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# EFFECT OF FATIGUE ON TRAFFIC VIOLATIONS OF BUS DRIVERS

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# PROJECT REPORT APPROVAL

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# DECLARATION OF CANDIDATE

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of Dr. Shakil Mohammad Rifaat and this work has not been submitted elsewhere for any purpose (except for publication).


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# DEDICATION

We dedicate our thesis work to our family. A special feeling of gratitude to our loving parents.

We also dedicate this thesis to our many friends who have supported us throughout the process. We will always appreciate all they have done.

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## ABSTRACT

Road accident has become a daily and deadly phenomenon in Bangladesh which has one of the worst crash rates in the world, at more than 60 per 10,000 registered motor vehicles. The official death toll for road traffic accidents is about 4,000 a year, but Nirapad Sarak Chai gave a higher figure of 5162 accident related deaths in 2013, which also include deaths en route to hospital and deaths after release from hospitals.

Road Accident and casualties Statistics of Bangladesh Road Transport Authority (BRTA) shows that around 19,450 number of accident has occurred during the year 2009-2016.In those accident 18,510 people lost their life and about 14,442 people became injured (Bangladesh Road Transport Authority, BRTA). In Bangladesh, according to the official statistics (police statistics), at least 2437 accidents were reported in 2010 of which 1911 were directly fatigue related fatal accidents.

The fatigue related fatality is increasing tremendously and it has become an alarming event causing huge loss of lives and assets. A study revealed that about 83% drivers in Bangladesh were directly or indirectly involved in fatigue related disability and faced psycho-social disorders (Talukder et al., 2013). However, bus drivers does not take the matter seriously. Even the bus company owners overlook the drivers’ fatigue fact.

This study aims for identifying and analyzing factors that cause fatigue-induced road violations to isolate the most extreme group of drivers. Previously fatigue related study has not been explored much in Bangladesh. This study will help to create public awareness and attain mitigation measures to improve the current situation by addressing the ‘fatigue’ issue.

In our study we conducted a questionnaire survey on selected locations. Based on the survey data the model was developed to predict the number of violations by fatigue induced drivers. The questionnaire was prepared on other studies, literature review and local context. The study will help to identify the factors which affects the violations of drivers due to fatigue. Alcohol consumption, breaks between trips, fitness of vehicle, drivers’ monthly income, work pattern, trip distance etc. are significant factors which have influence on drivers’ fatigue induced violations

This study will help policy makers to set up an environment to minimize traffic casualties and ensure road safety by reducing fatigue

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# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND

Every year Nearly 1.3 million people die in road crashes, on average 3,287 deaths a day. An additional 20-50 million are injured or disabled. Road traffic crashes rank as the 9th leading cause of death and account for 2.2% of all deaths globally. Over 90% of all road fatalities occur in low and middle-income countries, which have less than half of the world's vehicle (The Association for Safe International Road Travel (ASIRT). Road Accident and casualties Statistics of Bangladesh Road Transport Authority (BRTA) shows that around 19,450 number of accident has occurred during the year 2009-2016.In those accident 18,510 people lost their life and about 14,442 people became injured (Bangladesh Road Transport Authority, BRTA). In Bangladesh, according to the official statistics (police statistics), at least 2437 accidents were reported in 2010 of which 1911 were directly fatigue related fatal accidents. It was also opined that the number could be bigger and ranging from 10000-12000 fatalities in each year (Haque et al., 2006). The database of the Accident Research Institute, Bangladesh (ARI) shows that the numbers of fatalities have been increasing and while it was reported 1009 in 1982 and got increased to 2443 in 2010.

Research shows that driver fatigue may be a contributory factor in up to 20% of road accidents, and up to one quarter of fatal and serious accidents. These types of crashes are about 50% more likely to result in death or serious injury as they tend to have high speed impacts (IRAP 2008, International Road Assessment Program). To relevant consequences and fatality situation, it was predicted that the number of people killing on roads would rise by at least 80 percent over the next 20 years especially in developing countries like Bangladesh.

The fatigue related fatality is increasing tremendously and it has become an alarming event causing huge loss of lives and assets. A study revealed that about 83% drivers in Bangladesh were directly or indirectly involved in fatigue related disability and faced psycho-social disorders (Talukder et al., 2013). But bus drivers does not take the matter seriously. Even the bus company owners overlook the drivers fatigue fact. But It is mentionable that the human rights violation and inadequate implementation of ILO Social Safety Convention 1952 (Sl-102) in Bangladesh through which the Government and Private sector stakeholders are directly liable to the fatigue related accidents.

**1.2 FATIGUE: DEFINITION AND SYMPTOMS**

In simple words fatigue is the being sleepy, tired, drowsy or exhausted. Fatigue is the transitory period between awake and sleep and if uninterrupted, can lead to sleep (Lal & Craig, 2001).Psychological fatigue is defined as a subjectively experienced disinclination to continue performing the task at hand (Brown, 1994).Any activity if pursued long enough, will be associated with a difficulty in maintaining skilled performance and this is true for driving. Driver fatigue has been defined as a state of reduced mental alertness, which impairs performance of a range of cognitive and psychomotor tasks, including driving (Williamson et al., 1996). Professional drivers are more likely to be effected by fatigue because generally they are not free to determine their work schedules and other work related functions.

Some common symptoms of being fatigued are (Nordbakke & Sagberg, 2007)

- Difficulty focusing, frequent blinking, or heavy eyelids
- Daydreaming; wandering/disconnected thoughts
- Trouble remembering the last few miles driven; missing exits or traffic signs
- Yawning repeatedly or rubbing your eyes
- Trouble keeping your head up
- Drifting from your lane, tailgating, or hitting a shoulder rumble strip
- Feeling restless and irritable
- Slower reaction to traffic events
- Misjudgment of road or traffic

## 1.3 CATEGORIZATION OF FATIGUE

Fatigue is generally categorized as acute or chronic (Mohren et al., 2007; Brenu et al., 2010).

### 1.3.1 Chronic Fatigue

Chronic fatigue syndrome (CFS), also known as myalgic encephalomyelitis (ME), is an illness that affects a person's nervous system (commonly called a 'neurological illness'). It can occur at any age and can affect children as well as adults. Due to the lack of restorative sleep over a sustained period of time, drivers can become chronically fatigued. The lack of restorative sleep can occur for a variety of reasons, such as disruption to sleep patterns experienced by shift workers, insomnia or a lack of sleep after becoming a new parent.

Studies in the US suggest that between 10% and 20% of the adult population suffer from chronic insomnia (Doghramji, 2006). However, there is a lack of literature assessing the effects of chronic fatigue on drivers.

### 1.3.2 Acute Fatigue

Acute fatigue is a sudden onset of physical and mental exhaustion or weariness, particularly after a period of mental or physical stress. Physical factors usually include an accumulation of the waste products of muscle contractions. Boredom is a common mental factor. Recovery follows a period of rest and restoration of energy sources. (Mosby's Medical Dictionary, 9th edition. 2009, Elsevier.)

Whereby chronic fatigue develops over a longer period of time, acute fatigue can occur as a result of a single event; for example one bad night of sleep.

## 1.4 OBJECTIVE OF THE STUDY

- To identify the reasoning of violations of traffic law due to fatigue induced factors through developing a suitable statistical model

- To check the effect of variables from the literature review on the prediction model
- To isolate the extreme group of drivers who are often involved in fatigue related violation

## 1.5 CONTRIBUTION TO THE FIELD OF SAFETY

Seven out of 44 serious road accidents are triggered by fatigue of professional bus and truck drivers between 2005 and 2008 (Phillips & Bjornskau, 2015). Thus, we can see fatigue driving is an alarming issue for both developed and under developing countries like Bangladesh but the number of study done on this issue is very much low. A study found that the drivers of Bangladesh are aware of fatigue but they don't know the main causes and consequences of it (Haque et al., 2006). Overall the owner's association does not bother the mental condition of the drivers as they only focus to gain maximum profit. As a result the drivers face heavy workload and as there is a huge crisis for experienced driver the unexperienced young driver grabs the steering wheel. Thus, it's very essential to conduct study on estimating the factor that effect the drivers fatigue to make the driver aware of the facts as well as to enable the policy makers to make effective policy and regulation for the vehicles owners.

This study will also contribute to advancing knowledge in the field because relatively few studies have been conducted in the developing country context like Bangladesh, compared to developed countries (Barua & Tay, 2010). Since the road environment, driver behavior, vehicle type are very different, some of the contributing factors identified in developed countries may have different effects in a developing country context.

It will provide evidence-based recommendations to prohibit causing of drivers fatigue and minimize the fatal or serious road accident due to driver's fatigue.

This study will also explore many factors that have thus far received relatively little attention in the literature, including etc. Merely the study specially involves major findings on the causes of driver’s fatigue.

## 1.6 SCOPE OF THE RESEARCH

This thesis will include two main studies. The first study will develop negative binomial model to analyze the effect of different variable on fatigue of drivers and the second study will include inspecting factors and conditions related to the improvement of better driving policy for drivers

## 1.7 THESIS OUTLINE

The remainder of this thesis is organized in six chapters. In chapter 2, a literature review on research related to the factors and components that influence the drivers fatigue are presented. Chapter 3 describes the methods that are used to address the objectives of this research. Chapter 4 provides conceptual framework for modeling, the statistical analysis and discussion of results. The implications of analytic results and policy implications are presented in chapter 5 together with direction for further research.

# CHAPTER 2

# LITERATURE REVIEW

According to (Grandjean, 1979; Lal & Craig, 2001; Boksem et al., 2005), fatigue relates to a gradual disinclination towards effort that accumulates over time and results in a reduction in performance levels. In other words completing the task wears out the person completing it (Broadbent, 1953).

Fatigue has a huge impact on driving and can affect the ability to drive safely, similar to the effect of drunk driving. Research shows that being awake for 17 hours has the same effect on your driving ability as a BAC (blood alcohol concentration) of 0.05. Going without sleep for 24 hours has the same effect as a BAC of 0.1, double the legal limit. Fatigue is a likely factor in almost one third of single-vehicle crashes in rural areas. (Dawson & Reid, 1997; Williamson & Feyer, 2000).

The purpose of this study is to clearly identify the causes of fatigue on various drivers and to execute a similar study in aspect of Bangladesh. The literature review is organized in a way to briefly compare and contrast between previously published studies to link up the relevance and importance of this study.

This part of the review aims to group on topics where authors drew similar conclusions

## 2.1 DRIVERS' SOCIO-DEMOGRAPHIC CHARACTERISTICS

Drivers' socio-demographic and background characteristics has a substantial effect on driver's fatigue which is briefly explained below:

### 2.1.1 Gender and Age:

Varied peak time of fatigue is observed based on driver's age. Significant number of drivers reported to be fatigued are male and young.

According to (Horne & Reyner, 1995) a significant number of drivers (50%) who were reported to be fatigued were male and under the age of 30. The younger and older drivers were found fatigued respectively in morning and afternoon (Brown, 1997). Another study in Australia (The New South Wales Risk Management Research Center) found out that 50% of the younger drivers despite of being fatigued, insisted to continue driving in fatigued condition (Hatfield et al., 2005).

#### *2.1.1.1 Younger Drivers*

Younger drivers are associated with higher accident rates. Researchers now argue that the causes are complex and only partly related to limited driving experience.

McConnell et al. (2003) found that younger drivers aged 15–21 were more at risk for sleep-related motor vehicle crashes. Corfitsen (1999) found that young male drivers were aware of, and ready to accept, driving at very low levels of arousal, which suggested they were a particularly high-risk group. Smith et al. (2005) found that young drivers frequently drove while at risk of crashing, both at times of predicted sleepiness (by circadian rhythm) and at times they themselves felt sleepy. Lucidi et al. (2002) found that alcohol accentuated fatigue in young drivers, and nightclubbing increased fatigue disproportionately (taking into account the parallel effects of alcohol). Horne et al. (2003) found that modest and legally acceptable levels of alcohol intake by young males significantly impaired their driving. Ulleberg (2001) identified sub-groups of young drivers (using attitudinal scales) and found that low-risk sub-groups were more likely to respond positively to media safety campaigns. The high-risk subgroups were characterized by high levels of sensation seeking and driving-related aggression, and featured a male bias. Vassallo et al. (2007) also found that young drivers engaging in risky driving behaviors (including driving while fatigued) differed from control groups by temperament, behavior problems, social competence, and adjustment to school, and interpersonal relationships. A more complex view of causality is emerging to support the view that specific sub-groups require specific measures. Hatfield et al. (2005) found that most young Australian drivers reported driving while fatigued – about a quarter did so, and on a weekly basis. They found that young drivers' understanding of the risk of driving fatigued was low, and might be inaccurate because they compared it with the higher risks of speeding and/or drink-driving. A parallel study by Grunstein et al. (2004) also found that young males had the lowest knowledge about fatigue and the poorest sleep habits. Hatfield et al. (2005) noted that young drivers also underestimated personal risk (being overly optimistic) and overestimated the effect of behaviors and situations reducing fatigue risks (such as drinking coffee or driving a short distance only).

In the absence of fatigue-related legislation and enforcement, the authors argued that campaigns might best focus on the perceived risks of crashing and related social censure. But they also observed that little was known about the social norms for young-driver fatigue, aside from general views on its 'irresponsibility'. The authors suggested that public education campaigns on driver fatigue in New South Wales have presented information in ways that produce denial, propagate myths of driver fatigue, and are unclear about appropriate behavior. The authors pointed to static and upward trends in fatigue-related crashes during the campaigns. In particular, they argued that fatigue-related campaigns should specifically target young people. In a secondary study, the authors developed and tested a pamphlet that provided fatigue-risk information with a risk-assessment tool (a 'risk ladder'), and a section debunking myths about fatigued driving. The pamphlet produced significant changes in beliefs and intended behaviors.

Note the aim of the pamphlet study was to understand how to successfully educate young drivers, as a key step towards achieving behavioral outcomes. Subsequent effects on driver behaviors were not assessed and there is clearly more work to be done in this area. Other studies cited in this review more specifically explored the links between driver education and behavioral outcomes. A number of recent evaluations have also assessed other safety programs, including legislation, enforcement, education and media campaigns. These are noted in the final sections of this report. Ferguson (2003) noted that graduated driver licensing (GDL) has been successful in managing a range of risks arising for younger drivers in the US, and for example, the extended learning period could reduce the per-driver crash rate by 5–32 percent. Grunstein et al. (2004) recommended inclusion of fatigue-related education in driver-licensing programs, to address the high levels of ignorance about fatigue found among young drivers.

Note that fatigue is now included in GDL training programs in New Zealand (NRSC 2008) – the impacts of this have yet to be studied. It is a complex area, as risks among young drivers arise from a range of factors, found both in isolation or combination, including ignorance about fatigue, risky driving, alcohol use, seatbelt non-use, driver distraction and fatigue and vehicle choice. GDL and other restrictions (such as night-time driving) may limit risks such as driving while fatigued, but do not remove them entirely, and some restrictions are not actually fully supported by research. Ferguson (2003) suggested that further research would be important for defining risks and appropriate measures against them.

#### *2.1.1.2 Older Drivers*

Older drivers are seemed to be more skillful in times when they feel fatigued. A study by McCarthy (2005) pointed out that the proportion of older people in the general driver population was steadily increasing, and specific programs were required to ensure they continued to drive in safety.

Campagne et al. (2004) found that overall, older drivers' driving errors increased more with fatigue than those of younger drivers. But Philip et al. (2004) found that although the response times of older drivers were slower overall, they were much less likely to degrade when fatigued. Older drivers were also more accurate in their assessment of their driving performance when fatigued. In terms of measures to counter fatigue in older drivers, recent studies are rare. Donmez et al. (2006) found that older drivers were more willing to accept and trust technologies that enhanced driver alertness (by reducing the impact of distractions). Drivers overall were more accepting of visual than auditory warnings. Note that older drivers were more trusting of either type of warning, including when the technologies failed to register risks, suggesting some over-reliance on the technology and thus (paradoxically) potential crash risks. Owsley et al. (2004) found that visually impaired older people who were given generic driver safety education regulated their driving behaviors more carefully and avoided challenging situations more than control groups, but these behaviors did not result in a lower crash rate. Current work on older drivers is evolving with greater clarity, and it already suggests some reasons for developing measures that are specific to older drivers

### 2.1.2 Driving Experience:

Driving behaviors were likely to be affected by the driving experience. A study in China showed that as new drivers indiscriminately accept, read, and process large amounts of information while driving because of their limited experience, this leads them to use tremendous amount of energy within a short period of time resulting to face fatigue (Li et al., 2010).

In Shanghai an investigation based on driving habits referred that fatigue-related crashes are associated with the experience of drivers (Ren et al., 2007). It may be initially assumed that people with limited driving experience are at high risk of causing traffic accidents. However, drivers with extensive driving experience tend to overestimate their ability when dealing with emergencies. Their overconfidence may lead to more involvement in accidents (Li et al., 2010). Liu et al. (2008) found that Chinese drivers who have driven for either less than 3 years or approximately 10 years have the highest probability of causing traffic accidents.

### 2.1.3 Work and Lifestyle of Driver:

Working pattern and lifestyle was found to be an effector on driver's driving performance.

Fatigue driving behaviors are also commonly observed in people who drive frequently and work for long hours in the US (Novak & Auvil-Novak, 1996).

In addition to that the combination of fatigue and alcohol or drugs increases the probability for drivers to cause traffic accidents (Horne et al., 2003; Roth, 2001). Even professionalism could be a prominent risk of causing traffic accidents because of fatigue in Turkey (Öz et al., 2010), (Gnardellis et al., 2008).

### 2.1.4 Education and Income:

Though education and income has a little association on driver's intention to sleep but in a study it was found that in particular people with greater income and educational standing spent less time in bed, while people with lower incomes showed longer sleep latency and slept less even though time in bed was similar. (Novak & Auvil-Novak, 1996)

### 2.1.5 Partner/Marital Status:

The effect of driver's marital condition may seem to be overlooked but studies claims that being married could be a beneficial factor to fatigued driving.

Bültmannet et al. (2002) found employees who lived alone had significantly higher fatigue; although, it is not clear whether they also worked longer hours than partnered employees. However, studies suggests that a marital or partnered lifestyle somehow lessens fatigue.

From the mentioned data it can be concluded that drivers' socio-demographic and background characteristics is an important aspect for identifying the cause of fatigue which will help to form the questionnaire for the data collection methodology.

## 2.2 VEHICLE TYPE

In identifying fatigue as a major industry problem Light drivers were much less likely than Heavy drivers. Occurrence of fatigue was reported prolonged by Heavy drivers (11h) rather than Light drivers (6h) from the beginning of driving. Elevated fatigue susceptibility in the afternoon between around 13:00 and 18:00 h but Heavy drivers were much more likely than

Light drivers to report fatigue late at night and in the early hours of the morning, especially between 02:00 and 06:00 (Friswell & Williamson, 2013).

These study reveals comparison between light and heavy vehicles which is important in finding drivers' fatigue, but in aspect of Bangladesh, the effect of vehicle type on fatigue could be changed as the country's vehicle type can be differently grouped. This leads to emphasize on bus and truck drivers which is clearly included on heavy vehicles.

An analysis of over 600 truck accidents in Europe identified fatigue as the main cause in 6% of the accidents investigated, with 37% of these resulting in a fatality (International Road Transport Union, 2007).

Accidents recorded in the Department for Transport's Heavy Vehicle Crash Injury Study Fatal Accident Database determined that fatigue was recorded as a contributory factor in 4.1% of fatal accidents involving an HGV, 5.5% of fatal accidents involving an LCV, and 1.1% of fatal accidents involving a PSV (Parkes et al., 2009).

Accidents involving an HGV shows an increased level of severity when the driver is fatigued (1.26 fatalities per accident involving a fatigued driver) in comparison with all HGV accidents (1.11 fatalities per accident involving a fatigued driver) (Parkes et al., 2009).

PSV accidents involving a fatigued driver show a higher level of severity (2.00 fatalities per accident) than for all PSV accidents (1.11 fatalities per accident) (Parkes et al., 2009).

## 2.3 ROAD GEOMETRY

Road geometry plays an important role on driver's fatigue as it directly changes and influences driving path and pattern resulting the driver to take sudden decisions. Monotonous road can be an easy medium for divers to be fatigued while driving. Factors related to road geometry are described below:

### 2.3.1 Road Facilities and Conditions:

Many researchers believe that a complicated, dynamic environment increases the chance of fatigue for drivers. Liu & Wu (2009) found that the change of road conditions from complicated to simple exacerbates driver fatigue by examining the effect of different road conditions on driving and cognitive behavior of Chinese drivers, Liu & Wu (2009) found that the change of road conditions from complicated to simple exacerbates driver fatigue.

Different road facilities also affect fatigue driving. Several researchers have found that 59% of fatigue driving behaviors occur in multi-lane interstate highways in the US at the speed above 55 miles/h, 23% of fatigue driving behaviors occur in two-lane public roads at the speed above 45 miles/h, while only 8% of severity of fatigue-related crashes. The effect of the differences between urban and rural roads on fatigue driving is also considered.

### 2.3.2 Type of Road:

Roads which involve sustained, monotonous driving, with little visual stimulus for the driver, and where drivers are not required to attend to either the vehicle's controls or respond to multiple road users and junctions, are more likely to have sleep related accidents. Urban roads are less prone to fatigue crashes because the level of activity is so much greater, and helps to keep drivers active and alert (Reissman, 1996).

A study by Horne & Reyner (1995) reveals that two-thirds of sleep related accidents occurred on a roads, 9% on motorways, 16% on B roads and 9% on minor roads. More to be mentioned that Maycock (1995) found higher rates on motorways (20%) and non-built-up roads (14%) than on built-up roads (5%).

### 2.3.3 Road Side Environment:

The ascending activity clearly helps drivers to remain awake during driving hours as for roads which involve sustained, monotonous driving, with little visual stimulus for the driver, and where drivers are not required to attend to either the vehicle's controls or respond to multiple road users and junctions, are more likely to have sleep related accidents. As the level of activity is so much greater in urban roads, they are less subjected to fatigue crashes. (Reissman, 1996).

## 2.4. TIME

Time is an important factor to be considered for the analysis of identifying the causes of fatigue. As the duration of driving increases the possibility of fatigued driving increases. Again the time of driving could be another factor for fatigue.

### 2.4.1 Shift Patterns:

It may seem that shifting pattern can reduce fatigue driving but studies shows that the result of shift pattern could be a prominent cause of fatigue driving. Split schedules for drivers' plays a negative effect on fatigue than those working straight schedules (Thobias et al., 2010).

### 2.4.2 Break Time:

Break time for drivers reduces the fatigue in a varied way. Taking one, two, and three rest breaks can reduce drivers' fatigue odds by 68%, 83%, and 85%, respectively, compared to drivers who did not take any rest breaks (Chen & Yuanchang, 2014).

Another study shows that increasing total rest-break duration can consistently reduce fatigue-related crash risk (Chen & Yuanchang, 2014). Sparrow et al. (2016) found that when drivers had only one nighttime period (01:00–05:00) in their restart break, this was associated with driving primarily at night. Also, when drivers had only one nighttime period in their restart break, they experienced greater nighttime fatigue during duty cycles.

### 2.4.3 Duration of Driving:

Driving for a long period of time directly influences drivers' fatigue. A study by Ting et al. (2008) shows that most fatigue-related highway accidents are caused by drivers who spend long hours on the road. The statistical analysis revealed that driving time had a significant effect on the subjective fatigue. (Lianzhen & Yulong, 2014)

### 2.4.4 Impacts of Off Duty Time:

Driver fatigue has been a major contributing factor to fatal commercial truck crashes, which accounted for about 10% of all fatal motor vehicle crashes that happened between 2009 and 2011. Commercial truck drivers' safety performance can deteriorate easily due to fatigue caused by long driving hours and irregular working schedules. To ensure safety, truck drivers often use off-duty time and short rest breaks during a trip to recover from fatigue. This study thoroughly investigates the impacts of off-duty time prior to a trip and short rest breaks on commercial truck safety by using Cox proportional hazards model and Andersen-Gill model. It is found that increasing total rest-break duration can consistently reduce fatigue-related crash risk. Similarly, taking more rest breaks can help to reduce crash risk. The results suggest that two rest breaks are generally considered enough for a 10-hour trip, as three or more rest breaks may not further reduce crash risk substantially. Also, the length of each rest break does not need to be very long and 30min is usually adequate. In addition, this study investigates the safety impacts of when to take rest breaks. It is found that taking rest breaks too soon after a trip starts will cause the rest breaks to be less effective. The findings of this research can help policy makers and trucking companies better understand the impacts of multiple rest-break periods and develop more effective rules to improve the safety of truck drivers (Chen & Xie, 2014).

### 2.4.5 Time of the Day:

A fixed-base driving simulator with a virtual track was provided to participants who drove while performing the secondary visual reaction time task in six sessions spanning the 24-hour day. The authors found that performance on the driving task was poorest at 0600 and 0200 hours, with an afternoon dip around 1400 hours (Lenné et al., 1997). These results confirm the crucial importance of circadian phase on performance, which obviously extends to complex skills such as driving.

Lenné and colleagues' results are not too different from those of a macro-analysis of driving accident data by Folkard (1997). He found a significant peaking accident rates around 0300 hours and hypothesized that this effect might be due to circadian influence. Maycock (1997) likewise found an afternoon peak in rates of sleep-related accidents. Thus, circadian rhythm provides an oscillating baseline of potential fatigue state against which all other factors must be framed.

## 2.5 EFFECT OF SLEEP

Sleep-deprived driving (commonly known as tired driving, drowsy driving, or fatigued driving) is the operation of a motor vehicle while being cognitively impaired by a lack of sleep. Sleep deprivation is a major cause of motor vehicle accidents, and it can impair the human brain as much as alcohol can. According to a 1998 survey, 23% of adults have fallen asleep while driving. According to the United States Department of Transportation, male drivers admit to have fallen asleep while driving twice as much as female drivers.

In the United States, 250,000 drivers fall asleep at the wheel every day, according to the Division of Sleep Medicine at Harvard Medical School and in a national poll by the National Sleep Foundation, 54% of adult drivers said they had driven while drowsy during the past year with 28% saying they had actually fallen asleep while driving. According to the National Highway Traffic Safety Administration, drowsy driving is a factor in more than 100,000 crashes, resulting in 1,550 deaths and 40,000 injuries annually in the USA.

### 2.5.1 Sleep Debt:

Loss of sleep is also implicated in driver fatigue, and consequently, reduced performance. Fell & Black (1997) investigated driver fatigue incidents in cities, and found that 57% of drivers who had a fatigue-related incident reported insufficient sleep on the night before the incident happened. According to Brown (1994) loss of sleep "exacerbates the effects of fatigue on driving…and interacts with circadian rhythmicity" (p. 310). Williamson et al. (1996) investigated the influence of work practices on fatigue among long distance truck drivers. They also found that in addition to work regimen, pre-trip fatigue levels (loss of sleep before the trip) influenced overall fatigue levels. A study by Bogstrand et al. (2012); Walsh et al. (2004) tells that lack of sleep, can pose a threat to driving safety. Another study revealed that sleep disorders directly or indirectly affect the quality and quantity of one's sleep or otherwise cause excessive daytime fatigue (Smolensky et al., 2011).

When a person does not get an adequate amount of sleep, his or her ability to function is affected. As listed below, their coordination is impaired, have longer reaction time, impairs judgment, and memory is impaired.

## 2.6 ASSOCIATED DISEASES

There are many diseases associated with abnormal sleeping and waking. These diseases affect drivers' health and degrade driving performance in a varied way. So it can be concluded that these associated diseases plays an important role on fatigue related road accidents.

### 2.6.1 Narcolepsy:

There are many diseases associated with abnormal sleeping and waking. One of the most common is narcolepsy. Narcolepsy is a dysfunction involving the central nervous system and bouts are characterized by immediate Rapid Eye Movement (REM) sleep where non-REM sleep would be expected.

That is, the sufferer may experience sudden sleep attacks, hypnagogic hallucinations and/or paralysis on wakening or falling asleep (Mitler et al., 1987). This disorder may have potentially catastrophic consequences both for the sufferer when driving and other road users. Narcolepsy appears to be hereditary, and most suffers are well aware of their condition by adulthood (Bendel, 1995).

### 2.6.2 Obstructive Sleep Apnea:

Obstructive sleep apnea (OSA) is the most common type of sleep apnea and is caused by complete or partial obstructions of the upper airway. It is characterized by repetitive episodes of shallow or paused breathing during sleep, despite the effort to breathe, and is usually associated with a reduction in blood oxygen saturation. These episodes of decreased breathing, called "apneas" (literally, "without breath"), typically last 20 to 40 seconds.

Obstructive sleep apnea syndrome (OSAS) is characterized by disturbed nocturnal sleep and daytime consequences, mainly excessive daytime sleepiness (EDS). It affects from 2% to 4.4% (women) and from 4% to 11% (men) of the middle-aged population according to current diagnostic criteria and epidemiologic data. (The New England Journal of Medicine, 1993).

Obstructive sleep apnea is characterized by repetitive episodes of partial or complete obstruction of the upper airway (throat) during sleep. These episodes are the result of sleep related loss of muscle tone in an already narrow floppy throat. Predisposing factors include anatomical obstructions (such as enlarged tonsils and adenoids), increasing age and obesity. Loud snoring is a usual accompaniment, also reflecting throat narrowness and floppiness. Each obstructive episode is terminated by arousal which is usually momentary.

In more severe cases hundreds of such episodes can occur per night, with attendant marked disruption of sleep. The most obvious consequence of this to the patient is daytime sleepiness (Farrell & Barnes, 1996). The overriding effect of OSA is sleepiness and actually falling asleep and obviously this has major implications for social and family life, for work and particularly for driving. Road accidents are common amongst sleep apnea individuals and this occurs particularly in monotonous situations such as motorway driving.

### 2.6.3 Excessive Daytime Sleepiness:

Excessive daytime sleepiness (EDS) results from disturbance of the sleep pattern, including the reduction of time spent in rapid eye movement (REM) sleep. As a result the individual may have a natural inclination to sleep during the daytime. Farrell and Barnes (1996) argue that this condition has obvious implications in any situation where mental concentration is required, such as driving a vehicle. For example when the disease reaches a severe stage, lack of sleep can cause the sufferer to drop off while waiting for traffic lights to change.

Driving is a complex psychomotor task that requires an adequate level of alertness to interact efficiently with the road environment but, in parallel, involves several perceptual, motor, and cognitive processes. The recent awareness of sleepiness-related crashes is mirrored by the medico legal aspects concerning fitness to drive and consequent physicians' referral of patients with medical conditions (Horne & Reyner, 1995).

Concerning individual ability to drive safely, sleepiness-related crashes can result from falling asleep while driving or from more subtle phenomena, such as inattention or other minor cognitive impairments (eg, risk perception or decision making) ascribed to drowsiness itself. Moreover, sleepiness perception while driving in the real traffic environment is a key factor for accident prevention because it can alert drivers to use countermeasures (eg, stop driving, drink caffeine beverages) to avoid car crashes (Horne, 1999).

Several studies have confirmed the negative impact of sleepiness on driving performance, as measured by driving simulator or on-road testing (George, 2003).

Even if the ability to perform in a simulated driving test could not be translated into real fitness to drive, Philip and coworkers demonstrated that the driving impairment after sleep restriction (measured by means of inappropriate line crossing of the vehicle) is qualitatively comparable in real driving and driving simulators but of higher amplitude under simulated conditions. (Philip et al., 2005).

Few studies on driving simulation in patients with OSAS have evaluated the relationship between objective sleepiness measurement and driving performance. George and coworkers found that tracking error on a divided-attention driving task correlated with MSLT sleep latencies in baseline conditions ($r = -0.42$, P value = 0.01), and both parameters were improved after the use of nasal continuous positive airway pressure therapy ($r = 0.65$, P value < 0.01) (George et al., 1996)(George et al., 1997).

We confirmed the correlation between MSLT sleep latencies and lane-position variability in patients with OSAS ($r = -0.47$, P value = 0.008), together with other performance parameters, using our monotonous driving simulation test (Pizza et al., 2008).

Interestingly, Hack and coworkers showed a significant improvement in the driving performance of patients with OSAS on steering simulator after therapeutic nasal continuous positive airway pressure that was not correlated with changes in MWT sleep latencies, suggesting that reduced vigilance was not the single impairing factor for steering performance (Hack et al., 2000). Recently, studies of sleep deprivation (with or without alcohol consumption) and patients with OSAS disclosed the predictive validity of the MWT toward driving performance (Banks et al., 2005).

Sagaspe and coworkers found a higher correlation between mean sleep latency at MWT and lane-position variability on a driving simulation compared with previous MSLT studies of patients with OSAS ($r = -0.51$, P value $< 0.01$) (Sagaspe et al., 2007).

## 2.7 ROAD AND DRIVING ENVIRONMENT

A situational factor often connected with long drives is monotony. The belief that driving in monotonous conditions (e.g., on a motorway) enhances driver fatigue follows the assumption that lower amounts and variation of stimulation lead to lower arousal (Thiffault & Bergeron, 2003).

According to Horne and Reyner (1999), only a few sleep-related accidents occur on urban roads "because the driving conditions are relatively stimulating, and usually there is much for the sleepy driver to see and do." However, Fell and Black (1997) reported that according to official statistics in the State of New South Wales, Australia, 42% of fatigue-related accidents have occurred in a city. In this context, traffic density has been studied as an important mediating factor: for example, the greater the traffic density on a motorway, the lower the proportion of sleep-related accidents (Flatley et al., 2003). This finding was explained by the fact that the presence of other vehicles in otherwise monotonous motorway driving may trigger drivers' attention and keep them more alert (Pandi-Perumal et al., 2006).

### 2.7.1 The Situation in a Vehicle:

Besides factors outside the vehicle, the situation in a vehicle contributes to drivers' fatigue/sleepiness. The heat, noise and vibrations (McDonald, 1984), and air quality (Sung et al., 2005; Utell et al., 1994) in vehicles have been reported as causes of driver fatigue. On the other hand, the comfortable seats and sound reduction that modern cars offer might unintentionally enhance driver sleepiness (Horne & Reyner, 1999).

### 2.7.2 Presence of Passenger:

Having passengers in a car should, at least in most cases, reduce drivers' boredom and consequent fatigue. Furthermore, a passenger might notice signs of driver fatigue (e.g., facial expressions or drifting of the vehicle) and their seriousness before the driver does. Therefore, having passengers might be regarded as a protective measure against falling asleep behind the wheel. However, if the passengers are asleep, the driver is again on his/her own. On the other hand, the presence of passengers in a car driven by a young adult might even have a counterproductive effect because young male adults are susceptible to peer pressure and might continue driving despite increased fatigue or sleepiness (Näätänen & Summala, 1976; Rice et al., 2003; Summala & Mikkola, 1994).

## 2.8 OTHER FACTORS

### 2.8.1 Drowsiness Due to Motion:

Graybiel & Knepton (1976) observed a collection of responses to motion including marked drowsiness, which they termed "spite syndrome" (from the Latin sopire, meaning "to put to sleep"). Spite syndrome sufferers exhibit drowsiness despite adequate rest. They also demonstrate difficulty concentrating, irritability, apathy, feelings of detachment, disinclination for work, and sleep disturbances. Graybiel & Knepton (1976) suggested that spite syndrome might be a sole manifestation of motion sickness, implying that it is a form of motion sickness that can occur without what might be considered the traditional symptomology of motion sickness (e.g., nausea, dizziness). It can occur after adaptation to sickening motion (Graybiel & Knepton, 1976), in mild motion settings involving vehicular transportation (such automobiles, airplanes, boats, trains, etc.), or in settings involving apparent self-motion (i.e., vection), such as simulators and virtual environments (Lawson & Mead, 1998). However, Graybiel et al. (1960) found that persons lacking a normally functioning labyrinth were immune to the effects of spite syndrome, suggesting that it is a phenomenon rooted in the vestibular system. In addition, spite syndrome can manifest itself in fully rested persons in situations in which drowsiness cannot be attributed to boredom. Further, Spite syndrome can occur in dynamic, stimulating environments. A pilot suspected to be particularly susceptible to spite syndrome once had the opportunity to ride tandem in a Navy F-18 jet, only to find he had difficulty staying awake half-way through the trip (Mead & Lawson, 1997)

### 2.8.2 Use of Drugs:

The effects of specific drugs differ depending on how they act in the brain. For example, marijuana can slow reaction time, impair judgment of time and distance, and decrease coordination. Drivers who have used cocaine or methamphetamine can be aggressive and reckless when driving. Certain kinds of sedatives, called benzodiazepines, can cause dizziness and drowsiness. All of these impairments can lead to vehicle crashes.

Study strongly revealed that use of drugs can cause tiredness, fatigue, drowsiness in addition to their other impairment effects (NHTSA, 1998) and tends to have a larger effect to the risk of fatal and serious injury accidents than on the risk of less serious accidents (Elvik, 2013).

Research studies have shown negative effects of marijuana on drivers, including an increase in lane weaving, poor reaction time, and altered attention to the road. Use of alcohol with marijuana made drivers more impaired, causing even more lane weaving. (Lenné et al., 2010)

It is difficult to determine how specific drugs affect driving because people tend to mix various substances, including alcohol. But we do know that even small amounts of some drugs can have a measurable effect. As a result, some states have zero-tolerance laws for drugged driving. This means a person can face charges for driving under the influence (DUI) if there is any amount of drug in the blood or urine. It's important to note that many states are waiting for research to better define blood levels that indicate impairment, such as those they use with alcohol.

## 2.9 FATIGUE AND ACCIDENT

Driver fatigue (‘falling asleep at the wheel’) is a major cause of road accidents, accounting for up to 20% of serious accidents on motorways and monotonous roads in Great Britain. (Horne & Reyner, 2000).

A recent study by the Sleep Research Centre indicates that driver fatigue causes up to 20% of accidents on monotonous roads. This suggests that there are several thousand casualties each year in accidents caused by drivers falling asleep at the wheel (Horne & Reyner, 2000).

An earlier study (Horne & Reyner, 1995) of road accidents between 1987 -1992 found that sleep related accidents comprised 16% of all road accidents, and 23% of accidents on motorways.

Research by the TRL (Maycock, 1995) found slightly lower proportions of sleep related accidents: 9% - 10% of accidents on all roads, and 15% of accidents on motorways involved driver sleepiness. In this study, 29% of drivers reported having felt close to falling asleep at the wheel at least once in the previous twelve months.

In the USA, several studies (NCSDR/NHTSA Expert Panel, Report HS 808 707, 1998), 10-15 in recent years have produced various estimates of the level of sleep related road accidents. The National Highway Traffic Safety Administration (NHTSA) estimate that there are 56,000 sleep related road crashes annually in the USA, resulting in 40,000 injuries and 1,550 fatalities.

One study (Johnson, 1998) calculated that 17% (about 1 million) of road accidents are sleep related. A 1995 study suggested that 2.6% of accidents caused by driver inattention were due to fatigue (Wang, 1996).

A study (Reissman, 1996) of road accidents on two of America’s busiest roads indicated that 50% of fatal accidents on those roads were fatigue related. Another study (Safety Study. Factors That Affect Fatigue in Heavy Truck Accidents. National Transportation Safety Board, Washington, USA) claims that 30% - 40% of accidents involving heavy trucks are caused by driver sleepiness.

VicRoads, an Australian road safety organization, estimates that 25% - 35% (and possibly up to 50%) of road crashes are sleep related (VicRoads Road Accident Factsheet, www.vicroads.vic.gov.au/road_safe/index.htm). A 1994 study (Fell, 1994), estimated that driver sleepiness accounts for 6% of road accidents, 15% of fatal accidents and 30% of fatal crashes on rural roads.

A study of motorway accidents in Bavaria (Hell et al., 1997) estimated that 35% of fatal motorway crashes were due to reduce vigilance (driver inattention and fatigue).

Between 1996 and 1998, 114 fatal road crashes (8% of all fatal crashes) and 1,314 injury road crashes (5% of injury accidents) were thought to be fatigue related (Land Transport Safety Authority, 1998). A study (Gander et al., 1998) of 370 heavy motor vehicle crashes in 1997, found that driver fatigue was listed as a contributing factor in 7% of accidents.

A questionnaire survey (Sagberg, 1999) of 9,200 accident-involved drivers found that 3.9% of the accidents were sleep related, but almost 20% of night-time accidents involved driver drowsiness.

In terms of fatal accidents, fatigue and alcohol seem to be less significant problems for truckers than for car drivers (Brown, 1993).

Baker (1967), who reported that in single-vehicle accidents, fatigue was a contributing factor in about 30% of cases if the driver was below 30 years of age and in about 20% of cases with drivers older than 30.

Fatigue is a recognized risk factor for road traffic crashes (Connor et al., 2002).

Fatigue is a recognized risk factor for road traffic crashes (Connor et al., 2002). In order to minimize the risk it is important to know the outcome of fatigue. From the previously described topic on outcome of fatigue, it can be concluded that to identify the cause of fatigue has a significant effects to reduce fatigued driving.

The literature review indicates on studies where various authors have concluded on possible causes of fatigue in a similar perspective. The comparison and contrast of these studies reveal the importance of various factors those are directly or indirectly lead to fatigued driving. The results found from various studies stated the demarcation as they were evaluated in different locations. As this study aims to assess similar approach in aspect of Bangladesh, the possible findings might be different from previous studies and may also include new possibilities for further assessment, which indicates the relevancy of this study. The choice of methodological approach and avoiding irrelevant impedance of this study can be guided from the limitations and discrepancy of previous studies. The outcome and effects of fatigue are described in other part of the review where the importance of identifying causes of fatigue can be easily understood. This point of view can help to build up a questionnaire survey and further analysis to discover the causes of fatigue driving in Bangladesh through developing a suitable prediction model.

# CHAPTER 3

# DATA AND METHODOLOGY

## 3.1 INTRODUCTION

This chapter describes the data collection procedure, formulation of data and the methodology used. Negative binomial regression model will be used to identify the different factors causing divers' fatigue and law violations. The formulation of this model will help us to understand how these models can be employed to fulfill the main objective of the study; which is to identify the reasoning of violation of traffic law involving major and minor crashes due to fatigue induced factor and to check the effect of other variables from the literature review on the prediction model. The sources of database used in this study are discussed before describing the mathematical formulation of the model, its assumptions and estimation procedures.

## 3.2 MAIN STEPS IN METHODOLOGY

In order to achieve the objectives of the study, suitable statistical models need to be selected. The models will be developed using real collision data that correlates crashes with roadway geometrics, socioeconomic and demographic factors. Model calibrations will then be done to find the best model among the competing set of models. The result of the final model will then be analyzed to find the critical factors contributing to fatigue as well as related severities.

The methodology can be divided into three main steps:

(a) Preparation of Questionnaire to carry out the survey process. Selection of statistical models to express law violation as a function of various geometric, traffic, socioeconomic and demographic characteristics of different communities

(b) Collection and processing of crash data as well as geometric and demographic data to develop the safety performance function or regression equation in the model

(c) Analysis and interpretation of model findings; that is, engineering judgment of factors causing fatigue as well as law violation

## 3.3 QUESTIONNAIRE DETAILS

The questionnaire is prepared based on three fundamental sources. The first sources are the previous studies conducted on the topic, the second source is the local context and the third source is drivers' interview. The first set of questions based on the demographic content and socio-economic background of drivers. This set is followed by fatigue related information, vehicle and licensing, road geometry related questions, travel pattern, trip details, accident data etc

## 3.4 DEVELOPING QUESTIONNAIRE AND SURVEY DETAILS

The main steps in the survey processes are listed below

Selection of the main locations.

The locations selected are listed below:

1. Mohakhali inter district bus stand
2. Gabtoli inter district bus stand

The questionnaire is shown below:

**01. Drivers Demographic Data**

**Name of the Driver:**

**Age**

- 21-25
- 26-35
- 36-45
- 46-55
- 56-60
- Upper 60

**Educational Background**

- Primary
- Secondary
- SSS
- HSC
- Honors
- Masters

**Monthly Income level**

- Below 10,000 taka
- 10,000- 20,000 taka
- 20,000-30,000 taka
- 30,000-40,000 taka
- 40,000-50,000 taka
- Upper 50,000 taka

**Marital status**

- Married
- Unmarried

**Job Type**

- Full Time
- Part Time

**02. Information Regarding Fatigue**

**Is the driver aware about fatigue?**

- Yes
- No

**Did he ever faced**

| | | |
|---|---|---|
| **Difficulty of focusing** | **Yes** | **No** |
| **Drifting from lane** | **Yes** | **No** |
| **Slower reaction Time** | **Yes** | **No** |
| **Feeling restless** | **Yes** | **No** |
| **Missing traffic signal** | **Yes** | **No** |

**03. Vehicle and licensing**

**Type of Vehicle**

- Passenger Bus
- Truck

**Fitness of Vehicle**

- Very poor
- Poor
- Normal
- Good
- Well facilitated

**Does he have a license** Yes No

**Got the license before**

- 1 month
- 1-6 month
- 6-12 month
- 2 years
- 5 years
- More than 5 years

**<u>04. Work related information</u>**

**Daily Driving Hour**

- Below 5 hour
- 5-8 hour
- 8-10 hour
- 10-12 hour
- 12-14 hour
- Upper 14 hour

**No of Trips per day**

- Single trip
- Multiple trip
- More than multiple trip
- Not certain

**Per trip distance Driven**

- Below 200 km
- 200-400 km
- 400-600 km
- 600-800 km
- 800-1000 km
- Upper 1000 km

**Number of break taken during a trip**

- None
- Once
- Twice
- More than Twice

**Duration of the break (if taken)**

- Below 5 minutes
- 5-15 minutes
- 15-30 minutes
- Upper 30 minutes

**Gap between trips**

- Below 1 hour
- 1-5 hour
- 6-10 hour
- 11-15 hour
- 16-20 hour
- Upper 20 hour

**Shift type**

- Day shift
- Night shift

**Shift patterns**

- Straight
- Split
- Irregular

**Off day in a week**

- None
- Not fixed
- One
- Two
- Three
- More than Three

**On off day usually does**

- Does another job
- Goes for recreational purpose
- Spends time with family
- Does personal work
- Sleeps
- Other

## 05. Sleep related Questions

**Daily sleeps**

- Below 4 hours
- 4-6 hours
- 7-9 hours
- 10-12 hours
- 13-15 hours
- Upper 15 hours

**On duty day sleeps**

- Below 4 hours
- 4-6 hours
- 7-9 hours
- 10-12 hours
- 13-15 hours
- Upper 15 hours

**Does have any Sleep delated diseases**

| | | |
|---|---|---|
| Excessive daytime sleepiness | **Yes** | **No** |
| Obstructive sleep apnea syndrome | **Yes** | **No** |

Others

## 06. Road Geometry related Questions

**Basic Route**

- Dhaka to
- Not specified

| | | |
|---|---|---|
| **Feels the road environment monotonous?** | **Yes** | **No** |
| **Does the roads have enough resting facility?** | **Yes** | **No** |

**<u>07. Drug consumption</u>**

| | | |
|---|---|---|
| **Tobacco Consumption** | Yes | No |
| **Prescribe/non-prescribed medicine consumption** | Yes | No |
| **Alcohol Consumption** | Yes | No |

**<u>08. Accident data</u>**

**How many accident faced in past 5 years:**

**How many of the fatal accident in past 5 years:**

**How many of the accident were due to fatigue in past 5 years:**

**How many of the accident were fatal which occurred due to fatigue in past 5 years:**

**<u>09. About the Vehicles owners</u>**

**Relation with the owner/employer/supervisor**

- Very bad
- Bad

- Moderate
- Good
- Very Good

| | | |
|---|---|---|
| **Faced pressure for doing over time** | Yes | No |
| **Ever Granted leave for fatigue** | Yes | No |

Figure 3.1: Data Collection


## 3.5 STATISTIC MODEL

The principal objective of a statistical model is to identify a probabilistic system of the form

$$Y = f(X)$$

Where the dependent variable $Y$ is a function of a set of independent variables X. The regression analysis of the above-mentioned form examines: a) whether the observed patterns in the data are consistent with theoretical prediction; and b) the relationship between a quantitative dependent variable and one or more quantitative or qualitative independent variables.

Many accident frequency studies show that the dependent variable Y usually represents the total number of annual traffic accidents as a count outcome and the independent variables X represent the associated roadway geometrics, traffic and regulatory controls, and other relevant characteristics. The theoretical effect of X on Y is called systematic effect (Winkelmann, 1997).

Traffic planners and researchers are mainly interested with the systematic variations as it can be affected by changes in geometry and other road features. The other component, called the random variation, disturbs the identification of the systematic variation. It is the coexistence of the systematic and random effects that is addressed by statistical regression models.

This section gives a detail description of the statistical models which will be used for accident frequency analysis, their mathematical form, assumptions and limitations. These models are poisson and negative binomial regression models. A detail description of model evaluation that includes tests based on AIC criteria and goodness of fit will then be discussed. Finally, a method to find the elasticity of independent variables will be described.

$$\mathbf{Y = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \ldots\ldots\ldots\ldots\ldots + \beta n\ Xn + €} \ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Y will be

- Involvement in violation of traffic law

X will be

The factors that influence drivers' fatigue

Example – drivers age, duration of driving, type of road etc.

### 3.5.1 Multiple Linear Regression Model

The most widely used regression model to analyze collision frequency data is the multiple linear regression model (Hakkim, 1984) which is given by:

$$\boldsymbol{y} = \boldsymbol{X\beta} + \boldsymbol{\varepsilon} \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where y is the number of collisions

X is a vector of explanatory variables

$\boldsymbol{\beta}$ is a vector of parameters to be estimated

$\boldsymbol{\varepsilon}$ Is the error term

The assumptions of the MLR model are:

a) Expectation of the error term is zero

b) Homoscedasticity: variance of the errors is the same regardless of the value of X

c) Normality: the error is normally distributed

d) Independence: the observations are free from autocorrelation.

However, since accident data are usually random, discrete, nonnegative, and sporadic and count data, there are a lot of undesirable properties in MLR such as assumption of normality and common variance as well as the possibility of negative outcomes that results in misinterpretation of count data (Jovanis and Chang, 1986). To overcome the problems associated with MLR models, Jovanis and Chang (1986) proposed that the Poisson regression should be instead used for modeling accident frequencies.

### 3.5.2 The Poisson Regression Model

Joshua and Garber (1990), Miaou et al. (1992) and Miaou and Lum (1993) studied the relationship between highway geometric factors and accidents and all of them came to the conclusion that Poisson regression model is superior to MLR to describe discrete, random, non-negative, sporadic accident data.

The basic assumptions of Poisson distribution are:

a) Probability of more than one event occurring in a short period of time is zero;
b) Probability of one count in a subinterval is the same for all subintervals and proportional to the length of the subinterval; and
c) Count in each subinterval is independent of other subintervals.
If event $n$ occurs according to a Poisson process with parameter $\mu$, then the Poisson distribution can be written as:

$$\Pr(n_{it}|\mu_{it}) = \frac{e^{(-\mu it)} * (\mu it)^{n_{it}}}{n_{it}!} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

By simplifying

$$\ln \mu_{it} = \beta\, x_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

$\mu_{it}$ = Number of violations

$x_{it}$ = The factors that influence drivers' fatigue

The main limitation of using Poisson regression model for accident analysis, as described in a considerable number of studies (Cox, 1983; Dean and Lawless, 1989), is that the variance of the data is restrained to be equal to the mean

### 3.5.3 Negative Binomial Model

In many previous studies, it has been observed that accident frequency data tend to be over-dispersed; that is, the variance is significantly greater than the mean (Shankar et al., 1995; Poch and Mannering, 1996). Consequently, the choice of Poisson distribution model can lead to erroneous coefficient estimate and wrong inference. To overcome this problem, the negative binomial distribution, which includes a gamma-distributed error term in the parent Poisson model, was developed. This relaxes the Poisson‘s mean variance equality constraint and takes the unobserved heterogeneity into account.

The negative binomial model is derived by rewriting equation

$$\ln \mu_{it} = \beta x_{it} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.5$$

Where $\varepsilon_{it}$ is an error term with a mean one and variance

The resulting probability distribution under the negative binomial assumption is:

$$\Pr( n_{it}|\mu_{it}, k) = \frac{\sqrt{(n_{it}}+1/k)}{\sqrt{\left(\frac{1}{k}\right)}n_{it}\,!}\left(\frac{k\mu_{it}}{1+k\mu_{it}}\right)^{n}\left(\frac{1}{1+k\mu_{it}}\right)^{\frac{1}{k}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.6$$

in which k > 0 is often referred to as over-dispersion parameter. If k reduces to zero, then the NB model reduces to the Poisson regression model. In this way, the Poisson regression model is nested within the NB and a t-test for k = 0 can be used to evaluate the significant presence of over-dispersion in the data. In negative binomial model, it is assumed that unconditional mean $\mu it$ is independently distributed over time. For this specification, the mean and variance will respectively be:

$$E\,(n_{it}|\mu_{it}, k) = \mu_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.7$$

$$Var(n_{it}\ \mathrm{I}\ \mu_{it}, k) = \mu_{it}(1+ k\mu_{it}) \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.8$$

The mean variance relationship of the distribution is given by

$$Var(n_{it}\ \mathrm{I}\ \mu_{it}, k) = E(n_{it})[1+ kE(n_{it})] \quad \ldots\ldots\ldots\ldots\ldots\ldots \; 3.9$$

This function is maximized to obtain coefficient estimates for $\beta$ and k. Several researchers have employed this negative binomial (NB) distribution and they have proved that NB model is better than Poisson model to analyze accident data (Miaou, 1994; Kulmala, 1995; Shankar et al., 1995; Poch and Mannering, 1996; Abdel-Aty and Radwan, 2000).

## 3.6 SUMMARY OF STATISTICAL MODELS USED IN THE STUDY

The mathematical form, assumptions and limitations of Poisson regression model is presented in the previous topic. Negative binomial regression model will be employed in our study instead.

The negative binomial distribution, especially in its alternative parameterization described above, can be used as an alternative to the Poisson distribution. It is especially useful for discrete data over an unbounded positive range whose sample variance exceeds the sample mean. In such cases, the observations are over dispersed with respect to a Poisson distribution, for which the mean is equal to the variance. Hence a Poisson distribution is not an appropriate model. Since the negative binomial distribution has one more parameter than the Poisson, the second parameter can be used to adjust the variance independently of the mean.

# CHAPTER 4

# RESULTS AND INTERPRETETION

## 4.1 INTRODUCTION

The analysis will be conducted in the study: Analysis of data for finding out key factors that cause fatigue and law violation in inter-district bus drivers; to isolate the most extreme group of drivers which will help policy makers to take required measures to minimize accidental occurrences and ensure road safety.

In the analysis one model is employed: Negative binomial regression model, as the accident frequency data tend to be over-dispersed; that is, the variance is significantly greater than the mean (Shankar et al., 1995; Poch and Mannering, 1996).

The preliminary analyses is performed, and the final model is estimated, using STATA 12.

## 4.2 MODEL DEVELOPMENT

An important task in developing the models would be the selection of appropriate factors. Three approaches were used to select these factors. First, we reviewed similar research to determine which factors had been examined. Second, we focused on the local context to determine other variables that might have some influence. At last, we conducted a questionnaire survey on bus drivers for collecting necessary data for the prediction model.

The independent variable set consists of three main contexts. The contexts are demographic background, socio-economic background and travel pattern of the drivers. No variables were excluded in the model and all of them were incorporated in the model to figure out list of significant factors that affect the depended variables. Some of the independent variables are age, gender, monthly income, education level, trips per day etc.

The model contains 113 variables formed from 32 factors as shown in Table 4.1. The coefficient, standard error, Z-value, P-value etc. of the 13 variables are also recorded in Table 4.2

## 4.3 RESULTS

Table 4.1: Summary Statistics

| Variables | Mean | Std. Dev |
|---|---|---|
| **Location** | | |
| Gabtoli | 0.746 | 0.437 |
| Mohakhali | 0.237 | 0.427 |
| **Age** | | |
| Up to 25 | 0.018 | 0.132 |
| 25 to 44 | 0.465 | 0.501 |
| 45 to 60 | 0.509 | 0.502 |
| >60 | 0.009 | 0.094 |
| **Educational Background** | | |
| Primary | 0.711 | 0.456 |
| JSC | 0.202 | 0.403 |
| SSC | 0.070 | 0.257 |
| HSC | 0.018 | 0.132 |
| Honors | 0.000 | 0.000 |
| **Monthly Income(BDT)** | | |
| Below 10000 | 0.026 | 0.161 |

| | | |
|---|---|---|
| 10000-20000 | 0.702 | 0.478 |
| 20000-30000 | 0.272 | 0.447 |
| 30000-40000 | 0.009 | 0.094 |

| | | |
|---|---|---|
| **Marital Status** | 0.868 | 0.340 |
| **Pattern of work** | 0.377 | 0.487 |
| **Chronic diseases** | | |
| Diabetes | 0.123 | 0.330 |
| Hypertension | 0.026 | 0.161 |
| Heart diseases | 0.009 | 0.094 |
| Others | 0.070 | 0.257 |
| None | 0.491 | 0.502 |
| **Aware of Fatigue** | 0.447 | 0.499 |
| **Fitness of vehicle** | | |
| Very poor | 0.000 | 0.000 |
| Poor | 0.053 | 0.224 |
| Normal | 0.439 | 0.498 |
| Good | 0.421 | 0.496 |
| Well facilitated | 0.088 | 0.284 |
| **Safety education** | 0.254 | 0.437 |
| **License obtained from** | | |
| Within 6 months | 0.000 | 0.000 |
| 6 months-1 year | 0.000 | 0.000 |
| Within 2 years | 0.000 | 0.000 |
| Within 5 years | 0.175 | 0.382 |

| | | |
|---|---|---|
| More than 5 years | 0.825 | 0.382 |

| | | |
|---|---|---|
| **No of trips per day** | | |
| Single trip | 0.386 | 0.489 |
| Double trip | 0.489 | 0.491 |
| More than Double trip | 0.009 | 0.094 |
| **Daily driving hour** | | |
| Below 5 hours | 0.000 | 0.000 |
| 5-8 hours | 0.000 | 0.000 |
| 8-10 hours | 0.053 | 0.224 |
| 10-12 hours | 0.105 | 0.308 |
| 12-14 hours | 0.351 | 0.479 |
| Upper 14 hours | 0.491 | 0.502 |
| **Distance per trip** | | |
| Less than 100 km | 0.000 | 0.000 |
| 100-200 km | 0.175 | 0.382 |
| 200-300 km | 0.307 | 0.463 |
| 300-400 km | 0.465 | 0.501 |
| >400 km | 0.053 | 0.224 |
| **No of break** | | |
| None | 0.140 | 0.349 |
| Once | 0.807 | 0.396 |
| Twice | 0.035 | 0.185 |
| More than twice | 0.018 | 0.132 |

| | | |
|---|---|---|
| **Gap between trips** | | |
| Below 1 hr | 0.140 | 0.349 |
| Up to 1 hr | 0.000 | 0.000 |
| 1-2 hr | 0.202 | 0.403 |
| 2-5 hr | 0.368 | 0.485 |
| Not continuous | 0.289 | 0.456 |
| **Pedestrian** | 0.807 | 0.396 |
| **Heavy food** | 0.412 | 0.494 |
| **Horne** | 0.912 | 0.284 |
| **Total crash** | 3.684 | 4.818 |
| Fatal accident | 0.211 | 0.792 |
| Injured/Hospitalized | 1.711 | 3.119 |
| Property damage | 1.746 | 2.492 |
| **Law violation** | 5.228 | 5.411 |
| Over speeding | 2.188 | 2.653 |
| Wrong siding | 1.789 | 2.359 |
| Signal breaking | 0.140 | 0.808 |
| Wrong route | 0.000 | 0.000 |
| Illegal parking | 0.658 | 1.885 |
| Others | 0.465 | 2.108 |

| | | |
|---|---|---|
| **Off day activity** | | |
| Does another job | 0.000 | 0.000 |
| Goes for recreational purpose | 0.000 | 0.000 |
| Spends time with family | 0.579 | 0.496 |
| Does personal work | 0.167 | 0.374 |

| | | |
|---|---|---|
| Sleeps | 0.246 | 0.432 |
| Other | 0.009 | 0.094 |
| **Off day sleeping hour** | | |
| Below 4 hours | 0.000 | 0.000 |
| 4-6 hours | 0.035 | 0.228 |
| 7-9 hours | 0.070 | 0.257 |
| 10-12 hours | 0.263 | 0.442 |
| 13-15 hours | 0.281 | 0.451 |
| Upper 15 hours | 0.368 | 0.485 |
| **On day sleeping hour** | | |
| Below 4 hours | 0.679 | 0.469 |
| 4-6 hours | 0.316 | 0.467 |
| 7-9 hours | 0.009 | 0.094 |
| 10-12 hours | 0.009 | 0.094 |
| 13-15 hours | 0.000 | 0.000 |
| Upper 15 hours | 0.000 | 0.000 |
| **Drug consumption** | | |
| Medicine due to sleep | 0.070 | 0.257 |
| Other medicine for health problem | 0.202 | 0.403 |
| **Tobacco consumption** | | |
| Never | 0.123 | 0.330 |
| Regularly | 0.763 | 0.427 |

| | | |
|---|---|---|
| Occasionally | 0.061 | 0.241 |
| **Alcohol consumption** | | |
| Never | 0.816 | 0.389 |
| Regularly | 0.000 | 0.000 |
| Occasionally | 0.053 | 0.224 |
| **Relation with owner** | | |
| Very bad | 0.000 | 0.000 |
| Bad | 0.000 | 0.000 |
| Moderate | 0.272 | 0.447 |
| Good | 0.614 | 0.489 |
| Very good | 0.114 | 0.319 |
| **Fatigue due to jam** | 0.956 | 0.207 |
| **Improper driving of other vehicle's driver** | 0.947 | 0.224 |

| | | |
|---|---|---|
| **Driving season** | | |
| Summer season | 0.482 | 0.502 |
| Winter season | 0.307 | 0.463 |
| Rainy season | 0.228 | 0.421 |
| **Driving route** | | |
| Dhaka-Mymensingh | 0.088 | 0.284 |
| Dhaka-Panchagarh | 0.544 | 0.500 |
| Dhaka-Khulna | 0.035 | 0.185 |
| Dhaka-Chittagong | 0.228 | 0.421 |
| Dhaka-Dinajpur | 0.018 | 0.132 |
| Dhaka-Faridpur | 0.114 | 0.319 |

## 4.4 MODEL EVALUATION

To confirm suitability of the fitted model, the likelihood-ratio chi-square test that the dispersion parameter alpha is equal to zero. The test statistic is negative two times the difference of the log-likelihood from the poisson model and the negative binomial model, Likelihood-ratio test of alpha=0: chibar2 (01) = 76.10. The Pseudo $R^2$ value is 0.1302. The model can be considered to fit satisfactorily.

## 4.5 INTERPRETATION OF SIGNIFICANT VARIABLES IN THE MODEL.

After performing the analysis, 13 factors were retained in the model. These factors are shown in under socioeconomic and demographic characteristics which were used mainly as control variables.

Negative binomial regression | Number of obs = 114
LR chi2(13) = 81.35
Dispersion = mean | Prob > chi2 = 0.0000
Log likelihood = -271.6613 | Pseudo R2 = 0.1302
Likelihood-ratio test of alpha=0: chibar2(01) = 76.10 Prob>=chibar2 = 0.000

Table 4.2: Significant Factors

| **Factors** (Violation Law) | **Coeff.** | **Std.Err** | **Z** | **P Value** | **[95% Conf. Interval]** | |
|---|---|---|---|---|---|---|
| Unauthorized movement of pedestrian | 0.912 | 0.278 | 3.280 | 0.001 | 0.366 | 1.457 |
| No break taken by the driver during trip | -1.520 | 0.318 | -4.770 | 0.000 | -2.144 | -0.896 |
| Two break taken by the driver during trip | 2.304 | 0.864 | 2.670 | 0.008 | 0.610 | 3.998 |
| Fitness of the vehicle (well facilitated) | -1.632 | 0.486 | -3.360 | 0.001 | -2.585 | -0.679 |
| relation of the driver with the owner very good | -0.927 | 0.381 | -2.430 | 0.015 | -1.673 | -0.181 |
| If the driver had any safety education course or training | -0.438 | 0.221 | -1.980 | 0.048 | -0.872 | -0.004 |
| if the drivers consume alcohol occasionally | 0.928 | 0.347 | 2.680 | 0.007 | 0.249 | 1.607 |
| Marital Status of the driver | 0.513 | 0.264 | 1.940 | 0.052 | -0.005 | 1.031 |
| Monthly Income of the driver 20,000-30,000 taka | 0.609 | 0.248 | 2.450 | 0.014 | 0.122 | 1.095 |
| Per trip distance driven by the driver 200-300 km | -0.377 | 0.192 | -1.960 | 0.050 | -0.754 | 0.000 |
| relation of the driver with the owner moderate | 0.326 | 0.189 | 1.720 | 0.086 | -0.046 | 0.697 |
| Fitness of the vehicle good | -0.472 | 0.190 | -2.490 | 0.013 | -0.843 | 0.697 |
| If the pattern of work of the driver is alternative | -0.514 | 0.225 | -2.280 | 0.023 | -0.955 | -0.072 |

Table 4.3: Summary of Results

| **Factors** | **Negative/Positive impact** |
|---|---|
| Driver's safety education (course or training) | - |
| Drivers alcohol consumption | + |
| Fitness of the vehicle (good) | - |
| Fitness of the vehicle (well facilitated) | - |
| Marital Status of the driver | + |
| Monthly Income (BDT 20,000-30,000) | + |
| Number of break taken during trip (twice) | + |
| Number of break taken (None) | - |
| Pattern of work of the driver | - |
| Per trip distance driven (200-300 km) | - |
| Relation with the owner (moderate) | + |
| Relation with the owner (very good) | - |
| Unauthorized movement of pedestrian | + |

N.B: '+' → Factors increase violations

'-' → Factors decrease violations

## 4.6 SUMMARY FINDINGS

The first variable (unauthorized pedestrian movement) has a coefficient value of (+ve) .9118156 that denotes that it increases the possibility of causing divers' fatigue as well as law violation. It can be easily explained that due to under-developed pedestrian movement facility in Bangladesh the drivers are subjected to disturbance caused by the pedestrian. It can easily fluctuate the drivers' concentration on wheels. Whereas the second variable which is (No breaks taken by the driver) has a (-ve) value of 1.5198 which refers that it decreases the probability of law violation and accidents occurrences. At first assumption it may lead to a contradictory situation but it can be explained from a different perspective which might be that-drivers taking no breaks in trips have higher concentration on wheels due to lack of distraction or time management. As they know that they have enough time and no hurry in reaching destination.

The third variable- drivers taking two breaks in a trip has a (+ve) value of 2.3041 that indicates that it could significantly increase law violation as well as accidents. This might be a result of time management problems that projects a distraction and stress on drivers' schedule and driving behavior. Usually the breaks are for about 20-30 minutes each, which can significantly lessen the driving hour while driver are active. A psychological stress is overlaid on drivers driving behavior leading increased law violation and fatigued state.

The next variable is about the well-facilitated fitness of the vehicle which has a (-ve) effect on law violation. In cases where the vehicle has a well-supported facility including good suspension, air conditioning system, best motor and chassis condition and breaking system are less likely to be involved in law violation.

The fifth variable denotes drivers 'good relationship with owners can be a preventive measure for diminishing crash/accidents/law violation in Bangladesh as the analysis shows that it has a negative value of coefficient.

From the quantitative and qualitative survey we expected that those divers having any kind of training or safety education should be in less risk than those who have no training. As the variable has a negative value of 0.43801, it supports the presumption and proves that it decreases the law violation possibility.

Occasional consumption of alcohol could lead to significant risk in driving hours. This results in hallucination, lengthen response time, compromising diving skills and decision making. Thus this variable has a (+ve) value of 0.9280.

As the next variable which is married drivers, has a (-ve) coefficient value, denoting that it could lead to increase the possibility of law violation. This might be the excessive family stress which is responsible for distraction for drivers while driving.

Monthely income of approximately 20000-30000 BDT has a positive coefficient on law violation. This may be a result of excessive driving hours to income more in every trip because all the drivers we have talked have no certain monthly salary rather per day income for each trip.

From the next variable which is the driving distance per trip of 200-300km. Is has a coefficient of (-ve) value showing that long route trips are less subjected to fatal accidents and law violation. As the transport system in Bangladesh is way lagging behind comparing with developed countries, sometimes traffic condition, slower speed might help drivers to maintain certain concentration.

As before it was explained that drivers having good relationship with owners have lower risk, whereas in contrast drivers with moderate relationship with owners are likely to be involved in more law violation as it has a (+ve) coefficient.

The last variable (Alternative pattern of work) shows that it decreases the possibility of law violation. This can be explained as- drivers with continuous pattern of work are subjected to more stress which easily make them fatigue and assist in violating law.

# CHAPTER 5

# CONCLUSIONS AND RECOMMANDATIONS

From this study we can conclude that drivers having alternative pattern of work are less likely to be involved in law violation whereas continuous pattern of work could be significantly responsible for accidental risks as well as crashes and law violation.

On the other hand having any kind of safety education or training could change the driving behavior of a driver in a positive manner that can allow to have a safe driving as well as avoiding serious crashes due to fatigue.

Furthermore in this study we have seen that consumption of alcohol could be a significant factor which causes mental distraction, deterioration of response time in a word hinders driver's normal skills. This could lead to serious law violation which might include fatal crashes.

Fitness of the vehicle is also a considerable factor in road safety. From the previous discussion we found that vehicles those have good fitness and other facilities including comfortable environment, safety kits, good performance are likely provide an upper hand for the drivers to drive safely.

Unauthorized pedestrian movement can directly affect the driving performance and it might be an initial cause of causing road accidents. In Bangladesh presence of numerous industries, factories, markets, educational institution etc. beside highways trigger the roadside accidents which should be considered as well.

## 5.1 RECOMMENDATIONS

To promote safe road environment and minimizing crashes and accidents it is very much important to identify driver's fatigue and the factors those causes fatigue. Road accident has become a daily and deadly phenomenon in Bangladesh which has one of the worst crash rates in the world, at more than 60 per 10,000 registered motor vehicles. The official death toll for road traffic accidents is about 4,000 a year, but Nirapad Sarak Chai gave a higher figure of 5162 accident related deaths in 2013, which also include deaths en route to hospital and deaths after release from hospitals.

Road safety activists blame shoddy roads, poorly maintained vehicles and reckless drivers for such fatal accidents causing thousands of deaths every year. Studies researches show multifaceted causes of road accident ranging from population explosion, unplanned urbanization, and tremendous growth of motorized as well as non-motorized and para-transit vehicles. The situation has also been accelerated by engineering defaults of roads and highway including architecture of vehicles.

To minimize this worst case scenario policy makers and respective authorities should provide pedestrian safety through constructing foot over bridge, widened footpath and regulations on constructing academic, industrial, residential institution beside busy and important roads. Creating awareness could help in implementing this mitigation measures.

Vehicle fitness should be strictly checked and maintained by proper law enforcement. Bus owner and various governmental and non-governmental organization should focus on various safety educational training, seminars, awareness campaign for drivers. This could improve the current situation in a grand scale. Research and experience both suggest that effective progress here requires a holistic response covering awareness, legislation, regulatory capacity, quality engineering, professional capacity, appropriate transportation policy, trauma care and victim support.

## 5.2 LIMITATIONS AND FUTURE RESEARCH

The research has been conducted considering several limitations. In this study, some variables that might have significant effect on solution choice are omitted due to lack of data which is an inherent problem in many applied research.

We can get a comparison between different studies and find out new variables that are playing a significant role in solution preference. New variables will increase the predictability power of the model in general and outcome of the model will be much stronger and precise for practical implementations. The data collected in the study can be used to develop other prediction models. The data used in this study can be used to formulate different models including travel pattern models, mode choice models etc.

This study has been performed in a micro scale that included only Dhaka city. A macro scale study approach will strengthen the results of this study by developing a more precise statistical analysis. The response rate could be increased through previous notification; such as seminars, awareness booth etc. FGD (Focused group discussion) and KII (Key informant interview) approach can be applied.

In this study it was our primary goal to identify the most extreme group of drivers so that further research can be conducted for a more precise, accurate and advanced approach.

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