has increased over the decade. One of the most

prominent reason is, lack of aggregate research and empirical evidence is available and unreliable data have been used in the analysis in most countries.

Therefore, future research should focus on different road areas and road categories in LMICs to empirically identify the most hazardous elements and on how governments can intervene to improve road infrastructure to prevent RTAs. Future research also needs to contemplate how a driver's behaviour changes over time due to road types and road characteristics by observing road accidents and how vehicle types influence driver attitude or behaviour while driving or riding on the streets.

As can be seen from the review, the majority of the studies used data that suffered from underreporting of accidents with lack of information. Therefore, without complete data, it is impossible to develop effective road safety interventions because this problem created a bias in the results due to the omission many important factors that influence RTAs. Further research should focus mainly on developing the data quality and exploring the factors (driver attitudes, road infrastructure and other issues) related to RTAs in developing countries by using statistical models, because accurate data with all the necessary explanatory variables will provide more reliable results for policymakers. We believe that, by providing new evidence on these issues, policymakers could implement new effective policies to enhance the people's awareness level about RTAs, which will ultimately lead to reducing road accidents.

Chapter 2

Determinants of Awareness About Road Accidents and Knowledge of Traffic Rules: Empirical Evidence from Khulna City in Bangladesh

2.1. Introduction

Over the last four decades, fatalities and injuries related to road traffic accidents (RTAs) have increased consistently (World Health Organisation, 2018). Consequently, RTAs have become one of the major challenges in all developing countries (DCs), particularly in the least developed ones (Anwaar *et al*., 2012). The consensus in the existing literature is that road accidents have a negative impact on society, due to the loss of human lives and the loss of wealth (Rubayat & Sultana, 2013). RTAs are the eighth leading cause of death worldwide (Ameratunga, Hijar & Norton, 2006), and are expected to be the fifth leading cause of death by 2030 (Naghavi *et al*., 2015; World Health Organisation, 2013). In low-and middle-income countries (LMICs) in recent years, RTAs caused more than 90% of deaths and injuries, and losses of up to 5% of GDP, compared to losses of 3% of GDP in other countries globally (World Health Organisation, 2015; 2018).

Rapid economic growth, motorisation, and urbanisation are the leading causes of the increase in RTAs in LMICs (Peden *et al*., 2004; Staton *et al*., 2016). In addition, lack of awareness of drivers and the public about RTAs, as well as overpopulation, the low quality of roads, lack of driver training, over speeding, and increasing alcohol consumption are causing more RTAs (Balasubramanian & Sivasankaran, 2019; Biswas, 2012; Bougueroua & Carnis, 2016; Kakkar *et al*., 2014; Mohamed & Bromfield, 2017; Osayomi, 2013; Puvanachandra *et al*., 2012; Raina *et al*., 2016; Rasool *et al*., 2015; Sarkar, Tay & Hunt, 2011; Singh *et al*., 2016). Working class people and commuters (who are required to often be in traffic), lower socio-economic group of society and are mostly between 18 to 45 years of age, are the main victims of RTAs. (Abegaz

et al., 2019; Ahmad *et al*., 2018; Baset *et al*., 2017; Goswami *et al*., 2018; Kamruzzaman, Haqu & Washington, 2014; Khare *et al*., 2012; Kyu *et al*., 2016; Lin *et al*., 2013; Mashreky *et al*., 2010; Raina *et al*., 2016; Rubayat & Sultana, 2013; Shrestha *et al*., 2017; Zhang, Yau & Chen, 2013).

In line with this global trend, RTAs are also a major problem in Bangladesh. In fact, RTAs have become more common in Bangladesh than in other DCs in South Asia. The country's lack of adequate resources to help deal with RTAs leads to massive amounts of social and economic losses in terms of fatalities and property damage. RTAs are one of the main causes of these losses (Ahsan *et al*., 2011; Banik *et al*., 2011). Despite the growing burden caused by RTAs in Bangladesh, road safety remains a neglected issue, and relatively little knowledge exists on the factors contributing to the high number of RTAs. A report published by The Daily Star monthly forum in 2012 stated that, on average, 60 to 150 deaths per 10,000 motor vehicles occurred per year in Bangladesh, and the majority of the fatalities occurred due to drivers and public unawareness (Ahsan, 2012), which had the highest fatality rates compared to other developing countries in Asia, such as India (25.3), Sri Lanka (16), Malaysia (5.5), Cambodia (7), and Lao People's Democratic Republic (8) (Anjuman *et al*., 2007; Kamruzzaman, Haqu & Washington, 2014).

2.1.1 Research motivation

According to a report by the Bangladesh University of Engineering and Technology (BUET), nearly 12,000 people died and 35,000 others were injured due to road accidents in Bangladesh in 2012 (Labib *et al*., 2019). The most recent report published by the World Health Organisation (2018) estimated that in 2016, 24,954 people were killed by RTAs in Bangladesh. Mortality and morbidity rates of RTAs were significantly higher for males, pedestrians, and vehicle passengers (Ahmad *et al*., 2018; Baset *et al*., 2017; Goswami *et al*., 2018). Therefore, to prevent RTAs and improve the safety of roads, the Government of Bangladesh (GoB), as

well as private institutions, civil societies, communities, and other non-government organisations, have taken several initiatives over the last decade (Mahmud *et al*., 2013). The most common measures are road construction and maintenance, safety improvement of existing roads, road-safety user guidelines, increase of police agents on roads, traffic legislation to decrease unlicensed transport, and increased traffic signs on the roads (Ahmed, Ahmed, & Hainin, 2014; King, 2018; Mahmud, Hoque & Shakur, 2011; Mahmud *et al*., 2013). Despite all these initiatives taken by the government and non-government organisations, the rate of RTAs did not decrease significantly in Bangladesh. Therefore, it can be assumed that the RTAs problem will remain severe in the future if public awareness of RTAs is not improved in Bangladesh.

Many studies have explored the types, causes, and consequences of RTAs in Bangladesh (Anjuman *et al*., 2007; Banik *et al*., 2011; Baset *et al*., 2017; Jabbar *et al*., 2009; Kamruzzaman, Haqu & Washington, 2014; Rubayat & Sultana, 2013). However, few studies have been conducted on the public awareness of RTAs and people's knowledge of traffic rules, mainly due to data limitations (Baset *et al*., 2017). To the best of our knowledge, only one study, conducted by Islam *et al*. (2018), focused on identifying the fundamental determinants that were associated with the knowledge of traffic rules in Bangladesh. However, yet no empirical study is conducted on how people's awareness level can enhance regarding RTAs in Bangladesh. Hence, the current research particularly takes deep contemplation on "what are the factors that increase the awareness level of an individual regarding RTAs". We believe that the finding will make a significant impact on the reduction of RTAs. Furthermore, it is also worthwhile to note that our study is quite different from that of Islam *et al*. (2018) since we focus our analysis simultaneously on two interrelated aspects, namely (i) the awareness level of the victims of RTAs, and (ii) victims' knowledge level of traffic rules. There is no

doubt that a reduction in road accidents does not solely depend on people knowing traffic rules but also on their awareness level. Therefore, it is necessary to focus on both aspects.

This study explores the relationship between unobserved factors regarding the awareness of RTAs and the knowledge of traffic rules by using a bivariate probit model. One crucial factor, the victim's previous experience with RTAs, is considered in our case, whereas it was ignored in the model by Islam *et al*. (2018). Since it is still unclear what factors drive public awareness of RTAs and increase public knowledge of traffic rules, this study assesses the effect of social, demographic, economic, and other determinants of public awareness of RTAs and of knowledge of traffic rules. Our findings would be useful for policymakers and aid in developing effective policies to reduce the rate of RTAs in Bangladesh.

The remainder of this paper is organised as follows. Section 2 is the literature review, followed by the conceptual framework of this study in Section 3. Sections 4 and 5 describe the data and the methodological assumptions adopted in the analysis, with a brief description of the main determinants. Section 6 discusses the results. Finally, section 7 concludes the study with the policy implications and limitations of the paper.

2.2. Literature review

Sociodemographic and economic empowerment related training increases people's skills and awareness of various socio-economic aspects of life (Hilton *et al*., 2016; Kabir *et al*., 2018; Mahmud *et al*., 2017). Therefore, it also creates opportunities to increase the understanding of RTAs issues and the knowledge of traffic rules (Banik *et al*., 2011; Abega *et al*., 2014; Khare *et al*., 2012; Nadesan-Reddy & Knight, 2013; Touahmia, 2018). According to Zimmerman *et al*. (2015) and others accessing road traffic training is a pressing need for people willing to increase their knowledge and awareness about road traffic rules and accidents (Chen, 2009; Chang & Yeh, 2007; Ali & Tayfour, 2012; Anarkooli, Hosseinpour & Kardar, 2017; Potoglou, Carlucci, Cirà & Restaino 2018; Shrestha *et al*., 2017). However, a literature review conducted

by Lin and Kraus (2009) showed that drivers who receive training have no significant reduction in the risk of motorcycle crashes. They argued that age, gender, location of licensing and other factors of a person also can significantly impact on RTAs even though that individual receive training regarding traffic rules. Furthermore, they also claimed that individuals who received training may have more confidence in their operating skills and drive with more risk-taking behaviors.

Education is an essential factor in knowledge acquisition. It is closely related to the living standard of a person and also acts as a catalyst for enhancing their analytical skills (Anderson, Chisholm, & Fuhr, 2009; Hilton *et al*., 2016; Mahmud *et al*., 2014; Mahmud *et al*., 2017). In the context of RTAs, education facilitates the understanding of road traffic rules formally (Kumar & Srinivasan, 2013; Lin *et al*., 2013; Najaf *et al*., 2017; Pebalo *et al*., 2012; Staton *et al*., 2016; Shrestha *et al*., 2017). Similarly, gender also remains one of the main determinants of awareness about road accidents. In most cases, males are killed or injured in road accidents at a higher percentage compared to females (Abegaz & Gebremedhin, 2019; Balasubramanian & Sivasankaran, 2019; Tulu *et al*., 2017). However, the influence of gender is still unclear. For example, Diaz (2002), Latremouille *et al*. (2004), Rosenbloom (2009), and Abegaz and Gebremedhin (2019) demonstrated that females were more careful than males while crossing the road. In contrast, Latremouille *et al*. (2004) and Rosenbloom *et al*. (2004) found that women were less concerned than men while crossing a busy and dangerous road. In Bangladesh, it is generally believed that women are less aware of road traffic rules and accidents than men because they do not travel frequently. Likewise, previous RTAs experience enhances people's awareness of traffic accidents and encourages them to learn more about traffic rules (Horswill & McKenna, 1979; Watts & Quimby, 2004).

Apart from the factors mentioned above, other important demographic and socio-economic factors, such as age, marital status, income, occupation, residence, and access to media also

influence the awareness and knowledge of road traffic rules and accidents. All these factors help people acquire knowledge, build awareness and create opportunities to develop different skills. Age is an essential factor related to the decision-making capacity and experience of a person. Undoubtedly, age significantly impacts the awareness of RTAs (Abegaz & Gebremedhin, 2019; Pebalo *et al*., 2012; Singh *et al*., 2016). When an individual is relatively very young or very old, that person has the highest risk of falling into the RTAs "trap" (Dandona *et al*., 2011; Tay, 2008; Eustace & Wei, 2010; Chiou, Hwang, Chang & Fu, 2013; Shrestha *et al*., 2017). The main reason for this segment of people being victims are reckless driving, over speeding, unawareness of road traffic rules, physical changes and poor driving ability at night (Abegaz, & Gebremedhin, 2019; Arafa, ElSetouhy & Hirshon, 2019; Ahmad, Ahmed, Wali & Saeed, 2019). A married person is more concerned about traffic rules and accidents than an unmarried person (Pebalo *et al*., 2012). This is because married people drive more carefully than unmarried persons, as they generally have more at stake regarding their family and more aware of the harmful consequences of reckless driving (Akalanka *et al*., 2012; Ipingbemi, 2008).

People's occupations and places of residence are also important factors to consider (Abegaz & Gebremedhin, 2019; Chen *et al*., 2016; Raina *et al*., 2016; Singh *et al*., 2016). In Bangladesh, formal or high-skilled workers (professional/official jobs and businesses that require good skills or formal education) comparatively have a higher level of road-safety knowledge and know more about rules and regulations than informal or low-skilled workers (farmers, labourers, and other job holders who are less educated and do not have any particular skill) because the majority of them are illiterate and have inadequate training regarding RTAs. Researchers observed that, due to a lack of awareness and information accessibility, as well as infrequent travel to other locations, farmers or workers living in rural areas are less concerned

about road traffic rules and accidents than people living and working in urban areas (Ipingbemi, 2008; Mahmud, Hoque, & Qazi, 2009; Zajac & Ivan, 2003).

Income is considered an essential factor in gaining more knowledge about traffic rules and road accidents (Anwaar *et al*.,2012; Abegaz & Gebremedhin, 2019). People with lower economic status are more likely to be victims of road accidents than others (Jeepura & Pirasath, 2012; Yongchaitrakul, Juntakarn & Prasartritha, 2012). A person with an adequate income can spend much more on driving safer vehicles and having access to information related to traffic rules and regulations, as compared to a person with low income. Media can also play a pivotal role in building social and economic awareness of RTAs (Kabir *et al*. 2018). Some researchers reported that having access to media increased the likelihood of people acquiring knowledge about traffic rules and also helped them gain access to daily information about road accidents (Whittam *et al*., 2006; Iipinge & Owusu-Afriyie, 2014; Bonnet, Lechat & Ridde, 2018). As a result, people with access to media can become quickly and adequately aware of issues related to road accidents.

2.3. Conceptual framework

Based on the literature review it can be said that people social, economic, demographic and other factors not only important to find out what are the main factors affecting the RTAs and their severity but also vitally essential to understand how these factors influence their awareness level regarding RTAs and know about traffic rules. So far, we have found that previous studies have been conducted to examine the main factors affecting RTAs. However, no individual research or empirical evidence so far exists on "what are the key social, demographic, economic and other factors that impact people awareness level regarding RTAs?" and "how these factors can be developed for individuals to drop RTAs?". Therefore, add original empirical evidence regarding some of the issues discussed in the literature review, this study hypothesises that the victims' awareness of RTAs and knowledge of traffic rules are

significantly affected by their social, demographic, and economic characteristics together with other related factors. Such factors include age, gender, marital status, level of income, educational qualification, previous road accident experience, former training of traffic rules, occupation, residence, and media access.

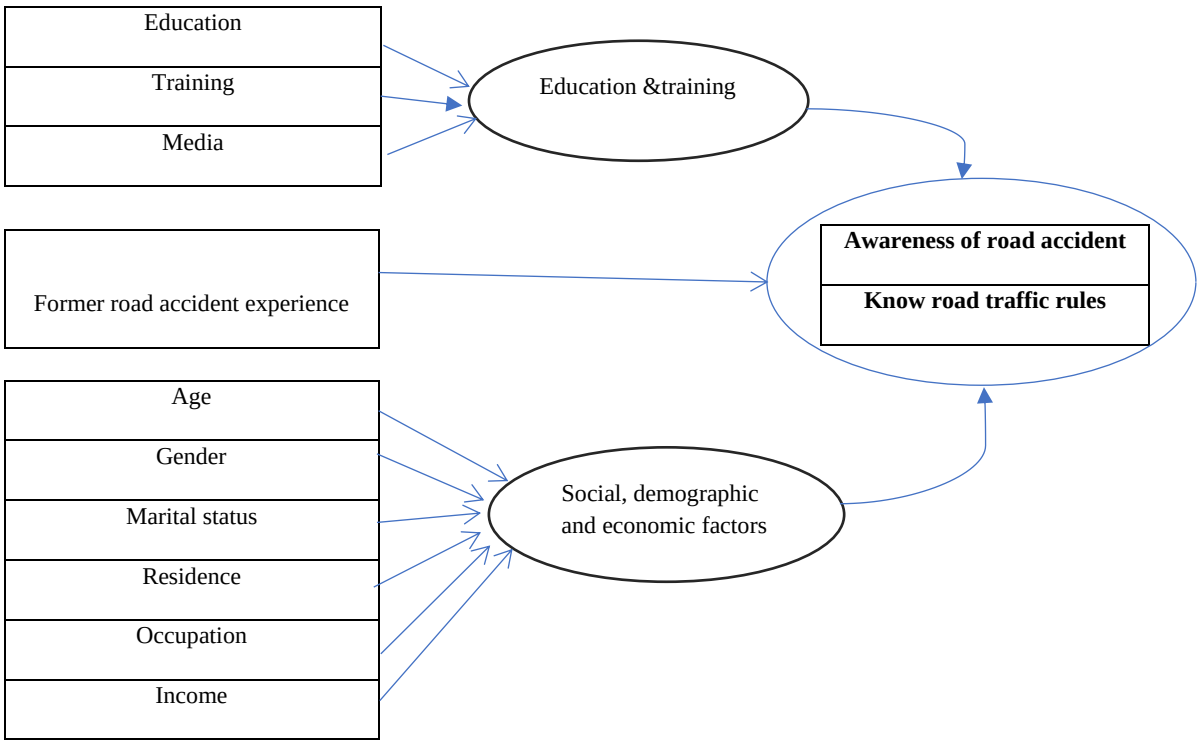

Figure 2.a. The conceptual framework of increasing victims' Awareness of RTAs and Knowledge of traffic rules.

We refer to the conceptual framework shown in Figure 2.a, where we assume that:

H_1: Social, demographic, and economic factors influence the victims' awareness of road accidents and knowledge of traffic rules.

H_2: General education, media exposure, and specific traffic rules training increase victims' awareness of road accidents and knowledge of traffic rules.

H_3: Victims' previous experience of RTAs increases their awareness of RTAs and knowledge of traffic rules.

2.4. Data collection

The present study uses primary data collected by Islam *et al*. (2018) between January and February 2017 on victims who were admitted after road accident in the Orthopaedics, Neurosurgery, and general wards of Khulna Medical College Hospital, Satkhira Sadar Hospital, and several private clinics from the Khulna and Satkhira districts. Data were collected using a questionnaire with face-to-face interviews from the 200 respondents who were admitted to the hospitals. Data were mainly collected from this survey on the victims' social, demographic, and economic profiles, injury information, and information related to knowledge and awareness of RTAs.

2.5 Methodology

In this study, we used a probit model to assess the victim's overall knowledge of traffic rules and awareness levels of road accidents. Both binary logistic regression and probit models are widely accepted and commonly adopted when the dependent variable is dichotomous (Ai & Norton, 2003; Hoetker, 2007). The model is developed and estimated by two separate, independent probit models to empirically investigate what social, demographic, and economic factors drive the victim to be aware of RTAs and increase their knowledge about traffic rules. Furthermore, as a robustness check, we also used a bivariate probit model. The first dependent variable (y_1) is a dummy variable that is coded as "one" if the victims are aware of RTAs and "zero" otherwise. The second dependent variable (y_2) is a dummy variable that is coded as "one" if the victims know about traffic rules and "zero" otherwise. The probit models can be written as:

$$\boldsymbol{y_1 = \beta X_i + \varepsilon}$$

$$y_2 = \beta X_i + \varepsilon$$

In this model, the vector of independent variables within *X* includes the following factors: Age = Age of the victims (Logarithm of years), Gender = Gender of the victims (Dummy: male =1, female =0), Marital status = Marital status of the victims (Dummy: Married =1, otherwise 0), Urban residence = Residence of the victims (Dummy: urban =1, otherwise 0), Degree = Educational qualification of the victim's (Dummy: Degree = 1, i.e., College degree or years of schooling is more than 12, otherwise 0), Higher skilled job = If the victim has a high quality or regular job (profession/formal/official job that requires good skills or formal education) (Dummy: yes = 1, otherwise 0), Lower skilled job = If the victim has a low quality or irregular job (farmers, labourers, and other jobs that do not require education or skills) (Dummy: yes = 1, otherwise = 0), Income = monthly income of the victim's family (logarithm of income in Taka, the currency of Bangladesh), Previous experiences of RTAs = Previous road accident experiences of the victim (Number), Previous training experience = Whether the victim has experience in road accident=-related training (dummy: yes =1, otherwise 0) and Media exposure = Whether the victim has access to media (dummy: yes =1, otherwise 0). β = Indicates the vector of coefficients to be estimated, and ε = the equation's error term.

2.6. Social, demographic and economic status of the respondents

Descriptive statistics of the sample are shown in Table 2.a, which lists the variables used in the model to estimate the victim's awareness of RTAs and knowledge of traffic rules. The table shows the mean, standard deviation, minimum, and maximum of the variables from a total of 200 observations. Of the 200 respondents, 128 (64%) claimed that they were aware of road accidents and 116 (58%) knew traffic rules. Respondents aged 15–44 years were the group most affected by RTAs, representing 65% of the total number of respondents, and among the remaining victims, 7% were 0–14 years old and 28% were over 44 years old. The average age

of the victims was 35. The majority of victims were male (87%), predominantly working-age, and 64% of victims were married. Among all respondents, approximately 53.5% had at least one road traffic injury in the past. The highest proportion of accidents occurred among people

Table 2.a. Descriptive statistics.

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Awareness of RTAs	200	0.64	0.48	0.00	1.00
Knowledge of traffic rules	200	0.58	0.49	0.00	1.00
Age	200	3.44	0.49	1.95	4.25
Income	200	9.81	0.67	8.01	11.70
Previous experiences of RTAs	200	0.535	0.86	0.00	3.00
Gender	200	0.87	0.34	0.00	1.00
Previous training experience	200	0.665	0.47	0.00	1.00
Lower skilled job	200	0.32	0.48	0.00	1.00
Higher skilled job	200	0.47	0.50	0.00	1.00
Media exposure	200	0.385	0.49	0.00	1.00
Marital status	200	0.64	0.48	0.00	1.00
Degree	200	0.505	0.50	0.00	1.00
Urban residence	200	0.33	0.47	0.00	1.00

living in rural areas. The respondents were most commonly high skilled job holders or businessmen (47%), followed by farmers and lower-level workers (32%), and the remaining 21% were unemployed. More than half (50.5%) of the victims had a degree. Finally, among the victims, 66.5% had previous training experiences regarding road traffic rules and regulations, and 38.5% had access to media.

2.7. Results of the probit regression analysis

Two separate probit models were estimated to identify the factors that were significantly associated with the awareness of RTAs and knowledge of traffic rules. All analyses were conducted using STATA-64. The estimated results of the probit models are presented in Table

2.b. These results suggest that the individual's awareness of RTAs shows a positive and highly significant association with gender (β = 0.792, p < 0.05), previous training experience (β = 0.933, p < 0.01), access to media (β = 1.004, p <0.01), previous road accident experiences (β = 0.425, p < 0.01), and having a degree (β = 0.826, p < 0.01). The estimated marginal effects in Table 2.c show that a male individual is 21.9% more likely to be aware of RTAs than females. Similarly, individuals who have training experience and access to media and higher education are 25.9%, 27.9%, and 22.9%, respectively more likely to be aware of RTAs than those with no training experience, no access to media and no higher education. Furthermore, for each additional experience of a previous road accident, individual respondents are 11.8% more likely to be awareness of the risk of RTAs than those who have no previous experience of a road accident. Turning to the remaining control and other variables, low-skilled or irregular job holders (β = 0.476, p > 0.10) and marital status (β = 0.215, p > 0.10) exhibit a positive but insignificant association with the awareness of RTAs. Age (β = –0.401, p > 0.10), income (β = –0.279, p > 0.10), high-skilled or regular jobs (β = –0.098, p > 0.10), and living in the city (β = –0.002, p > 0.10) show a negative and insignificant association with awareness of RTAs. The results and the marginal effects of victims awareness of RTAs in this study are consistent with predicting H_2 and H_3. However, this result is partially confirmed for H_1. Only gender remains consistent with H_1, and remaining variables such as low-skilled or irregular job holders, marital status, age, income, high-skill or regular job, and living in the city reject H_1. The results for knowledge of traffic rules are slightly different from those of the first model. Among the same independent variables used in the previous regression, the increase in victim's knowledge of traffic rules also shows a positive and significant association with having a previous training experience (β = 0.851, p < 0.01), access to media (β = 2.241, p < 0.01), previous road accident experiences (β = 0.286, p < 0.05), and having a degree (β = 0.596, p < 0.10), with the exception of gender. Highly skilled workers (β = 1.087, p < 0.05) and persons who live in cities (β =

0.486, p < 0.10) also have a positive and significant correlation. Gender (β = 0.549, p > 0.10) and low-skilled workers (β = 0.407, p > 0.10) have a positive but insignificant correlation with the victim's knowledge of traffic rules. Regarding age (β = –0.566, p > 0.10), income (β = –0.304, p > 0.10), and marital status (β = –0.049, p > 0.10), the results show a negative and

Table 2.b. Results from maximum likelihood estimation of probit models.

Dependent variables	**Awareness of RTAs**	**Knowledge of traffic rules**
Explanatory Variable	**Coefficient**	**Coefficient**
Age	-0.401 [0.314]	-0.566 [0.357]
Income	-0.279 [0.205]	-0.304 [0.231]
Previous experiences of RTAs	0.425 [0.148] ***	0.286 [0.145] **
Male	0.792 [0.348] **	0.549 [0.466]
Previous training experience	0.933 [0.230] ***	0.851 [0.284] ***
Lower skilled job	0.476 [0.415]	0.407 [0.463]
Higher skilled job	-0.098 [0.353]	1.087 [0.431] **
Media exposure	1.004 [.0243] ***	2.241 [0.353] ***
Marital status	0.215 [0.316]	-0.049 [0.403]
Degree	0.826 [0.304] ***	0.596 [0.324] *
Urban residence	-0.002 [0.232]	0.486 [0.275] *
_cons	1.966 [2.027]	2.282 [2.282]
Model parameters		
LR chi2(11)	64.88	124.07
Prob > chi2	0.000	0.000
Pseudo R2	0.248	0.456

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

insignificant association with the knowledge of traffic rules of the victims. The estimated marginal effects in Table 2.c show that male respondents are 11.2% more likely to have knowledge of traffic rules than females. Finally, individuals who have training experience, access to media, a degree, high-skill jobs, and live in the city are 17.4%, 45.9%, 12.2%, 22.2%, and 9.9% respectively more likely to have knowledge of traffic rules than those respondents

who have, respectively, no training experience, no access to media, have no degree, have low-skilled jobs, and live in rural areas. Consequently, for each additional experience of a previous road accident, individuals are 5.9% more likely to know traffic rules. The results and the marginal effects of knowledge of traffic rules in this study are also consistent with predictions

Table 2.c. Marginal effect results of Awareness of RTAs and Knowledge of traffic rules.

	Awareness of RTAs	**Knowledge of traffic rules**
Explanatory Variable	**dy/dx**	**dy/dx**
Age	-0.111 [0.086]	-0.116 [0.071]
Income	-0.078 [0 .056]	-0.062 [0.046]
Previous experiences of RTAs	0.118 [0.038] ***	0.059 [0.028] **
Male	0.219 [0.093] **	0.112 [0.094]
Previous training experience	0.259 [0.055] ***	0.174 [0.053] ***
Lower skilled job	0.132 [0.114]	0.083 [0.094]
Higher skilled job	-0.027 [0.097]	0.222 [0.083] ***
Media exposure	0.279 [0.059] ***	0.459 [0.044] ***
Marital status	0.059 [0.087]	-0.010 [0.082]
Degree	0.229 [0.080] ***	0.122 [0.064] *
Urban residence	-0.001 [0.064]	0.099 [0.054] *

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

H_2 and H_3, while for H_1 the result is partially confirmed. Only high-skilled workers and persons who live in the city remain consistent with H_1 and remaining variables such as gender, marital status, age, income, and low-skilled or irregular job holders reject H_1. Taking into consideration the marginal effects of the variables, we noticed that victims with a degree, previous specific training on road traffic systems, and access to media have a comparatively higher chance of awareness of RTAs and knowledge of traffic rules.

In general, both models fit the data quite well, with an acceptable Pseudo R-square statistic of 0.248 (with an average chi-squared of 64.88 at the 0.001 significance level) and 0.456 (with an

average chi-squared of 124.07 at the 0.001 significance level), with an overall accuracy of 78.5% and 80%, respectively. Furthermore, we checked for possible high correlation problems among the variables, and in both models, there were no multicollinearity problems.

2.7.1 Robustness checks

For the robustness check, we use a bivariate probit regression. This model can be generalised as:

$$y_1^* = x_1'\beta_1 + \varepsilon_1$$

$$y_2^* = x_2'\beta_2 + \varepsilon_2$$

The model specifies the outcome as:

$$y_1 = \begin{cases} 1 \ if \ y_1^* > 0 \\ 0 \ if \ y_1^* \leq 0 \end{cases}$$

$$y_2 = \begin{cases} 1 \ if \ y_2^* > 0 \\ 0 \ if \ y_2^* \leq 0 \end{cases}$$

where y_1^* and y_2^* represent the two dependent variables, x_1' and x_2' are the same set of independent variables used in the previous section, and ε_1 and ε_2 are the error terms in the model. The model is completed by assuming that the latent errors ε_1 and ε_2 have a bivariate standard normal joint distribution with correlation ρ. The bivariate probit model is a joint model for two binary outcomes when the two dependent variables are highly correlated. Table 2.d reports the bivariate probit regression results, which show that the victim's awareness of RTAs and the victim's knowledge of traffic rules are relatively consistent with our Probit results. Finally, the ancillary parameter rho measures the correlation of the residuals from the two models. As it turns out, the two equations are strongly associated, having rho = 0.89, which is significant (chi2 (1) = 35.03 Prob > chi2 = 0.0000) and indicates that the bivariate probit model

has a significant correlation coefficient between the bivariate outcomes.

Table 2.d. Results from maximum likelihood estimation of bivariate probit models.

Dependent variables	**Awareness of RTAs**	**Knowledge of traffic rules**
Explanatory Variable	**Coefficient**	**Coefficient**
Age	-0.439 [0.314]	-0.626 [0.360] *
Income	-0.289 [0.198]	-0.324 [0.216
Previous experiences of RTAs	0 .485 [0.155] ***	0.288 [0.139] **
Gender	0.832 [0.347] **	0.355 [0.483]
Previous training experience	0.951 [0.232] ***	0.689 [0.269] **
Lower skilled job	0.416 [0.405]	0.419 [0.459]
Higher skilled job	-0.193 [0.355]	1.061 [0.412] **
Media exposure	0.989 [0.239] ***	2.184 [0.320] ***
Marital status	0.293 [0.319]	0.1686 [0.392]
Degree	0.911 [0.302] ***	0.634 [0.319] **
Urban residence	-0.016 [0.229]	0.563 [0.259] **
_cons	2.101 [1.966]	2.780 [2.25]
athrho = 1.417***		**rho = 0.889**
LR test of rho=0: chi2 (1) = 35.03		Prob > chi2 = 0.00

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

2.7.2 Marginal effects for the Bivariate probit Model

The estimated marginal effects from the bivariate probit model are shown in Table 2.e pmarg1 and pmarg2 are the average marginal probabilities for awareness of RTAs and knowledge of traffic rules. The conditional marginal probabilities are pcond1, which represents the marginal probability of awareness of RTAs, giving the condition that individuals know traffic rules, and pcond2, which represents the marginal probability of knowledge of traffic rules, giving the condition that an individual is aware of RTAs. According to the average marginal probabilities, a male is 30.1% more likely to be aware of RTAs than females. Individuals with previous

training experience, individuals with access to media, and individuals with higher education were 34.4%, 35.8%, and 32.9%, respectively, more likely to be aware of RTAs than individuals with no training experience, no access to media, and higher education. For each additional

Table 2.e. Marginal effects for the average and conditional probabilities of Awareness of RTAs and Knowledge of traffic rules.

	Pmarg1	**Pmarg2**	**Pcond1**	**Pcond2**
Age	-0.159 [0.11]	-0.225 [0.13] *	-0.010 [0.09]	-0.095 [0.09]
Income	-0.105 [0.07]	-0.117 [0.08]	-0.023 [0.06]	-0.038 [0.05]
Previous RTAs experiences	0.175 [0.06] ***	0.104 [0.05] **	0.089 [0.04] **	-0.009 [0.04]
Male	0.301 [0.13] **	0.128 [0.18]	0.179 [0.12]	-0.054 [0.13]
Previous training experience	0.344 [0.07] ***	0.248 [0.10] **	0.150 [0.08] **	0.018 [0.08]
Lower skilled job	0.150 [0.15]	0.151 [0.17]	0.041 [0.11]	0.041 [0.11]
Higher skilled job	-0.069 [0.13]	0.381 [0.15] **	-0.263 [0.11] **	0.337 [0.12] ***
Media exposure	0.358 [0.09] ***	0.785 [0.10] ***	-0.128 [0.10]	0.435 [0.11] ***
Marital status	0.106 [0.12]	0.061 [0.14]	0.055 [0.09]	-0.007 [0.10]
Degree	0.329 [0.11] ***	0.228 [0.12] **	0.149 [0.08] *	0.010 [0.08]
Urban residence	-0.005 [0.08]	0.202 [0.10] **	-0.113 [0.06] *	0.163 [0.08] **

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

experience of a previous road accident, individuals are 17.5% more likely to be aware of RTAs. The average marginal effect of knowledge of traffic rules is slightly different from the average marginal effect of awareness of RTAs. Individuals with training experience, access to media, higher education, high-skilled jobs, and residence in urban areas are 24.8%, 78.5%, 22.8%, 38.1%, and 20.2%, respectively, are more likely to have knowledge of traffic rules than individuals with no training experience, no access to media, no higher education, low-skilled jobs, and residence in a rural area. For each additional experience of a previous road accident,

an individual is 10.4% more likely to know traffic rules. Therefore, the average marginal effects from the bivariate probit model and standard probit models show robust similarities.

On the other hand, the marginal effect for conditional probabilities shows quite different and interesting results. The results from pcond1 confirm that previous experiences of RTAs, previous training experience, and higher education increase the awareness of RTAs when the knowledge of traffic rules is already present. High-skilled jobs and residences in urban areas decrease awareness of RTAs when knowledge of traffic rules is already present. Media exposure and being a male have large marginal effects (pmarg1) on the individual's awareness level for RTAs. However, when considering the conditional probability (pcond1), these marginal effects become non-significant when the knowledge of traffic rules is already present. The results from pcond2 show that previous experiences of RTAs, previous training experience, higher education, and being a male no longer significantly affect or increase traffic rules knowledge when individuals' awareness of RTAs is already present. High-skilled jobs, residence in urban areas, and access to media increase the knowledge of traffic rules even when individuals are already aware of the RTAs.

2.7.3 Discussion

The connections between social, demographic, and economic factors and RTAs have been the subject of a great deal of attention in recent years (Kayani, King & Fleiter, 2011; Osayomi, 2013; Kumar & Srinivasan, 2013; Wiebe *et al*., 2016; Ahmad *et al*., 2018; Abegaz & Gebremedhin, 2019). RTAs exposure were significantly associated with economically productive and young-aged people. In this study, we find that the most productive age groups most affected by RTAs are also those who are most active in the job market, and road accidents caused an apparent clear loss of productivity. Similar results were also found in prior studies conducted in Bangladesh and other DCs such as Ghana, Egypt, Bhutan, Afghanistan, Zambia, Nepal, Tanzania, Kenya, Nigeria, Malaysia, Yemen, Pakistan, and more (Adhikari, 2016;

Alfalahi *et al*., 2018; Bachani *et al*., 2012; Biemba *et al*., 2015; Coleman, 2014; Fouda *et al*., 2017; Goswami *et al*., 2018; Grimm & Treibich, 2010; Huang *et al*., 2016; Karim *et al*., 2011; Karkee & Lee, 2016; Mashreky *et al*., 2010; Saeed *et al*., 2016; Wang *et al*., 2018; Zimmerman *et al*., 2015).

In Bangladesh, inequality between males and females is extremely high in social and economic terms (Baset *et al*., 2017; Mahmud *et al*., 2019). The current findings highlighted that male are more conscious about RTAs than female. One of the main reason is females are usually in more subordinated positions than males because of society's patriarchal norms (Mahmud *et al*., 2019). In particular, rural women still have a lack of mobility, and their economic activities are often confined to household chores, while men have broader roles (Baset *et al*., 2017; Mahmud *et al*., 2014; Mahmud *et al*., 2019), and in most cases, men have the authority to take care of their family. For this reason, males travel more frequently than females and get more aware about RTAs. This result is consistent with the first hypothesis. Similar findings are also highlighted by Kumar and Srinivasan (2013), Tulu *et al*. (2017), and Abegaz and Gebremedhin (2019), who showed that men in Nepal and Ethiopia had more travel on the road because of their higher participation in work, business, or studies, while women were often restrained to their houses and were responsible for taking care of household chores.

As mentioned earlier, the impact of formal education on various aspects of people's daily lives can never be ignored (Hilton *et al*., 2016; Kabir *et al*., 2018; Mahmud *et al*., 2014; Mahmud *et al*., 2017). This study's empirical results are consistent with the second hypothesis. The results demonstrate that higher education had a positive link with the increase in knowledge of traffic rules and awareness of RTAs, which are critical factors for reducing RTAs. This result is also consistent with previous studies in the context of both developed and DCs (Akalanka *et al*., 2012; Degais *et al*., 2018; Jeepura & Pirasath, 2012; Baset *et al*., 2017; Mashreky *et al*., 2010;

Sharma, 2008; Seid *et al*., 2015; Tulu *et al*., 2017; Yongchaitrakul, Juntakarn & Prasartritha, 2012).

Previous training on traffic rules and the availability of media access also increase the chance of reducing RTAs by increasing awareness and knowledge of traffic rules (Abegaz *et al*., 2014). Undoubtedly, a trained person is more aware of risks and takes more judicious decisions (Hilton *et al*., 2016). Training helps novice drivers decrease their risk-taking attitude while driving as well as increases their understanding of the risks of dangerous behaviour (McKenna *et al*., 2006; Nadesan-Reddy & Knight, 2013;). Similarly, media (radio, television, newspaper, internet services, etc.) encourages individuals to know about road traffic systems' rules and regulations and raises awareness about road accidents (Blantari *et al*., 2005; Salvarani, Colli, & Júnior, 2009). The present study also highlights this finding by showing that training experience and media access have a robust association with the awareness of road accidents and knowledge of traffic rules, consistent with the second hypothesis. A similar finding was also reported in a study on traffic accident prevention programmes conducted in Brazil (Salvarani *et al*., 2009).

People's place of residence and employment status can also affect their level of awareness and knowledge of traffic rules. Raina *et al*. (2016) indicated that rural people were behind urban people in RTAs knowledge. Consequently, it was reported that in Ethiopia and some other DCs, more than two-thirds of all traffic accidents involved rural residents who were unskilled and unemployed or involved in informal economic activities (Abegaz & Gebremedhin, 2019; Jeepura & Pirasath, 2012; Kumar & Srinivasan, 2013; Shrestha *et al*., 2017; Zwerling *et al*., 2005). The current study finds that people living in urban areas and people with a highly skilled job or business have a higher chance of knowing about traffic rules and regulations compared to people who live in villages or are unemployed. This result also confirms the hypothesis proposed in this study.

Moreover, involvement in a past road accident makes people more concerned about taking extra care of themselves during their travel. The current study shows that previous experience of road accidents has a positive association with a person's level of awareness of RTAs and knowledge of traffic rules, which confirms the third hypothesis. A previous study by Watts and Quimby (1979) also had similar findings indicating that there was a strong correlation between past accident experience and an increase in awareness level. They demonstrated that drivers with previous road accident records had fewer accident records afterward.

Finally, from the empirical results, it is worthwhile to mention that a high level of education increases the chance of a person being aware of RTAs and having knowledge of traffic rules. Moreover, the estimated effect of access to media and previous training programmes on road traffic systems also increases the chance of being aware of RTAs and acquiring knowledge of traffic rules.

2.8. Conclusions and future research directions

Road accident-related injuries and fatalities are exceptionally high in Bangladesh and disproportionally affect the economically productive segment of the population. The Government of Bangladesh and the governments of other developing countries should consider RTAs as a threat to their populations. However, by improving people's relevant social, demographic, and economic factors, the number of road accidents can be reduced. This paper shows that gender, road accident experience, availability of media connections, educational qualifications, job characteristics, place of residence, and past training about road traffic rules can improve an individual's awareness level of traffic accidents and knowledge of traffic rules. The Government of Bangladesh needs to increase the number of specific training courses on road traffic rules for all citizens and encourage the media to increase coverage about road traffic systems.

Therefore, necessary steps should be taken by policy makers to provide training to people about RTAs. It is essential for to provide hands-on training, conducted by experienced trainers, for long durations. Training manuals about RTAs should be updated and provided to trainees at a low cost or for free. Necessary training allowances should be given so that people are encouraged to participate in future training programmes. Essential steps should be taken to conduct mass media campaigns to build awareness of the prevalence and dangers of RTAs. Government and non-government organisations (NGOs) should provide necessary support to produce high-quality public service announcements, documentaries, dramas, etc. on RTAs.

Governments or policy makers should take initiatives to include introductory courses related to road traffic systems in the education curriculum, so people gain knowledge regarding traffic rules early and be aware of RTAs. Moreover, government should focus on developing infrastructure that meets international standards by building effective partnerships among different stakeholders (government agencies, NGOs, and donor agencies).

The main implication of this study is that these results provide new empirical evidence to support government and NGOs' policies to reduce RTA-related injuries and fatalities by strengthening factors that drive people to be aware of RTAs and increase their knowledge of traffic rules. Conversely, the following limitations should be considered while interpreting the findings of the study. First, this study considers only some specific public and private hospitals in Khulna city. Second, since the sample is limited to only 200 respondents involved in RTAs, the findings may not be generalised to all road traffic victims. Further research is required to extend the data collection to all the hospitals in Khulna city and other cities in Bangladesh to increase the sample size and assess this paper's result's external validity.

Chapter 3

Factors Associated with Crash Severity on Bangladesh Roadways: Empirical Evidence from Dhaka City

3.1. Introduction

In most developing countries, road traffic accidents (RTAs) are a common and complicated phenomenon (World Health Organization, 2013, 2015, 2018). The World Health Organization's (WHO) 2008 to 2016 data estimates that of the total number of people who died from RTAs, around 93% lived in low-and middle-income countries (Wambulwa, Job, & Turner, 2020; World Health Organization, 2020). Although many governments of these developing countries usually claim that RTA rates have decreased because of their efforts, in reality, RTA occurrences have increased over time (Gebru, 2017). According to some studies, road accidents not only damage human lives, but also have negative impacts on a country's social and economic activities (Rifaat *et al*., 2014; Kazmi & Zubair, 2014; Raina *et al*., 2016; Yasmin & Eluru, 2013; Gebru, 2017; Wang *et al*., 2018).

In Bangladesh, the movement of people and goods mainly relies on road transport systems, due to the scarcity of rail and other mass public transport structures. Although roadways are the main way to transport people and goods, they commonly create severe RTA threats for many vulnerable people (Barua & Tay, 2010; Kamruzzaman, Haque, & Washington, 2014). In Bangladesh, where the situation has rapidly deteriorated over the years, RTAs are a source of growing concern, as they have become one of the major causes of severe injury and violent death, due to unaware drivers, passengers, and pedestrians; poor traffic management and road conditions, as well as dangerous road infrastructures (Kamruzzaman *et al*., 2013; Kamruzzaman, Haque, & Washington, 2014; Rifaat *et al*., 2014; Baset *et al*., 2017; Chowdhury, 2018). According to Baset *et al.* (2017), RTA related mortality rates are

6.8/100,000 population per year, which amounts to more than 12,000 people in an overall population. Specifically, the WHO (2015) estimated that 21,316 people died from road accidents in Bangladesh in 2012. In the same year, the estimated economic cost of RTAs was approximately 2% to 3% of Bangladesh's total GDP (Kamruzzaman *et al*., 2013; Kamruzzaman, Haque, & Washington, 2014).

In Dhaka city, the impact of RTAs is extremely significant, as people frequently travel in this area for more job and business opportunities (Ahmed & Ahmed, 2012). The Bangladesh Accident Research Institute revealed that the Dhaka metropolitan areas have double the deaths compared to other major cities, due to population and vehicle overcrowding (Ahmed, Ahmed, & Hainin, 2013, 2014; Chowdhury, 2018). As a result, these areas have experienced an alarming rise in RTAs and severe injuries. Therefore, to find ways to prevent these problems, it is necessary to identify the important factors that are significantly associated with road accidents and severe injuries. Despite the recent growth of RTAs, Bangladesh has not yet to carry out any significant steps to collect road accident data, nor enough comprehensive road safety policies for preventing this problem have been implemented in the country (Kamruzzaman *et al*., 2013; Kamruzzaman, Haque, & Washington, 2014; Rifaat *et al*., 2014; Baset *et al*., 2017; Chowdhury, 2018). Therefore, to help design and implement relevant prevention policies in Bangladesh and possibly in other countries, this study's main objective is to analyse the major risk factors related to RTAs and their severity. The findings of this study will help to design and implement the policies related to preventing RTAs and severe injuries in Bangladesh and elsewhere. This paper is organised as follows: section 2 reviews the previous research and drown current research direction; section 3 explains data collection and methodology; sections 4 and 5 discuss the descriptive statistics and show main results of the estimated models; section 6 discusses further the results and finally, section 7 concludes with the policy implications and limitations of the paper.

3.2. Literature review

Many factors contribute to the frequency and severity of motor vehicle collisions in developing countries. For example, La *et al*. (2013) found that in Vietnam, driver age, type of driving license, employment status, adequate income, seat belt usage, and traffic violation history were the major causes of severe accidents and injuries. Another study conducted in Vietnam showed that low education levels, marital status, high daily travel distances, regular smoking, and using a mobile phone while driving were the most important factors relate with RTAs (Nguyen-Phuoc *et al*., 2019). In India, Balasubramanian and Sivasankaran (2019) determined that being male, driving without a legal license, the presence of central dividers, uncontrolled junction roads, and single-lane roads significantly influenced accident severity. Quddus, Noland, and Chin (2002) showed similar results regarding the effect of traffic and road characteristics on road safety.

Analysing motorcycle crash data within Rawalpindi city, Pakistan, Waseem, Ahmed, and Saeed (2019) revealed that the probability of fatal/severe injuries was significantly associated with the following factors: 25–50 year age groups, lack of education, high-speed roads, undivided streets, unregistered motorcycles, heavy vehicle involvement, and fixed objects, such as utility poles, trees, and steep slopes. Shrestha *et al*. (2017) found similar results in Nepal. In Malaysia, Anarkooli, Hosseinpour, and Kardar (2017) discovered that poor visibility, rainy weather conditions, the involvement of a heavy vehicle, improper overtaking, vehicle age, traffic volume and composition, number of travel lanes, speed limit, undulating terrain, presence of central median, and unsafe roadside conditions are significantly associated with injury severity. Similarly, Yau (2004) and Chiou *et al*. (2013) found poor visibility to be one of the major causes of severe road accidents in Hong Kong, and Taiwan respectively.

Several researchers have conducted related studies in Ethiopia, revealing that location, time of collision (day and night), driving above the speed limit, careless driving, type of vehicle, not

giving priority to other vehicles, pedestrians, and pedestrian errors were significantly associated with RTA fatality rates (Asefa, Assefa, & Tesfaye, 2014; Mekonnen, 2018). In Brazil, Almeida *et al*. (2013) analysed the main victim, road, and vehicle characteristics, as well as the risk factors, and found that driving without a license, collisions with pedestrians, fixed obstacles, and motorcyclists; presence of unskilled drivers, being male, traffic on roads under federal jurisdiction, and early morning hours were the most frequently responsible factors for accidents and severe injuries. Accordingly, Chang and Yeh (2007), and Chiou *et al*. (2013) found similar results in Taiwan. In China, Zhang, Yau, and Chen (2013) revealed that traffic violations were a major threat to road safety, and that young, unmarried and novice drivers, street light conditions, weather conditions, and visibility levels were significant factors associated with road accident severity. Moreover, study conducted in South Nigeria, Uganda and Sri-Lanka also demonstrated that married person is more concerned about traffic rules and accidents than an unmarried person (Ipingbemi, 2008; Akalanka *et al*., 2012; Pebalo *et al*., 2012).

We can generalise the similar results found in the United States, Australia, Canada, Spain, Italy**,** Saudi Arabia, Israel, and Singapore to developing countries, because the problems are quite similar. Studies on these countries have revealed the following factors as having a significant influence on high severity accidents: driver's age (65 and above), intoxicated driving, not wearing seat belts, driving in high-speed zones, lack of pedestrian control, non-paved road conditions, driver aggression, roadside (fixed) objects (e.g. trees, guard rail, lamp posts, etc.), misleading traffic signs, parked vehicles that are not following parking rules, four-way intersections, and night time driving in areas without proper lighting (Eluru & Bhat, 2007; Rifaat & Chin, 2007; Rifaat, Tay, & de Barros, 2011; Shinar & Gurion, 2019; Yasmin & Eluru, 2013; Abdel-Aty & Keller, 2005; Potoglou *et al*., 2018; Altwaijri, Quddus, & Bristow, 2012; Lardelli-Claret *et al*., 2005; Russo *et al*., 2014; Anarkooli *et al*., 2019).

Despite the extensive amount of research being done on the topic, few studies have been conducted in Bangladesh to examine the factors affecting RTA severity. Most studies have focused on severe accidents within different age groups, bus crashes, the relationship between rural road infrastructures and accidents, fatal accident risk factors within different areas, and factors influencing pedestrian-vehicle crash severity (Kamruzzaman *et al*., 2013; Kamruzzaman, Haque, & Washington, 2014; Rifaat *et al*., 2014; Baset *et al*., 2017; Chowdhury, 2018; Zafri *et al*., 2020). The present research differs significantly from other studies on RTAs in Bangladesh, as we focused on all types of severe accidents and included all vehicle types (buses, trucks, motorcycles, bicycles, and three-wheeled vehicles). Our study also examined the severity of RTAs irrespective of gender, religion, location, and age groups. Moreover, previous studies relied on police report data, which in most cases, were incomplete and inaccurate, because there was insufficient information on individuals' knowledge of safety practices, and the respondents were not always the victims or eyewitnesses involved in the accidents. To fill these gaps, we directly collected the data from accident victims and eyewitnesses, and examined their safety knowledge. Furthermore, the current study estimates the Heckman selection probit model for correction of sample selection bias to provide consistent and asymptotically efficient estimates for all the parameters in the model. This has not been done/addressed in previous studies in Bangladesh and elsewhere and fails to tackle this issue of selectivity vias in their estimations. Hence, we believe that the current finding will add a new dimension in the reduction of RTAs.

3.3. Data collection

We restricted the population to people currently living in Dhaka City, Bangladesh, because of this region's comparatively high accident rates (Ahmed, Ahmed, & Hainin, 2013). We administered the survey in several universities (Southeast University, Independent University, South Asia University, Asian University, and Northern University) located in different Dhaka

areas (Khilkhet, Rupganj, Uttara, Rampura, Kaliganj, and Tongi), some major hospitals (Dhaka Medical College Hospital, Dhaka Pongu Hospital, and Ashiyan Medical College Hospital), and some local private medical clinics and pharmacies.

We surveyed a sample of 786 individuals, who agreed to participate before we sent the questionnaires or scheduled face-to-face interviews. Although this sample is not representative of the country's overall population, it can be considered a representation of Dhaka city, which mostly consists of young, educated, and economically active individuals. We only asked the individuals who had been directly involved in road accidents in the last two years (n=525) to answer the full questionnaire, which collected information on personal characteristics and main RTA experience (e.g. injury level, accident location, type of vehicles, etc.). The remaining 261 individuals, without direct involvement in road accidents, completed a shorter questionnaire, which collected a set of individual characteristics. If required, we clarified the questions during the interviews and for hospital victims, we only interviewed those with normal conditions who were able to comfortably respond.

3.4. Methodology

Among the numerous regression models that can be used to estimate the factors related to accident severity levels, previous studies have widely used binary or ordered logit and probit models (Eluru & Bhat, 2007; Chiou *et al*., 2013; La *et al*., 2013; Abegaz *et al*., 2014; Hosseinpour, Yahaya, & Sadullah, 2014; Kamruzzaman, Haque, & Washington, 2014; Anarkooli, Hosseinpour, & Kardar, 2017; Ahmad *et al*., 2019; Waseem, Ahmed, & Saeed, 2019). Thus, we used a probit model to estimate injury severity levels for those 525 individuals who declared that they were directly involved in road accidents. We conducted the analysis using STATA-64 software. As a robustness check, we used a set of Heckman (1979) selection probit model for the entire sample of 786 individuals to distinguish the factors affecting RTA probability from those affecting injury severities. This model is estimated using maximum

likelihood methods with corrections for sample selection bias, in order to provide consistent and asymptotically efficient estimates for all parameters. The dependent variable of the selection equation (estimated for the entire sample) is a dummy variable coded as 1 if the respondent had a direct experience with at least one RTA in the last two years and 0 otherwise. Similarly, for the sample of 525 individuals who directly experience an RTA, the dependent variable in the probit model (*y*) is a dummy variable that we coded as 1 if the victim suffered long-term injuries (LTI) or permanent injuries (PI) and 0 if the victim suffered short-term or minor injuries. X represents the independent variables. β refers to the parameters to be estimated and ε is the error term:

$$y = \beta X_i + \varepsilon$$

In this model, the vector of independent variables within X includes the following factors: victim age (Logarithm of years), victim gender (Dummy: Male = 1, Female = 0), victim's marital status (Dummy: Married = 1, Not married = 0), victim's residence (Dummy: Rural = 1, Urban = 0), victim's educational background (Dummy: No degree or less than 13 years of schooling = 1, otherwise = 0), victim's monthly family income (Logarithm of income in Taka, Bangladesh currency), employment status in the business, service, or farming sectors (Dummy: yes = 1, otherwise = 0), accident occurring in highway areas (Dummy: yes = 1, otherwise = 0), accident occurring in city areas (Dummy: yes = 1, otherwise = 0), accident involving four-wheeled vehicles, such as a truck, bus, car, or four-wheeled van (Dummy: yes = 1, two or three-wheeled vehicles = 0), presence of on-site police officer manually controlled traffic system (dummy: yes = 1, no = 0), lack of speed control signs (Dummy: yes = 1, no = 0), poor street lighting (Dummy: yes = 1, no = 0), lack of road dividers (Dummy: yes = 1, no = 0), unplanned intersection (Dummy: yes = 1, no = 0), lack of parking rules or nearby dedicated parking spaces (Dummy: yes = 1, no = 0), competition among drivers (Dummy: yes = 1, no = 0), driving the wrong way (Dummy: yes = 1, no = 0), victim's unawareness of RTA risks (Dummy: yes = 1,

no = 0), and victim's lack of road traffic rules and regulations training (Dummy: yes =1, no = 0).

The structure of the Heckman probit selection model can be written as follows. The probit selection equation has the following specifications:

$$y_{1i} = f(x_i\beta + u_1 > 0)$$

The second outcome equation, observed only when $y_{1i}=1$, can be written as

$$y_{2i} = f(z_i\gamma + u_2 > 0)$$

with the following distributions of the error terms,

$$u_1 \sim N(0,1)$$

$$u_2 \sim N(0,1)$$

$$corr(u_1, u_2) = \rho$$

In the selection equation, x_i denotes the vector of observable independent variables of the selection equation, explaining the probability of being involved in RTAs. β refers to the parameters to be estimated and u_1 is a normally distributed error term with a mean of 0. In the outcome equation, z_i is the vector of the observable regressors, including the same variables x_i, which explain the likelihood of having suffered from LTI or PI and are conditional upon being involved in at least one RTA. Furthermore, γ represents the vectors of the parameters to be estimated, and u_2 is a normally distributed error term with a mean of 0 and a standard deviation equal to 1. The parameter ρ represents the correlation between the two error terms. Specifically, if $\rho = 0$, there is no sample selection and the likelihood functions of the two probit models for the outcome and the selection equations are independent.

3.5. Results

3.5.1 Victim demographics, socioeconomic characteristics, and other factors related to RTAs

Table 3.a presents the descriptive statistics of the variables involved in the probit model estimation, specifically with regards to the 525 respondents, who were directly involved in RTAs in the last two years. Almost half of the victims had LTI or PI and the majority were predominantly in the working age group. Specifically, the largest group affected by RTAs was aged between 15 and 45 years (representing 96.57% of the total sample). Among the remaining victims, only 0.57% were aged 14 years or younger and the remaining 2.86% were more than 45 years old. The victims' average family earnings per month was 74,655.24 Taka. The highest percentage of accidents occurred in highway areas (45.1%), followed by city areas (34.5%) and rural areas (20.4%). The main vehicles involved in road accidents were four-wheeled (e.g. cars, buses, minibuses, and trucks) (56.2%), and the other relevant variables associated with severe road accidents as well as their occurrence percentages are listed in the table.

Table 3.a. Descriptive statistics.

Variables	Mean	Std. Dev.	Min	Max
LTI/PI	0.497	0.500	0	1
Victim's age (log)	3.156	0.214	2.40	4.17
Victim's gender (male)	0.798	0.401	0	1
Victim's marital status (married)	0.186	0.390	0	1
Victim's residence in a rural area	0.32	0.466	0	1
Victim's residence in an urban area	0.68	0.466	0	1
Lack of educational degrees	0.181	0.385	0	1
Income of the victim's family (log)	10.87	0.785	8.01	13.82
Employed	0.228	0.420	0	1
Unemployed	0.772	0.420	0	1
Accident occurred in a rural area	0.204	0.403	0	1
Accident occurred on a highway	0.451	0.498	0	1
Accident occurred in a city area	0.345	0.476	0	1
Accident occurred with four-wheeled vehicle	0.562	0.497	0	1

Accident occurred with other vehicle	0.438	0.497	0	1
Manual traffic control system	0.638	0.481	0	1
No speed control signs	0.392	0.488	0	1
Not enough street lights	0.567	0.495	0	1
No divider to separate the road	0.605	0.489	0	1
Unplanned intersection	0.609	0.488	0	1
No parking rules	0.348	0.476	0	1
Competition among drivers	0.647	0.478	0	1
Driving the wrong way	0.539	0.498	0	1
Victim unaware of the road accident risk	0.354	0.478	0	1
Victim did not receive training	0.699	0.459	0	1

3.5.2 The probit regression analysis

As shown in Table 3.b, the probit model revealed that the probability of suffering LTI or PI from RTAs was positively and significantly associated with being married, city or highway locations, four-wheeled vehicles, lack of speed control signs, poor street lighting, and driving the wrong way. The other variables were insignificant. In general, the model fits the data quite well, with an overall accuracy of 65.33%. We also checked for possible high correlation problems among the independent variables in the model and detected no multicollinearity issues.

Table 3.b. Maximum likelihood estimation of the probit model.

Dependent and explanatory variables	**LTI/PI** **Coefficient [standard error]**
Victim’s age (log)	0.068 [0.344]
Victim’s gender (male)	-0.164 [0.148]
Victim’s marital status (married)	0.327 [0.192] *
Victim’s residence in a rural area	-0.078 [0.133]
Lack of educational degree	0.214 [0.171]
Income of the victim’s family (log)	0.001 [0.079]

Unemployed	0.026 [0.165]
Accident occurred on a highway	0.565 [0.173] ***
Accident occurred in a city area	0.314 [0.168] *
Accident occurred with four-wheeled vehicle	0.232 [0.121] *
Manual traffic control system	0.012 [0.121]
No speed control signs	0.204 [0.125] *
Not enough street lights	0.287 [0.118] **
No divider to separate the road	-0.030 [0.119]
Unplanned intersection	0.145 [0.122]
No parking rules	0.138 [0.128]
Competition among drivers	0.154 [0.127]
Driving the wrong way	0.260 [0.121] **
Victim unaware of the road accident risk	0.076 [0.119]
Victim did not receive training	-0.037 [0.126]
Constant	-1.259 [1.440]
Model parameters	
LR chi2(11)	50.53
Prob > chi2	0.002
Pseudo R2	0.069

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

The estimated marginal effects in Table 3.c show that married victims are 12% more likely to face LTI or PI than unmarried victims, and the associated variables were city areas, highways, lack of speed control signs, and poor street lighting. Accidents involving four-wheeled vehicles and wrong-way driving are more likely to cause LTI or PI than other types of vehicles and non-frontal crashes. Considering the marginal effects of other variables, we noticed that the highest LTI and PI risks were associated with accidents occurring on highways, on roads with insufficient street lights, and when driving the wrong way.

Table 3.c. Marginal effect results of LTI.

Explanatory variables	dy/dx
Victim's age (log)	0.025 [0.127]
Victim's gender (male)	-0.060 [0.054]
Victim's marital status (married)	0.120 [0.070] *
Victim's residence in a rural area	-0.029 [0.049]
Lack of educational degree	0.079 [0.063]
Income of the victim's family (log)	0.001 [0.029]
Unemployed	0.009 [0.061]
Accident occurred on a highway	0.209 [0.062] ***
Accident occurred in a city area	0.116 [0.061] *
Accident occurred with four-wheeled vehicle	0.085 [0.044] *
Manual traffic control system	0.004 [0.044]
No speed control signs	0.075 [0.046] *
Not enough street lights	0.106 [0.043] **
No divider to separate the road	-0.011 [0.044]
Unplanned intersection	0.053 [0.045]
No parking rules	0.051 [0.047]
Competition among drivers	0.057 [0.046]
Driving the wrong way	0.096 [0.044] **
Victim unaware of the road accident risk	0.028 [0.044]
Victim did not receive training	-0.014 [0.046]

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

3.5.3 The Heckman selection probit model

Table 3.d reports the Heckman probit regression results, for the outcome (y_{2i}) and then the selection (y_{1i}) equations, which show that the outcome equation's results are relatively consistent with the probit model, except for three variables. On the one hand, accidents that occurred in city areas and on streets with no speed control signs were not significantly associated with LTI or PI in the Heckman probit model's outcome equation, but they were

significant in the probit model. On the other hand, victims with educational degrees were significantly associated with LTI or PI in the outcome equation, but not in the probit model. The estimated results from the selection equation (y_{1i}) suggest that the occurrence of RTAs has a positive and highly significant association with residing in rural area, family income, and being unaware of RTA risks. Regarding other variables, respondents' age, marital status, lack of educational degree, and lack of training have a negative and significant association with RTAs, while the rest of the other variables are not statistically significant. In general, the model fits the data quite well, with a positive and significant rho statistic, and a p-value of 0.001, which measures the correlation between the residuals from the two models, the outcome and selection equations.

Table 3.d. Maximum likelihood estimation of the Heckman probit model.

Outcome equation. Dependent variable: (y_{2i})	**LTI/PI**
Explanatory variables	**Coefficient [standard error]**
Victim's age (log)	0.206 [0.317]
Victim's gender (male)	-0.088 [0.147]
Victim's marital status (married)	0.451 [0.182] **
Victim's residence in a rural area	-0.186 [0.137]
Lack of educational degree	0.286 [0.155] *
Income of the victim's family (log)	-0.109 [0.095]
Unemployed	0.087 [0.157]
Accident occurred on a highway	0.471 [0.184] **
Accident occurred in a city area	0.250 [0.165]
Accident occurred with four-wheeled vehicle	0.216 [0.109] **
Manual traffic control system	0.018 [0.107]
No speed control signs	0.177 [0.114]
Not enough street lights	0.266 [0.108] **
No divider to separate the road	-0.023 [0.105]
Unplanned intersection	0.132 [0.109]

No parking rules	0.136 [0.113]
Competition among drivers	0.122 [0.118]
Driving the wrong way	0.218 [0.119] *
Victim unaware of the road accident risk	-0.119 [0.157]
Victim did not receive training	0.046 [0.126]
constant	-0.144 [1.472]
Selection equation. Dependent variable: (y_{1i})	**Being involved in RTAs**
Explanatory variables	**Coefficient [standard error]**
Respondent's age (log)	-0.448 [0.239] *
Respondent's gender (male)	-0.180 [0.131]
Respondent's marital status (married)	-0.457 [0.153] ***
Respondent's residence in a rural area	0.346 [0.113] ***
Lack of educational degree	-0.259 [0.125] **
Income of the respondent's family (log)	0.380 [0.070] ***
Unemployed	-0.155 [0.140]
Respondent unaware of the road accident risk	0.629 [0.115] ***
Respondent did not receive training	-0.277 [0.118] **
constant	-1.810 [1.062]
Goodness-of-fit assessment	
rho	0.359
Wald Chi-square	65.74
Prob > chi2	0.000

Note: * = significant at the 10% level; ** = significant at the 5% level; *** = significant at the 1% level.

3.6. Discussion

3.6.1 Factors related to RTAs

In recent years, scholars have been consistently interested in the factors related to RTAs and their severity levels (Kayani, King, & Fleiter, 2011; Osayomi, 2013; Kumar & Srinivasan, 2013; Wiebe *et al*., 2016; Ahmad *et al*., 2018; Abegaz & Gebremedhin, 2019). In our study, we found that the most at-risk individuals were those who were married, in younger age groups,

and unaware of the RTA likelihoods. Individuals residing in rural areas and with high family incomes also had a higher risk of being victims of RTAs. The importance of the other variables in the model remained quite low, as they did not play a significant role in predicting the target variable. Previous studies conducted in other developing countries have also highlighted the aforementioned significant factors and stressed the necessity to consider these variables when establishing policies to prevent RTAs (Lin & Kraus, 2009; Wanvik, 2009; Yannis *et al*., 2010; La *et al*., 2013; Abegaz *et al*., 2014; Gicque *et al*., 2017; Pirdavani *et al*., 2017; Zhang *et al*., 2019; Shinar & Gurion, 2019; Nguyen-Phuoc *et al*., 2019).

3.6.2 Factors related to injury severity

According to the probit and Heckman selection probit models (Tables 3.b and 3.d), RTA related LTI and PI have a positive and highly significant relationship with some socio-demographic factors, road characteristics or infrastructures, accident location, type of vehicles, reckless driving, and riding behaviours.

3.6.2.1 Socio-economic factors

Marital status is one of the most important factors having a significant correlation with LTI severity (Factor, Mahalel, & Yair, 2008; Ipingbemi, 2008; Brody *et al*., 2010; Zhang, Yau, & Chen, 2013; Raina *et al*., 2016; Irianti & Prasetyoputra, 2017; Nguyen-Phuoc *et al*., 2020). Generally, the risk of being a victim of RTAs increases with unmarried people, because it is assumed that married persons are more aware and less likely to engage in risk-taking behaviours (Raina *et al*., 2016). However, the probit model and outcome equation results estimated that the risk of LTI and PI increases with married individuals. We expected this result for a few reasons: (1) the majority of LTI and PI occurred on highways, (2) Dhaka city is surrounded by highways, and (3) a large number of married people use highways to commute to their jobs or businesses, because they mostly live in remote rural areas where houses are less expensive. In the majority of cases, married persons have to work more than other members in

Bangladesh and are responsible for almost all economic and social activities. As a result, these individuals may face family problems, including external challenges (quarrelling with other family members, dealing with financial problems, and bearing social stress), which can increase their emotional stress and lead to a lack of attention while driving, crossing, or walking on the street. Ultimately, this may result in more severe RTA caused LTI or PI and an increase in the associated social costs, when these victims are the only sources of income for their families. The current findings are consistent with those of previous studies conducted in other developing countries (da Silva-Júnior *et al*., 2009; Kumar & Srinivasan, 2013; La *et al*., 2013; Alavi *et al*., 2017; Woldu, Desta, & Woldearegay, 2020).

Regarding other social and economic aspects, we must consider the impact of education, as previous studies have suggested that educated people are more concerned with and involved in every aspect of living (Hilton *et al*., 2016; Mahmud *et al*., 2017). The results from the Heckman probit selection equation revealed that a lack of education has a positive association with severe crashes, as is consistent with previous studies in the context of both developed and developing countries (Factor, Mahalel, & Yair, 2008; da Silva-Júnior *et al*., 2009; Kumar & Srinivasan, 2013; Mehmandar *et al*., 2014; Alavi *et al*., 2017; Shrestha *et al*., 2017; Mekonnen, 2018; Waseem, Ahmed, & Saeed, 2019; Nguyen-Phuoc *et al*., 2019).

3.6.2.2 Road characteristics or infrastructures

We found that a lack of speed control signs or intersection indications increased the risk of RTAs and severe injuries, which have been significantly investigated in several studies (Chang & Wang, 2006; Haque, Chin, & Huang, 2010; Chen, Cao, & Logan, 2012; Chiou *et al*., 2013; Hosseinpour, Yahaya, & Sadullah, 2014; Haleem & Abdel-Aty, 2010; Sarkar, Tay, & Hunt, 2011; Kamruzzaman *et al*., 2013; Kumar & Toshniwal, 2016; Anarkooli, Hosseinpour, & Kardar, 2017; Balasubramanian & Sivasankaran, 2019; Yasmin & Eluru, 2013). We expected this result, because the presence of speed control signs or intersection indications is quite rare

in Bangladesh. For this reason, it may be difficult for drivers to instantaneously slow down or take control of their vehicles at these points.

We also found that the absence of streets lights and poor visibility conditions present a high severe accident risk while driving at night or in the dark (Yau, 2004; Chiou *et al.*, 2013; Zhang, Yau, & Chen, 2013; Abegaz *et al.*, 2014; Zhang, Yau, & Gong, 2014; Anarkooli, Hosseinpour, & Kardar, 2017; Kim, Kho, & Kim, 2017; Gebru, 2017; Baru, Azazh, & Beza, 2019). These factors were two of the most significant predictors of LTI or PI, which was understandable, because in Bangladesh, most roads have no lighting systems and the streets do not have enough lights. These results are also consistent with those of previous studies in the context of both developed and developing countries (Eluru & Bhat, 2007; Wanvik, 2009).

3.6.2.3 Vehicles and place-related factors

As in many other developed and developing countries, four-wheeled vehicles (e.g. cars, buses, trucks) are the most common for commercial and public transportation in Bangladesh, and due to this common usage, they are also frequently involved in road crashes (Anarkooli, Hosseinpour, & Kardar, 2017; Waseem, Ahmed, & Saeed, 2019). The major causes of the severe accidents and injuries are reckless driving, driving without a valid driving license, and not taking safety precautions, such as not using seat belts (Dong *et al*., 2011; Boniface *et al*., 2016; Wangdi *et al*., 2018). The present study also confirmed these findings, showing that four-wheeled vehicles are responsible for most severe accidents, which ultimately result in LTI or PI. Shrestha *et al*. (2017), Kumar and Toshniwal (2016), and Adeloye *et al*. (2016) similarly found that four-wheeled vehicle crashes had a higher severity risk. Barua and Tay (2010) and Baset *et al*. (2017) further confirmed this result when examining crash severity in Bangladesh. Additionally, crashes occurring in city areas and on highways increase the likelihood of LTI or PI, and this is true in Bangladesh as well (Sarkar, Tay, & Hunt, 2011; Kamruzzaman, Haque, & Washington, 2014). Inefficient or lacking traffic control systems, high speeds, hitting fixed

objects or parked vehicles, and lack of road dividers are the central causes of RTAs resulting in LTI and PI in these areas (Barua & Tay, 2010; Ishtiaque & Ahmed, 2013; Rubayat & Sultana, 2013; Kamruzzaman, Haque, & Washington, 2014; Zafri *et al*., 2020). The current study also highlighted these findings, as did Kim *et al*. (2008) and MacLeod *et al*. (2012). Additionally, Salvarani, Colli, and Júnior (2009) reported a similar result in their study of a traffic accident prevention programme in Brazil, finding a robust association between accidents occurring in highway sections and LTI or PI.

3.6.2.4 Driver related factors

Driving the wrong way increases RTA probability, and in Bangladesh, this is a common problem and cause of RTAs resulting in LTI or PI (Joewono, Vandebona, & Susilo, 2015; Rodrígue, Peñaloza, & Montoya, 2015; Ahmad *et al.*, 2019; Banik *et al.*, 2011). In fact, disobeying traffic rules, reckless driving, lack of road dividers, poor road traffic regulation systems, and lack of traffic rule enforcements (e.g. an effective punishment system) are the central causes of these kinds of collisions on the streets of Bangladesh (Anjuman *et al.*, 2007; Banik *et al.*, 2011; Kamruzz-aman, Haque, & Washington, 2014). The present study also indicated that wrong-way driving increases the chances of being in more severe accidents that are responsible for LTI or PI, similar to others who found that these head-on collisions lead to more severe crash injuries (Ahmad *et al*., 2019, May; Al-Ghamdi, 2002; Yasmin & Eluru, 2013; Venkataraman, Ulfarsson, & Shankar, 2013; Waseem, Ahmed, & Saeed, 2019).

3.7. Conclusions and future research directions

The recent increasing trends of RTAs in Bangladesh, and the resulting alarming injury severity levels represent urgent and important issues, which require strong and effective interventions. This study used probit and Heckman selection probit models to assess the significant factors affecting RTAs and crash injury severity. We found that unawareness of RTA risks, high family incomes, and residing in rural areas were the main factors significantly related to RTAs.

The result also showed that unmarried people are more at risk of being in RTAs, while married people are at a higher risk of LTI or PI. Other factors significantly related to LTI or PI severity were accident location (city areas and highways), type of vehicles (four-wheeled), lack of adequate street lighting and speed control signs, driving the wrong way, and not holding an educational degree.

Based on these findings, we drew some policy implications. First, prevention strategies to reduce RTAs and severe injuries can increase individual awareness levels regarding road accidents. Thus, establishing road safety awareness campaigns can be especially useful for four-wheeled drivers with lower incomes and education levels who live in rural areas. Specifically, this would involve implementing speed control signs on the old streets and new under construction roadmap and increasing road safety awareness centred on preventing driving the wrong way and competition among drivers, which can play a pivotal role in road safety and decrease LTI or PI. Second, it is also quite important to monitor and establish road infrastructures, such as street lights, to enhance road security and improve visibility for both former and new roadmap. Strict police enforcement and proper road traffic legislation must be applied to stop reckless driving. In this regard, efforts are also needed to ensure and enforce pedestrian rights, monitor city and highway traffic systems (e.g. speed control signs), build well-planned intersections and road crossings with digital traffic control systems, and implement a proper punishment system by increasing traffic police to prevent drivers from breaking traffic rules. With regards to the latter, strict punishments should be implemented if, for example, the driver violates traffic signals and if pedestrians cross the road without using the designated crossing points. By doing this, drivers and pedestrians will be aware of the impact and presence of RTAs, which may help decrease severe road accidents and the number of related deaths.

The main strength of this study lies in the fact that the results support both governmental and non-governmental organisations in their efforts to reduce RTAs and the resulting injuries and fatalities, by strengthening the importance of the new evidence (e.g. socio-demographic and economic, street light and traffic signs effect). Indeed, government agencies and authorities play a pivotal role in reducing RTAs, and they should strengthen and increase the amount of resources being allocated to road safety management authorities to allow them to regularly monitor and improve road safety. Conversely, the following key limitations should be considered while interpreting the findings: (1) we only collected survey data in specific places: universities, and public and private hospitals in Dhaka City, and (2) the sample is limited (786 respondents) and the findings may not be generalised to all road traffic victims. Further research is required to extend the data collection to other parts of the city and other cities in Bangladesh to increase the number of respondents. Future studies should also try to address the so-called survivorship bias problem that usually affects these types of analyses and in our case, stemmed from the difficulty of collecting data on RTAs that caused deaths.

Thesis Conclusion

The problem of deaths and injury as a result of road accidents is now acknowledged to be a global phenomenon. As a result, authorities in all low- and middle-income countries (LMICs) of the world are now concerned about the growth in the number of people killed and seriously injured on their roads. Hence, my aim in writing this dissertation has been to provide a better understanding of the determinants of road accidents in LMICs. The current thesis contained three essays to examine, theoretically and empirically, the factors influencing road traffic accidents (RTAs). The first study applied a systematic literature review to investigate what are the risk factors that mainly contribute to road accidents and their severity, in order to find out, and possibly fill, the previous research gaps. Throughout the review, I have found that people's awareness level is significantly and positively correlated with RTAs, but, so far, no particular research or empirical evidence exists on what are the factors that make people more aware about RTAs and how the people awareness level regarding road accidents can be enhanced. This review also highlighted that there is a higher correlation between road accidents and 'road infrastructures and reckless driving' in many LMICs. Despite this result, little progress has been made towards the goal of a reduction of road accidents in these countries, as the number of deaths and injuries caused by RTAs has increased. One of the main reasons is that systematic efforts to collect road traffic data are not well developed and most of the collected data suffered from underreporting problems. The other issue is that the majority of the studies only focused on some specific factors for which data are available. Therefore, without complete data on all the necessary explanatory variables, it is impossible to find all the contributing factors on RTAs and provide reliable results for policymakers. Hence, the current research focused mainly on collecting novel data of better quality, by carrying out a detailed survey with questionnaires on all the potential factors, such as the location of the accident, the condition of the road, the type of vehicles involved, the road-user behavior, etc., so that the major contributory factors of

accidents taking place in these countries could be identified. I believe that, by providing new evidence on these issues, policymakers could implement new effective policies to enhance the people's awareness level about RTAs, which will ultimately lead to reducing road accidents.

In the second paper, I used probit and bivariate probit models, on data collected from Islam *et al*. (2018) in Bangladesh, to investigate what are the main factors that can increase the individuals' awareness about RTAs and help them to be informed about road traffic rules. The bivariate probit model is a joint model for two binary outcomes when the two dependent variables are highly correlated. The results showed that gender, road accident experience, availability of media connections, educational qualifications, job characteristics, place of residence and having received previous training about road traffic rules can improve an individual's awareness level of road traffic accidents and knowledge of traffic rules.

In the third paper, I used probit and Heckman selection probit models to investigate the significant factors affecting RTAs and crash injury severity. The Heckman probit model has been estimated with maximum likelihood methods with correction for sample selection bias, in order to provide consistent and asymptotically efficient estimates for all the parameters in the model. This model has been estimated on a sample of 786 surveyed individuals (of whom 525 have been directly involved in road accidents in the last two years and 261 were not involved) to explore which different factors significantly and simultaneously influence the likelihood of being involved in RTAs and the level of crash severity. I found that unawareness of RTA risks, high family incomes, residing in rural areas, and being married were the main factors significantly related with the probability of being involved in RTAs. Other factors significantly related to the level of injury severity were the accident location (city areas and highways), type of vehicles (four-wheeled), lack of adequate street lighting and speed control signs, driving the wrong way, and not holding an educational degree.

The main contributions of this thesis, which distinguish it from other studies that have been conducted previously in different countries (including Bangladesh) lay on the novelty of the data collected and on the originality of some of the methodologies and results of the empirical analysis.

The main implication of this study is that these new results provide new empirical evidence to support the government and non-government organizations to reduce RTAs and the resulting rate of injuries and fatalities. The concerned government agencies and authorities of course play a pivotal role in the reduction of RTAs. The resources and attention by road safety management authorities on these issues should be strengthened and increased, so that they can regularly monitor and improve road safety, by acknowledging the factors that let people to be aware of RTAs and increase their knowledge about traffic rules.

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