PERFORMANCE EVALUATION OF FLYOVERS CONSTRUCTED OVER LEVELCROSSINGS IN DHAKA CITY

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A Thesis Submitted to the Department Of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, in partial fulfillment of the degree of

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by

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The thesis titled **"PERFORMANCE EVALUATION OF FLYOVERS CONSTRUCTED OVER LEVELCROSSINGS IN DHAKA CITY"**, submitted by **Md. Rakibul Islam**, Student number- 0416042403 P and session April, 2016 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of **Master of Science in Civil Engineering (Transportation)** on 12th of June, 2018.

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DECLEARATION

This is to declare that, except where specific references are made to other investigators, the work embodied in this thesis paper is the result of investigation carried out only by the author under the supervision of Dr. Md. Shamsul Hoque, Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Neither the thesis nor any part of it has been submitted to any other university or other educational establishment for a degree, diploma or other qualification.

মোঃ রাকিবুল ইসলাম

June, 2018

Md. Rakibul Islam
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DEDICATION

I dedicate this thesis to my

Father Md. Robiul Islam

and

Mother Fatema Khatun

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LIST OF ABBREVIATIONS OF TECHNICAL SYMBOLS AND TERMS

ARI	Accident Research Institute
BIWTA	Bangladesh Inland Water Transport Authority
BR	Bangladesh Railways
BRT	Bus Rapid Transit
BRTA	Bangladesh Road Transport Authority
BRTC	Bureau of Research Testing and Consultation
CNU	Congress for New Urbanism
DHUTS	Dhaka Urban Transport Network Development Study
DITS	Dhaka Integrated Transport Study
DMA	Dhaka Metropolitan Area
DMP	Dhaka Metropolitan Police
DNCC	Dhaka North City Corporation
DSCC	Dhaka South City Corporation
DTCA	Dhaka Transport Co-ordination Authority
DUTP	Dhaka Urban Transport Project
FFS	Free Flow Speed
ft	Foot
GOB	Government of Bangladesh
GS	Grade Separation
km/h	Kilometers Per Hour
LGED	Local Government Engineering Department
LOS	Level of Service
MRT	Mass Rapid Transit
RAJUK	Rajdhani Unnayan Kartripakkha
RHD	Roads and Highway Department
SDHPT	Texas State Department of Highways and Public Transportation
SMG	Seoul Metropolitan Government
STP	Strategic Transport Plan

TTI	Texas Transportation Institute
vph	Vehicle Per Hour

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ABSTRACT

So far eight flyovers have been constructed in Dhaka city with an aim to mitigate traffic congestion, enhance mobility and ensure a reliable transportation system. Although, full grade separation has the potential to eliminate conflicts between rail-road traffic and thereby can reduce both congestion and accidents, out of the eight flyovers, six of them are partially grade separated flyovers. Hence, methodological survey and extensive analyses have been performed incorporating temporal variation (weekday, day; weekday, night; weekend, day; weekend, night) to assess how far the objectives have been met through the construction of these flyovers in Dhaka city.

Assessment of classified vehicle data reveals that Banani Overpass has been proved to be most successful in segregating traffic to above-grade facilities (86% segregation) while remaining studied flyovers have performed poorly. Modal assessment revealed that all the flyovers have evidently failed to provide any facilities to non-motorized vehicles and have instead inclined private car and smaller sized vehicles. However, Jatrabari-Gulistan Flyover have been observed to provide maximum usage to the public transport (48 % bus travelling above grade) while remaining are performing very poorly. Assessment of travel speed and free flow speed revealed that Banani overpass (average vehicle travel speed of 36 km/h above-grade and 17 km/h at-grade) has been proved to be most successful in facilitating mobility. Remaining flyovers are performing at their worst. Assessment of queue length and accident data revealed that, Khilgaon flyover has shown the maximum queue length (882 m) and compared to previous studies, Jatrabari-Gulistan Flyover has shown highest increase in congestion rate (168% within last two years). Hence, these two flyovers are the worst in mitigating traffic congestion.

Overall analyses have revealed that the flyovers constructed over the rail-road conflicting points have not been generally successful in segregating traffic to above-grade from at-grade, providing any facility to non-motorized vehicles and public transport, enhancing mobility in urban road, reducing perennial conflicts between rail-road traffic and mitigating traffic congestion in Dhaka. Rather, construction of flyovers is reducing the at-grade road carriageway, making public transport unpopular, shifting traffic congestion from one location to another and diminishing

the future scope for public transit oriented development. Finally the study puts forward suitable recommendations from the light of the study findings to alleviate the associated problems and guides towards a sustainable solution.

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

Due to the increase in world population and the progressive departure of national economies from merely agricultural systems, cities have been undergoing a rapid and often uncontrolled growth [1]. The world population has increased six times and the urban population has multiplied 100 times in the past 200 years [1], [2]. By 2050, 70 percent of the world's population, that is, about 6.3 billion people, will live in the world's major urban areas. ''The fate of our climate will be shaped by the world's cities,'' the CEO of Siemens AG said in November 2009 [3]. At the forefront of the urbanization trend, we see the development of so-called ''megacities'' which, by definition, have a population exceeding 10 million inhabitants. Urban areas across the world, in both developed and developing countries, have become increasingly automobile-dominated and less sustainable [4]. According to recent forecasts, constant population growth and urbanization will bring an additional load of 2.9 billion vehicles to road networks by 2050.

With the acceleration of urbanization process and the limitations of existing road networks in city, traffic congestion is frequently reported to be a megacity's most pressing infrastructural problem [3]. Lindley termed it as a serious and worsening national problem back in 1987 [5]. People's demand for an unobstructed road has surpassed the expansion speed of urban road traffic networks. So the traffic congestion during the peak period has become a great challenge for every city [6]. This will certainly lead to increased air pollution concerns, highly congested roads putting more strain on an already deteriorated infrastructure, and may increase the risk of accidents on the roads as well [7].

In developing countries in particular, cities have experienced a rapid growth in transport-related challenges, including pollution, congestion, accidents, public transport decline, environmental degradation, climate change, energy depletion, visual intrusion, and lack of accessibility for the urban poor [4]. A large amount of economic losses to the local city is caused due to prodigious traffic congestion and will directly affect the city's image and development of the city. A 2011 US urban transport report shows that the travel time delays and fuel consumption are estimated to be $ 121 billion in economic losses and it will increase to $ 190 billion in the future. In China, the most influential of the top ten cities every day cause economic losses estimated at $ 1 billion because of traffic congestion. In addition to the United States and China, traffic congestion in the rest of the world is also a severe challenge [6]. Additionally, the growth in the numbers and usage of the motor vehicle has taken its toll of the environment in many ways, not least of which is through road congestion and vehicle noise and emissions [8]. Banister identified transport sector as a major contributor to environmental pollution. He denoted that with increases in emissions of greenhouse gases (some 26% of carbon dioxide) from transport vehicles, contribution to acid rain (54% of nitrogen oxides and small amounts of sulphur dioxide) and other gases which have effects on morbidity, fertility and mental development (57% of lead, some 74% of carbon monoxide, and 28% of particulate matter – PM10) also increases [9]. Apart from these, driving in highly congested traffic condition would result in higher state stress than driving in low congestion [10]. Shinar claimed that driver aggression is caused by frustration because of traffic congestion and delays [11].

As urban areas are the most dynamic regions on earth and their size has been constantly increased during the past and this process will go on in the future [12], it will be the task of the transport planner and traffic engineer to cope with the uninvited problems like traffic congestion resulting from the escalation of prodigious traffic growth along with unplanned urban sprawl [5], [8]. After anticipating the perennial problems caused by traffic congestion, different approaches have been taken to mitigate the effects of traffic congestion and ensure mobility in urban cities around the world. It was from the 1920's when economists recognized road pricing as a simple way for taxing transportation's external costs – congestion, accident risks, noise and emissions of pollutants. The concept of road pricing was 'revived' in the early 1960's both by American and British transport academics that saw it as one of the few solutions left to deal with the ever-growing problems associated with road congestion [13].

Singapore introduced Area Licensing Scheme (ALS) back in 1975. The scheme requires cars entering or leaving the central business district (CBD) to display an area license in peak periods. Cars carrying at least four passengers were exempt from the charge; so were buses and commercial vehicles, but not taxis. Later in 1990, Singapore introduced "Quota System" to limit the purchase of new cars by Singapore residents to reduce the effect of traffic congestion. In order to be allowed to purchase a new vehicle, individuals must obtain a "certificate of entitlement" (COE) [14].

Arnott considered six categories of alternative or supplementary policies to road pricing as means to alleviate traffic congestion: i) Expansion or upgrading of existing roads, ii) expansion or upgrading of mass transit, iii) regulation, iv) information, v) non-road transport pricing, and vi) changing driver behavior [15].

World Economic Forum demonstrated seven ways how major cities around the world are tackling with traffic congestion. Stockholm's electronic road pricing scheme charges motorists for entering the central city on weekdays, between 06.30 and 18.30. Exemptions apply to buses, taxis, eco-fuel cars, emergency vehicles and drivers coming and going from the isolated island. Parking management and traffic control cameras are two aspects that Barcelona has tried to improve urban mobility with smart technology. The sensors at parking spots and video with analytics provide real-time data on parking availability, which are transmitted through the city's WiFi infrastructure, linking devices belonging the end user and local authorities. Traffic control cameras are connected by fibre optics to the transport authority to monitor traffic in real time, providing the control centre means to increase or reduce the frequency of green lights according to the traffic conditions. Transport for London's online journey planner provides instant advice on routes in the UK capital, with users able to opt for multiple modes of transport, including walking, tube train, bus, over ground train, river transport and bicycle. The key to the success of the integrated journey planner is the willingness of operators to share information and to provide it to the general public. Further mobile versions of the journey planner was developed by private mobile application developers, providing the same experience on the move with the added bonus of GPS tracking, taxi booking and real-time traffic monitoring, giving greater freedom for commuters to choose between modes of transport. Public Light Buses (PLBs), known as mini-buses, complement the standard Hong Kong bus lines, serving areas that are hard to reach efficiently. With the carrying capacity of 16 seats, PLBs are typically faster and more efficient with higher frequency and offer non-stop service. Mini-buses can respond quickly to market demands and provide a more direct, comfortable route for the "last mile". It is a solution to overcome the “last mile” issue, and a solution to regulating illegal transport in megacities. The Danish capital’s integrative system aims to avoid or mitigate traffic congestion. It brings together three transport operators plus information links to agencies, companies and the government. The integrative ticketing system provides ease in ticketing via smart phone application or SMS, providing easy information about location, destination and tickets. It gives users greater flexibility and efficiency when boarding and transferring to different mode of transport. GPS technology enables bus priority on the road, shortening travelling time. The Chinese city of Hangzhou has one of the world’s largest public bike-sharing programmes. The city boasts 67,000 public bikes with 3,000 service points, and had an average daily renting volume of 230,000 bikes in June 2013. One reason for the popularity of the system is its ease of use. Bikes can be rented using either a smart card that can also be used for other types of public transport, or with a cash deposit paid by non-local travelers who do not have a smart card. The convenience of the bike-renting system has proved popular for daily transport and also, in particular, for travelling between different public transport services. Two keys to success of the system have been its integration with tourism in the city -– the service has become a popular activity for tourists – and the innovative bundling of advertisement rights to generate revenue. To tackle the extremely variable traffic flow of the M42, which handles over 120,000 vehicles per day, an active traffic management (ATM) system was piloted in November 2005. This acted as a test-bed to develop a fully flexible, controlled motorway. Variable Message Signs (VMS) are displayed over each lane to allow the speed and lane use to be varied, and specifically to manage traffic flow and lane use at peak times and in response to traffic incidents to combat congestion. During peak hours, speed limits can be reduced using the VMS, so increasing the carrying capacity of the road. The further option of creating new lanes is also available by the temporary opening of hard shoulders to traffic. ATM will also alert drivers of congestion and incidents ahead, giving motorists time to choose alternative routes. The overall system was developed for five times less than the cost of a conventional widening of the motorway according to the Automobile Association. Emissions from vehicles also fell by 10% due to the traffic’s faster travelling speeds and lower fuel consumption due to less gear changing. Although ATM may not be suitable for all highways, it can offer a cost-effective method to tackle congestion for more developed road systems [16].

Pojani and Stead critically reviewed the potential role and impact of nine commonly considered options for sustainable urban transport in cities in developing countries: (1) road infrastructure; (2) rail-based public transport; (3) road-based public transport; (4) support for non-motorized travel modes; (5) technological solutions; (6) awareness-raising campaigns; (7) pricing mechanisms; (8) vehicle access restrictions; and (9) control of land-uses [4]. They proposed some of the key strategies to be considered in the developing cities to ensure sustainable transport include: (1) street conditions conducive to green modes via low-cost interventions such as sidewalk maintenance and speed restraint; (2) pedestrian-only zones in areas with heavy pedestrian traffic; (3) exclusive lanes for buses and bicycles, which are adequately protected from car traffic; (4) reasonable parking fees; (5) more attention to road infrastructure maintenance rather than the construction of new infrastructure; and (6) awareness-raising and education campaigns [4].

The aforementioned strategies have been proven to be scientific and effective tools to mitigate, reduce, avoid or control traffic congestion. However, Dhaka, the capital of Bangladesh, is listed as the second worst livable city in the world [17] and the escalation of prodigious traffic growth along with unplanned urban sprawl of Dhaka city induces an unendurable chronic traffic congestion [1], [18]–[21], which eventually results into safety hazards, economical subsidies and environmental degradations [22]–[24]. However, transport, because of its pervasive nature, occupies a central position in the fabric of a modern-day urbanized nation [8] and serves as channel for economic development of a country [21], various attempts were taken by governments including special meeting with the agencies concerned to devise means to help reduce the intensity of traffic problem in Dhaka city [25]. Unfortunately, the government, the traffic decision makers and the implementers have overlooked the technically proven strategies, as described earlier, adopted by the cities those are successful in mitigating traffic congestion. Rather, a number of flyovers have been built to mitigate traffic congestion in Dhaka city. As development of transportation facilities involve huge amount of resources and time and in most cases transportation investment are irreversible [21], this study is being carried out in an effort to assess how far the objectives have been met through the construction of flyovers [26]–[30].

1.2 Motivation of the Study

Dhaka city's traffic system is considered to be one of the most chaotic ones in the world. The residents are compelled to undergo physical stress and suffer financial losses in terms of man-hours lost on working days [25]. Between 2010 and 2016, the population of Dhaka city, the capital of Bangladesh, has escalated by around 20%, while for the same period the vehicle fleet has grown by about 60% to approximately 950,000 vehicles, reflecting on the enormity of this bustling city [31], [32]. The media, both print and electronic, have been constantly highlighting the sufferings of the commuters in Dhaka city because of the nagging traffic problem. Yet no solution to the problem, apparently, is in sight, at least, in the short and medium terms, though a lot has been said and a big-enough programme, undertaken with the assistance from a multilateral lender to improve the traffic situation of the capital city in recent years [25]. As most of Dhaka city is built-up area [33], there is little provision for at-grade expansion of existing roadway [25]. Hence, a presumptive reliance based local knowledge has been shifted to flyovers to mitigate traffic congestion. Consequently, several flyovers have been built in Dhaka City to improve safety and mobility of at-grade traffic [26]–[30], [34], [35]. This study is carried out in an effort to assess how far the objectives have been met. Regular articles featured on newspapers as well as the author's personal observations revealed that the constructed flyovers may not be performing as expected under given traffic operational conditions [26], [36]–[38]. In addition to that, for a developing country like Bangladesh, grade separations can be very expensive solution and less feasible. So far, all the flyovers constructed in Dhaka city except Kuril and Bijoy Sarani-Tejgaon Link Road flyovers are partially grade-separated i.e. part of the vehicle stream moves at at-grade level remaining through the flyover. With this configuration obviously rail-road conflicts remain as it is underneath the flyover. The full grade separation has the potential to eliminate conflicts between rail-road traffic [39] and thereby can reduce both congestion and accidents. Since fully grade separated flyovers i.e., multi-directional Kuril flyover, do not pose any problem at the level crossing. The study focuses solely on partially grade separated flyovers constructed in the worst livable Dhaka city [40]. In this study a total of six partially grade separated flyovers were studied, which were constructed at a total cost of 2624.5 crore taka [41]–[46]. The present study analyzes the data collected at 4 periods: weekend day, weekend night, weekday day and weekday night and make a comparison among them. Finally, the study compares 2015 data with 2017 data to assess the yearly trend. To the best of the author's knowledge, so far no comprehensive or methodological study has been undertaken at home and abroad to assess the post-construction efficacy of these partially grade-separated flyovers. This motivates the author to conduct a methodological study on performance evaluation of these partially grade-separated flyovers constructed over railway lines in Dhaka.

1.3 Objective of the Study

The main objective of this study is to evaluate the functional effectiveness of the existing flyovers constructed over level crossing and assess how far they are successful in mitigating congestion and enhancing mobility in Dhaka city.

The specific objectives of this study are:

1. To assess the relative level of usage of road space under and over the flyovers.
2. To find the usage of flyover spaces by non-motorized vehicles and public transport.
3. To evaluate the mobility and road accessibility conditions of vehicles both at-grade and above-grade level.
4. To assess the effectiveness of flyovers in terms of reducing traffic congestion levels and improving safety at level crossings.

1.4 Scope of the Study

Significant number of researches have already been done to evaluate the performance and suitability of flyovers in urban city intersection or level-crossing around the world. But these kinds of researches are yet to be conducted in Bangladesh and very few examples are there from other developing countries. From this perspective, the present study is guided by analyses using the data of traffic flow, speed, queue length, and accident record at level-crossings collected by field survey and previous studies. The study covers all the partially grade-separated flyovers constructed over level-crossing within the urban fabric of Dhaka city, the capital of Bangladesh.

It is expected that this research will help transport planners, decision makers and stakeholders to realize that how far the flyovers constructed over level crossings in

Dhaka city are effective in mitigating traffic congestion and enhancing mobility along with road accessibility. They will apprehend the problems imbedded with the solution strategies they are adopting. The study will provide some basic conceptions about flyovers and their applicability in particular situation. Additionally, the study will also facilitate the stakeholders with the real scenario of traffic flow and mobility in context of Dhaka city. This will enable the responsible authorities to take appropriate measures, which in turn, will help to mitigate traffic congestion in Dhaka city and consequently, will improve the mobility condition of the studied area.

On top of that, the study will guide planners, implementers and decision makers to a more reliable, sustainable solution to mitigate traffic congestion and improve mobility within the limited resources for all the cities that are facing chronic traffic congestion. Additionally, the study will facilitate all the cities of developing countries like, Bangladesh with the information that what specific strategies can be taken to mitigate traffic congestion and improve mobility.

1.5 Organization of the Thesis

Apart from this introductory chapter, the remainder of the thesis is structured into five more chapters.

Chapter 2 outlines the theoretical literature reviews relevant to this research. The chapter begins with the conceptual development of flyovers and then describes extensively the historical background of construction of flyovers. It also describes the world's recent views regarding flyovers and finally, it delineates the perspective of flyovers in Dhaka city. It has elaborately described the demographic characteristics of Dhaka city along with the existing transportation system of Dhaka city. It also elaborates the explanations to the emergence of flyovers in Dhaka and gives an insight to find the research conducted to deal with the issue of Flyovers in Dhaka.

Chapter 3 elaborately describes the all the six studied flyovers and presented their schematic layout and also described the methodology adopted to conduct this research. It discusses the selection of the study area along with a brief discussion about those areas. A brief description of reconnaissance survey along with the methodology of the classified traffic count, speed measurement, queue length measurement and sources of secondary data are also described systematically.

Chapter 4 gives a brief description of data collection and presents the collected data in a systematic manner with extensive analyses. It also presents a brief analysis for data collected from secondary sources. This chapter basically describes and presents all the data analyses and study outcomes in four major sections. In the first section, it describes the analyses for assessment of level of usage of road space i.e., at-grade and above-grade. The next section describes the analyses for assessment of flyover usage by non-motorized vehicles compared to motorized vehicles. Section 3 extends and delineates the analyses for assessment of the mobility condition of the vehicles travelling along the flyover corridor. In the final section, a brief analysis has been performed to observe the congestion level and safety condition along the corridor of the studied flyovers. To this end, this chapter provides with the basic outcomes of the study and presents the results extracted from the analyses to fulfill the research objectives.

Chapter 5 sets out the conclusion of the thesis and is organized with the summary of the study as concluding remarks, research contributions, recommendations of the study, limitations of the study, and finally the scope of future studies.

1.6 Overview

This chapter clearly describes the background of this study, why author is motivated to conduct this study, the main and specific objectives of this study, specified scope of this study and finally ends with organization of this thesis work that will be maintained throughout the study. The next chapter systematically elaborates on the literature review related to flyovers and at-grade rail-road conflict and forms a basis to evaluate the performance of the constructed flyovers over level-crossings in Dhaka city.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter aims to outline the theoretical reviews of this research. The following review provides a conceptual overview of development of flyovers as a traffic congestion mitigation tool from the beginning of flyover history. The review studies used in this study placed little emphasis on concepts dealing exclusively with design of flyover. Rather, studies were chosen as if it offered conceptual ideas that could be used as a basis for initiating flyovers oriented towards the improvement of arterial streets. Author also focuses on the developed and western world’s recent views regarding flyovers and how they are dealing with such type of that were previously constructed with a view to mitigating traffic congestion. In addition, this chapter provides a detailed discussion about the overall demographic characteristics and transportation system and policies in Dhaka city. It also covers the regulatory measures and construction related measures proposed in different transportation policies in order to reduce traffic congestion. Besides, this chapter also details an overview on transportation policies that direct the policy-makers and government to construct flyovers with objective in mind to reduce traffic congestion. Finally, a detailed discussion on scientific researches that deal with the flyovers in Dhaka city along with their findings have been presented while the main focus of this study has been clearly stated.

2.2 Conceptual Development of Flyovers

Flyovers first came in concept in early 1970's, when financial and environmental constraints abruptly ended the freeway building programs of the 1950's and 1960's [39]. In that time period, major cities throughout the nation were experiencing considerable surges of population growth and consequently, the traffic demands on each city's transportation infrastructure were increased tremendously. Increased traffic demands raised the overwhelming problem of decreased mobility. Sources of public transportation helped to alleviate congestion to some degree, but the majority of mobility was still handled by highway systems [47]. Transport planners realized that arterial highways will have to carry an ever increasing share of these rapidly expanding travel demand. The growth of residential population and attendant increased in major trip generators and attractors along principal transportation corridors in many urban communities produced traffic volumes which saturated not only the freeway system, but the major arterials as well. Arterial intersections, unable to provide the capacity necessary to maintain safe and efficient traffic movement, produce bottlenecks, long traffic queues and generally retard flow along travel corridors [39]. Therefore, the need to improve these systems had become a matter of utmost importance [47].

The adaptation of grade separation concepts in the form of urban flyovers holds significant potential as an effective and inexpensive strategy for reducing conflicts at major intersections while increasing arterial capacity, efficiency and safety by eliminating stoppage of traffic flow at signals. In addition to that, the rapid construction time for the prefabricated flyover structures offered considerable advantage over conventional bridge construction at locations where the adjacent property was fully developed. The disruption to traffic caused by a conventional bridge construction schedule of 18-24 months would create serious impacts for surrounding businesses. The 30-day construction time schedule offered through use of prefabricated structures greatly minimized this disruption [39].

Bonilla considered conventional interchanges as a solution to these. But they were land hungry and would typically require acquisition of extra right-of-way. Acquiring additional right-of-way to increase the intersection capacity may be contrary to arterial objectives, expensive, and time-consuming. Seemingly contradictory objectives often stall measures to increase the intersection capacity, and the arterial may remain underused indefinitely. Thus he proposed “Flyovers” as a solution to such a dilemma. Bonilla further added that flyovers are warranted when the intersection is a bottleneck and conventional traffic engineering measures cannot resolve the capacity problem; A minimum of four through lanes already exists and maximum use of the intersection right-of-way has been made; The sum of critical lane volumes approaches or exceeds 1,200 vph; It is time-consuming, expensive, or contrary to public objectives to obtain additional right-of-way; A minimum right- of-way of 100 ft is available; Impact to adjacent properties and minor streets limited to right turn only is not severe; The accident rate is significantly larger than for nearby intersections on the same arterial [34].

Lang and Machemehl identified at-grade intersections as a constraint of primary roadway capacity, they considered grade separation as a best means of handling capacity problems. According to them, due to various design constraints and cost constraints, there exists an inherent order in which improvements can be provided to an arterial street. In general, surface treatments such as signal optimization, channelization, and pavement re-striping represent the most cost and time effective means of increasing mobility. They suggested to introduce grade separated facilities whenever all of these relevant at-grade solutions have been exhausted and mobility problems continue to plague an arterial street. The then studies found that because of construction expenses, time requirements, land acquisition problems, and traffic flow disruptions, grade separation was becoming popular in earlier time. Many cities with congested arterial streets developed plans to alleviate their traffic congestion through the strategic placement of grade-separated facilities at overly saturated intersections [47].

It was believed that the installation of flyovers could reduce vehicle delay not only for the installation sites, but also for the intersections immediately downstream from these sites, through a dispersal of the vehicular platoons that form as a result of traffic signal control. Lang and Machemehl demonstrated that grade-separation has the potential to increase intersection capacity, thereby improving mobility and decreasing delay [47]. In addition to that, limited access highways in the city were considered as the epitome of modernity, reflecting the ever increasing speed of everyday life and the distancing of individuals from communities and place [48].

Throughout the 1950s and 1960s, cities across the United States saw huge infrastructure investments in their downtowns in the form of freeways. The freeways, viewed as a necessity and sign of progress, were aimed at expanding mobility, promoting economic development, and helping to revitalize inner-urban areas [49].

Flyovers were used extensively and successfully in both Europe and the Middle East around 1980. [50]. In many European cities flyovers were widely used to alleviate traffic congestion, but design standards imposed by the highway establishments in the United States had severely limited the construction of such interchanges. American grade separation structures were built with heavy-weight, high-speed trucks in mind, while on the other hand European flyovers are typically meant to alleviate automobile traffic exclusively. With this in mind and the fact that flyovers; use minimal right-of-way, require very little installation time, and have the potential to reduce energy consumption and car emissions, Pleasants suggests that flyovers are a viable solution for American arterials [47], [51].

Policy supporting flyover construction is often justified on the grounds that the capacity expansions provide benefits through 'travel time savings'. The arguments put forward the fact that a reduced travel time enhances accessibility to goods and services, creates economies of scale, increases property values and facilitates the opening of new opportunities (e.g. companies, retail shops or other) along a capacity expanded corridor [52].

All these factors lead to the flourishing of flyovers in the earlier time period.

2.3 Flyover and Its Historical Development

This section provides the definition of "Flyover" delineated by the previous literatures and the key findings from freeway history mostly with the after-effects with respect to mitigate congestion, enhance mobility, and accessibility in the cities; where they were implemented. Rationale for presenting previous implications established from the historical development of flyovers is to acknowledge their probable connection with the ongoing flyover projects in Dhaka city and thereby create a basis for evaluating their functional effectiveness in terms of mobility and accessibility.

2.3.1 Definition of Flyovers

Flyovers are light-weight, low-cost, prefabricated steel structures that elevate only one or two lanes over a traffic-choked city intersection but dramatically reduce congestion [51].

Flyovers are used at congested arterial intersections as a means of "unlocking" signal optimization strategies to produce a network of "continuous flow boulevards" or "super streets" [50].

The flyover is a grade-separated structure that allows arterial through traffic to go over a crossing arterial or collector without slowing down or stopping for an at-grade signal capacity [34].

Flyovers are an important component of transport infrastructure, and are constructed at busy intersections or along the highways in order to facilitate the uninterrupted movement of traffic. The intended purpose of flyover construction is to reduce congestion in urban areas [53]

The term 'Flyover' is commonly used in the United Kingdom and in most Commonwealth countries to describe a grade separated or elevated bridge, road, railway or similar structure that crosses over another road or railway. It has the similar meaning of overpasses-known in the United States, yet with some differences. They have variable names in different countries and thus the term flyover is not fixed or agreed upon [54].

At an intersection, separating the grade and allowing the heavy traffic-movement to flow uninterrupted can mitigate congestion. Flyover is one such grade separation, where the through traffic-movement is bridged over an intersection [55].

2.3.2 Historical Development of Flyovers

Flyovers are not a new concept. In the late 1950s and early 1960s, Chicago built three arterial flyovers to overcome capacity problems. The then-called "through-lane-overpass" successfully re-moved congestion at bottleneck intersections without impacting nearby ones. The capacity of each of the three arterials where an overpass was built increased from 114 to 300 percent, whereas the peak-hour demand at nine intersection approaches increased by an average of 33 percent. The peak-hour delay decreased from 82 to 17 sec per vehicle, for savings of 80,000 vehicle-hours per year and accidents decreased from 186 to 92 per year, after the flyover became operational, or about a 50 percent reduction [34].

With Congressional approval of the Federal-Aid Highway Act of 1956, United States has spent billions of tax dollars building and maintaining flyovers [54], [56]. Londoners were becoming familiar with these infrastructures after 1960 with the construction of the Westway flyover, which cut a large swathe through north Kensington, and passed very close to Acklam Road, overlooking many residents' windows and the Hammersmith flyover. Partially completed Hammersmith flyover-designed to reduce traffic congestion from central London to the West [57]. At this contemporary time period, a spate of new urban highways were built in Brazil during the dictatorship in the 1960s and 1970s, such as Rio de Janeiro's Rebouças Tunnel and the Freyssinet Viaduct that cut a direct route between the downtown and the fashionable South Zone of Copacabana, Ipanema, and Leblon [54].

An extensive analyses of the design and construction of a flyover were presented by Kroger in 1971. Kroger presented an engineering analysis of a flyover at a congested Hannover traffic circle. Kroger reported that all municipality expectations were met [39], [58].

In 1973, the Red Book provided some general guidelines for building grade separations within the existing right-of-way of arterials [59]. However, it did not incorporate any performance based analysis of flyovers.

Bagon outlined many design aspects of flyover bridge built in Brussels, Belgium (Le. the AB-1 bridge completed in February of 1975.) Although this article is oriented specifically towards bridge design, it pointed out that flyovers can be constructed quickly, thereby reducing the potential interference with traffic operations [47], [60].

Pleasants considered the flyover a distinct traffic improvement alternative not to be confused with conventional grade separation techniques. According to him, by removing 2000 cars per hour from the intersection, flyovers can make a considerable contribution to reducing gasoline consumption by eliminating stop-and-go driving [39], [51].

Byington (1981) pointed out that intersection accidents can be reduced by flyovers if proper attention is given in the structure's end treatment and good advance signing and roadway markings are used. Byington further considered demand volume and capacity, reviewing a range of flyover design formats, and stressed the need to consider not only the traffic utilizing the flyover, but also the remaining ground level flows [61]. Issues of intersection layout, construction time span and flyover costs are treated by Bagon [60], Byington [61], Kroger [58] and Nobels-Kline [39].

During 1983, District 15 of the Texas State Department of Highways and Public Transportation (SDHPT) requested the Texas Transportation Institute (TTI) to investigate the feasibility of using flyovers to reduce congestion at some critical state-maintained intersections. In one case, the evaluation showed that a flyover would be cost-effective, whereas in another no such gain was apparent. These analyses provided useful results but they were time-consuming and costly due to the lack of a simple procedure to evaluate flyovers [34].

Haefner (1985) illustrated and justified the traffic engineering efficiency of a flyover by comparing the capacity of an at-grade signalized intersection to that of the same intersection with a flyover installed [47], [62].

Recker, Root and McNally (1985) identified flyovers as prefabricated low-cost grade separation bridges. Additionally, they examined the feasibility of the development of high flow urban arterials by means of an integration of flyover technology with signal optimization. The findings of the study showed that the use of prefabricated flyovers, in conjunction with signal optimization, can effectively reduce travel delays and stops along heavily congested major arterials. The resulting high flow arterials can function effectively as "continuous flow boulevards," even when embedded in relatively dense urban traffic networks [39].

Bonilla and Urbanik (1986) demonstrated that the capacity of congested arterials can be increased in a cost effective manner through the use of grade separation. This was shown by relating flyover benefits to average approach volumes of the current plus 20 year forecast. Flyover benefits were shown to be dependent on the amount of traffic diverted to the flyover and the ability of the improved intersection to process the remaining at-grade traffic. The report also identified operational considerations, proposed warranting conditions, and suggested implementation guidelines for the flyover development [47], [63].

Bonilla (1987) examined the following design considerations for flyovers: the minimum cross section for a given right-of-way, the at-grade treatments, the traffic capacity, the structures length, the intersection geometrics, the cost-effectiveness of construction, and general warrants for flyover construction. Overall it is pointed out that the implementation of flyovers becomes cost effective when less expensive at-grade solutions have been exhausted [34], [47]. However, it excluded relevant analysis of accessibility and mobility.

Witkowski (1988) made a comparison between an urban-grade separated interchange and an at-grade intersection in terms of the delay, vehicle operating cost, accidents, and vehicle emissions for several traffic demand levels. The study revealed that the urban-grade separated interchange may be economically viable at an average daily demand as low as 40,000 total entering vehicles [64].

All these study's outcomes paved the way to flourish flyovers in that time period and thus, flyovers were considered then as a traffic mitigation tool which can be built quickly with optimum cost and had the potential to decrease delay, increase capacity of the road segment and provide congestion free urban roads.

2.4 Dismantling of Flyovers

"Elevated freeways have done even worse damage to the areas through which they pass. They have blocked out light and air; they have brought blight into the city through their great shadows on the ground and through the noise of their traffic. Worse still, the surfaces under them have been devoted to parking lots, automobile junkyards, cyclone fences, and rubbish. These elements more surely than the freeway itself have gone far to uglify the cities through which it passes." [65].

Flyovers were pushed through the social and physical fabric of many cities without regard to the fact, that they ripped neighborhoods, created physical barriers and blight, exposed residents to negative environmental conditions such car exhaust and excessive noise, forced residents out of their homes, and squandered valuable open space and parkland [49], [54]. The process of planning and implementation of flyovers around the USA nation took place in a short period of time resulting in unexpected negative consequences in entire urban areas [54], [56]. Environmentally brutal with no attempt at landscaping, these flyovers turned locals against similar development. At some point in the 1960s, many Americans too came to focus on the negative consequences of freeway building, as opposed to the demonstrable advantages of modern, high-speed, express freeways serving a nation addicted to automobiles and to mobility [54], [66].

In the 1960s and 70s, civil rights activists and environmental activists joined together in the anti-freeway movement and demanded changes in transportation policy. They criticized the transportation planning process for inadequate treatment of the social and environmental impacts of transportation facilities; for focusing only on long-term plans and ignoring more immediate problems; and for using rigid technical procedures to justify bad projects [54], [67].With time, the opposition to freeways resulted in a “freeway revolt” movement which gained its momentum in the late 1960s and early 1970s. To oppose their growth, influential urbanists such as Jane Jacobs, Lewis Mumford, Herbert Gans and others voiced criticism of urban highways, freeways, expressways and other similar developments, calling for the end of highway construction in inner cities [54].

The proponents of freeways became successful in halting a number of planned freeway projects in USA. By the mid-1970s the combination of the anti-freeway movement, environmental movement, increasing flexibility in federal transportation funding and more local and state control over this funding seemed to be effective in halting the progression of a number of freeway projects across the country. By the early 1990s, the era of new freeway construction in urban areas was largely over. Many cities are re-evaluating past highway policy that pushed elevated interstate highways through central cities, with consequent severe damage to housing, business, and neighborhoods. Moved by the teardown movement of Congress for New Urbanism (CNU), at least two dozen American cities have discusses or planned removals or teardowns of inner city elevated expressways or at least segments of them, and replace them with at-grade boulevards to reclaim the resulting land for housing, recreational space and commercial development as well as to re-knit the urban fabric that was destroyed [68].

More than 30 years ago, Portland, Oregon, Razed Harbor Drive freeway and thus provided the first U.S. example of freeway removal. Since then, San Francisco, California; Milwaukee, Wisconsin; New York City; and Toronto, Canada, have removed elevated freeways, and a number of other cities are currently debating the future of the aging freeway infrastructure [49].

All over the world there is growing consensus against flyovers. Flyovers are not only eye sore but also failed to curb traffic congestion. There is growing consensus among transport planners that demand management is better solution than increased supply. Building flyover is supply solution and it would create its own demand. There is high probability that it would increase congestion. For example, to eradicate traffic congestion in Bangkok Thai government implemented an ambitious plan of series of flyovers with metro (consisting of underground and elevated rail) in and around Bangkok in the early 1990s. However, it did not eradicate problem instead it encouraged people to buy more car. In boom period 1000 cars were added daily in Bangkok traffic and now congestion of 1980s is returning to Bangkok [69].

Today, elevated roadways have become targets of removal for their suppression of development in an increasingly densifying metropolis and the dangers they pose to urban air quality. Boston, New York, Portland initiated such teardowns [54], [68]. The Seoul Metropolitan Government (SMG) recently considered eliminating some useless overpasses that had once played a significant role in maintaining continuous traffic flow but soon lost their original, positive function and became an environmental burden. Seoul has already removed the city's first overpass-Ahyeon Overpass, after torn out 15 freeways in the past 12 years [70].

Researchers also contributed by analyzing the necessity of flyovers from factual point of view. Retrospective analyses of several bypasses were undertaken by Agent in 1975 to determine if accident cost savings would have justified higher initial costs of interchanges. He considered following conditions: a freeway development, elimination of bottlenecks or sport congestion, elimination of hazards, site topography, road-user benefits, and traffic volume warrant. Cost-benefit ratios were calculated from data available from 35 major intersections. He concluded that even with the best possible controls on these bypasses, numerous accidents will continue to occur [71]. In 1981, Byington showed that flyovers are not low-cost permanent solutions for congestion and safety problems at urban and rural intersections [61]. Recker, McNally and Root identified grade separation as a capital intensive approach. They clarified that grade separation is conventionally associated with freeway construction, since the associated standard design expenses in terms of construction dollars, time required, annexation of private lands and disruption of traffic flow restricts their application in urban areas. They concluded that the effects of flyovers on either the diffusion or transfer of congestion is unclear past the spot improvement stage [39]. Bonilla further added that with unlimited right-of-way, there would be no need for a flyover because conventional interchanges can be built and these provide more at-grade capacity than do flyovers [34]. Lang and Machemehl also discouraged flyovers along urban arterials where adjacent right-of-way is generally restricted, and where the acquisition of property is a difficult and expensive venture [47].

Napolitan and Zegras suggested that flyover removal will take place only when (a) the flyover's condition raises concerns about its integrity and safety; (b) a window of opportunity exists, some event that enables a flyover removal alternative to gain serious consideration; (c) the value of mobility is lower than other objectives such as economic development; and (d) those in power value other benefits more than they value the benefits associated with flyover infrastructure [49].

Based on empirical evidence, researchers have questioned the purported benefits of adding or expanding roads [72], [73] . Rahman (2017) has shown that the benefits are overstated due to the omission of 'induced demand' effects in the modelling of traffic growth [52].

Recent studies in Asian region are also highly demotivating the construction and flourishing of flyovers. Bansal and Singh made an approach to cover sustainable designing and construction of series of flyovers, Underpasses, River Bridges and other infrastructure projects taken up in the new millennium in New Delhi, the capital city of India. Delhi had just five flyovers at the end of 1982. At the end of 2014, the number has increased to 74. The findings of the study revealed that half of the increased roadway capacity is consumed by added traffic in about five years, 80 % of increased capacity is eventually consumed by induced traffic. They alarmed that it will be impossible to keep adding to infrastructure beyond its physical limits [74].

Maji et al. (2015) also doubted the overall benefit of flyover in non-lane based heterogeneous traffic state condition in developing countries like Bangladesh. The study described that traffic operations underneath a flyover remain unmanaged and often pose a major concern in developing countries with non-lane-based heterogeneous traffic. According to them, The overall benefits of a flyover may be reduced in such traffic scenario [55].

To this end, flyovers were discouraged to build when the negative consequences of construction of flyovers came to lime light. The process of dismantling of flyovers started around the world since the scientific research investigations and articles recommended it as a capital intensive demand inducing solution with little benefits to mitigate traffic congestion and enhance mobility.

2.5 Perspective of Flyovers in Bangladesh

In recent times, flyovers have been constructed as a priority measure on roadway intersections to reduce traffic congestion in Dhaka city. This section provides a brief overview of Dhaka city along with the city's inter related demographic and traffic characteristics. The study also gives an insight into the basic policies and studies that help to emerge flyovers as a traffic congestion mitigation tool in Dhaka city as well as in Bangladesh. Finally, the present study is aimed to go in depth to the scientific research studies done on these flyovers and conclude why it is imperative to evaluate the performance of these flyovers.

2.5.1 Demographic Characteristics of Dhaka

Dhaka, the capital of Bangladesh and the nation's gateway as well as the economic, business, political, administrative, social, cultural hub of the country, has now been turned into one of the densest megacities of the world. The city is centrally located in Bangladesh, in the southern part of the district of Dhaka. It is situated between latitudes 24º40´ N to 24º54´ N and longitudes 90º20´ E to 90º30´ E and defined by the Buriganga river in the south; the Balu and the Shitalakhya rivers in the east; Tongi Khal in the north and the Turag river in the west [75].

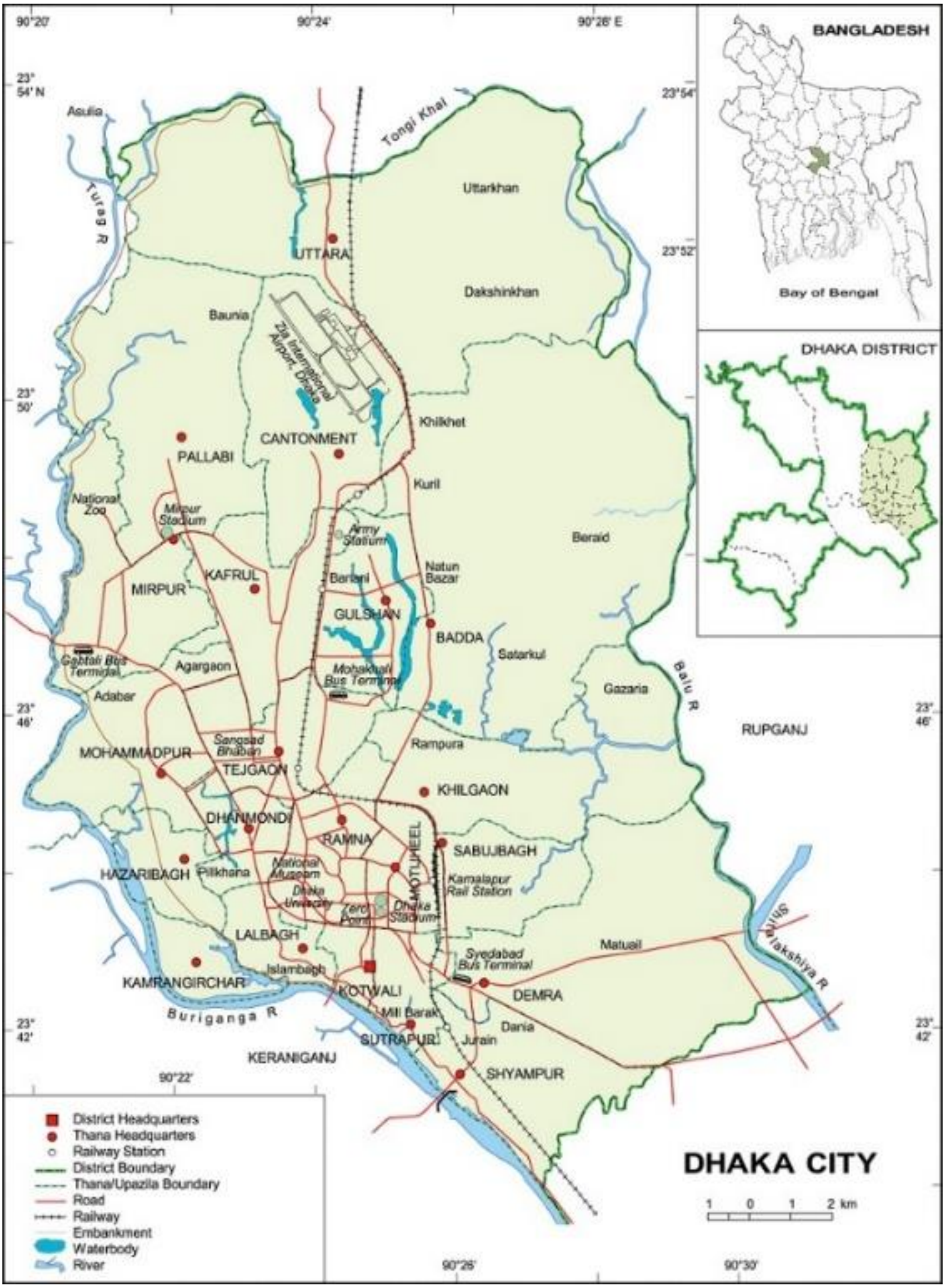
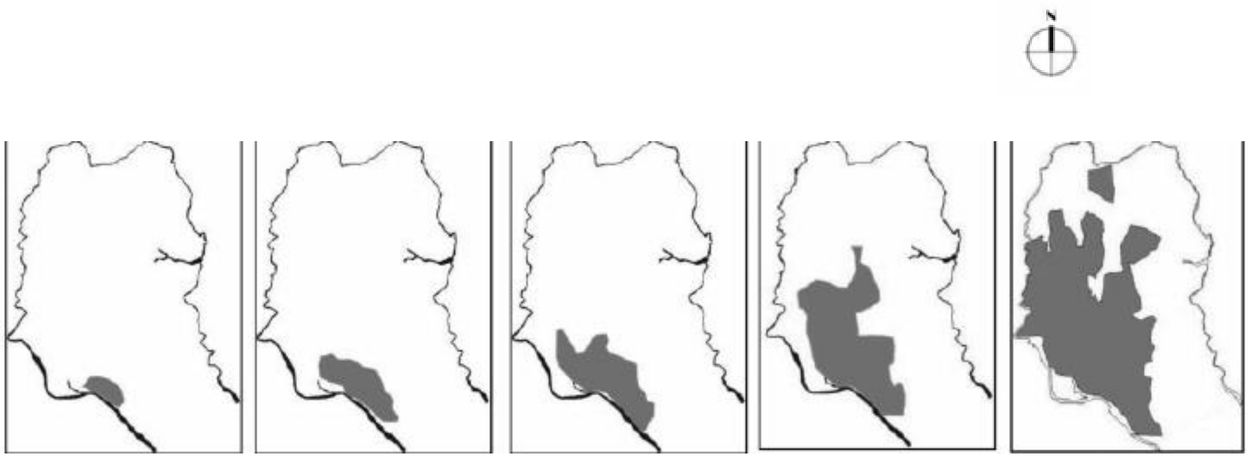


Figure 2.1: Dhaka City Map with Road, Rail and Water Network

Source: [76].

Since Independence, Dhaka is witnessing a tremendous growth in population for the availability of more socio-economic opportunities [54]. According to World Population Review report; Dhaka, with its current population of 19.58 million people in 2018 with a growth rate of 3.62%, bears the distinction of being the fastest-growing in the world [77]. Interestingly, although Dhaka City’s area is less than one percent of the country’s total land area, it supports about 10 percent of the total population of the country [26].



(a) (b) (c) (d) (e)

Figure 2.2: City boundary of Dhaka city over the year.
(a) Pre Mughal (1205–1610), (b) Mughal (1620–1757, (c) British (1758–1947), (d) Pakistan (1947–1971) and (e) Bangladesh (1971 onward).

(Source : [78])

Between 1990 and 2005, the city doubled in size from 6 to 12 million. Migration from rural areas of the country to urban Dhaka is a strong contributor to the population growth. Dhaka is now attracting a significant amount of rural-urban migrants from all over the country due to better job opportunities, better educational, health and other daily life facilities [1]. According to Social Watch Report 2012, Dhaka controls 70 percent of the country's total money supply, and thus it attracts 60 percent of total investment. Due to this centralization policy, close to half a million people move to Dhaka every year [29]. This rural migration accounted for 60% population growth throughout the 1960s and 1970s. While this growth has slowed since that time, Dhaka continues to show steady growth, with estimates placing the 2020 population at almost 21 million, while 2030 may see as many as 27.3 million residents [52], [77]. If this trend continues, it will be the 3rd largest city of the world by 2025. The city will expand towards north and north-west direction in the future approximately an additional 20% of the metropolitan area will be converted into built-up land by 2030 [1]. The impact of such rapid growth has major consequences on the ability of the transport sector to provide mobility for all people as they seek to take advantage of employment, education, health and social opportunities [54].

2.5.2 Transportation System in Dhaka City

Dhaka is struggling hard to cope with tremendous population pressure in terms of providing decent and sustainable public transport services. Dhaka has existing waterways and railways from the British period; nonetheless their use is limited within the metropolitan area. Unlike other mega cities where trains play a significant role in facilitating everyday travel, this mode of transport serves little ease of travel for intra city travel in Dhaka. Although there are waterways surrounding the city, there is no water based transport system for city dwellers. In addition, these waterways are not properly linked to the road transport system. As a result, people rely heavily on a road based transportation system. Hence, continuous focus on road based transport system has weakened the potentialities and attractiveness of other modes of transportation system [52], [54].

The transportation system of Dhaka is primarily road based. The major roads in the old part of Dhaka have been developed in the east-west direction and major roads in the new part have been developed in the north-south direction [54]. The road network in Dhaka is nearly 3,000 km with 200 km primary, 110 km secondary, 50 km feeder, 2640 km narrow roads and few alternative connector roads. The proportion of road surface to built-up area is approximately 7%, much lower than the 25% recommended for a good city planning. There are more than 100 open street markets 3,000 shopping malls all built alongside roads without adequate parking provisions [79]. In addition to that, there are no marked bicycle lanes and cyclists share the road with other motorized and non-motorized vehicles. Traffic movements at intersections are mostly operated manually by traffic police, even though all large intersections (a total of 70) are equipped with traffic lights and signal controllers [80]. The road width varies from six to forty metres. The main roads are fifteen to twenty-five metres wide and newly built roads are forty metres wide, whereas the road width in old Dhaka is less than six metres. Dhaka is also well connected to the rest of the country by air, road, rail, and river, therefore, people also come to Dhaka from its outskirt areas. These roads and railway links are developed and maintained by different governmental organizations, such as, Dhaka Transport Co-ordination Authority (DTCA), Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), Rajdhani Unnayan Kartripakkha (RAJUK), Bangladesh Road Transport Authority (BRTA), Dhaka Metropolitan Police (DMP), Roads and Highways Department (RHD), Local Government Engineering Department (LGED) and Bangladesh Railways (BR). The Dhaka Transport Co-ordination Authority provides overall coordination of transport projects (upgrading existing roadway or development of new road infrastructures) preparation and implementation [52].

Metropolitan Dhaka has traditionally been served by a wide variety of transport modes. These modes can be broadly classified into two groups, the motorized transport (bus, mini-bus, truck, car, auto-rickshaw, auto-tempo, motorcycle and so on) and non-motorized transports (rickshaw, rickshaw van, bicycle, push cart and so on) [54]. It is estimated that approximately 43% of trips are generated by car/light vehicles among all motorized transport; however, this serves only 9.6% of the total population. It is also estimated that automobile ownership is approximately thirteen per 1,000 of population and other vehicle ownership (bus, trucks, taxis and CNG powered three wheelers) is thirty-two per 1,000 population [52]. Most of the inhabitants are unable to afford private transport and are dependent on low cost public transport. The Dhaka Integrated Transport (DITS) household survey data shows that the main users of motor vehicles in Dhaka are higher income households [54]. Majority of the passengers in Dhaka city generally use bus (either public bus or office bus) to reach their work places. The availability and low fare rate usually inspire them in choosing this mode of transport. Besides, CNG three wheelers and private cars are very popular in Dhaka city. When close to ten percent people usually prefer CNG three wheelers as a mode of transport, it is almost two times higher than this number for private cars. However, there is not much gender variation in selecting the modes of transport. But in general, women prefer to avoid adversity in public bus [29].

Public transport is used by 84% of people in Dhaka, whereas only 16% of people use their own travel modes [52]. Figure 3 shows that the people of Dhaka city use buses (30%), private cars (5.10%), CNG powered three-wheelers/auto rickshaws (6.60%), rickshaws (38.30%), railway (0.20%), and walking (19.80%) (Dhaka Structure Plan, 2015; Rahman, 2017).

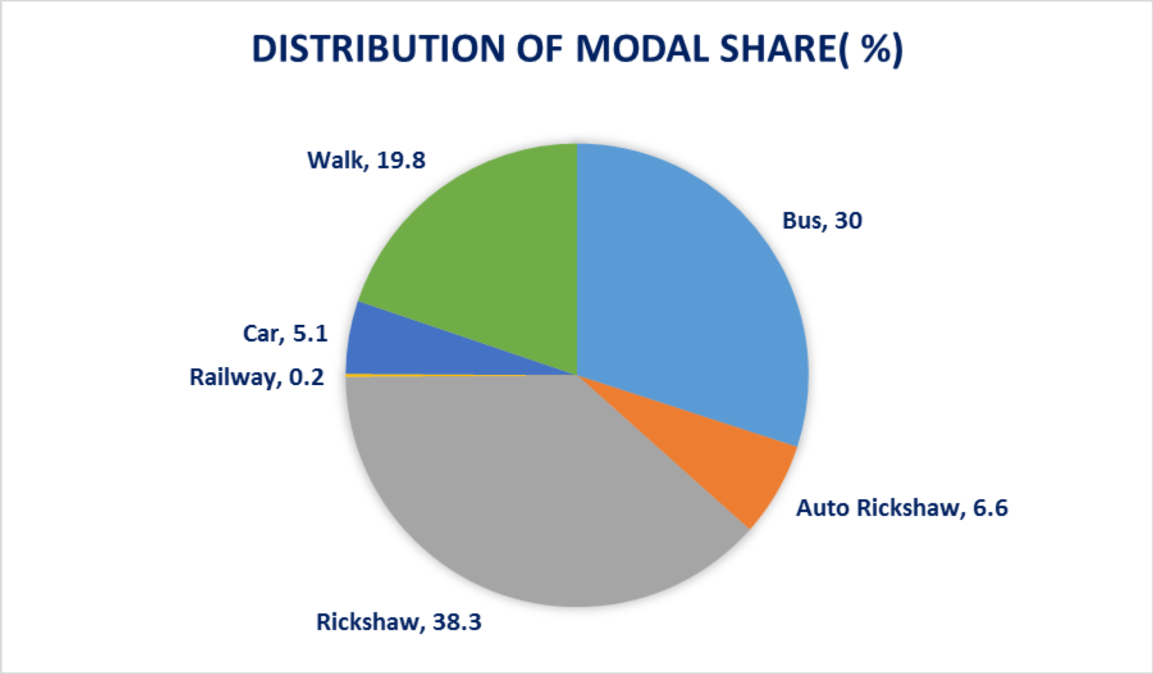


Figure 2.3: Distribution of Modal Share in Dhaka City

Source: [81]

In Dhaka, the average length of bus trip is 5.6 km, and rickshaw trip is 2.1 km. It is expected that by 2035 modal share of public transport will increase significantly whereas modal share of rickshaw trip will decrease to 20%. Out of all trips taking place each day, trips to school constitute 17.7%, to home 12.6%, and to work is 44.7% [81]. The average trip length of a bus is higher compared to other travel modes (private car, CNG powered three-wheelers, rickshaw, and walking). People who travel from one place to another for their daily purposes by walking cover 1.25km per trip. Average travel speed in Dhaka is 15.2km per hour, which comes down to 10-12km per hour during traffic congestion [52]. Table 2.1 shows the average trip length and journey speed of different travel modes in Dhaka.

Table 2.1: Average Trip Length and Journey Speed of Travel Modes in Dhaka.

Travel modes	Average trip length (km)	Average trip length (minutes)	Average journey speed (km/hr)
Bus	15	54	16.2
Private Car	10.4	37	15-20
CNG powered three-wheeler	6.7	45	16
Rickshaw	4.8	24	9.3
Walking	1.25	15	5

Source: [52], [82]

DUTP-II (1998) claimed that the vehicle population on road is growing as an average rate of 10% annually [54], [82]. However, recent study shows that the annual growth rate of freight transport in Dhaka is 8.2% and passenger transport 8.4%.[52]. The number of vehicles in Dhaka was 21,471 in 2004, which is more than tripled by 2011. The share of private automobiles is approximately 50 percent. In addition, the number of private cars has increased more than 400 percent within the last six years [52]. According to the Bangladesh Road and Transport Authority (BRTA), every year around 37,000 cars are added to Dhaka's roads, of which 80% are private cars. The number of private cars is likely to grow further given that currently only 10% of Dhaka's commuters own one [79]. In Dhaka the total number of registered vehicles are 1011270 and the total number of trips made by those vehicles in Dhaka city is 20.5 million per day. 20.5 million Trips generated in Dhaka metropolitan area every day, only 5% are carried out by private cars, which however use roughly 80% of the road space and are the main cause of traffic congestion. Yet 28% of the total trips are carried out by buses which only use about 5 % of the road space, the infrastructure doesn't match the scale of the city's traffic demand [83]. Figure 2.4 shows the yearly variation of motor vehicle in Dhaka. Analyzing the data from 1995 to 2017, it is found that total no of registered vehicle was reported at 139,982.00 Unit in Dec 2017. This is a record increase from the previous number of 110,520.00 Unit for Dec 2016. The data reached an all-time high of 139,982.00 Unit in 2017 and a record low of 14,548.00 Unit in 1999. Analysis also reveals that total number of registered vehicle have been increased 400% from 1995 to 2017 [84].

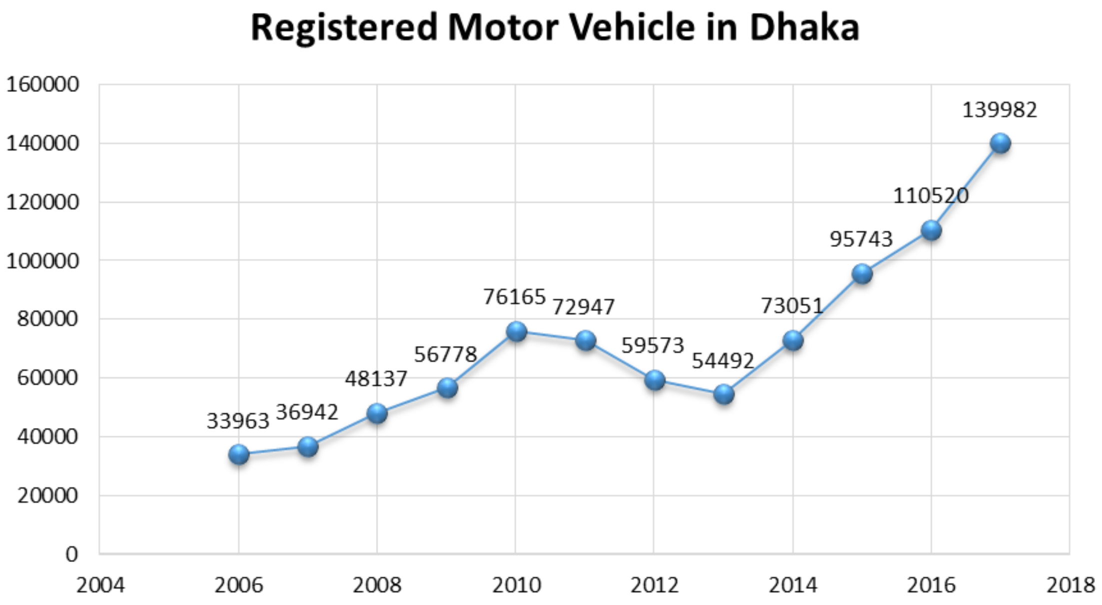


Figure 2.4: Total Registered Motor Vehicle in Dhaka (Year 2006-2017)

Source: [84]

Rapid urbanization process, high vehicular population growth and that of the mobility, inadequate transportation facilities and policies, varied traffic mix with over concentration of non-motorized vehicles, absence of dependable public transport system and inadequate traffic management practices have created a significant worsening of traffic and environmental problems in the metropolitan Dhaka. Road traffic congestion continues to remain a major problem and indeed is deteriorating rapidly resulting in massive socioeconomic losses [30]. In addition, concomitant land use pattern surrounding its roadways is also changing significantly. Careless unplanned development of land uses in Dhaka city has resulted in perpetual traffic congestion along with pollution, thereby aggravating its sustainability [20]. The city experiences a loss of around US$ 2,444 million per year owing to traffic congestion and road accidents. The annual loss of fuel costs approximately US$ 1,403 million. In addition, 3.2 million business hours are lost every day, which is equal to approximately one hour per working person. In Dhaka, people spend an average of 2.35 hours in a vehicle every day, of which 1.30 hours is due to traffic congestion. The working hours of vehicle operators is 12 hours every day; thus, they lose almost 25% of their working hours due to traffic congestion. Consequently, it is predicted that 60% of the major roads will become congested with a speed of less than 5 km/hr during peak hours by the year 2020 [52].

While exploring the causes of this untolerable phenomenon, Islam, Mostaquim and Biswas (2016) found 38% people identified private car as the main cause for road congestion problem. Since facilities of public buses are not good enough, many citizens choose to own cars. While rich people are dedicated to have cars for their individual family members, middle class families are actually forced to buy cars as the fare of CNG three wheelers have increased in recent years and also the service of public bus is not up to the mark. According to Bijoy Bhushan Paul, Director of Bangladesh Road Transport Authority (BRTA), only 10 to 15 percent people in Dhaka daily travel in private cars, but these occupy 85 percent of the roads. Every year the number of registered vehicles is increasing and it has increased in a significant number in last few decades [29]. According to the car importers, around 19,000 imported reconditioned cars have been added to Dhaka traffic in the 2015-16 fiscal year. Last year, an average of 75 private cars, microbuses and SUVs were introduced every day to the already congested streets of Dhaka. According to the Bangladesh Road Transport Authority (BRTA), Dhaka streets accommodate a total of 246,697 private cars at present. Added to that are around 5,000 buses and minibuses that are on the roads for public transport [85].

They also mentioned that the existing road network in Dhaka is not sufficient enough to hold the increasing number of vehicles. Nevertheless, this existing roads network has been excluded by the peddler which results in narrower the roads and therefore, it causes the traffic congestion. Possession of roads and sidewalks is a common problem in Dhaka. Day by day the business of hawkers is expanding and therefore, it is making the problem more complicated. Street vendors, hawkers and street front shop owners occupy 60% of the 163 km footpaths of Dhaka city. Even sometimes the sidewalks are filled up by construction materials and garbage which make the situation more worse [29].

Pedestrians are considered to be the most vulnerable roadway users. Unfortunately, they are most neglected elements in the design of roadway features in Dhaka city. Alarming growths of pedestrians, inadequate sidewalks and their haphazard movement have forced them to share the carriageway with the vehicles. This has led to a shocking number of accidents in the past as well as contributed to further increasing the congestion on the carriageway. At present nearly 60 percent of urban trips involved walking alone in Dhaka city and it is particularly prevalent for short trips. In terms of road usage, at some locations, pedestrians accounted for the highest number, representing nearly 62 percent of the total user groups in Dhaka. Low motorization levels, unplanned haphazard land use, road side industry, inadequate pedestrian facility and the severe lack of priority and attention given to pedestrians in the traditional transport planning and traffic management cause serious hazardous situations [23].

Only 9% of roadways and 6% of pavement area are available in this city, among which, 62 km is functional primary, 108 km secondary and 221 km connector roads. The percentage of avg. capacity loss of roads in Dhaka is 12.91%, whereas capacity loss due to On/Off street construction have found to be 13%. On street parking causes more than 10% of loss of capacity. Water logging causes nearly 8% and poor maintenance contributes to about 7% of total capacity loss [19].

Statistical data depicts the shortage of traffic police as only 558 sergeants out of the 3,327 traffic personnel, assigned to manage city traffic and moreover, 83 percent of the personnel, from constables to inspectors, appointed for controlling traffic without proper training [29]. In addition to that, while the president, the prime minister or the ambassadors travel in between the city roads, the general traffic are stopped for long period of time and consequently, it causes serious traffic congestion problem [29].

All these factors make the transportation system of Dhaka city a complex one.

2.5.3 Emergence of Flyovers in Dhaka

Economic growth has put a tremendous strain on existing transport networks in recent years, and transport issues, as part of broader environmental and financial reasons, have risen sharply on the political agenda of most countries, especially in areas where population density is the highest [13]. Dhaka, being one of the most populous megacities in the world, is suffering tremendously from perpetual traffic congestion and consequently, different transport policies regarding regulatory measures and construction related measures have been undertaken over the years to reduce the traffic congestion problem in Dhaka city. The Government of Bangladesh has prepared different transportation policies, not only to reduce traffic congestion, but also to build a reliable transportation system for Dhaka. The transportation policies, prepared for the development of the transport system in Dhaka, are:

- Greater Dhaka Metropolitan Area Integrated Transport Study (DITS), 1994
- Dhaka Urban Transport Project (DUTP), 1998
- National Land Transport Policy, 2004
- Strategic Transport Plan (STP), 2004
- Dhaka Urban Transport Network Development Study (DHUTS), 2010
- Urban Transport Policy, 2015
- Dhaka Structure Plan, 2015

The concept of the construction of flyovers emerged from the very beginning of the Dhaka's first comprehensive urban transport study, the Dhaka lntegrated Transport Study (DITS), which was commissioned by the Government of Bangladesh in 1992-93, conducted under the Planning Commission and UNDP and reported in 1994. Recommendations were made mainly concentrating on the traditional elements of urban transport planning: developing road infrastructure, constructing flyovers, developing bus terminals and bus routes, and improving traffic flow management at intersections and across the road network [86]. The Dhaka Integrated Transport Study (1994) also recommended that if a congested roadway junction can be solved by a low cost traffic management scheme (replacement of tempo by big buses or by a new road link built elsewhere), there would be no need to construct flyovers at roadway junctions. The then some transportation policies identified the locations (Jatrabari intersection, Sonargaon intersection, Mohakali and Airport road/Gulshan 1 road intersection and Malibagh rail crossing intersection) for the construction of flyovers to improve roadway intersections, whereas other transport policies provided recommendations for overall road transport network development, and there were no specific guidelines for construction of flyovers in Dhaka [52].

In 2005, Strategic Transport Plan (STP) for the Dhaka city was prepared for 20 years (2005 to 2025) in order to introduce a transport plan to cope up with the demand of the megacity, Dhaka. The document incorporated sets of objectives to introduce a safe and reliable public transport system which would be affordable to individuals [86]. STP only recommended construction of the Khilgaon flyover, and the re-study of the proposal for construction of the Moghbazar-Mouchak flyover, Kuril flyover and Jatrabari-Gulistan flyover, as a mass rapid transit system, and multimodal interchange stations were proposed at these locations. STP identified that the Cantonment Staff Quarters flyover (Mirpur flyover) proposed by the Roads and Highways Department would resolve the conflicts between road and railway traffic, as a Metro line was proposed in the same area [52]. Under three strategies STP considered ten options to solve the traffic problems of Dhaka. All the options (except the base) assumed that circular water way around Dhaka city would be completed and there would be major improvement in the railway system which would cost an estimated US$ 40 million and US$ one billion respectively over 20 years. The options were compared using eight objective functions including cost and eight subjective functions including affordability and social and economic development. The best two alternatives among these ten options propose neither subway nor flyover. However, unfortunately the elected representatives of people of Government of Bangladesh (GOB) decide the strategy for the Strategic Transportation Plan (STP) ignoring the expert and consultant opinion. And government decision on flyover and subway shows that government chooses worst of the proposals. The cost in either of these is more than double of the best two alternatives [69].

Dhaka Urban Transport Study (DHUTS) aims at formulating the Urban Transport Network Development Plan integrated with urban development plan of Dhaka Metropolitan Area (DMA) for the period up to 2025. Based on this plan, a general outline of the urban transport projects would be drawn which will be implemented on a priority basis The target year of the plan is set as the year of 2025, which consists short term (2010 -2015), medium term (2016-2020) and long term (2021-2025) [86]. The Dhaka Urban Transport Network Development Study (2010) identified flyover projects as very urgent, because they believed that these projects would be helpful in easing chronic traffic congestion and remove roadway intersection bottlenecks, and have no special problems for implementation [52].

The Dhaka Structure Plan (2015) proposed the construction of the Moghbazar-Mouchak flyover, while the Dhaka Structure Plan (2015) and the Urban Transport Policy (2015) gave more emphasis to construction of the BRT and MRT line rather than the construction of flyovers. On contrary, Dhaka Structure Plan (2015) also identified the construction of flyovers and other road infrastructures as a threat to the development of the future transportation road network in Dhaka, as they are not integrated with the overall road network development plan. The plan also identified that during the last few decades, a number of flyovers (Mohakhali, Jatrabari, Kuril, Banani, and Khilgaon) have been constructed in Dhaka without an integrated approach. The Moghbazar-Mouchak flyover currently under construction has not been integrated with the Hatirjheel project and the proposed Shantinagar-Jhilmil project at Keraniganj. Therefore, Dhaka Structure Plan (2015) recommended an integrated approach with consideration of multimodal transport facilities (BRT line, MRT line, ring road, and elevated expressway) before undertaking the construction of flyovers in Dhaka [52].

In addition, another factor that helps flyover to emerge as a traffic congestion mitigation tool is interruption between road and rail operation in Dhaka city. Railroad contributes significantly in mass transportation system of Dhaka city by providing access to transportation for industrial or personal purposes. From the beginning, it is playing an important role in unifying the country. Several roads including major arterial roads within the Dhaka City Corporation area intersect with these railroads. When these railroads are at the same grade with roads, they cause a conflict between two transportation modes, which are different in physical characteristics and operations. Consequently, a variety of problems including delay, safety incidents, waste of fuel and higher pollution are occurring [87]. Rail-road traffic conflict is prevailing in the developing countries and its' negative consequences are increasing prodigiously. Rail covers a length of 2,877.10 route kilometers including 2,541 rail-road crossings across the country. Unfortunately, eighty-five per cent of the railroad crossings are in a dangerous state as there is no lookout at 2,170 rail crossings. More than 2000 rail crossings have no traffic control devices. Lack of safety devices in level crossings have made them potential hotspots for accidents. Most victims of train accidents are pedestrians. On average, 12 people are killed in the accidents per month [88]. In particular for Dhaka city, there are altogether 51 (Fifty one) railway level crossing from Shyampur high school (Narayagonj) to Abdullahpur (Tongi), 37 authorized and 14 unauthorized. Among the 51 level crossing, 13 are in Kamalapur-Narayagonj corridor and others 38 are in Kamalapur-Tongi corridor. These 51 level crossing, in 12 point cross the bus operating major route, 5 are in Kamalapur-Narayagonj corridor and others 8 are in Kamalapur-Tongi corridor like Khilgaong, Malibagh, Moghbazar, FDC gate, Mohakhali, Kakoli, Banani and Bishaw road. Everyday 98 outgoing and incoming trains pass through the level crossing in the city. Among them 78 trains move through Kamalapur-Tongi corridor and other 20 moves Kamalapur-Narayagonj corridor. Out of 78 trains in the Kamalapur to Tongi corridor, 54 (67%) operate between 8.30 am to 10.30 pm. One an average a period of 3.5 minutes from Kamalapur to Mohakhali and 3.0 minutes from Bonani to Tongi is required to give a train its passage at each level crossing. In addition, 1.5 and 1 minutes times are required to come into normal condition of traffic flow at peck period and at off peck period respectively. However, train is creating interruption during passage of train on both sides of rail gates for an average of 5.0 to 6.0 hours in each day in each level crossing. Around 5.92 hours interrupting traffic flow every day in Moghbazar level crossing. Losses of man hour per day around 150,000 and loses of fuel for that interruption around 300 liters. Economic lose due to man-hour loss and fuel loss around 50,000 TK. per day. On the other hand, 238 employees are engaged for the controlling of the authorized level crossing and excluding other expenditure per month around 7.5 lac taka is losing only for their salary purpose [89]. In addition, the accidents that occurred in level crossing is 53% of all rail related accidents in Dhaka city [90]. To resolve this rail-road problem, a simple thought that came into the mind of policy-makers and decision-makers is to construct flyovers. Interestingly, almost all existing flyovers are built over the railway track to avoid congestion from waiting for the inter-district train that passes through the major intersections in the city [54].

However, the aforementioned policies and provisions are more based on pen & paper formalities and their findings and recommendations are merely implemented and followed. Decision is still dominated by the assumptions, political biases, and instilled human behaviors of the first highway-building era. The political leaders and city officials in Dhaka city developed their own visions of flyover that would speed autos to their destination, bypassing the monstrous traffic jams that clogged the major intersections. [54].

As the city is faring its worst with the congestion, the Government of Bangladesh (GOB) has focused on construction of flyovers and elevated expressways with a parallel interest in decongesting of the city. A number of mega flyover projects are on the table as a possible solution of Dhaka’s congestion problems and many of them are discussed at the higher level for quick implementation as a priority without undertaking any feasibility study. Ad hoc flyover projects were disparately and incoherently proposed and implemented by different government ministries with diffuse and divergent interests. The ongoing flyover projects are fragments of their grand urban vision to modernize Dhaka. Most of the initiatives are undertaking considering mainly the short term need without any long term vision, which is pushing the city in worse condition gradually. In addition to that, any construction projects require to prepare Environmental Impact Assessment (EIA), Social Impact Assessment (SIA) and Traffic Impact Assessment (TIA). Remarkably, such documents can merely be found for most of the flyover projects in Dhaka city. What is more awkward still is that these documents, prepared by the consulting firm are not cross-checked by any of the authorized organizations. Most of the time, they gain approval without any physical site visit by experts. Moreover, these documents never underwent thorough post evaluations [54].

In 1987, the Roads and Highway Department (RHD) of Bangladesh first recommended construction of grade separated flyovers at four congested rail-crossings intersections- within this situation at Mohakhali and Khilgaon intersections were so worst that they gave greatest emphasis on these two sites in their early recommendation [54], [91]. In 2004, Dhaka opened its first ever flyover connecting with the Mohakhali VIP3 road as a part of World Bank's Dhaka Urban Transport Project (DUTP-II). Since then, flyover has become a critical component of the infrastructure development strategies for Dhaka city and each year the number of flyover is rising. However, the resultant scenarios within ten years of their operation speak of something striking. Dhaka's flyover now dates back to the Long Island case: turbid mass of traffic in the elevated flyovers, pushed, packed and raised between two sides. Why the flyovers are constructing? Why are we putting these flyovers and what are we getting out of it? How long we can stand the flyovers that are peculiar to our large congested centers [54]? Now, this is the big question to everyone. Hence, the performance evaluation of these flyovers is imperative.

	
(a) source: [92]	**(b)** source: [93]
	
(c) source: [94]	**(d)** Source: [95]

Figure 2.5: Propagation of Traffic Congestion over Flyover in Dhaka City.

2.5.4 Flyovers related Studies in Dhaka

Given the prevalence of flyovers in Dhaka city, surprisingly few studies have approached this subject methodically. Islam and Saha (2005) studied the impact of Mohakhali flyover as an urban element, but since then several other flyovers have been constructed, whose influence on Mohakhali flyover had not been projected yet [96].

Taleb and Majumder (2011) conducted a research on two flyover projects at Mohakhali and Khilgaon intersections in Dhaka and investigated how people in adjacent land of newly constructed flyovers are affected. They conclude that some businessmen and land-owners have experienced reduced incomes after construction of flyovers. They argue that, the flyover construction deteriorated the visual impact and the benefits diverted to the local people are extremely negligible because they neither can use the flyover nor release from the traffic jam of the linked intersection [26], [54]. However, the study neither incorporated any performance based evaluation of these two flyovers nor did they guided any sort of traffic engineering performance based assessment for other flyovers.

In his article, A Big No to Flyover and Subway in Dhaka, Akhter (2009) looked at the city's Strategic Transport Plan (STP) and other policy documents related to transport and suggested that there is no scope for flyover in Dhaka from social, financial and economic point of view [54], [69].

Uddin (2006) made important discoveries regarding seismic loading on Khilgaon flyover. He performed static and dynamic linear analyses. He urged to design such kind of structure considering a probable earthquake and investigated the behavior of the Khilgaon flyover under seismic forces. However, the study was conducted from structural engineering point of view. It neither evaluated the performance of Khilgaon flyover nor the other flyovers from mobility and accessibility point of view [27].

In 2008, prior to the construction of Jatrabari-Gulistan Flyover, Bureau of Research Testing and Consultation (BRTC) identified problems associated with Jatrabari and Saidabad intersection and tried to offer rational solutions to those problems [97]. The study identified various forms of side frictions from which the corridor was seriously suffering from significant loss of effective width of carriageway and productivity. It diagnosed ill maintained untreated Jatrabari, Gulapbag and Saidabad intersections those were contributing traffic problems along the most critical section of this corridor. The study proposed various traditional low cost but very effective traffic control and roadway capacity augmentation measures to restore level of service (LOS) as well as functionality of this corridor before advocating any expensive measure including construction of flyover. The study also gave a warning by stating that f flyover is constructed without understanding the root causes of the problem, there is a strong possibility that instead of solving the problem it might be a permanent hindrance for implementing future transportation projects along this corridor, and as the corridor has not been treated effectively by applying any low cost capacity augmentation measure yet, it would not be wise at all to construct capital intensive flyover type measure directly without implementing these cost effective precursor measures [97]. However, the government and policy-makers ignored these study outcomes and went for capital-intensive solution by constructing flyover in this corridor considering it as a solution to this perennial traffic flow interruption problem.

Kader and Hoque (2009) investigated to the bending strength- deformation characteristics of the piers of Khilgaon Flyover in Dhaka. The study was performed completely from structural engineering point of view. Mobility, accessibility and performance evaluation of the flyover were out of the study consideration[98].

Kader and Hoque further worked with Khilgaon Flyover to analyses lateral strength and ductility of the piers of this flyover. They evaluated lateral strengths of the piers of Khilgaon flyover analytically under bending and shear mode of failure independently. The lateral strengths in bending were obtained using the results of nonlinear sectional analyses of the pier sections, while the shear strength of the piers are calculated using code defined equation taking into account the effect of depth, volumetric ratio of lateral steel, crushing strength of concrete, yield strength of steel. Finally, they presented the lateral strengths of the piers in normalized form [99]. However, the study also dealt mainly with the structural analysis and did not incorporate the traffic flow and mobility analysis.

Haque (2011), in his master's thesis, analyzed the railway accidents at level crossings in Dhaka city. In his study, he calculated the value of Traffic Moments of the accident-prone level crossings and suggested grade separation for highly accident prone level crossings, which is quite absurd and this doesn't match with aims of the current study [90].

Hassan and Alam (2013) worked on Jatrabari-Gulistan flyover project. Main focus of their research was to record and analyze noise levels in major intersections located at surrounding the flyover as well as key entities, such as hospitals, educational institutions; religious institutions etc. for both day and night and seven days of a week. They compared the Jatrabari-Gulistan flyover noise level data with the Khilgaon and Kuril flyover data. They also performed Noise modelling for generator and wheel loader used in the construction site of flyover [100]. However, their study was far away from evaluating the performance of the flyover on the basis of speed, flow and queue length.

Roushan (2013), in her undergraduate thesis, investigated on the spaces under the flyovers in Dhaka, and proposed some design interventions. According to Roushan (2013)'s study of the fly-under, it is very likely that most spaces under them will be inaccessible, forgotten and become a haven for illicit activities as the flyovers emerge out of the dense framework of the city. However, the study is excluded from any performance evaluation from mobility and accessibility point of view [54], [86].

Kabir (2014), in her Master's thesis, gave a new thought on the flyover projects in Dhaka city in terms of socio-spatial practices by the marginal occupants evolving from the breach in the formal planning and design of flyovers in dense urban areas. She extended investigations on the socio-environmental implications of flyover's neighborhoods: what changes the flyovers made in the adjacent areas, and how these changes are experienced by the marginal occupants in the neighborhood areas; what are their makeshift communal usages and how these uses differ from people's perception of flyovers as an object of mobility. Finally, She concluded by showing how the flyover blighted spaces are perceived, produced and inhabited by the marginal community in a densely populated mega city like Dhaka. However, the study didn't cover the performance evaluation of these flyovers projects [54].

Islam and Kabir (2014) dealt with the Tejgaon flyover and presented innovative use of space under the flyover in Dhaka city for the economically marginalized and the poor. Basically, the paper discussed of basic standards and necessities of built environment in the South Asian context along with the human perception & design possibilities for simple but quality space with low cost options suitable for the limited income group [101]. However, although the study incorporated the Tejgaon Flyover, it is out of the scope of the present study.

Hasnat, Hoque and Islam (2016) evaluated the economic, environmental and safety impact of at-grade railway crossings on Dhaka city. This study revealed the economic losses, environmental impact and safety hazard of the busiest 7.15 kilometer railway corridor which has six level crossings. It also calculated the delays and emission incurred by individual level-crossing and found that the yearly economic losses incurred by studied six level crossings was 32.95 million USD. However, the study neither dealt with any particular flyovers nor evaluated their functional effectiveness [102].

Kadir, Hasan, Sen and Mitra (2016) estimated vehicle operating cost and environmental cost for delay at major railroad intersections of Dhaka city corporation area. They studied nine major intersections with rail-road traffic conflict including Saidabad Level Crossing, Khilgaon Level Crossing, Maghbazar-Mouchak Level Crossing, Mohakhali Level Crossing and Banani Level Crossing. The study showed that total daily loss of time, annual cost of required additional fuel and cost of air pollution are 751.3 minutes, 103.59 million BDT and 8813.50 million BDT respectively for the studied nine intersections [87]. Although, the study dealt with rail-road traffic conflict in terms of vehicle operating cost and environmental cost, it did not incorporate any analysis regarding the flyover or traffic flow and mobility.

Mamun, Mohammad, Haque and Riyad (2016) evaluated the performance of Mohakhali flyover using VISSIM simulation software. They proposed to extend the flyover by constructing additional links to and from the Gulshan Mohakhali connecting road to increase the capacity of the flyover. They found remarkable improvement in the extended version of the flyover by simulating it in VISSIM. However, data for this study was collected during 9:30 to 10:30 am on Sunday and during 5:00 to 6:00 pm on Thursday. Hence, it can be concluded that the data was collected only for weekday, day period. It didn't consider the variation of flow and speed in weekday night, weekend day, and weekend night. In addition to that, it only incorporates the Mohakhali flyover. It doesn't take into consideration to the other flyovers in Dhaka city [103].

Anwari, Hoque and Islam (2016a) focused on operational effectiveness of the partially grade-separated flyovers built on level crossings in Dhaka city till February 2016. The evaluation criteria used include assessment of vehicular as well as pedestrian safety at level crossings under those flyovers, degree of congestion and speed characteristics. However, the study didn't incorporate the variation of flow during different times of the day and as well, exclude the flyovers inaugurated after this time framework [104].

Anwari, Hoque and Islam (2016b) further explored the reasons for poor traffic operation and rail-road conflict at Shaheed Ahsanullah Master Flyover. The study was conducted to identify and evaluate the at-grade traffic movement at Tongi Level Crossing under the flyover. This paper shed light on the traffic problems prevailing at

Tongi Railway Crossing. However, it is a fraction of the entire city and it didn’t cover the other flyovers in Dhaka city as a sum and assess the overall impact on mobility and accessibility in Dhaka city [105].

Rahman (2017), in his Master’s thesis, evaluated induced travel demand with the construction of transport infrastructure in Dhaka, using flyovers as a case study. He developed disaggregate induced travel demand models of transport infrastructure for Dhaka, Bangladesh. The main objectives of this research were: to measure induced travel kilometres or induced trips caused by the construction of transport infrastructure (flyovers); to analyse transport infrastructure induced mode and route switch behavior; and to investigate transport infrastructure induced residential mobility behaviour of individuals. The findings of this study contributed to guide policies that include the effects of induced travel demand when constructing new roadway facilities [52]. However, the study didn’t go for any performance evaluation of the existing flyovers in Dhaka from the perspective of mitigating traffic congestion and enhancing mobility.

Miyauchi (2017), using cell phone data, analyzed how the opening of Jatrabari-Gulistan Flyover in October, 2013 has changed the urban trip patterns. The research found that about 23.8% more trips are generated on the routes that crosses over flyover relative to other routes. The study also mentioned a within-day variation in the generated trips; in the mornings more trips are generated from suburban area (Narayangonj area) toward the central business district (Motijheel area), and the other way around in the evenings [106]. However, the study never dealt comprehensively with the performance evaluation of this flyover nor considered the other flyovers in Dhaka city.

Rasel, Huda and Barua (2018) evaluated the traffic characteristics of Moghbazar-Mouchak Flyover. The study analyzed total traffic volume along with the spot speed and their composition in week days and weekend days. They also analyzed the perceptions of the commuter towards the flyover [107]. However, the study neither analyzed the traffic characteristics in weekday, night nor in weekend-day, night. In addition to that, the study didn’t evaluate the performance of this flyover from traffic congestion mitigation point of view.

At present, there is no systematic analysis evaluating the performance and effectiveness of these flyovers constructed over rail-road level crossing in Dhaka city. There has been considerable research incorporating the issues of flyovers in abroad; however, these studies rarely include the performance evaluation of these flyovers in Dhaka city. The aforementioned literatures neither dealt comprehensively with the performance evaluation of these of flyovers nor did they quantify the identified problems. In addition to that, performance evaluation of these flyovers incorporating temporal variation of traffic flow and volume along with pedestrian consideration are completely missing. In this backdrop, this research is an attempt to investigate how the partially grade separated flyovers constructed at the level crossings of Dhaka City have facilitated city-dwellers in terms of mobility and accessibility. The main objectives of this study are to assess the relative level of usage of road space under and over the flyovers; find the usage of flyover spaces by non-motorized vehicles and public transport; evaluate the mobility and road accessibility conditions of vehicles both at-grade and above grade level and finally to measure the effectiveness of flyovers in terms of reducing traffic congestion levels and improving safety at level crossings.

2.6 Overview

This chapter has been methodologically delineated the literatures relevant to this study. First, Author has tried to establish a conceptual framework to develop the concept of flyovers from the beginning of the history. Then, Author has put an effort to clear the term “Flyover” and showed a historical development of flyovers throughout world since the beginning to today. In the next section, Author has shown how the developed world is dealing with flyovers now to avoid the negative consequences flyovers have raised in modern city life. Perspective of flyovers in Dhaka city as well as Bangladesh has been described briefly in the next of the Literature Review. In this section, demographic characteristics, transportation system of Dhaka city has been narrated in details. This section also covers how flyovers concept has come into limelight in Bangladesh. Finally, it has been concluded with relevant studies those have already been done incorporating the flyovers of Dhaka city and their findings of those studies have also been described to make differentiate those from the present study. To this end, the basic purpose of this extensive literature review is to form a basis on which the significance of the present study can easily be apprehended. However, the next chapter focuses on the methodology of the study and provides elaborative description of the study area and data collection technique of this study.

CHAPTER 3
METHODOLOGY OF THE STUDY

3.1 Introduction

This chapter describes the methodology adopted to conduct this research. Section 3.2 discusses the selection of the study area along with a brief discussion about those areas. To decide on the working steps and methodology, a reconnaissance survey was conducted and has been described in section 3.3. Section 3.4, 3.5, 3.6 and 3.7 outlines the methodology of classified traffic count, speed measurement, queue length measurement and sources of secondary data respectively. A summary of this chapter is given in Section 3.8.

3.2 Selection of the Study Area

The present study has considered the rail line that is running from Narayanganj Rail Station to Tongi Rail Station and has conflict with at-grade road. There are altogether 51 (Fifty one) railway level crossing from Narayagonj to Tongi, 37 authorized and 14 unauthorized. Among the 51 level crossing, 13 are in Kamalapur-Narayagonj corridor and others 38 are in Kamalapur-Tongi corridor [89]. Along the way, the rail line meets with eight flyovers, of which six are partially grade separated. The particulars of these flyovers are provided in Table 1.

Table 3.1: Descriptive Characteristics of Studied Flyovers

Name		Grade separation type	No. of Lanes	Length (km)	No of Ramps	Construction Cost (crore Taka)	Date of Commencement of Traffic Operations	Implementing Authority
Mohakhali Flyover		Partial	4	1.12	2	116.00	04 November 2004	RHD
Khilgaon Flyover		Partial	2	1.90	3	81.75	22 March 2005	LGED
Shaheed Ahsanullah Master Flyover		Partial	2	0.35	2	23.75	23 May 2010	RHD
Zillur Rahman Flyover at Banani		Full	4	1.79	8	199.88	27 March 2013	Bangladesh Army
Banani Overpass		Partial	6	0.81	2	103.00	27 December 2012	Bangladesh Army
Bijoy Sarani-Tejgaon Link Road Flyover		Full	4	1.14		168.00	20 April 2010	RAJUK
Kuril Flyover		Full	2	3.10	10	254.00	04 August 2013	RAJUK
Jatrabari-Gulistan Flyover		Partial	4	11.8	13	2,300.00	11 October 2013	Orion Group
Moghbazar-Mouchak Flyover	Phase 1	Partial	4	2	15	(total 1218.89)	30 March 2016	LGED
	Phase 2	Partial	1	2.25			15 September 2016	
			1	0.45			17 May 2017	
	Phase 3	Partial	2	4			26 October 2017	

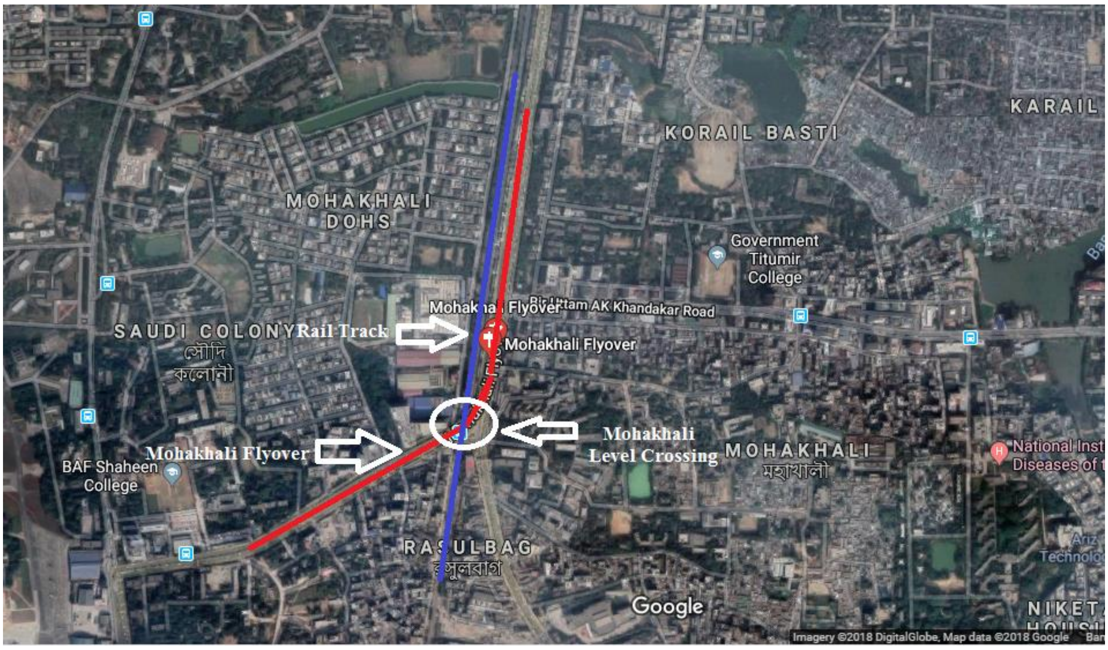
Source: [85], [97], [105], [106], [108]–[112].

Since the full grade separation has the potential to eliminate conflicts between rail-road traffic, the study deals only with the partially grade separated flyovers constructed of level crossing in Dhaka city. The details description of the studied six flyovers have been elaborated in the following sub-sections.

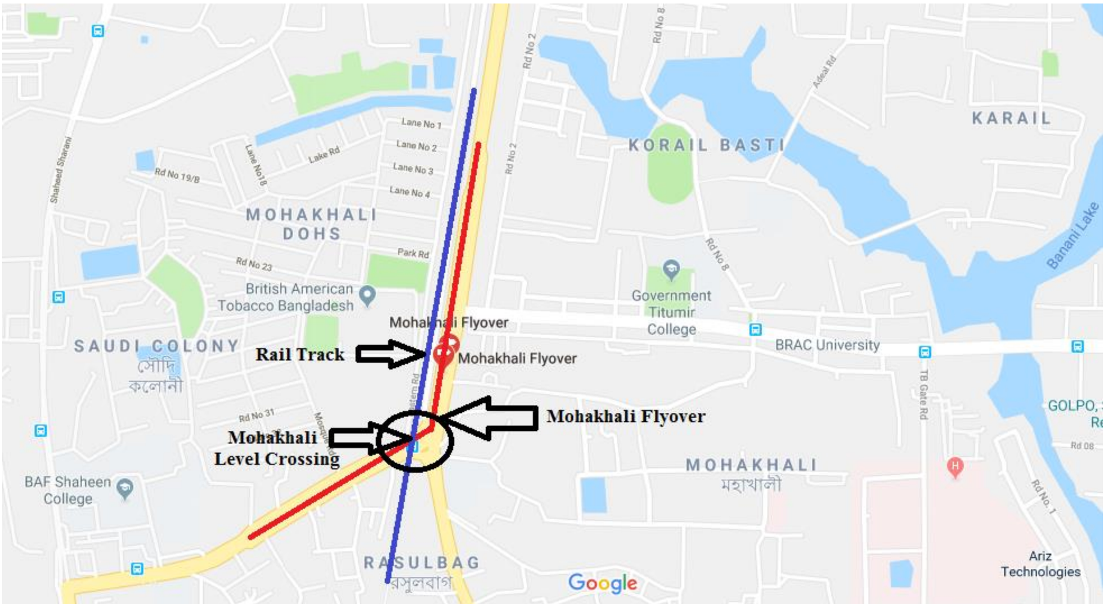
3.2.1 Mohakhali Flyover

The government undertook a number of remedial measures to address the public sufferings caused by intolerable traffic congestions in Dhaka city. Mohakhali rail crossing intersection was considered to be one of the most congested places within Dhaka city. As part of remedial measures, the first flyover in Bangladesh at Mohakhali was commissioned in October 4, 2004. The flyover is located at Mohakhali connecting Bir Uttam Ziaur Rahman Sarak and New Airport raod. The construction process of the flyover began in December 6, 2001. The 1.12 km flyover was built by Metallurgical Construction Limited, a Chinese firm, under the World Bank funded Dhaka Urban Transport Project. The Roads and Highways Department implemented the project. The construction cost was about BDT 116 crore. The four-lane flyover has one ramp going to the north towards the Airport Road is 147 meters and another ramp which length on the west, in front of Shaheen College is 177 meters [108]. The latitude and longitude of the flyover is 23° 46' 46.8696" N and 90° 23' 54.4272" E.

The location and layout of the Mohakhali Flyover has been shown in Figure 3.1. Figure 3.1(a) shows the Google Earth view and Figure 3.1 (b) shows the Google Map view. The red line in the Figure 3.1 shows the alignment of the flyover and indigo line shows the rail track passing through the flyover. Field study reveal that there is one rail-road conflict point underneath this flyover and it is denoted as Mohakhali Level Crossing in this study. The oval shape in Figure 3.1 (white color in Google Earth View and Black color in Google Map View) shows Mohakhali Level Crossing. The latitude and longitude of the Mohakhali Level Crossing are 23.778255 N and 90.397867 E respectively.



(a) Google Earth View



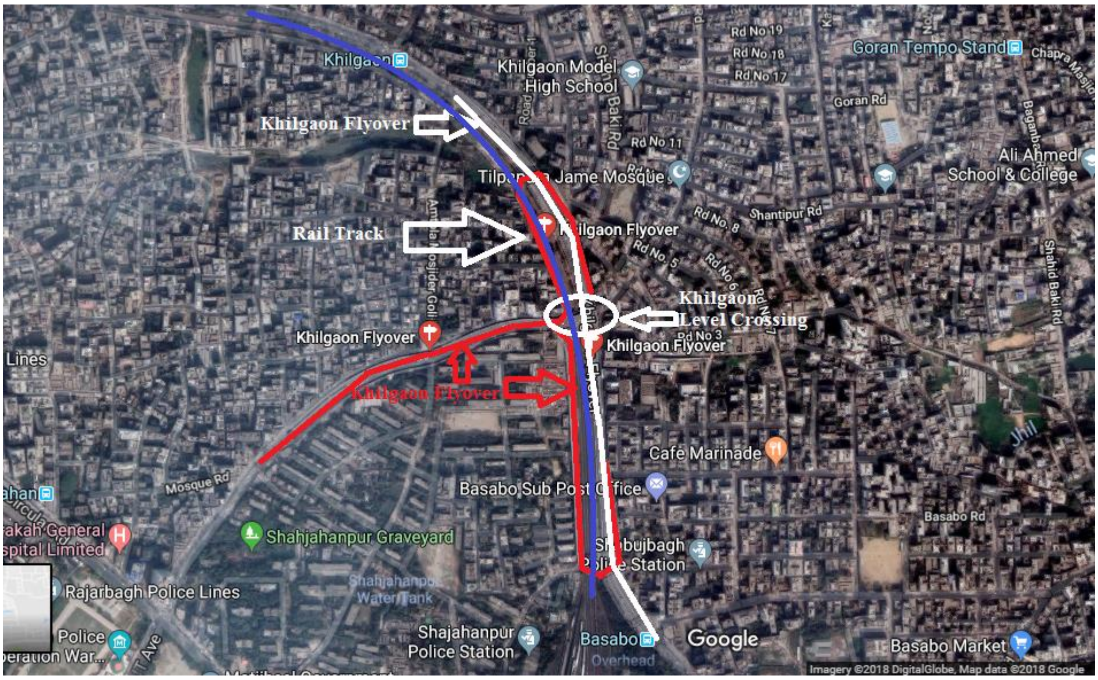
(b) Google Map View

Figure 3.1: Layout of the Mohakhali Flyover with Rail-Road Conflict Point.

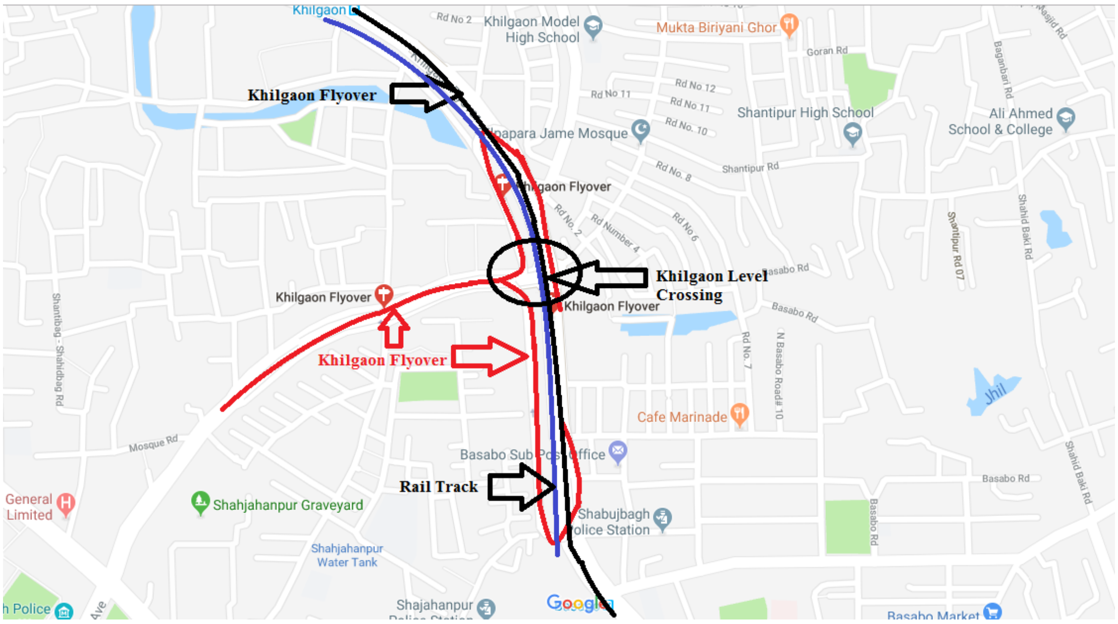
3.2.2 Khilgaon Flyover

As a part of the total initiatives to improve the traffic situation in Dhaka, the then government approved the Khilgaon Flyover project in the ECNEC meeting in 2000. It is the second flyover in Bangladesh and was commissioned on March 22, 2005. The construction process of the flyover began in September, 2001. The 1.9 km flyover made completely by the local experts. Local firm Development Construction Limited built the flyover on internal funds. The Local Government Engineering Department implemented the project. The flyover has been constructed at a cost of about BDT 81.75 crore. The two-lane flyover, which is 14 meters wide, has a 780-meters main bridge and three ramps. The length of the flyover towards Saidabad is 303 meters (in actual design), Malibagh 190 Meters and Rajarbagh 285 meters. The ramp towards Saidabad is 220 meters, Malibagh 202 meters and Rajarbagh 222 meters [108]. However, the implementation was not done as per original plan or design because the subsequent government (2001-2006) dropped one of the important loops (Saidabad side) from the project. This has seriously constrained the objectives and expected benefits of the flyover as originally planned. Till now the large volume of traffic coming from Progoti Sarani and eastern part of the city (Mothertek, Kadamtali, Basabo, Shepaibag, Meradia, Goran) cannot use the existing flyover and they do not have any other uninterrupted access toward Motijheel commercial area and Rajarbag [109]. The latitude and longitude of the flyover is 23° 44' 36.9888" N and 90° 25' 35.9472" E.

The location and layout of the Khilgaon Flyover has been shown in Figure 3.2. Figure 3.2(a) shows the Google Earth view and Figure 3.2 (b) shows the Google Map view. The red line and white line show in Figure 3.2(a) show the alignment of the flyover and indigo line shows the rail track passing through the flyover. The red line and black line show in Figure 3.2(b) show the alignment of the flyover and indigo line shows the rail track passing through the flyover. Field study reveal that there is one rail-road conflict point underneath this flyover and it is denoted as Khilgaon Level Crossing in this study. The oval shape in Figure 3.2 (white color in Google Earth View and Black color in Google Map View) shows Khilgaon Level Crossing. The latitude and longitude of the Khilgaon Level Crossing are 23.744155N and 90.426374 E respectively.



(a) Google Earth View

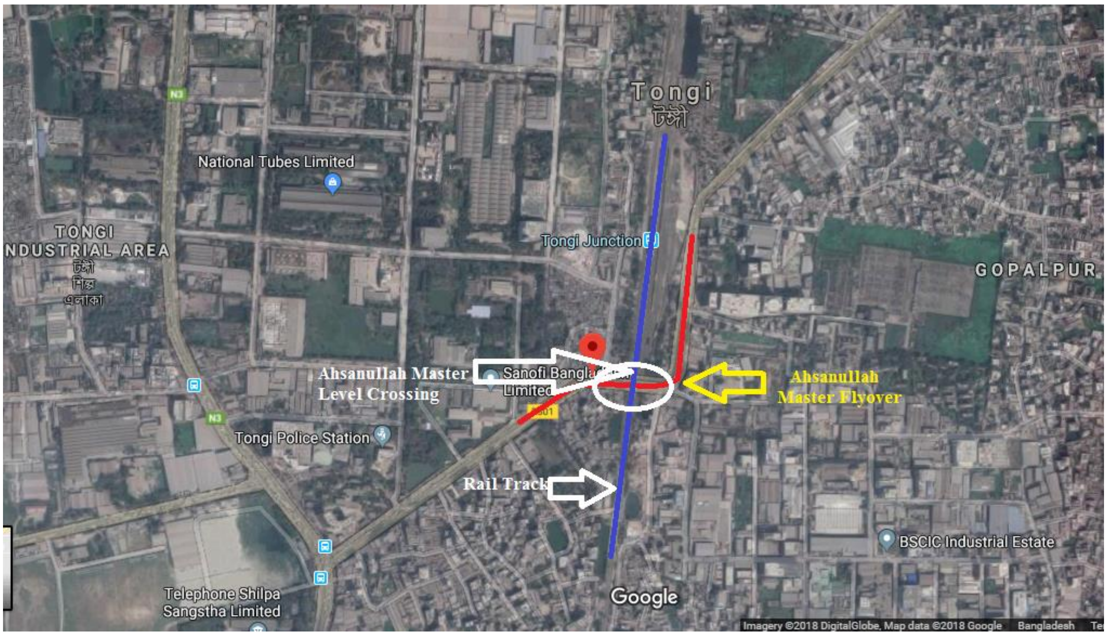


(b) Google Map View

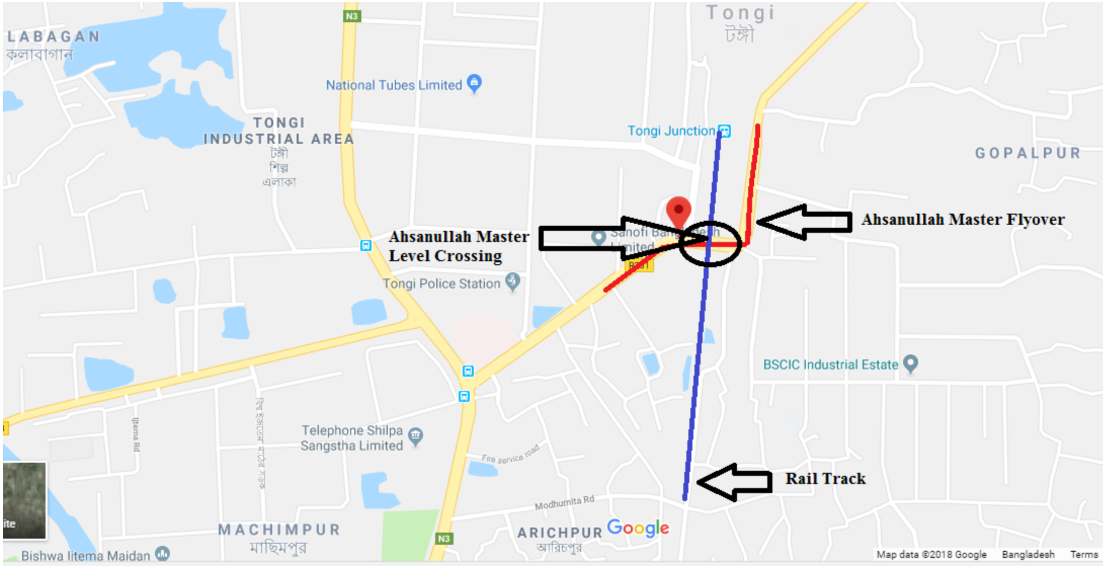
Figure 3.2: Layout of the Khilgaon Flyover with Rail-Road Conflict Point.

3.2.3 Shaheed Ahsanullah Master Flyover

The flyover is located on the southern side of Tongi Rail Station. It is 350 meters long and 7.5-metre space in each lane of the two-lane flyover with 0.6 metres wide footpath on each side. The link roads are 200 meters long. It has two ramps connecting to Tongi-Ghorashal Highway. The land on either side of the approach roads in mixed commercial and residential area. Most buildings are single-storied near the level crossing, but 5-storied buildings are also present. The construction of the flyover was started on March 26, 2006 and finished on April 7, 2015, at a cost of Tk 23.75 crore. It was inaugurated by Prime Minister Sheikh Hasina on April 11, 2015 [105]. It has connected Dhaka and Central Districts by allowing route connection with Narsingdi, Bhairab, Sylhet and Kishoreganj with Tongi by avoiding severe traffic congestion in Dhaka city and Kanchpur Bridge. Roads and Highways Department sources said the construction work of the flyover began on March 16 in 2006 and Tk 18.33 crore was earmarked to complete it on March 15 in 2008. In the preliminary design, the length of the flyover was 42.68 metres and the link roads on both sides were 450 metres. But the local people started movement demanding changes in its design, as there was no arrangement for movement of the people under the flyover. In the face of the movement, the work of the flyover stopped within 7-8 months. Later in June 2007, the work of the flyover resumed as per the revised design. In the changed design, its length was raised to 350 metres and the link roads reduced to 200 metres, while the cost increased to Tk 23.75 crore. The time fixed to complete the flyover was in March, 2010. An additional amount of about Tk 5.50 crore was spent due to changes in design and increase in time of construction work [44]. The latitude and longitude of the flyover is 23° 53' 45.8304" N and 90° 23' 24' 26.2008" E.



(a) Google Earth View



(b) Google Map View

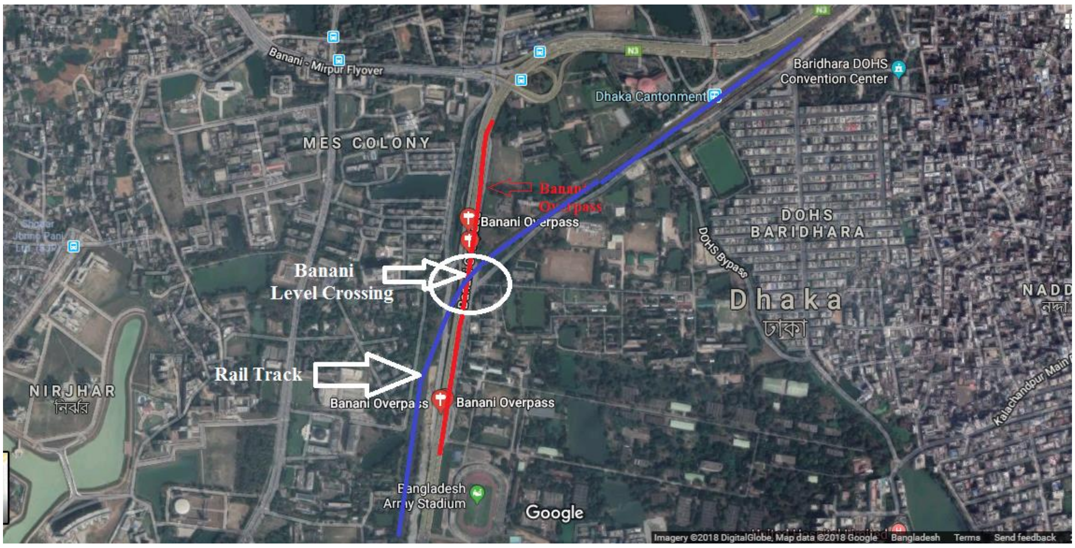
Figure 3.3: Layout of the Ahsanullah Master Flyover with Rail-Road Conflict Point.

The location and layout of the Ahsanullah Master Flyover has been shown in Figure 3.3. Figure 3.3(a) shows the Google Earth view and Figure 3.3 (b) shows the Google Map view. The red line in the Figure 3.3 shows the alignment of the flyover and indigo line shows the rail track passing through the flyover. Field study reveal that there is one rail-road conflict point underneath this flyover and it is denoted as Ahsanullah Master Level Crossing in this study. The oval shape in Figure 3.3 (white color in Google Earth View and Black color in Google Map View) shows Ahsanullah Master Level Crossing. The latitude and longitude of the Ahsanullah Master Level Crossing are 23°53'45.6"N and 90°24'29.1"E respectively. It is located 200m away from Tongi Rail Junction.

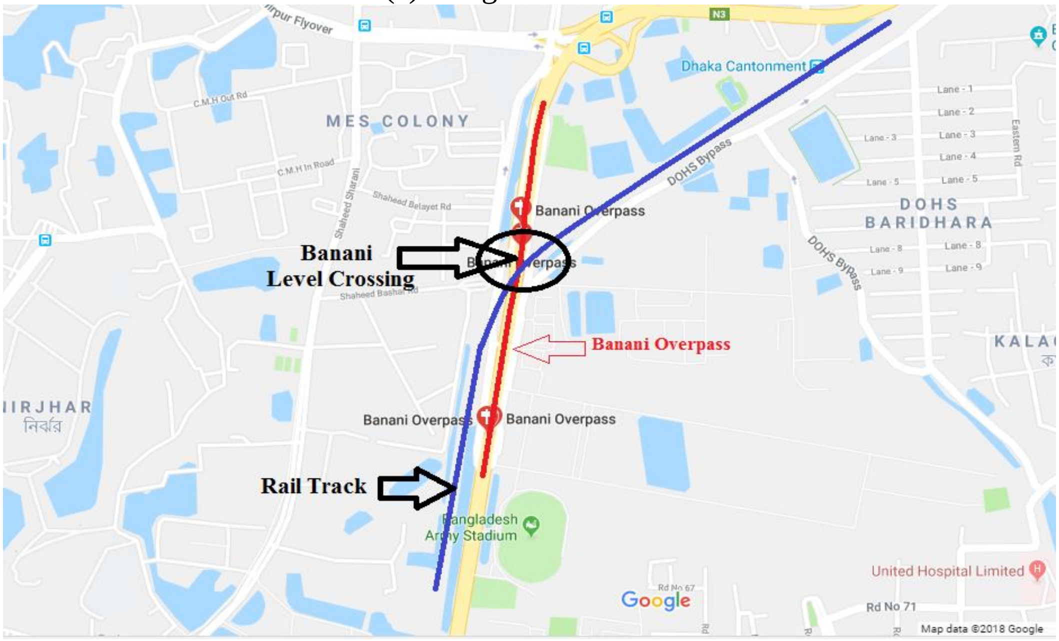
3.2.4 Banani Overpass

This flyover is a byproduct of the development of rail-road traffic conflict at Banani rail crossing. The present built up areas of Banani, have been developed on the crease of the undulating topography and developed mainly on earth filled platforms. Due to the conspicuous presence of Dhaka Cantonment in the middle of the city, the north-south connecting road, the New Airport Road takes a 90 degree turn just before crossing the railway that runs east-west. The Banani overpass construction project was launched in 2010 along with the Mirpur-Airport Road Flyover. The Roads and

Highways Department (RHD) launched the Mirpur Airport flyover and Banani overpass project under the supervision of Special Works Organization West [86]. The 805-metre Banani overpass in the capital was constructed at the cost 1.03 billion BDT and opened for traffic movement on 27 December, 2012 [110]. The overpass was built with the hope of reducing traffic jam on the Airport road enabling vehicles to cross the rail line without stopping during train crossing. Some 72 trains pass the Banani level crossing everyday which forces to stop all modes of vehicles for 10 to 15 minutes every time making long queues on both sides of the rail line [86]. The latitude and longitude of the flyover is 23° 48' 44.0352" N and 90° 24' 14.0184" E.



(a) Google Earth View



(b) Google Map View

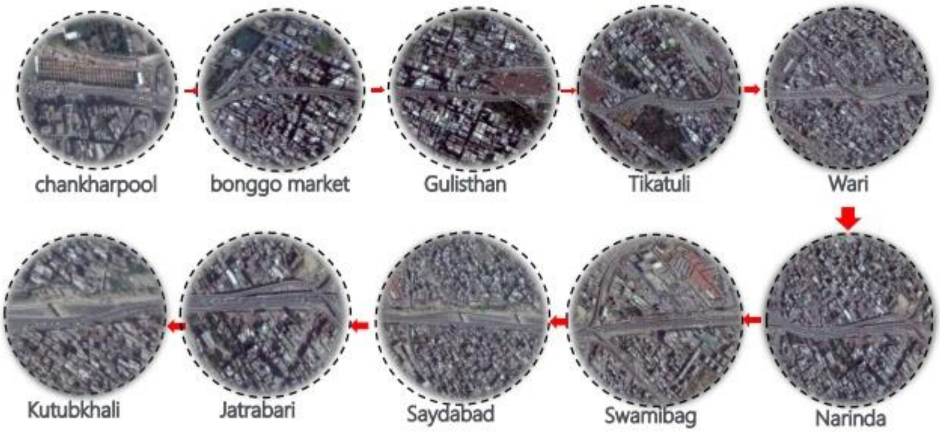
Figure 3.4: Location of the Banani Overpass.

The location and layout of the Banani Overpass has been shown in Figure 3.4. Figure 3.4(a) shows the Google Earth view and Figure 3.4 (b) shows the Google Map view. The red line in the Figure 3.4 shows the alignment of the flyover and indigo line shows the rail track passing through the flyover. Field study reveal that there is one rail-road conflict point underneath this flyover and it is denoted as Banani Level Crossing in this study. The oval shape in Figure 3.3 (white color in Google Earth View and Black color in Google Map View) shows Banani Level Crossing. The latitude and longitude of the Banani Level Crossing are 23.811273 N and 90.403905E respectively.

3.2.5 Jatrabari-Gulistan Flyover

Jatrabari-Gulistan Flyover, also known as Mayor Mohammad Hanif Flyover, is a 11.8km-long flyover opened on October 11, 2013. It has 4 lane divided carriageway and consists of 13 entry and exit ramps at major junctions for smooth inflow and outflow of traffic [111]. It extends from Jatrabari to Sayedabad, Tikatuli, Joykali Mondir, Kaptanbazar and Gulistan. In particular, it serves as a connecter to Central Business District (Motijheel area) and suburban area (Narayangonj area) [106]. In broader perspective, it is at the confluence point of three important national highways viz. Chittagong (N1), Sylhet (N2) and Mawa (N8) as well as Demra (old Chittagong) road. It is one of the major gateways to enter Dhaka City from at least 30 districts of Chittagong, Sylhet, Barisal and Khulna division, which essentially implies that Dhaka bound traffic stream from these three important national highways along with a large number of suburban city bound local traffic have to enter through the only roadway link between Jatrabari and Saidabad [97]. The construction started on June 22, 2010 as the largest public-private partnership investment in Bangladesh [106]. The latitude and longitude of the flyover is 23° 42' 37.728" N and 90° 25' 59.5524" E respectively.

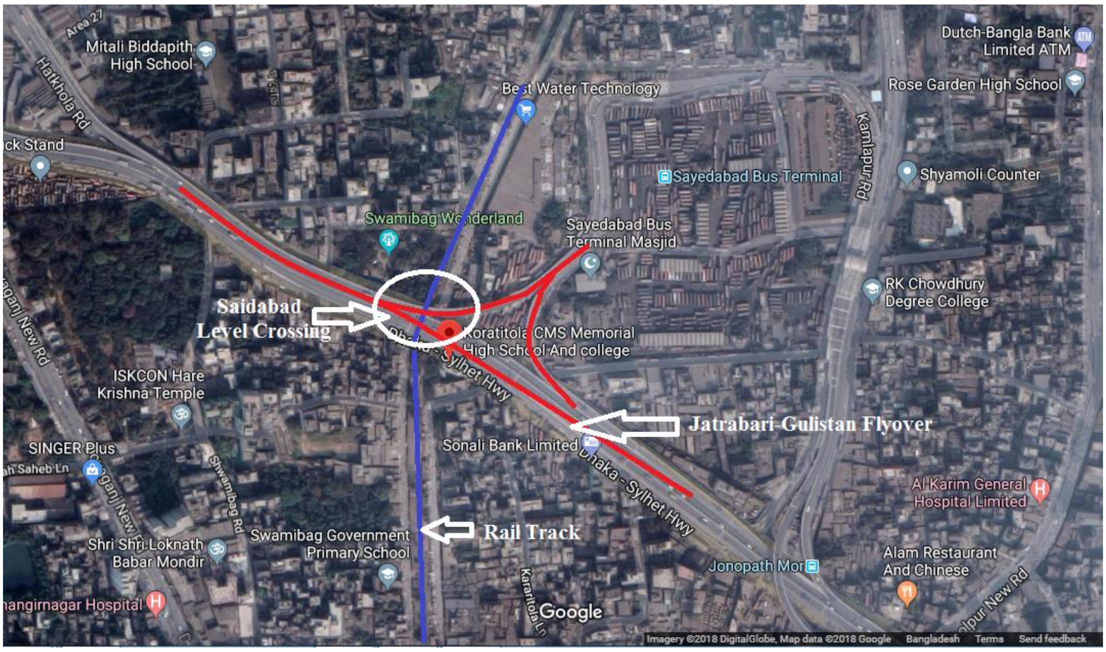
(a) Road Network (Google Earth View)



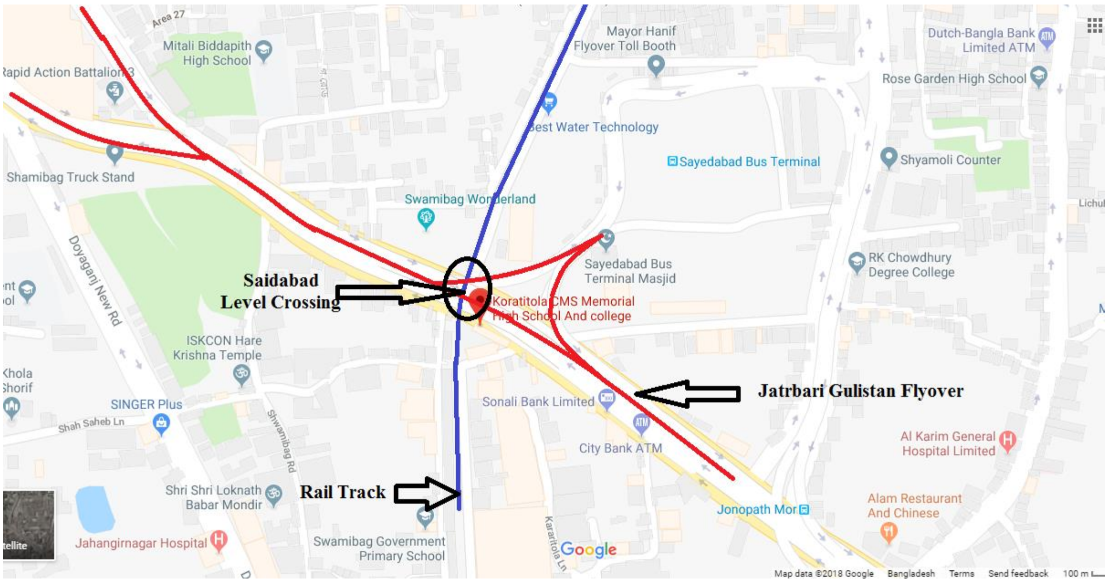
(b) Connecting Area. (Source: ([113])

Figure 3.5: Jatrabari-Gulistan Flyover.

The route of flyover is marked with red line in Figure 3.5. It shows the route of the flyover starting from Chankhar-Pool and then pass through Bongo-Market, Gulistan, Tikatuli, Wari, Narinda, Swamibag, Saidabad, Jatrabari and ends at Kutubkhali.



(a)



(b)

Figure 3.6: Location of the Saidabad Level crossing.
(a) Google Map View; (b) Google Earth View.

Field study reveal that there is one rail-road conflicting point underneath this flyover and it is denoted as Saidabad Level Crossing in this study and shown in Figure 3.6. The latitude and longitude of the Saidabad Level Crossing are 23.714322 N and 90.425341 E respectively.

3.2.6 Moghbazar-Mouchak Flyover

The total length of the Moghbazar-Mouchak Flyover is 8.7 kilometers along with ramps for smooth inflow and outflow from the major intersections of the covering area by this flyover. The length of the Tejgaon Satrasta to Holy Family Hospital Portion via Moghbazar circle and the extended portion till Sonargaon Rail Crossing is 2.555 kilometres, the length of the Shantinagar-Rajarbagh-Malibagh-Rampura portion is 3.937 kilometres while the length of the Banglamotor to Mouchak portion via Moghbazar circle is 2.208 kilometres. The flyover will help vehicular movement over eight road intersections and three level crossings i.e., Karwan Bazaar, Moghbazar and Malibagh, and will also help ease chronic traffic congestion for north-south traffic movement [112].

First phase of two-kilometre four-lane carriageway section of the flyover stretching from Shaheed Captain Mansur Ali Sarani near Holy Family Hospital to Saat Rasta intersection (Shaheed Tajuddin Ahmad Sarani) was opned to traffic on March 30, 2016 [114].

Second Phase was inaugurated on September 15. 2016 with 2.25-km section of the flyover connecting Bangla Motor and Mouchak [112], [115]. The 450-meter long part, Hatirjheel to Sonargaon intersection was opened to traffic on May 17, 2017 [116].

Third phase of the Moghbazar-Mouchak Flyover was opened to public on 26 October, 2017 with the completion of Kakrail-Malibagh, Rajarbagh-Mouchak, Rampura-Mouchak and Mouchak-Eskaton sections [114]. With the inauguration of the rest 4 km overpass of the entire 8.7 km one, vehicles can now go over eight road intersections and three level-crossings at Karwan Bazar, Moghbazar and Malibagh, substantially improving the city trips [116].

The project was originally scheduled to start in 2011 and completed by December 2015, but it started in 2013. In January 2015, the Executive Committee of the National Economic Council approved a revision of the project with an extension of 18 months till June 2017 and an increase in the cost by Tk 446.2 crore. The scheme is financed jointly by the Saudi Development Fund, OPEC Fund for International Development and the Government of Bangladesh [114]. The estimated cost of the flyover was Tk343.70 crores when the Executive Committee of the National Economic Council approved it in 2011. The project has missed a couple of deadlines and eventually the cost skyrocketed to Tk1,218.89 crore [115]. The latitude and longitude of Moghbazar-Mouchak Flyover is 23° 44' 44.1888" N and 90° 24' 43.1172" E

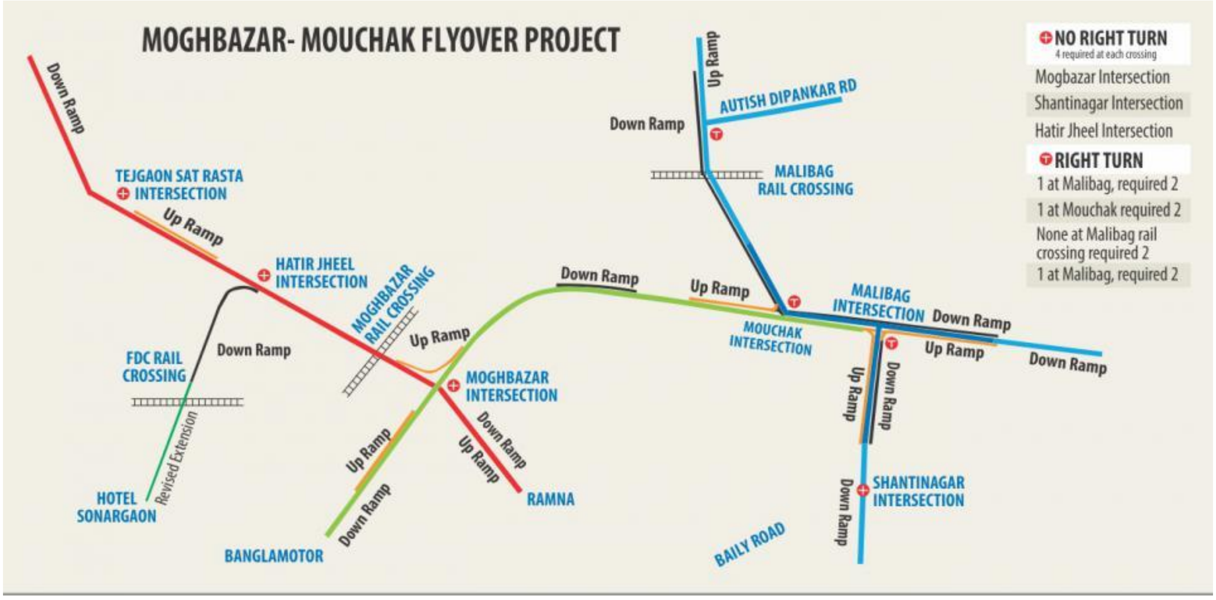


Figure 3.7: Layout of Moghbazar-Mouchak Flyover.

Source: ([117])

Figure 3.7 shows the layout of the Moghbazar-Mouchak Flyover including its' down-ramp, up-ramp and level crossings. There are three level crossings as shown in the figure i.e., FDC Level Crossing, Moghbazar Level Crossing and Malibag Level Crossing. The latitude and longitude of FDC Level Crossing 23.751662 N and 90.398134 E respectively; of Moghbazar Level Crossing 23.750168 N and 90.408769 E respectively; and of Malibagh Level Crossing 23.749736 N and 90.412653 E respectively.

The position of all these six flyovers in Dhaka city have been depicted in the following map to visualize and apprehend more about its geographical position, conflict zones with rail-road and probable demographic and traffic characteristics.

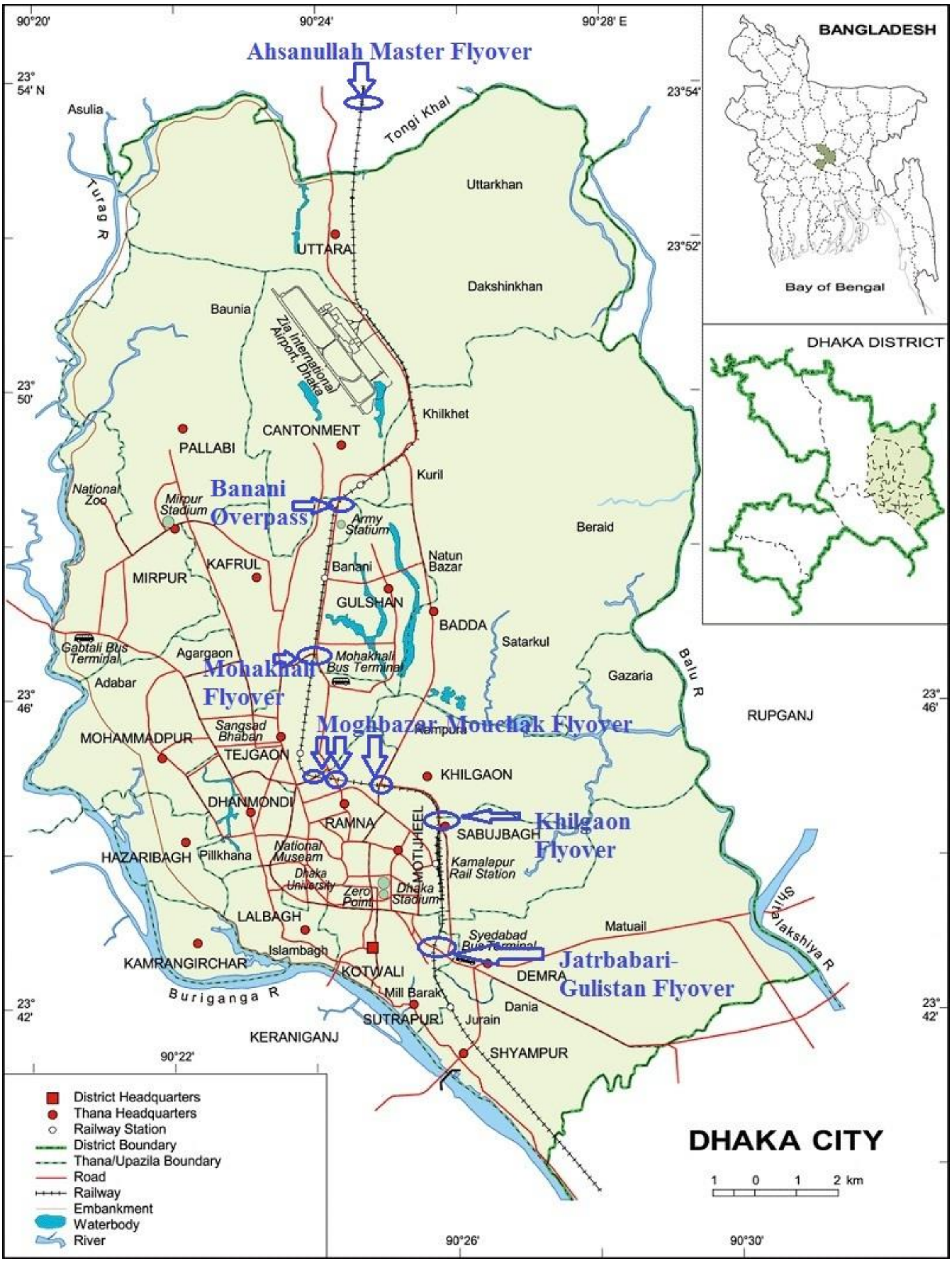


Figure 3.8: Position of six partially grade-separated flyovers in Dhaka city.

3.3 Reconnaissance Survey

After selecting the study area, a reconnaissance survey was conducted to decide the working steps and methodology. All the flyovers were visited at-first to visualize the field condition, how the surveys will be conducted, what types of analyses can be added and what sorts of latent variables may be considered throughout the study. Reconnaissance survey was conducted by walking along the each flyover corridor, the adjacent areas of each flyovers and also above-grade and at-grade visiting was conducted. Due to the long distance among the flyovers and considering temporal variation of the traffic count, flow and queue length, the survey could only be completed after several months of collecting huge volume of data. Hence, the survey started on 24 March, 2017 and ended on 11 October 2017

3.4 Classified Traffic Count at the Studied Flyovers

Classified vehicles count is the basic requirement for planning of road development and management schemes. Knowing the number and mix of different types of vehicles on a given roadway improves the understanding of what types of traffic are using this road, how these movements are affecting traffic operations, how this roadway section is performing to fulfill its' demand compared capacity and what sort of policies required to ameliorate this roadway section perform as desired. In addition, these data can help identify critical flow time periods, determine the influence of large vehicles or pedestrians on vehicular traffic flow, or document traffic volume trends. Further, classified traffic data forms an integral part of national economics and such knowledge is essential in drawing up a rational transport policy for movement of passengers and goods by both government and the private sectors. The length of the sampling period depends on the type of count being taken and the intended use of the data recorded. There are many different methods that can be used to gather classified vehicle count data, each with various levels of accuracy depending on the circumstance in which they are used.

However, in this study, short counts (15 minutes classified traffic count) were performed by Cordon count method during weekday, day; weekday, night; weekend, day and weekend, night to assess the relative level of usage of road space and to extract the percentage of different types of vehicles travelling through at-grade and above-grade during these time periods. Also this data will be analyzed to obtain the percentage of non-motorized vehicles and public transport travelling through above-grade and at-grade road. Those data were collected corresponding peak time identified from the field observations at these locations during weekday, day; weekday, night; weekend, day; and weekend, night, was used to determine traffic flow and percentage of different types of vehicles. Peak time were chosen because they represent the highest traffic flow. Under the flyover (at-grade), vehicles were videoed for 15 minutes in both directions at level crossing. Over the flyover (above-grade), vehicles were videoed for 15 minutes to measure the volume of vehicles passing over the rail line. Vehicles were then counted after analyzing video. At Ahsanullah Master Flyover, Banani Overpass and Mohakhali Flyover, the count was measured at one end, since the route is linear in each flyover. The count was then doubled to obtain two-directional volume, assuming the flow to remain same in each direction. The traffic volume in Khilgaon flyover was measured from a top of a residential building at a suitable height. Volume was measured for both directions. The traffic volume in Jatrabari-Gulistan flyover was collected by simultaneous sampling at 13 entry and exit ramps. Due to huge number of ramps (15), author has put an additional effort to assess the traffic count data for Moghbazar-Mouchak Flyover, which has been described in that particular section. The exact time with date and number of surveyors for collecting count data have been described in the particular classified description section for each flyover in the next chapter.

Since vehicles of various sizes and weights pass through the study area, it was indispensable to expedient their impact using a common measuring unit. Hence, the vehicle counts were converted to passenger car units using the following passenger car equivalent (PCE) factors prescribed by the Geometric Design Standards for Roads & Highways Department, Bangladesh: Rickshaw/Van: 2.00, Motorcycle: 0.75: Bicycle: 0.50, Car: 1.00, CNG: 0.75,Tempo: 0.75, Bus: 3.00, Utility: 1.00, Truck: 3.00, Bullock Carts: 4.00 (Table A.1) [118]. Accordingly, traffic flow in terms of PCUs were obtained by multiplying vehicle count data with their corresponding PCE factors. PCE factors have been depicted in the Table A.1 of the Appendix section.

3.5 Speed Measurement at the Studied Flyovers

To assess the mobility conditions of vehicles, speed of each types of vehicles were measured at each flyover, both at-grade and above-grade. Two different types of speed were measured in this study. The methodology of measuring those speeds have been described as follows:

3.5.1 Measurement of Travel Speed

Floating car method was used to assess travel speed at each direction of each flyover by recording the travel time (including motion time, segment delay and through vehicle delay) and dividing the segment length by the travel time. So this speed considers any stop-time delay. A permitted error of ± 1.0 miles/hour and 95% confidence interval was chosen to get speed difference (R) of 4 miles/hour between maximum and minimum value of travel times. As a result, a minimum of 10 test runs were required as per Manual of Transportation Engineering Studies [119]. Hence, 10 test runs over each segment was done during peak hour to determine the travel speed. Analyses of classified traffic counts data on a particular day will provide with the information of when the highest traffic flow occurred in that flyover corridor. As such, all subsequent data except free flow speed data were collected during these time period. The same procedure has been followed to measure travel speed at each and every studied flyovers.

3.5.2 Measurement of Free Flow Speed

Travel time measured using intra-frame scene capture based on superimposed image at free-flow conditions was used to determine space mean free flow speeds. HCM (2010) defines Free Flow Speed (FFS) as the average speed of the traffic stream when traffic volumes are sufficiently low that drivers are not influenced by the presence of other vehicles and when intersection traffic control is not present or is sufficiently distant as to have no effect on speed choice [120].

3.6 Queue Length Measurement at the Level Crossings

The typical characteristics of urban traffic are frequent stops due to congestion and intersections, and associated delays and pollution. One of the major reason for this is the presence of signalized intersections. Signalized intersections, while helping to make the traffic more organized and safe, may lead to more delays, especially during off-peak hours. The major parameters that are used to quantify the performance of a signal are the queue length and delays. Thus, the information of number of vehicles in queue and associated delay are useful for devising traffic management strategies that would help in improving the performance of traffic network [121]. Depending on the type of service provided, the queues that are formed may be either moving or completely stopped. Typically, moving queues are formed at locations where the flow of vehicles across the bottleneck or service area is never completely stopped. Stopped queues occur on the other hand when there are completely interruption of service for a significant amount of time. In respect to the present study, author has considered queues formed due to complete stop-situation at level crossing. The traffic flow is disrupted completely and delayed at level crossing because the traffic capacity is lower and road vehicles are forced to stop at level crossing to ensure uninterrupted free train movement than at other portions of the roadway. Traffic delays at level crossings include delays caused by deceleration of vehicles while approaching the level crossing, reduced vehicle speed surrounding area of the level crossing, time needed for vehicles to resume freeway speed after exiting from level crossing, and vehicle queues formed at the level crossing.

However, in this study, queue length is defined as the length of the line of motor vehicles that have been stopped at a level crossing in order for the trains to pass. It was measured at eight level crossings that experience significant road traffic operation using video based image processing technique. The name of the eight level crossings are as follows:

1. Saidabad Level Crossing
2. Khilgaon Level Crossing
3. Malibagh Rail Gate Level Crossing
4. Moghbazar Level Crossing
5. FDC Level Crossing
6. Mohakhali Level Crossing
7. Banani Level Crossing
8. Ahsanullah Master Level Crossing

The total queue was first videoed at a particular level crossing. The first and last car in a particular lane and direction were identified. The corresponding positions of the cars were then superimposed on the surrounding pedestrian footpath and marked physically using flower pots. Then, the length between the markers along the footpath was measured using measuring tape to measure queue length. The length was taken as that measured from the front bumper of the car stopping nearest to the level crossing to the front bumper of the car stopping at the end of that lane. Because the approach roads have multiple lanes, queue length was taken as the average measured length after considering all the lanes in a particular direction. Then, the queue lengths from all directions were added to get total queue length at an intersection. Number of surveyors and data collection were varying due to the distances among the survey locations and huge volume of data sets. The exact time and number of surveyors have been described in the particular level crossing description section for queue length in the next chapter.

3.7 Secondary Data

Secondary data were collected from the LGED, RHD, ARI, Ministry of Railways and Kamalapur Administration Building several times during the research period regarding flyover construction related information, traffic flow data, pedestrian accident data, flyover accident data, rail accident data, number of level crossings, number of trains passing through the study corridor and speed limits on route.

3.8 Overview

This chapter elaborately describes all the six studied flyovers and presented their schematic layout to clarify it to the reader. Also the road-rail conflict points underneath each of the flyover have been described and shown figuratively. Reconnaissance survey was conducted to finalize basic working strategies and has been described in the later section. Methodology of the classified traffic counts were described in the next section to assess the level of usage of the road by different types of vehicles. Then the basic measurement procedure for travel speed and free flow speed both at at-grade and above-grade have been described clearly to assess the mobility conditions in those flyovers corridor. Additionally, the methodology of measuring queue length has been described. And in the last portion of this chapter, secondary sources of data collection and types of collected data have been mentioned.

However, in the next chapter, all these collected data and their detailed analyses have been presented with relevant explanations and rationale justification.

CHAPTER 4
DATA ANALYSES AND RESULTS

4.1 Introduction

The study is aimed at the performance evaluation of all the flyovers constructed over rail-road level crossing in Dhaka City. To fulfill the objectives of the study, it is required to assess the relative level of usage of road spaces under and over the flyovers, usage of flyover spaces by non-motorized vehicles and public transport, evaluate the mobility and road accessibility conditions of vehicles both at-grade and above-grade level and finally, measure the effectiveness of flyovers in terms of reducing traffic congestion levels and improving safety at level crossings. To assess these parameters, classified vehicle count, travel speed, free flow speed, congestion degree and accident data are required to be collected from real-field condition. In addition to that, results need to be accurately assessed using information from actual traffic situations. In order to achieve that, data (classified vehicle count, travel speed, free flow speed, congestion degree and accident data) from the study sites were collected and extensively analyzed. Also some special investigations have been added in the last portion of this chapter. Hence, this chapter systematically represents the data collected from field and secondary sources, and outlines the analyses and results extracted from these data.

4.2 Assessment of Level of Usage of Road Space

After collecting classified traffic count data both manually and using video, comprehensive analyses of the collected data have been done and the findings are presented in the following sections. Classified traffic count was performed to assess the relative level of usage of road space under and over the flyover. Classified traffic count data were collected for four periods in each of the studied flyovers, as such, weekday, day; weekend, day; weekday, night; and weekend, night. Their analysis in respect to each flyovers have been presented in the following sub-sections.

4.2.1 Mohakhali Flyover

4.2.1.1 Data Collection Time

In Mohakhali Flyover, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 17.03.2017 (Friday); Weekend, Night data was collected at 8.30 pm - 8.45 pm on 18.03.2017 (Saturday). Weekday, Day data was collected at 5.15 pm - 5.30 pm on 16.05.2017 (Tuesday). Weekday, Night data was collected at 8.00 pm - 8.15 pm on 30.05.2017 (Tuesday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

4.2.1.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form. Table 4.1 shows the classified traffic count data collected from Mohakhali Flyover.

Table 4.1: Classified Traffic Count at Mohakhali Flyover (PCUs)

Mohakhali Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	79	0	916	184	0	39	33	1	4660	74.08	2.86: 1
	Under	2	35	17	213	56	55	28	9	5	1630	25.92	
Weekend, Night	Over	0	74	0	780	277	0	41	28	4	4439	69.69	2.30: 1
	Under	3	47	20	187	112	74	40	15	4	1931	30.31	
Weekday, Day	Over	0	93	0	813	304	13	42	31	6	4767	67.74	2.10: 1
	Under	8	69	8	329	85	62	24	22	4	2271	32.26	
Weekday, Night	Over	0	57	0	592	167	0	42	37	5	3452	59.46	1.47: 1
	Under	9	49	27	375	63	72	26	17	0	2353	40.54	

The total flow across different times of the day in Mohakhali Flyover are compared in Figure 4.1.

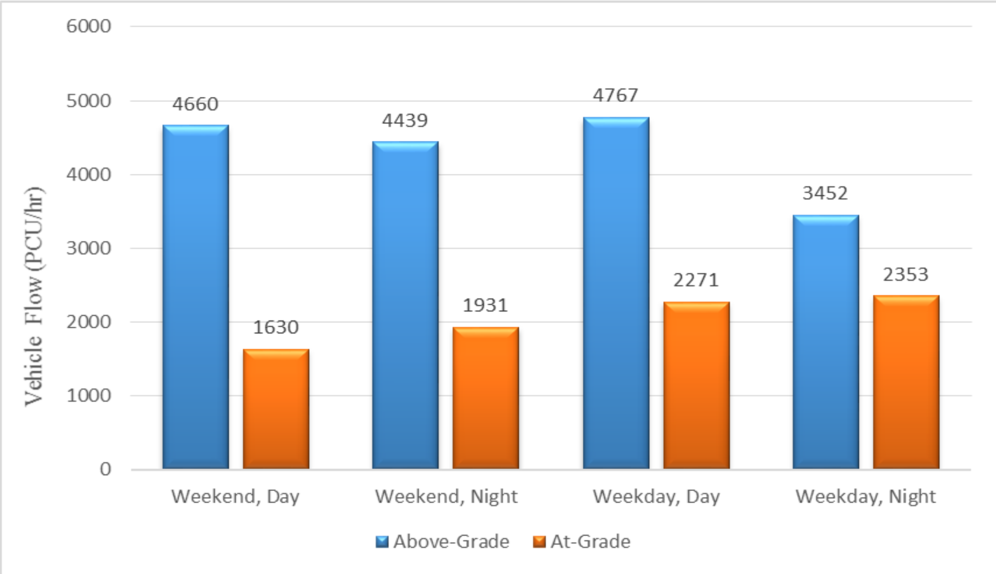


Figure 4.1: Grade-wise and Temporal Comparison of Vehicle Flow at Mohakhali Flyover

4.2.1.3 Analyses of the Collected Data

Table 4.1 and Figure 4.1 show that an overwhelming majority of vehicles are travelling through above-grade or using the flyover, hence, reducing the probability of rail-road traffic conflict in Mohakhali Level Crossing. The last column of the Table 4.1 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekend, day, with 25.92 % vehicles travelling at-grade and 74.08 % vehicles travelling above-grade. This variance decreases to a minimum of 59.46 % above-grade and 40.54 % at-grade respectively at weekday, night. Overall, the ratio of above-grade to at-grade flow is only 2.12:1. From Figure 4.1 it is observed that the highest flow at above-grade (4767.44 PCU/hr) occurs at weekday, day and at at-grade (2353.36 PCU/hr) occurs at weekday, night. This implies that maximum flow both at-grade and above grade-occur at weekday period. In addition to that, maximum flow at-grade occurs at night whereas maximum flow above-grade occurs at day. Further, weekend time period, night flow is 18.45% higher than that of day flow at-grade level and 4.74% less above grade. Whereas, in weekday time period, night flow is 3.65 %

higher than that of day flow at-grade level and 27.60% less above-grade. It indicates that flow decreases above grade and increases at-grade during night time and hence, it implies that road users are less interested to use flyover at night time. It may be due to the fact that at night time, the vehicular flow at this flyover corridor tends to be lower at-grade level and hence, road users feel comfortable to use at-grade road rather using flyover to save their fuel and time. The rationale for higher flow in weekday compared to weekend day time period may be explained by the fact that people from newly developed residential area like, Uttara, Basundhara Residential Area, Nikhunja and sub-urban area like, Abdullahpur, Tongi, Gazipur come to capital for work purpose. As house rent and life-expense is extremely high in Dhaka, people who work in capital with low salary prefer to live outside the main city to save their cost and they usually do not come to the capital during weekend days. Hence, Weekday flow in this flyover corridor is generally higher than weekend flow. Additional reason to explain this flow pattern is that the usage rate of car or personal motorized vehicle is comparatively higher in the surrounding region of the flyover, like, Gulshan, Uttara, Banani, which indicates that more affluent people live there.

4.2.1.4 Comparison with Previous Studies

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

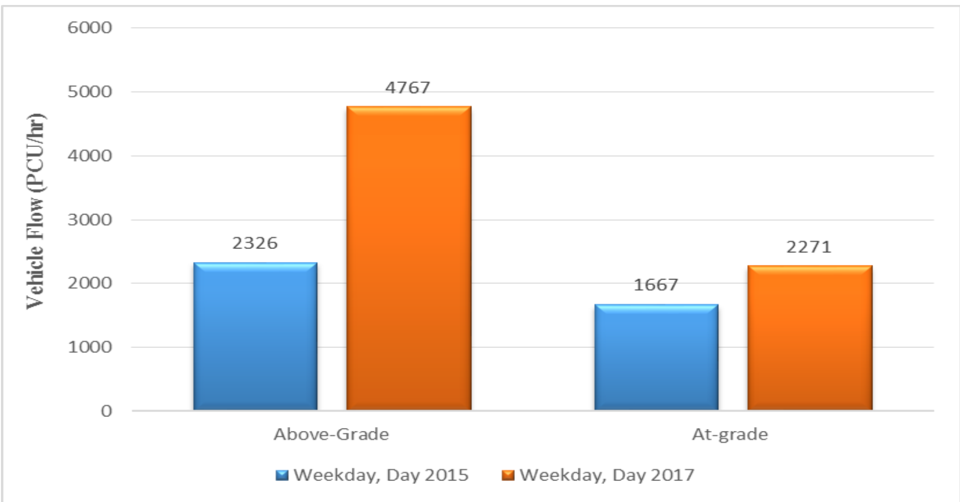


Figure 4.2: Comparison of Vehicle Flow on Yearly Basis at Mohakhali Flyover.

Figure 4.2 shows that the vehicle flow has increased at both grades (from 2325.76 PCU/hr to 4767.44 PCU/hr above-grade, and from 1667.04 PCU/hr to 2270.56 PCU/hr at-grade. Compared to 2015 weekday day period, flow has increased 104.98% at above-grade and 36.20% at at-grade respectively. In addition to that, the above-grade to at-grade flow ratio has increased from 1.40:1 to 2.12: 1, indicating a prodigious increasing trend for vehicles to move from at-grade to above grade. So, flyover has been successful in diverting greater portion of traffic at above-grade, although a significant proportion of vehicles are still forced to use at-grade road because of the flyover configuration.

4.2.2 Khilgaon Flyover

4.2.2.1 Data Collection Time

In Khilgaon Flyover, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 06.10.2017 (Friday); Weekend, Night data was collected at 8.30 pm -8.45 pm on 06.10.2017 (Saturday). Weekday, Day data was collected at 5.15 pm -5.30 pm on 11.10.2017 (Wednesday). Weekday, Night data was collected at 8.30 pm- 8.45 pm on 11.10.2017 (Wednesday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

4.2.2.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form.

Table 4.2 shows the classified traffic count data collected from Khilgaon Flyover. The total flow across different times of the day in Khilgaon Flyover are compared in Figure 4.3.

Table 4.2: Classified Traffic Count at Khilgaon Flyover (PCUs)

Khilgaon Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	424	1	589	366	1	196	23	3	6634	43.69	0.78:1
	Under	1091	27	51	51	14	18	4	6	1	8551	56.31	
Weekend, Night	Over	0	289	0	857	438	0	190	35	0	7387	59.61	1.48:1
	Under	622	31	18	26	40	36	0	1	0	5006	40.39	
Weekday, Day	Over	0	329	0	1719	254	0	358	69	2	12163	53.24	1.14:1
	Under	1376	37	33	42	33	32	2	4	2	10683	46.76	
Weekday, Night	Over	0	215	0	2253	238	0	353	58	5	13707	63.08	1.71:1
	Under	1015	46	54	23	37	40	0	8	0	8023	36.92	

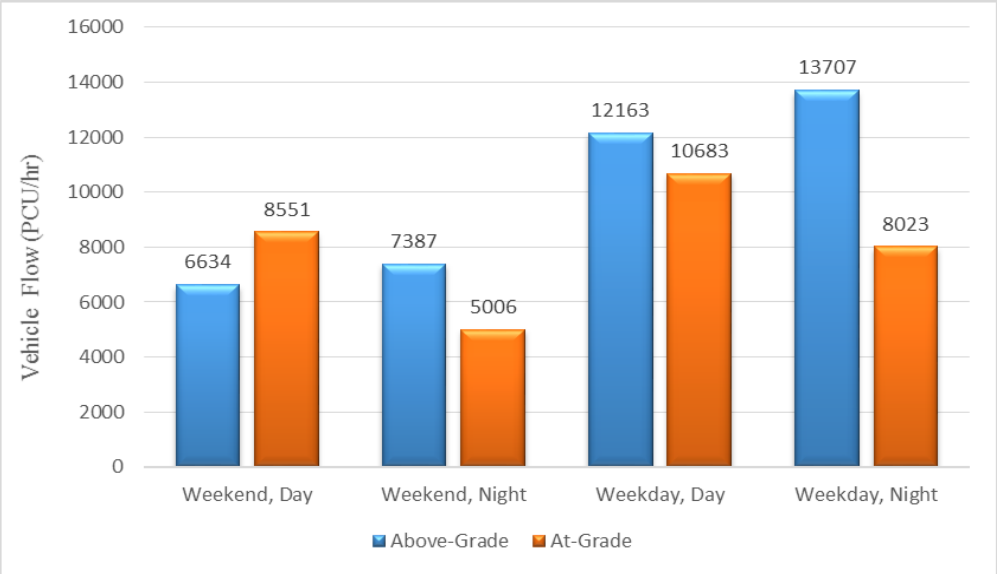


Figure 4.3: Grade-wise and Temporal Comparison of Vehicle Flow at Khilgaon Flyover

4.2.2.3 Analyses of the Collected Data

Table 4.2 and Figure 4.3 reveal an interesting information regarding Khilgaon Flyover. Comparatively a higher portion of vehicles travel above-grade or use the flyover in weekend night, weekday day and weekday night, hence, reducing the relative probability of rail-road traffic conflict in Khilgaon Level Crossing. However, a completely reversed scenario has been observed at weekend day. The last column of the Table 4.2 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekday, night, with 36.92 % vehicles travelling at-grade and 63.08 % vehicles travelling above-grade. The reverse case is observed in weekend, day, where 56.31 % vehicles travelling at-grade and 43.69 % vehicles travelling above grade. The rationale for this may be justified by the fact that the number of induced vehicles in this flyover corridor drastically decreases since, Khilgaon Flyover is very close to central business district, Motijheel. Another reason is that there is a large whole-seller market and green-grocer market. This induces customers from surrounding area and they prefer to use at-grade road to go this market.

Overall, the ratio of above-grade to at-grade flow is only 1.24:1. From Figure 4.3 it is observed that the highest flow at above-grade (13707.08 PCU/hr) at weekday, night and at at-grade (10683.04 PCU/hr) occurring at weekday, day. This implies that maximum flow both at-grade and above-grade occurs at weekday period. The rationale for higher flow in weekday compared to weekend day time period may be explained by the fact that people from surrounding districts and areas come to Motijheel for work purpose. As house rent and life-expense is extremely high in Dhaka, People who work in Motijheel area with low salary prefer to live outside the main city to save their cost and they usually do not come to main capital during weekend days. Hence, Weekday flow in this flyover corridor is generally higher than weekend flow.

In addition to that, maximum flow at-grade occurs at day whereas maximum flow above grade occurs at night. Further, weekend time period, night flow is 41.46% less than that of day flow at-grade level and 11.34% higher at above-grade. Whereas, in weekday time period, night flow is 24.90 % less than that of day flow at-grade level and 12.70% higher at above-grade. It indicates that flow increases above grade and decreases at-grade during night time and hence, it implies that road users are more likely to use flyover at night time. It may be due to the fact that Khilgaon is just beside the central business district. Many districts connecting vehicles take their passengers from the central area, i.e., Motijheel, Malibagh, Arambagh, Basabo and they pass through Saidabad-Jatrabari bus stand using this flyover. Hence, to save their time and make the journey faster along with avoiding the small-lane width road underneath the flyover, they prefer to use flyover at-night time.

4.2.2.4 Comparison with Previous Studies

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

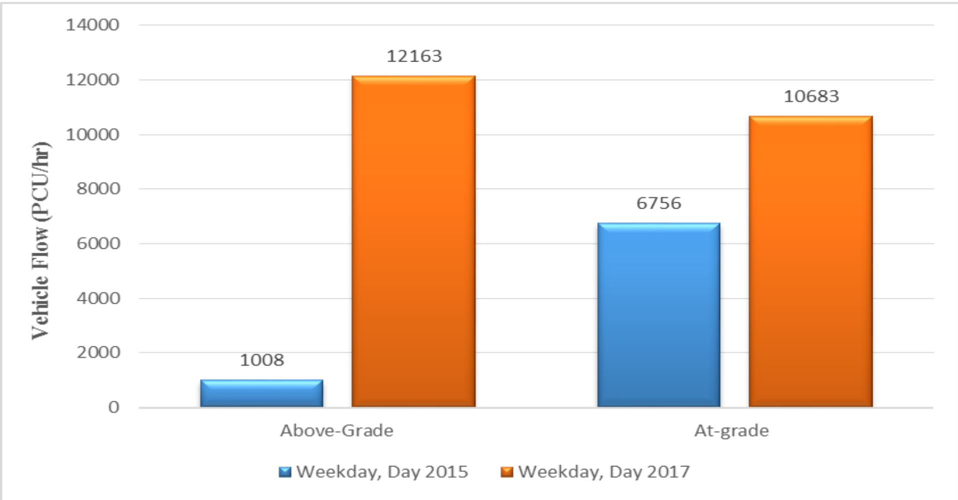


Figure 4.4: Comparison of Vehicle Flow on Yearly Basis of Khilgaon Flyover.

Figure 4.4 shows that the vehicle flow has increased at both grades (from 1008.32 PCU/hr to 12163.32 PCU/hr above-grade, and from 6755.56 PCU/hr to 10683.04 PCU/hr at-grade. Compared to 2015 weekday day period, flow has increased 1106.29% at above-grade and 58.14% at at-grade respectively. This implies that the yearly increase rate in above-grade traffic is much higher than that of at-grade, which is definitely a positive indication regarding the performance of this flyover. In addition to that statistics, the above-grade to at-grade flow ratio has increased from 0.149:1 to 1.138: 1, indicating a prodigious increasing trend for vehicles to move from at grade to above-grade. So, flyover has been successful in diverting greater portion of traffic at above-grade, although a larger proportion of vehicles are forced to use at-grade road because of the flyover configuration.

4.2.3 Shaheed Ahsanullah Master Flyover

4.2.3.1 Data Collection Time

In Shaheed Ahsanullah Master Flyover, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 24.03.2017 (Friday); Weekend, Night data was collected at 8.30 pm - 8.45 pm on 19.05.2017 (Friday); Weekday, Day data was collected at 5.15 pm - 5.30 pm on 20.04.2017 (Tuesday); Weekday, Night data was collected at 8.00 pm - 8.15 pm on 20.04.2017 (Tuesday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

Table 4.3: Classified Traffic Count at Ahsanullah Master Flyover (PCUs)

Ahsanullah Master Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	88	0	221	58	201	77	63	132	841	23.83	0.31:1
	Under	2289	8	11	44	19	124	0	114	77	2687	76.17	
Weekend, Night	Over	0	72	0	199	47	168	55	92	132	765	23.58	0.31:1
	Under	2186	14	9	40	22	124	0	63	22	2480	76.42	
Weekday, Day	Over	0	99	0	221	80	389	155	210	431	1584	35.66	0.55:1
	Under	2532	28	9	44	17	75	0	77	77	2858	64.34	
Weekday, Night	Over	0	33	0	81	36	240	88	81	210	769	44.33	0.80:1
	Under	515	41	18	85	163	44	0	55	44	966	55.67	

4.2.3.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form. Table 4.3 shows the classified traffic count data collected from Ahsanullah Master Flyover.

The total flow across different times of the day in Ahsanullah Master Flyover are compared in Figure 4.5.

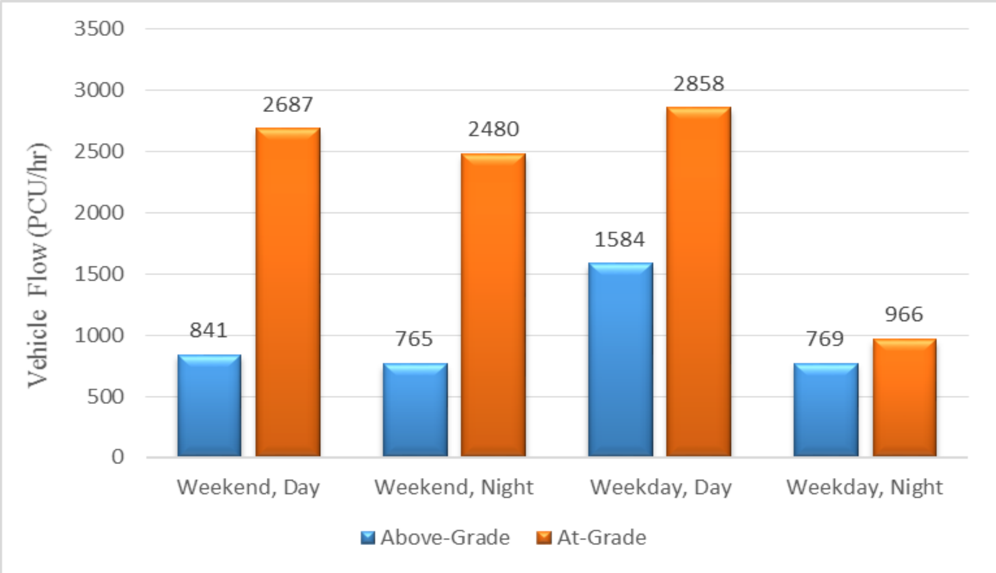


Figure 4.5: Grade-wise and Temporal Comparison of Vehicle Flow at Ahsanullah Master Flyover

4.2.3.3 Analyses of the Collected Data

Table 4.3 and Figure 4.5 reveal that an overwhelming majority of vehicles are travelling at-grade or avoid to use the flyover, hence, increasing the probability of rail-road traffic conflict in Ahsanullah Master (Tongi) Level Crossing. The last column of the Table 4.3 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekend, night, with 23.58 % vehicles travelling above-grade and 76.42 % vehicles travelling at-grade. The maximum percentage of vehicles that are using this flyover facility are only 44.33% at weekday, night. Hence, the percentage of vehicles using the flyover facilities varies from maximum 44.33% to 23.58%, which is really unexpected. The statistics imply that major portion of vehicles are using at-grade road and avoiding to use above grade facility and hence, degrading the rail-road traffic condition as well as increasing the probability of rail-road conflict. This may be due to the fact that Tongi is an industrial area. There are large number of industries surrounding this flyover. Many commercial vehicles as well as heavy loaded vehicles come this area to load/unload their products from the designated industry. If they use this flyover, they may have to travel longer distances in congested situation. Hence, these vehicles often avoid this flyover and use at-grade road. Another reason is that, there is a pick-up (utility vehicle) stand, as well as CNG and auto-rickshaw stand underneath this flyover. Hence, general people come to hire auto-rickshaw and CNG for travel trip purpose and hire pick-up for freight transfer purpose. All these factors increase vehicular flow at-grade level and turn the construction of flyover a useless one.

Overall, the ratio of above-grade to at-grade flow is only 0.44:1. From Figure 4.5 it is observed that the highest flow at above-grade (1584.24 PCU/hr) at weekday, day and at at-grade (2858.44 PCU/hr) occurring also at weekday, day. This implies that maximum flow both at-grade and above-grade occurs at weekday period. The rationale for higher flow in weekday compared to weekend day time period may be explained by the fact that Ahsanullah Master Flyover is situated at the northern corner of Dhaka city. It is actually northern-entry point of Dhaka city. Vehicles from North Bengal i.e., Narsingdi, Bhairab, Sylhet and Kishoreganj enter Dhaka through Tongi using this flyover. The rate of people coming from these districts for the search of job, official seminar, training, meeting, workshop and other purpose generally in weekday. Additionally, many people who work basically in capital and live in low living cost area like Tongi, Pubail, Kaliganj, Ghorashal, Palash, Narsingdhi and so on, come to capital for their daily work purpose and hence, flow generally higher than that of weekend days. Hence, Weekday flow in this flyover corridor is generally higher than weekend flow.

In addition to that, maximum flow at-grade occurs at day whereas maximum flow above-grade occurs also at day. Further, weekend time period, night flow is 7.70% less than that of day flow at-grade level and 8.97% less than that of above-grade. Whereas, in weekday time period, night flow is 66.21 % less than that of day flow at-grade level and 51.45% less than that of above-grade. It indicates that flow decreases at above-grade and at-grade during night time and the decreasing rate of traffic flow in night time is higher for above-grade level. It implies that during night time, overall flow is decreased but comparatively heavy vehicles, commercial vehicles, long destination bus are more likely to use this flyover.

4.2.3.4 Comparison with Previous Studies

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

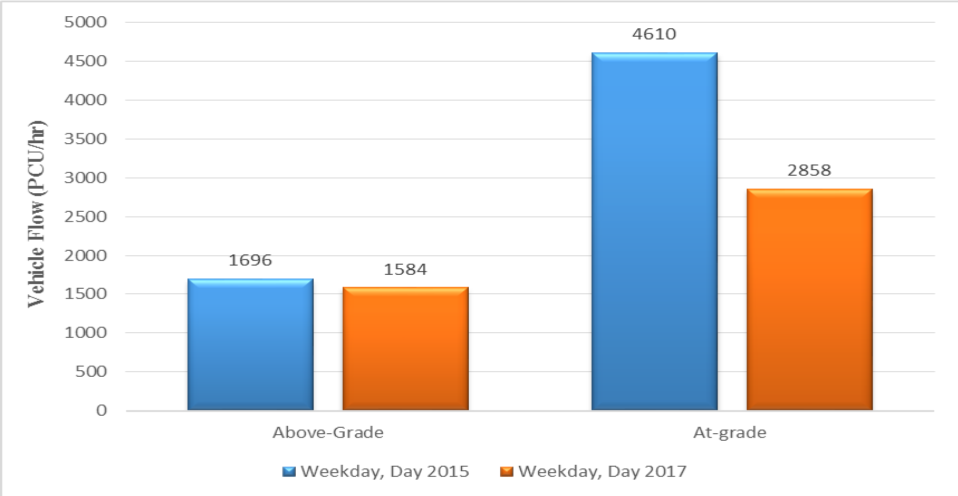


Figure 4.6: Comparison of Vehicle Flow on Yearly Basis of Ahsanullah Master Flyover

Figure 4.6 shows that the vehicle flow has decreased at both grades (from 1696.48 PCU/hr to 1584.24 PCU/hr above-grade, and from 4610.12 PCU/hr to 2858.44 PCU/hr at-grade). Compared to 2015 weekday day period, flow has decreased 6.62% at above-grade and 38% at at-grade respectively. This is quite interesting. The flow decreased both at-grade and above-grade level, which implies that fewer vehicles are using this corridor. Author has given an in-depth insight to this phenomenon and found out that, the roads connecting Tongi and Ghorasal through this flyover is completely broken. In addition to that, recently repair work has already begun. This introduce a new dimension of long queue of vehicles throughout his road. Hence, to avoid, rider discomfort, long queue of vehicles in this route, longer travel time and overall, complete uncertainty, road users avoid this flyover corridor route. As a result, flow in this flyover corridor has been decreased substantially.

However, the above-grade to at-grade flow ratio has increased from 0.37:1 to 0.55: 1 in between 2015 to 2017, indicating an increasing trend for vehicles to move from at-grade to above-grade, which really a positive sign for constructing this flyover. So, it is expected that in future, this flyover will divert more traffic at above-grade, although a larger proportion of vehicles in this flyover corridor will always use at-grade road because of the demographic and commercial importance of this region.

4.2.4 Banani Overpass

4.2.4.1 Data Collection Time

In Banani Overpass, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 17.03.2017 (Friday); Weekend, Night data was collected at 9.30 pm - 9.45 pm on 18.03.2017 (Saturday); Weekday, Day data was collected at 5.15 pm - 5.30 pm on 09.05.2017 (Tuesday); Weekday, Night data was collected at 9.30 pm - 9.45 pm on 20.04.2017 (Tuesday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

Table 4.4: Classified Traffic Count at Banani Overpass (PCUs)

Banani Overpass	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	49	0	463	178	0	90	46	6	3559	83.37	5.01:1
	Under	2	20	20	123	23	1	2	11	2	710	16.63	
Weekend,	Over	0	180	2	1351	558	0	98	50	15	8444	87.74	7.16:1
	Under	1	19	19	278	9	0	2	1	1	1179	12.26	
Weekday, Day	Over	0	73	0	1490	133	0	114	83	18	7814	82.97	4.87:1
	Under	4	39	25	339	23	0	3	6	5	1604	17.03	
Weekday, Night	Over	0	80	0	1355	263	1	80	120	84	8188	88.72	7.86:1
	Under	6	10	5	229	8	0	8	2	0	1041	11.28	

4.2.4.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form.

Table 4.4 shows the classified traffic count data collected from Banani Overpass. The total flow across different times of the day in Banani Overpass are compared in Figure 4.7.

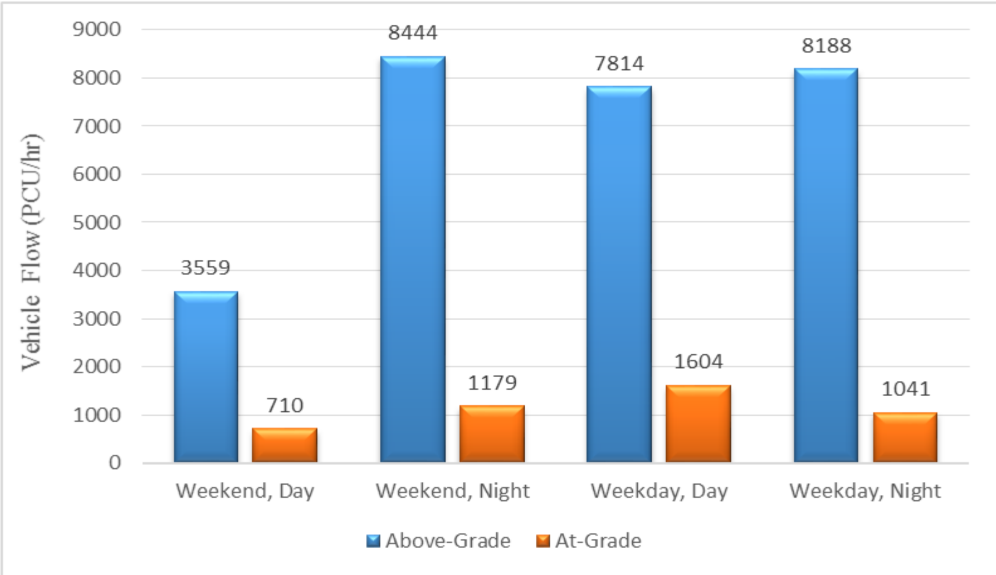


Figure 4.7: Grade-wise and Temporal Comparison of Vehicle Flow at Banani Overpass

4.2.4.3 Analyses of the Collected Data

Table 4.4 and Figure 4.7 reveal that an overwhelming majority of vehicles are travelling above grade or using the flyover, hence, reducing the probability of rail-road traffic conflict in Banani Level Crossing. The last column of the Table 4.4 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekday, night, with 88.72 % vehicles travelling above-grade and 11.28 % vehicles travelling through at-grade. This variance decreases to a minimum of 82.97 % and 17.03 % for above-grade and at-grade respectively at weekday, day. Overall, the ratio of above-grade to at-grade flow is only 6.17:1. The statistics implies that major portion of vehicles are using above-grade road and hence, improving the rail-road traffic condition as well as minimizing the probability of rail-road conflict. From this point of view, it can be concluded that so far the flyover has been successful in segregating the traffic from rail-road conflict and eventually shifting them to above-grade, which is definitely a positive sign.

From Figure 4.7, it is observed that the highest flow at above-grade (8443.76 PCU/hr) at weekend, night and at at-grade (1604.48 PCU/hr) occurring at weekday, day. This implies that maximum flow at-grade and above-grade occurs at weekday and weekend period respectively. Maximum flow at above-grade during weekend, night is quite peculiar. This may be due to the fact that most of inter-districts vehicles coming to Mohakhali Bus Terminal use this flyover corridor. In addition to that, people go for long drive and to have vacation in Gazipur and Sylhet area and they probably return using this corridor in Dhaka city at night time which cause higher flow in weekend night time of this flyover. The rationale for higher flow at-grade in weekday compared to weekend day time period may be explained by the fact that at-grade road of Banani Overpass is connecting the traffic of restricted area (Cantonment Area). First of all, the at-grade flow is much lower compared to above-grade flow due to this restricted zone. Most of roads connected with the flyover corridor is fully access controlled, hence, at-grade flow is much lower. Since, movement or activity is relatively higher in weekday-day time, at-grade flow is found maximum weekday, day.

4.2.4.4 Comparison with Previous Studies

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

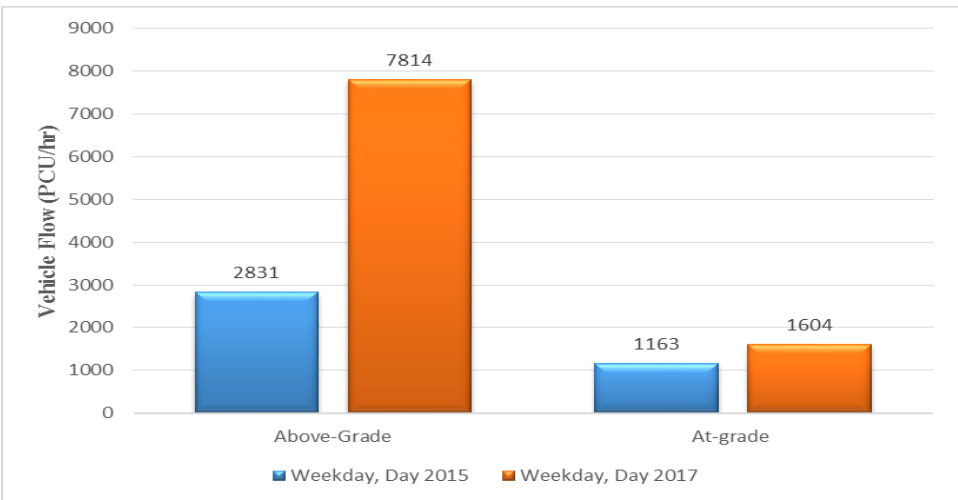


Figure 4.8: Comparison of Vehicle Flow on Yearly Basis of Banani Overpass

Figure 4.8 shows that the vehicle flow has increased at both grades (from 2830.84 PCU/hr to 7814.48 PCU/hr above-grade, and from 1162.88 PCU/hr to 1604.48 PCU/hr at-grade). Compared to 2015 weekday day period, flow has increased 176.05 % at above-grade and 37.98 % at at-grade respectively. This implies that the yearly increase rate in above-grade traffic is much higher than that of at-grade, which is definitely a positive indication regarding the performance of this flyover. In addition to that statistics, the above-grade to at-grade flow ratio has increased from 2.43:1 to 4.87: 1, indicating a prodigious increasing trend for vehicles to move from at-grade to above-grade. So, flyover has been successful in diverting greater portion of traffic from at-grade to above-grade, hence, mitigate the previously occurred traffic congestion at this level crossing.

4.2.5 Jatrabari-Gulistan Flyover

4.2.5.1 Data Collection Time

In Jatrabari-Gulistan Flyover, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 06.10.2017 (Friday); Weekend, Night data was collected at 9.30 pm - 9.45 pm on 17.03.2017 (Friday). Weekday, Day data was collected at 5.15 pm - 5.30 pm on 21.08.2017 (Monday). Weekday, Night data was collected at 8.00 pm - 8.15 pm on 21.08.2017 (Monday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

4.2.5.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form. Table 4.5 shows the classified traffic count data collected from Jatrabari-Gulistan Flyover.

Table 4.5: Classified Traffic Count at Jatrabari-Gulistan (PCUs)

Jatrabari-Gulistan Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	941	0	1785	613	163	1932	199	0	5632	79.78	3.95:1
	Under	957	58	13	26	14	0	342	18	0	1428	20.22	
Weekend, Night	Over	15	903	4	2046	1391	588	1998	309	298	7551	74.13	2.87:1
	Under	1906	72	20	33	33	0	563	7	0	2635	25.87	
Weekday, Day	Over	0	991	0	986	185	182	5288	442	0	8074	68.51	2.16:1
	Under	1259	55	6	416	58	66	1733	63	55	3710	31.49	
Weekday, Night	Over	0	1322	0	1439	414	511	5829	666	0	10181	66.08	1.94:1
	Under	2502	69	9	537	102	41	1833	99	33	5227	33.92	

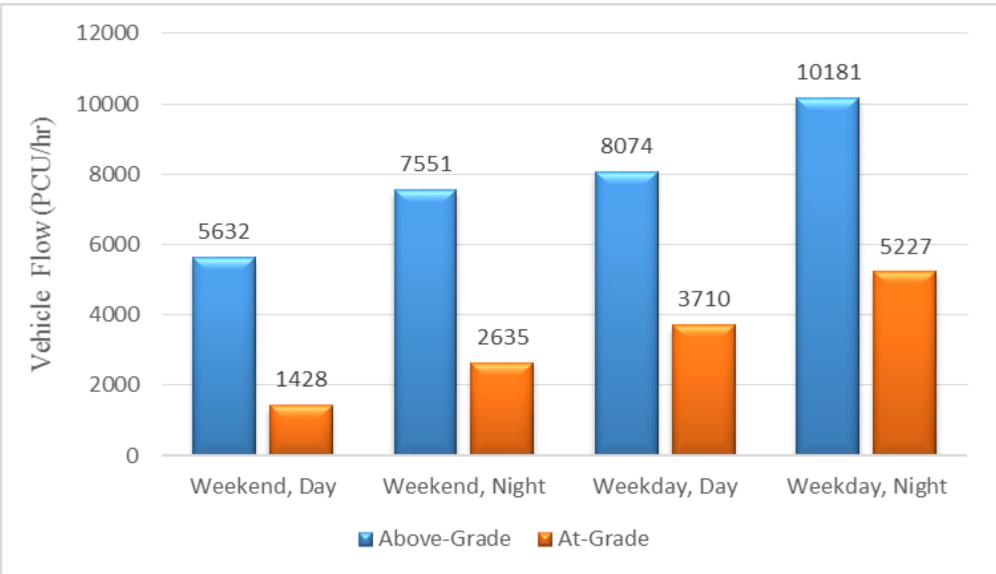


Figure 4.9: Grade-wise and Temporal Comparison of Vehicle Flow at Jatrabari-Gulistan Flyover

The total flow across different times of the day in Jatrabari-Gulistan Flyover are compared in Figure 4.9.

4.2.5.3 Analyses of the Collected Data

Table 4.5 and Figure 4.9 show that an overwhelming majority of vehicles are travelling through above-grade or using the flyover, hence, reducing the probability of rail-road traffic conflict in Saidabad Level Crossing. The last column of the Table 4.5 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekend, day, with 20.22 % vehicles travelling at-grade and 79.78 % vehicles travelling above-grade. This variance decreases to a minimum of 66.08 % at above-grade and 33.92 % at at-grade respectively at weekday, night. Overall, the ratio of above-grade to at-grade flow is only 2.42:1. From Figure 3 it is observed that the highest flow at above-grade (10180.72 PCU/hr) during weekday, night and at-grade (5226.52 PCU/hr) also occurring at weekday, night. The rationale for this may be explained by the fact that people from sub-urban area like, Narayanganj, Bhulta, Munshipur, Fatullah, Munshiganj are come to capital for work purpose and leave Dhaka after their office. Another reason may be added to the previous one is that as house rent and life-expense is extremely high in Dhaka, People who work in capital with less salary prefer to live outside the main city to save their cost. Additional reason is that the communication between port city, Chittagong and the capital, Dhaka is established through this route, number freight flow (truck) is extremely increased in night time as this type of vehicular flow is limited in day time in capital. Hence, it has been seen that number of trucks has been increased to 501.82% at night time compared with day time. In addition to that, considering the combined situation, total night flow exceeded the day flow by 29.38 % above-grade and 53.02 % at-grade. On the other hand, total weekday flow exceeded weekend flow by 38.46 % above-grade by 119.97% at-grade. This justifies the rationale explained earlier for high flow at night time in weekday.

4.2.5.4 Comparison with Previous Studies

A comparison has been drawn between the weekday, day data of Anwari, Hoque and Islam (2016) collected in 2015 with the present data set of this study to visualize the yearly variation of flow and also to observe whether the flyover is performing well than previous or not.

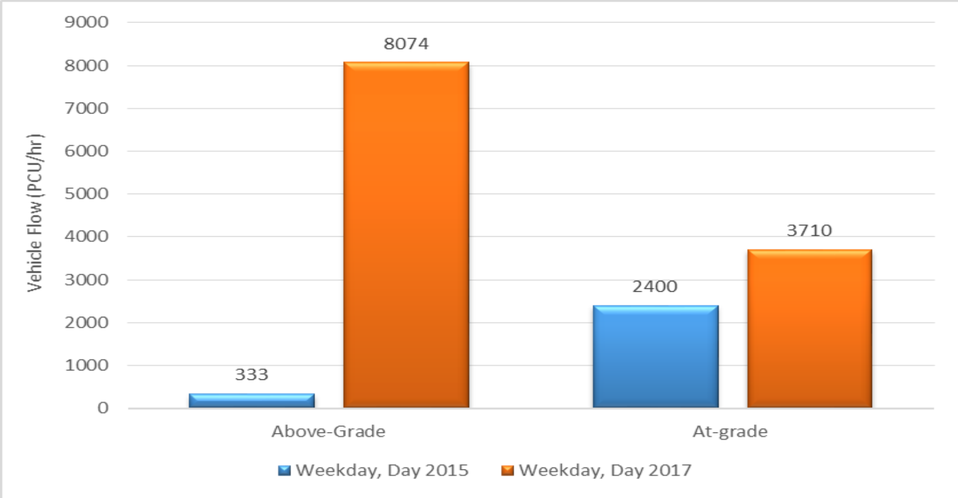


Figure 4.10: Comparison of Vehicle Flow on Yearly Basis of Jatrabari-Gulistan Flyover

Figure 4.10 shows that the vehicle flow has increased at both grades (from 333.04 PCU/hr to 8073.92 PCU/hr above grade, and from 2400.28 PCU/hr to 3710.36 PCU/hr at grade. The percentage increase in above-grade and at-grade are 2324.31% and 54.58%. In addition to that statistics, the above grade to at-grade flow ratio has enormously increased from 0.138:1 to 2.176: 1, indicating a prodigious increasing trend for vehicles to move from at grade to above grade. Since at grade motor traffic make conflicts with the train movements at the level crossings at this site, it can be evidently concluded that this flyover is successful in fulfilling the objectives of segregating rail and road traffic and thereby successful in eliminating congestion as well as to improve safety issues.

4.2.6 Moghbazar-Mouchak Flyover

4.2.6.1 Data Collection Time

In Moghbazar-Mouchak Flyover, Weekend, Day data was collected at 5.15 pm - 5.30 pm on 13.10.2017 (Friday); Weekend, Night data was collected at 8.30 pm - 8.45 pm on 13.10.2017 (Friday); Weekday, Day data was collected at 5.15 pm -5.30 pm on 16.10.2017 (Monday). Weekday, Night data was collected at 8.30 pm- 8.45 pm on 16.10.2017 (Monday). The time period for collecting data in weekday, day; weekday, night; weekend, day and weekend, night have been identified from the field observations of hourly traffic volume during the studied time period along the flyover corridor.

4.2.6.2 Data Representation

All these classified count data have been represented both in tabular form and a comparison among total flow across different times of the day have been presented in graphical form.

Table 4.6 shows the classified traffic count data collected from Moghbazar-Mouchak Flyover. The total flow across different times of the day in Moghbazar-Mouchak Flyover are compared in Figure 4.11.

Table 4.6: Classified Traffic Count at Moghbazar-Mouchak Flyover (PCUs)

Moghbazar-Mouchak Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total equivalent hourly flow (PCU)	Percentage of Total (%)	Ratio of Vehicles Passing over to those Under
Weekend, Day	Over	0	97	1	592	222	0	141	39	17	4949	63.16	1.71:1
	Under	107	69	0	301	106	7	23	25	13	2887	36.84	
Weekend, Night	Over	0	119	1	690	302	0	161	43	31	5981	79.45	3.87:1
	Under	81	19	1	133	30	8	25	4	1	1547	20.55	
Weekday, Day	Over	0	150	1	998	512	0	39	54	37	6539	70.42	2.38:1
	Under	131	30	2	369	49	3	15	8	0	2747	29.58	
Weekday, Night	Over	0	73	0	446	218	0	33	41	25	3236	64.87	1.85:1
	Under	108	20	1	171	32	9	12	7	0	1753	35.13	

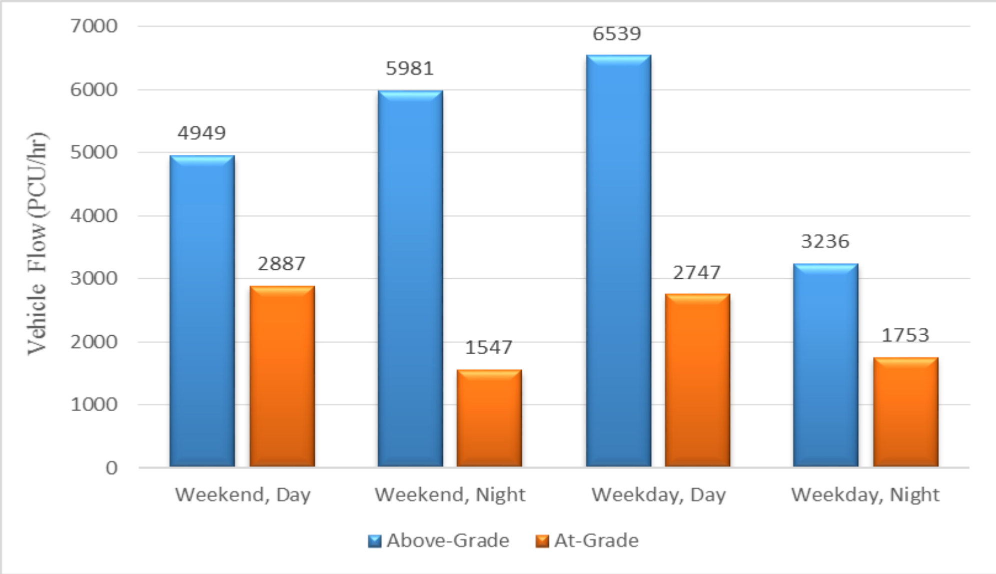


Figure 4.11: Grade-wise and Temporal Comparison of Vehicle Flow at Moghbazar-Mouchak Flyover

4.2.6.3 Analyses of the Collected Data

Table 4.6 and Figure 4.11 reveal an interesting information regarding Moghbazar-Mouchak Flyover. Comparatively a higher portion of vehicles are travelling through above-grade or using the flyover hence, reducing the relative probability of rail-road traffic conflict in FDC Level Crossing, Moghbazar Level Crossing and Malibagh Railgate Level Crossing. The last column of the Table 4.6 showing relative usage by vehicles of road space over and under the flyover clarifies this proposition. The greatest disparity in flows between different grades is at weekend, night, with 20.55 % vehicles travelling at-grade and 79.45 % vehicles travelling above-grade. This variance decreases to a minimum of 63.16 % at above-grade and 36.84 % at at-grade respectively at weekend, day. Overall, the ratio of above-grade to at-grade flow is only 2.32:1. This implies that major portion of vehicles are using above-grade road and hence, improving the rail-road traffic condition as well as minimizing the probability of rail-road conflict. From this point of view, it can be concluded that so far the flyover is successful in segregating the traffic from rail-road conflict and eventually shifting them to above grade, which is definitely a positive sign.

From Figure 4.11, it is observed that the highest flow at above-grade (6539.36 PCU/hr) at weekday, day and at at-grade (2886.96 PCU/hr) occurring at weekend, day. This implies that maximum flow at above-grade and at-grade occurs at weekday and weekend period. The rationale for higher flow over the flyover during weekday compared to weekend day time period may be explained by the fact that it is a mega-flyover and makes connection among the most congested Malibagh, Mouchak, Moghbazar, Tejgaon, Kawranbazar, Satrasta area and Banglamotor area. Vehicles coming from Mohakali, Uttara, Tongi, Gazipur, Norsingdi and other northern districts and wants to go Mogbazar, Kawranbazar or motijheel area can easily use tejgaon satrasta mor ramp to reach their destination. Similarly, Shantinagar-Rajarbagh-Malibagh-Rampura route and Banglamotor to Mouchak portion via Moghbazar route facilitate easy communication among the vehicles whose origin-destination satisfy the routes. All the aforementioned areas of this flyover corridor are at the center of the city. In addition to that, people need to pass this flyover corridor to reach the central business district, Motijheel, of Dhaka city. Consequently, vehicular flow increases above the flyover at weekday period. On the contrary, as the number of people, who come to Dhaka for official, administrative and commercial purpose, drastically decreases in this region during weekend day, the probability of getting at-grade road free from congestion is higher. Most importantly, Kawran Bazar is one of the largest wholesale marketplaces in Dhaka city. It is also one of the largest marketplaces in South Asia. People in Dhaka city prefer to go to market for their daily needs once a week and weekend time is the best suit for this purpose. They need to use at grade road to reach their shopping destination and hence, maximum flow at-grade is found at weekend period.

In addition to that, maximum flow both at-grade and above-grade occurs at day. Further, weekend time period, night flow is 46.43 % less than that of day flow at-grade level and 20.86 % higher at above-grade. Whereas, in weekday time period, night flow is 36.20 % less than that of day flow at-grade level and 50.52 % less at above-grade. It indicates that flow decreases at at-grade during night time and hence, it can be concluded that road users are more likely to use flyover at night time. It may be due to the fact that Moghbazar-Mouchak Flyover is just between the central business district and commercial business district. Many districts connecting vehicles take their passengers from the central area, i.e., Motijheel, Malibagh, Fakirapool, Panthopath and they pass through Gabtoli and Mohakhali bus terminal using this flyover. Hence, to save their time and make the journey faster as well as avoid narrow roads underneath the flyover, they prefer to use flyover at-night time.

4.2.6.4 Comparison with Previous Studies

When Anwari, Hoque and Islam (2016) collected data in 2015, Moghbazar-Mouchak Flyover was under construction. Hence, no data has been found and consequently, no comparison can be drawn between previous data and present data for this flyover.

However, from the light of the above discussion it can be concluded that from the perspective of segregating traffic from at-grade to above-grade, Banani Overpass has been proved to be most successful and rest of the flyovers are performing very poorly and the worst case has been found for Ahsanullah Master Flyover.

4.3 Assessment of Usage of Flyover Space by NMVs and Public Transport

Proportion of non-motorized vehicles (NMVs) and public transport travelling over and under flyover have been assessed and analyzed to apprehend the level usage of the flyover spaces by the non-motorized vehicles and public transport. In this study, rickshaw, van and bicycle are considered as non-motorized vehicles whereas, bus and mini-buses are termed as “public transport”. The analyses have been done for each of the studied flyovers and their findings have been presented in the following sections.

4.3.1 Mohakhali Flyover

4.3.1.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their anylyses have been presented in the following sections for both at-grade and above-grade of Mohakhali Flyover.

Table 4.7 and Figure 4.12 show the percentage of different types of vehicles at-grade and above-grade of the flyover corridor incorporating the four time period in this studied segment. i.e, Weekend, day; Weekend, night; Weekday, day and Weekday, night.

Table 4.7: Percentage of Different Types of Vehicles at Mohakhali Flyover

Mohakhali Flyover	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck
Weekend, Day, Over	0	4.68	0	72.34	10.9	0	9.24	2.60	0.24
Weekend, Day, Under	0.903	5.93	1.92	48.08	9.48	9.31	18.96	2.03	3.39
Weekend, Night, Over	0	4.60	0	64.66	17.2	0	10.2	2.32	0.99
Weekend, Night, Under	1.14	6.72	1.91	35.64	16.01	10.58	22.86	2.86	2.29
Weekday, day, Over	0	5.38	0	62.76	17.6	0.75	9.73	2.4	1.39
Weekday, Day, Under	2.6	8.39	0.65	53.32	10.33	7.54	11.67	3.56	1.94
Weekday, Night, Over	0	4.56	0	63.11	13.35	0	13.43	3.94	1.60
Weekday, Night, Under	2.81	5.75	2.11	58.64	7.39	8.44	12.2	2.66	0

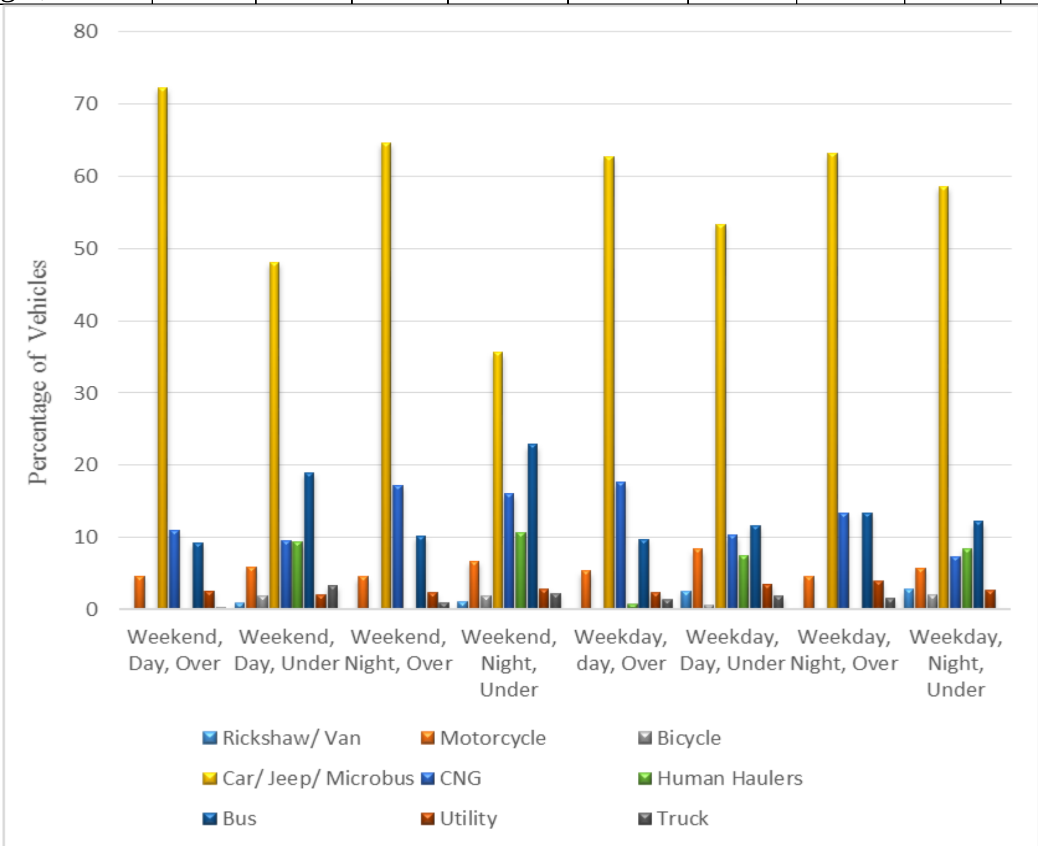


Figure 4.12: Temporal Variation of Different Types of Vehicles in Mohakhali Flyover

Table 4.7 and Figure 4.12 reveal that car/jeep/microbus is the main beneficary of this flyover. In the considered four time periods, both at grade and above grade, car is the dominating vehicle. In weekend, day time period, after car (72.34%), CNG (10.90%) is the next dominating vehicle at above-grade. At-grade scenario is slightly different. Here, car is dominating (48.08%) and after that major percentage of vehicles is bus (18.96%). Mini-Bus (9.31%) and CNG (9.48%) are also present in comparatively significant portion. Exactly the same scenario has been observed in the weekend, night period data analyses. In this time period, both above-grade and at-grade, car is the most dominating vehicle and its percentage is 64.66% and 35.64% respectively. CNG (17.22%) is the next dominating vehicles at-above grade.Whereas, bus (22.87 %) is the next major vehicle after car at at-grade. Mini-Bus (10.58 %) and CNG (16.08 %) are also present in comparatively significant portion at grade. Car also occupied the greatest share at grade (53.32 %) and above grade (62.76 %) in week-day, day period. CNG (17.6 %) is next to car at above-grade and, while bus (11.7 %) and CNG (10.32 %) occupy significant at-grade space in this time period. Car has again been found as the highest number of at-grade (58.64 %) and above grade (63.113 %) in week-day, night period. CNG (13.53 %) and bus (13.43 %) are next to car at above-grade and, bus (12.2 %) is at-grade for this time period. All the other types of vehicles i.e., Rickshaw/ Van, Motorcycle, Bi-cycle, utility vehicles and trucks are present in negligible percentage.

The analyses of the different types of vehicles reveal that most beneficiary of constructing flyovers is private car. Interestingly next to it is CNG, which is another private vehicle run on a rent basis (para-transit). The percentage of public transport is insignificant. Hence, it can be concluded that public transport are getting negligible benefits from this flyover. Since there is significant land usage beneath flyover, including residential and commercial spaces, people will continue to use at-grade facilities. Hence, public transport will continue to serve people at-grade.

In addition to that the percentage of NMVs in this flyover is negligible Further analyses have been performed to understand the NMVs's fact more clearly.

4.3.1.2 Analysis of NMVs

Table 4.8 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

Table 4.8: Proportion of NMVs Travelling Above Grade and At-Grade at Mohakhali Flyover

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekend, Night	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

A complete absence of NMVs at above-grade in Mohakhali Flyover can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 1.15 % of total traffic are NMVs in Mohakhali Flyover and 100 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover.

However from the light of above discussion, Mohakhali Flyover has completely failed to provide any facility to the NMVs. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict-free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

4.3.2 Khilgaon Flyover

4.3.2.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their analyses have been presented in the following sections for both at-grade and above-grade of Khilgaon Flyover.

Table 4.9 and Figure 4.13 show the percentage of different types of vehicles at-grade and above-grade of the flyover corridor incorporating the four time period in this studied segment. i.e, Weekend, day; Weekend, night; Weekday, day and Weekday, night.

Table 4.9: Percentage of Different Types of Vehicles at Khilgaon Flyover

Khilgaon Flyover	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Human Hauler	Bus	Utility	Truck
Weekend, Day, Over	0	17.64	0.03	32.67	15.23	0.042	32.62	1.28	0.5
Weekend, Day, Under	93.9	0.87	1.1	2.19	0.45	0.58	0.52	0.26	0.13
Weekend, Night, Over	0	10.8	0	42.7	16.37	0	28.4	1.74	0
Weekend, Night, Under	91.45	1.71	0.66	1.91	2.21	1.98	0	0.07	0
Weekday, day, Over	0	7.47	0	52.01	5.76	0	32.5	2.09	0.18
Weekday, Day, Under	94.8	0.96	0.57	1.45	0.85	0.83	0.21	0.14	0.21
Weekday, Night, Over	0	4.33	0	60.49	4.79	0	28.43	1.56	0.40
Weekday, Night, Under	93.11	1.58	1.24	1.06	1.27	1.38	0	0.37	0

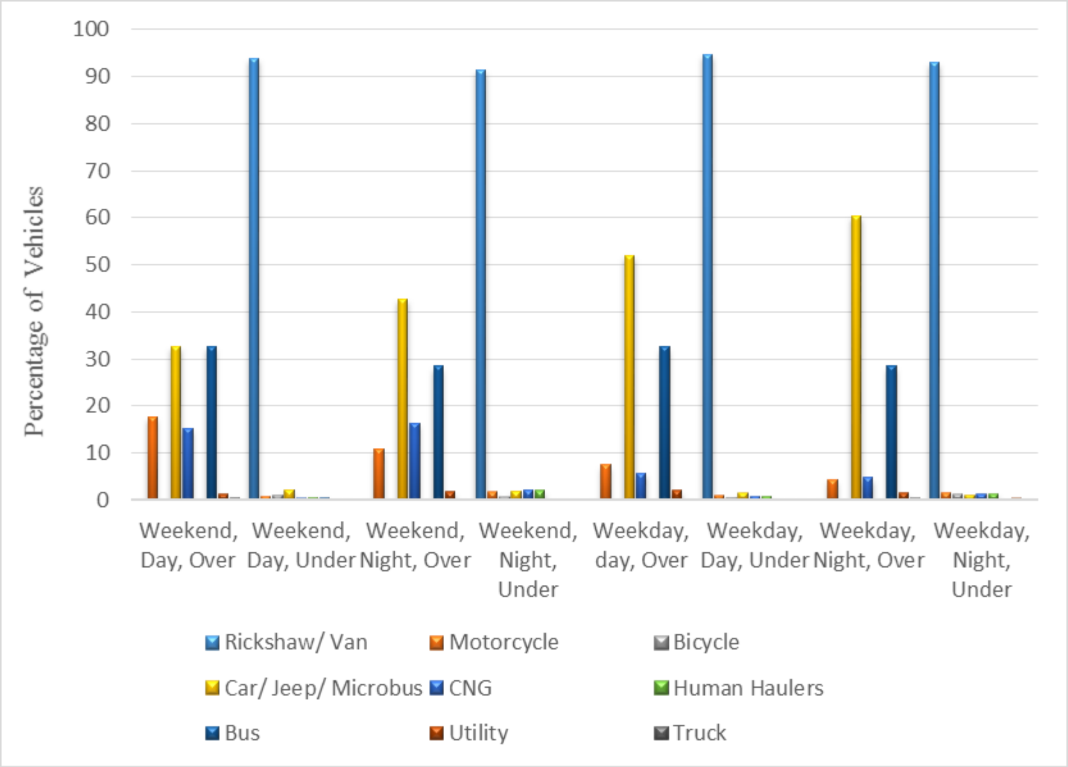


Figure 4.13: Temporal Variation of Different Types of Vehicles in Khilgaon Flyover

Table 4.9 and Figure 4.13 reveal that car/jeep/microbus is the main beneficary of this flyover. In the considered four time periods, car is the dominating vehicle at above-grade, and Rickshaw/Van is dominating vehicle at at-grade. In weekend, day time period, Car (32.67%), Bus (32.62%) and CNG (15.23%) are dominating vehicles at-above grade. At-grade scenario is completely different. Here, Rickshaw/Van is dominating (93.90%) exclusively. All the others vehicle's percentage is negligible in this time framework. Almost same scenario has been observed in the week-end, night period data analyses. In weekend, night time period, Car (42.7%), Bus (28.4%) and CNG (16.37%) are dominating vehicles at-above grade. At-grade scenario is completely different. Here, Rickshaw/Van is dominating (91.45%) exclusively. All the others vehicle's percentage is negligible in this time framework.

Car has also been found as the highest number road user at above-grade (52.01 %) in week-day, day period. Bus (32.5 %) is in next to car at above-grade. Rickshaw/Van is dominating (94.8%) exclusively at at-grade in this time period. Again, Car has again been found as the highest number road user at above-grade (60.49 %) in week-day, night period and Bus (28.43 %) is found next to car. Rickshaw/ Van (93.11 %) is also dominating at at-grade of this fyover corridor. All the other types of vehicles i.e., Motorcycle, Bi-cycle, utility vehicles and trucks are present in negligible percentage.

The analyses of the different types of vehicles reveal that most beneficiary of constructing flyovers is private car. Almost all private cars, which were supposed to use at-grade road previously, now they are using above-grade road for passing this flyover corridor. However, unfortunately a significant percentage of vehicles in this corridor are NMVs and they are using at-grade road. Consequently, they are exposed to rail-road conflict point and hence, they are completely deprived of using this flyover facility. Further analyses have been performed to understand the NMVs's fact more clearly.

4.3.2.2 Analysis of NMVs

Table 4.10 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

Table 4.10: Proportion of NMVs Travelling Above Grade and At Grade at Khilgaon Flyover

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	1.92	98.08	0.02	99.98
Weekend, Night	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

A negligible presence of NMVs (only 1.92% bicycles of total NMVs at weekend, day) travelling above grade can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and

Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 42.26 % of total traffic are NMVs and only 0.01% of total NMVs are using this flyover whereas, 99.99 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover.

However from the light of above discussion, Khilgaon has completely failed to provide any facility to the NMVs. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

4.3.3 Shaheed Ahsanullah Master Flyover

4.3.3.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their analyses have been presented in the following sections for both at-grade and above-grade of Ahsanullah Master Flyover.

Table 4.11: Percentage of Different Types of Vehicles at Ahsanullah Master Flyover

Ahsanullah Master Flyover	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck
Weekend, Day, Over	0	10.5	0	26.26	6.89	23.96	9.2	7.44	15.75
Weekend, Day, Under	85.18	0.31	0.41	1.64	0.72	4.62	0	4.25	2.88
Weekend, Night, Over	0	9.38	0	25.96	6.13	21.99	7.2	12.02	17.31
Weekend, Night, Under	88.13	0.55	0.37	1.63	0.89	5.01	0	2.52	0.89
Weekday, day, Over	0	6.27	0	13.94	5.052	24.56	9.8	13.24	27.18
Weekday, Day, Under	88.57	0.97	0.32	1.54	0.58	2.61	0	2.7	2.7
Weekday, Night, Over	0	4.30	0	10.53	4.67	31.22	11.5	10.53	27.27
Weekday, Night, Under	53.33	4.3	1.90	8.76	16.86	4.57	0	5.71	4.57

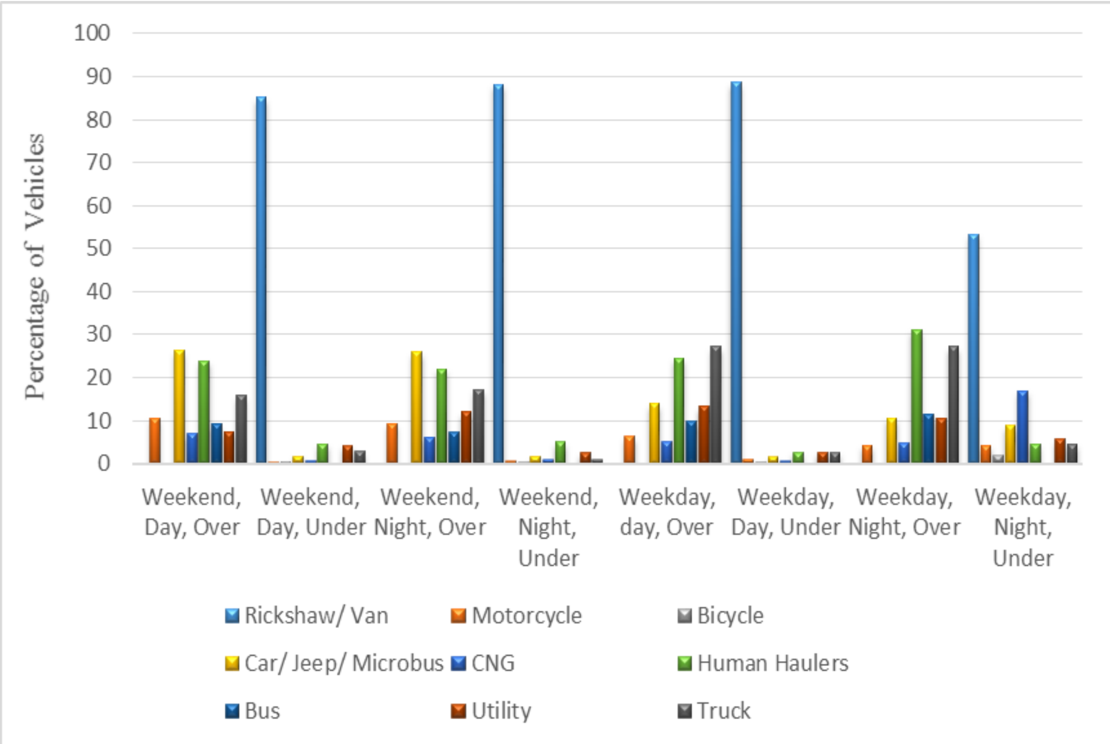


Figure 4.14: Temporal Variation of Different Types of Vehicles in Ahsanullah Master Flyover

Table 4.11 and Figure 4.14 show the percentage of different types of vehicles at-grade and above-grade of the flyover corridor incorporating the four time period in this studied segment. i.e, Week-end, day; Week-end, night; Week-day, day and Week-day, night.

Table 4.11 and Figure 4.14 reveal that Car/Jeep/Microbus and Mini-Bus are the main beneficaries of this flyover. In the considered four time periods, mini-buses and car are the dominating vehicle at above-grade, and Rickshaw/Van is dominating vehicle at at-grade. In weekend, day time period, Car (26.26 %), Mini-Bus (23.96 %) and Truck (15.75) are dominating vehicles at-above grade. At-grade scenario is completely different. Here, Rickshaw/Van is dominating (85.18 %) exclusively. All the others vehicle's percentage is negligible in this time framework. Almost same scenario has been observed in the week-end, night period data analyses. In weekend, night time period, Car (25.96 %), Human Hauler (21.99 %) and Truck (17.31 %) are dominating vehicles at-above grade, whereas, Rickshaw/Van is dominating (88.13 %) exclusively at-grade. All the others vehicle's percentage is negligible in this time framework. In week-day, day time period, Truck (27.18 %), Mini-Bus (24.56 %), Utility (13.24 %) and Car (13.94 %) are dominating vehicles at-above grade. Rickshaw/Van (88.57 %) is the main user of at-grade road during week-day, day period. In week-day, night time period, Mini-Bus (31.22 %), Truck (27.27 %), Utility (10.53 %) and Car (10.53 %) were found to be most dominating at-above grade. Whereas, Rickshaw/ Van (53.33 %) and CNG (16.86 %) were found significant at-grade road during week-day, night period. This statistics indicate that the flyover is in the region of industrial area and field study justified that Tongi is basically an industrial area, which is rationale with the study findings.

The analyses of the different types of vehicles reveal that most beneficiary of constructing flyovers is private car, Human Hauler and Truck in this flyover corridor. Most of the private cars, mini-buses and trucks are using above grade road, whereas, rickshaw, van, CNG and vice versa, are using at-grade road. However, unfortunately a significant percentage of vehicles in this corridor are NMVs and they are using at-grade road. Consequently, they are exposed to rail-road conflict point and hence, they are completely deprived of using this flyover facility. Further analyses have been performed to understand the NMV's situation more clearly.

4.3.3.2 Analysis of NMVs

Table 4.12 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

Table 4.12: Proportion of NMVs Travelling Above Grade and At-Grade at Ahsanullah Master Flyover

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekend, Night	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

The total absence of NMVs travelling above grade can be attributed to the dimensions and grades of the approach ramps of flyovers that make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari et al. (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The authors emphasized on this problem in Ahsanullah Master Flyover as the largest number of vehicles passing underneath those flyovers is NMVs. Comparing with 2015 data it is found that 100% of NMVs continue to use at-grade road, strengthening the proposition that NMVs will not be the beneficiary of constructing new flyovers. The present study reveals that 58.45 % of total traffic are NMVs and 100% NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover.

From the light of above discussion, Ahsanullah Master Flyover has completely failed to provide any facility to the NMVs. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

4.3.4 Banani Overpass

4.3.4.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their analyses have been presented in the following sections for both at-grade and above-grade of Banani Overpass.

Table 4.13: Percentage of Different Types of Vehicles at Banani Overpass

Banani Overpass	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Human Hauler	Bus	Utility	Truck
Weekend, Day, Over	0	3.8	0	47.87	13.80	0	27.91	4.76	1.86
Weekend, Day, Under	2.07	7.77	5.18	63.73	8.94	0.39	3.11	5.7	3.11
Weekend, Night, Over	0	5.88	0.043	58.88	18.24	0	12.81	2.18	1.96
Weekend, Night, Under	0.624	4.45	2.96	86.74	2.11	0	1.87	0.31	0.94
Weekday, day, Over	0	2.58	0	70.17	4.7	0	16.11	3.91	2.54
Weekday, Day, Under	1.83	6.71	2.87	77.75	3.96	0	2.064	1.38	3.44
Weekday, Night, Over	0	2.7	0	60.9	8.86	0.034	10.79	5.39	11.32
Weekday, Night, Under	4.24	2.65	0.88	80.92	2.12	0	8.48	0.71	0

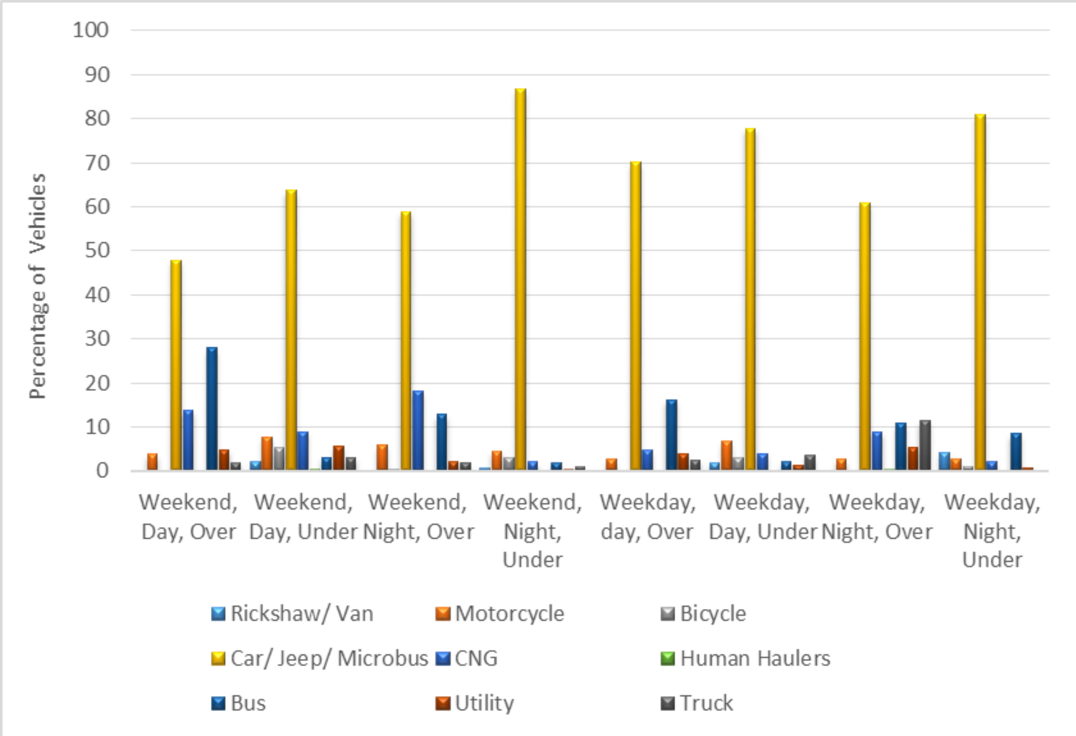


Figure 4.15: Temporal Variation of Different Types of Vehicles in Banani Overpass

Table 4.13 and Figure 4.15 reveal that car/jeep/microbus is the main beneficary of this flyover. In the considered four time periods, both at-grade and above-grade, car is the dominating vehicles. In week-end, day, Bus (27.91%) and CNG (13.80%) are next dominating vehicles to car (47.87%) at-above grade. At-grade, car (63.73%) and CNG (8.94%) are dominating in this time period. Exactly the same scenario has been observed in the week-end, night period data analyses. In this time period, both above-grade and at-grade, car is the most dominating vehicle and its' percentage is 58.88% and 86.74% respectively. CNG (18.24%) is the next dominating vehicles at-above grade.Whereas, any sorts of public transport is absent in at-grade road. That indicates that this flyover is successful in providing facilities to public transport and segregating them from rail-road conflict. Car has also been found as the highest number of at-grade (77.75 %) and above grade (70.17 %) in week-day, day period. Bus (16.1 %) is in next to car at above-grade and, Motorcycle (6.71 %) is in comparatively significant portion at-grade in this time period. Car has again been found as the highest number of at-grade (80.92 %) and above grade (60.9 %) in week-day, night period. Truck (11.32 %) and Bus (10.79 %) are in next to car at above-grade and, bus (8.48 %) is at-grade for this time period. All the other types of vehicles i.e., rickshaw/ van, bicycle, mini-buses and utility vehicles are present in negligible percentage.

The analyses of the different types of vehicles reveal that Banani overpass has provided facility to public transport sufficiently and segregating them from rail-road traffic. However, the number of cars have been increased in that level that flyover has failed to carry these heavy loads. Both at-grade and above-grade in this time period, the major dominating vehicle in this flyover corridor is car.

In addition to that the percentage of NMVs in this flyover is negligible Further analyses have been performed to understand the NMVs's fact more clearly.

4.3.4.2 Analysis of NMVs

Table 4.14 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

Table 4.14: Proportion of NMVs Travelling Above Grade and At-Grade at Banani Overpass

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekend, Night	0.00	100.00	9.52	90.48	8.00	92.00
Weekday, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

A negligible presence of NMVs (only 9.52% bicycles of total NMVs at weekend, Night) travelling above grade can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that only 0.69 % of total traffic are NMVs and only 1.63% NMVs of total NMVs are using this flyover whereas, 98.37 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover.

However from the light of above discussion, Banani Overpass has partially failed to provide any facility to the NMVs. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

4.3.5 Jatrabari-Gulistan Flyover

4.3.5.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their analyses have been presented in the following sections for both at-grade and above-grade of Jatrabari-Gulistan Flyover.

Table 4.15 and Figure 4.16 show the percentage of different types of vehicles at-grade and above-grade of the flyover corridor incorporating the four time period in this studied segment. i.e, Weekend, day; Weekend, night; Weekday, day and Weekday, night.

Table 4.15: Percentage of Different Types of Vehicles at Jatrabari-Gulistan Flyover

Jatrabari-Gulistan Flyover	Rickshaw / Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck
Weekend, Day, Over	0	16.71	0	31.69	10.88	2.89	34.3	3.53	0
Weekend, Day, Under	67.01	4.06	0.9	1.80	0.97	0	23.97	1.29	0
Weekend, Night, Over	0.19	11.95	0.05	27.1	18.42	7.79	26.46	4.09	3.95
Weekend, Night, Under	72.35	2.72	0.8	1.26	1.26	0	21.4	0.28	0
Weekday, day, Over	0	12.27	0	12.22	2.29	2.26	65.5	5.47	0
Weekday, Day, Under	33.92	1.49	0.15	11.21	1.56	1.78	46.7	1.69	1.49
Weekday, Night, Over	0	12.99	0	14.13	4.07	5.02	57.26	6.54	0
Weekday, Night, Under	47.88	1.3	0.2	10.28	1.96	0.79	35.06	1.9	0.63

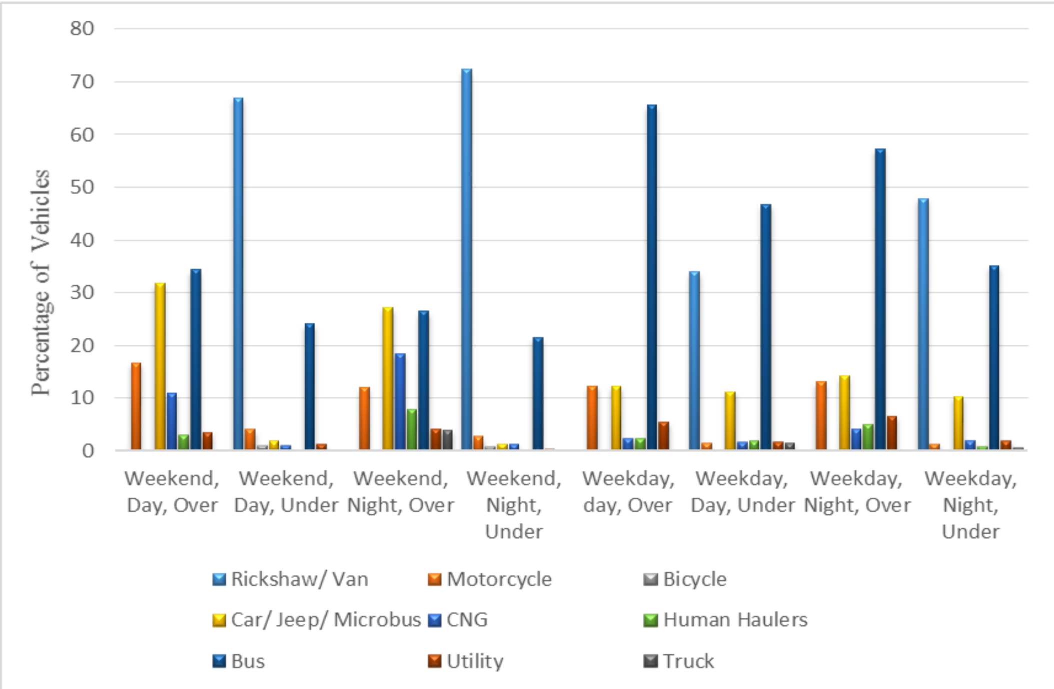


Figure 4.16: Temporal Variation of Different Types of Vehicles in Jatrabari-Gulistan Flyover

Table 4.15 and Figure 4.16 reveal that Bus and car/jeep/microbus are the main beneficaries of this flyover. In week-end, day, Car (31.69%) and CNG (13.80%) are next dominating vehicles to Bus (34.3%) at-above grade. At-grade, Rickshaws/Van (67.01%) and Bus (23.97%) are dominating in this time period. Almost similar scenario has been observed in the week-end, night period data analyses. In this time period, at above-grade, Car (27.1%) and Bus (26.4) are dominating along with CNG (18.42%). Whereas, Rickshaws/Van (72.35%) and Bus (21.4%) are dominating in this time period. Presence large number of vehicles at-grade road indicates that the flyover is not sufficient to fulfill the demand in this road corridor. Bus has been found as the most dominating vehicle both at above-grade (65.5 %) and at-grade (46.7%) during week-day, day time period. Also it is the most dominating vehicle at above-grade (57.26%) during week-day, night period. Rickshaws/Van (47.88%) and Bus (35.06%) are dominating at-grade during weekday, night time. All the other types of vehicles i.e., bi-cycle, motorcycle, mini-buses, utility vehicles and trucks are present in negligible percentage. However, bus dominates at grade and above grade in all time period, implying that high movement of public transport is present in this corridor and this flyover has failed to segragate all the vehicles from at-grade to above-grade. In addition to that, the percentage of NMVs in this flyover is significant. Further analyses have been performed to understand the situation of NMVs more clearly.

4.3.5.2 Analysis of NMVs

Table 4.16 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

Table 4.16: Proportion of NMVs Travelling Above-Grade and At-Grade at Jatrabari-Gulistan Flyover

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekend, Night	0.77	99.23	15.38	84.62	0.95	99.05
Weekday, Day	0.00	100.00	0.00	100.00	0.00	100.00
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

A negligible presence of NMVs (only 0.95% at weekend, night) travelling at above-grade can be attributed to the dimensions that the grades of the approach ramps of flyovers make it difficult for NMVs to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 29.25 % of total traffic will pass underneath the studied flyover. Among these at-grade traffic 51% are NMVs. In addition to that, 99.76 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not the beneficiary of constructing this flyover. It has completely failed to provide any facility to the NMVs. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

4.3.6 Moghbazar-Mouchak Flyover

4.3.6.1 Proportion of Different Types of Vehicles

To apprehend the real field scenario of what types of vehicles are present and what is their proportion in the studied road segment, classified vehicles counts were analyzed to obtain the percentage of different types of vehicles. From these analyses, non-motorized vehicles and public transport were identified and their analyses have been presented in the following sections for both at-grade and above-grade of Moghbazar-Mouchak Flyover.

Table 4.17: Percentage of Different Types of Vehicles at Moghbazar-Mouchak Flyover

Moghbazar-Mouchak Flyover	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck
Weekend, Day, Over	0	5.41	0.04	44.02	12.38	0	31.46	2.9	3.79
Weekend, Day, Under	27.28	6.6	0	38.37	10.13	0.67	8.8	3.19	4.97
Weekend, Night, Over	0	5.49	0.03	42.46	13.94	0	29.72	2.65	5.72
Weekend, Night, Under	38.55	3.39	0.12	31.65	5.35	1.43	17.85	0.95	0.714
Weekday, day, Over	0	6.33	0.03	56.16	21.60	0	6.58	3.039	6.25
Weekday, Day, Under	35.09 7	3.01	0.13	49.43	4.92	0.30	6.03	1.07	0
Weekday, Night, Over	0	6.23	0	50.72	18.59	0	11.26	4.67	8.53
Weekday, Night, Under	45.35	3.15	0.11	35.91	5.04	1.42	7.56	1.47	0

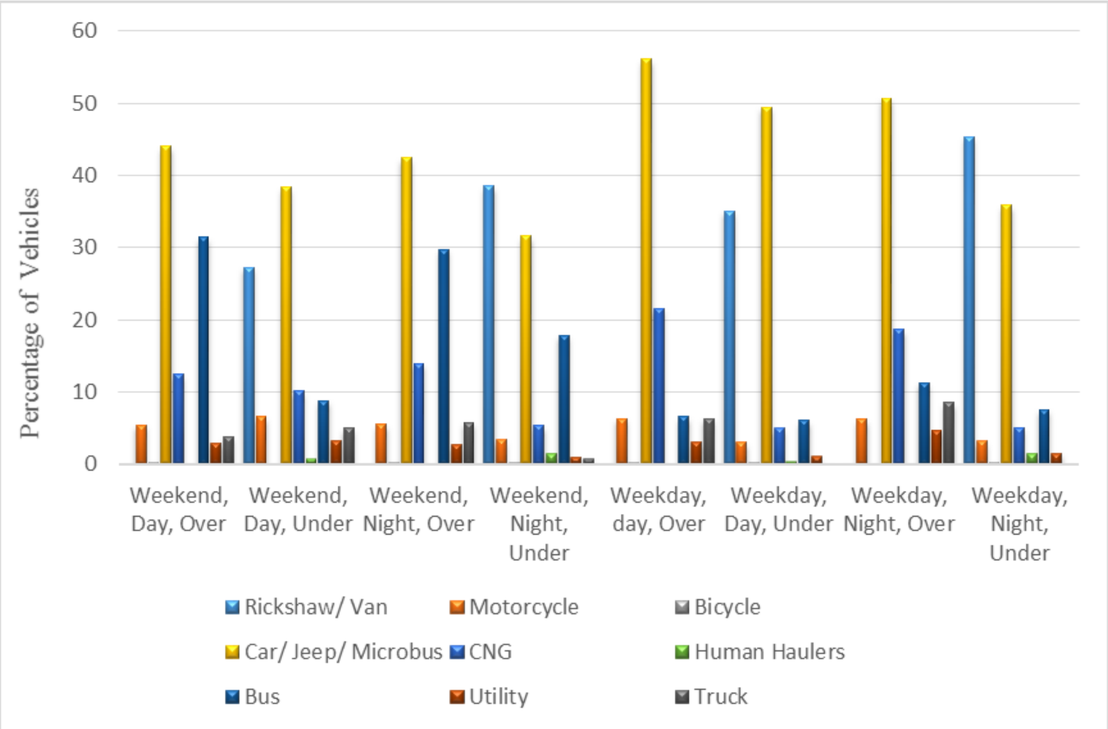


Figure 4.17: Temporal Variation of Different Types of Vehicles in Moghbazar-Mouchak Flyover

Table 4.17 and Figure 4.17 show the percentage of different types of vehicles at-grade and above-grade of the flyover corridor incorporating the four time period in this studied segment. i.e, Weekend, day; Weekend, night; Weekday, day and Weekday, night.

Table 4.17 and Figure 4.17 reveal that Bus and car/jeep/microbus are the main beneficaries of this flyover. In week-end, day, Car (44.02%) and Bus (31.46%) are most dominating vehicles at-above grade. At-grade, Car (38.37%) and Rickshaws/Van (27.28 %) are dominating in this time period. Almost similar scenario has been observed in the week-end, night period data analyses. In this time period, at above-grade, Car (42.46%) and Bus (26.4) are dominating along with CNG (13.94%). Whereas, Rickshaws/Van (38.55%), Car (31.65%) and Bus (17.85%) are dominating in this time period. Presence large number of vehicles at-grade road indicates that the flyover is not sufficient to fulfill the demand in this road corridor. Car has been found as the most dominating vehicle both at above-grade (56.16 %) and at-grade (49.43%) during week-day, day time period. Also it is the most dominating vehicles at above-grade (50.72%) and at-grade (35.91%) during week-day, night period. Rickshaws/Van (45.35%) are also dominating at-grade during weekday, night time. All the other types of vehicles i.e., bi-cycle, motorcycle, mini-buses, utility vehicles and trucks are present in negligible percentage. However, car dominates in at-grade and above in all time period implies that high presence of private vehicle commences in this corridor and this flyover is failed to segragate all the vehicles from at-grade to above-grade. In addition to that the percentage of NMVs in this flyover is significant. Further analyses have been performed to understand the NMVs's fact more clearly.

4.3.6.2 Analysis of NMVs

Table 4.18 shows the proportion of non-motorized vehicles (NMVs) travelling over and under the flyover. NMVs refer to rickshaws/ vans and bicycles in this study.

A significant presence of Bicycles travelling at above-grade can be attributed to the dimensions that bicycle user find this flyover route very user friendly for them. However, the absence of Rickshaw/ Van attributes to the fact that the grades of the approach ramps of flyovers make it difficult for these types of vehicles to get on the flyover. This means that a significant portion of traffic will always be forced to travel at-grade and come in conflict with rail, implying that there will always be conflict with rail at level crossings whether or not flyovers are present. Consequently, it can be concluded that it is never completely possible to eliminate conflicts at level crossings by continuing the design approaches adopted for flyover design in Bangladesh. Anwari, Hoque and Islam (2016) observed that nearly half of at-grade flow of all flyovers is attributed to NMVs. This implies that nearly 50% of existing vehicles will continue to come in conflict with rail. The present study reveals that 30.14 % of total traffic will pass underneath the studied flyover. Among these at-grade traffic 35.26% are NMVs. In addition to that, 99.83 % NMVs of total NMVs are forced to use at-grade road. Hence, it is clearly evident that NMVs are not that much benefitted through the construction of this flyover. In addition to that, the flow interruption and level of congestion will get worsen with the ever growing size of motorized and non-motorized vehicle fleet along with high degree of pedestrian movement. Therefore, it is evident that it would not be able to make conflict-free movements for both rail and road traffic in the studied flyover, which is the prerequisite of controlling congestion and improving safety.

Table 4.18: Proportion of NMVs Travelling Above-Grade and At-Grade at Moghbazar-Mouchak Flyover

Time	Percentage of Rickshaws/ Vans		Percentage of Bicycles		Percentage of NMVs	
	Above grade	At grade	Above grade	At grade	Above grade	At grade
Weekend, Day	0.00	100.00	100.00	0.00	0.23	99.77
Weekend, Night	0.00	100.00	50.00	50.00	0.31	99.69
Weekday, Day	0.00	100.00	33.33	66.67	0.19	99.81
Weekday, Night	0.00	100.00	0.00	100.00	0.00	100.00

However, from the light of the above discussion it can be concluded that from the perspective of providing facilities to non-motorized vehicles, all the flyovers have evidently failed to provide any facilities to non-motorized vehicles. Rather, the NMVs are using at-grade road as before, deteriorating the level of service of the at-road by prolonging traffic congestion. In addition to that, at the touch-down points of the flyover at at-grade road, they are creating hindrance to above-grade flow and hence, disturbing smooth flow at the above-grade. From the perspective of public transport, it can be concluded that Jatrabari-Gulistan Flyover has been proved to provide maximum usage to the public transport and Moghbazar-Mouchak Flyover also shares a significant portion of flyover space with public transport. However, rest of the flyovers are performing very poorly to provide facilities for public transport.

4.4 Assessment of Mobility Condition

Speed of each type of vehicle was measured at all the studied flyover to assess the mobility conditions of vehicles both at-grade and above grade. Data have been presented and analyses have been done in the following sub-sections for each of the flyovers.

4.4.1 Mohakhali Flyover

4.4.1.1 Travel Speed

Travel speed of each type of vehicle was measured at Mohakhali Flyover to assess the mobility conditions of vehicles both at-grade and above grade. Travel speed has been calculated by dividing the segment length of the studied road segment by the sum of total time in motion, segment delay and through vehicle delay. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.18.

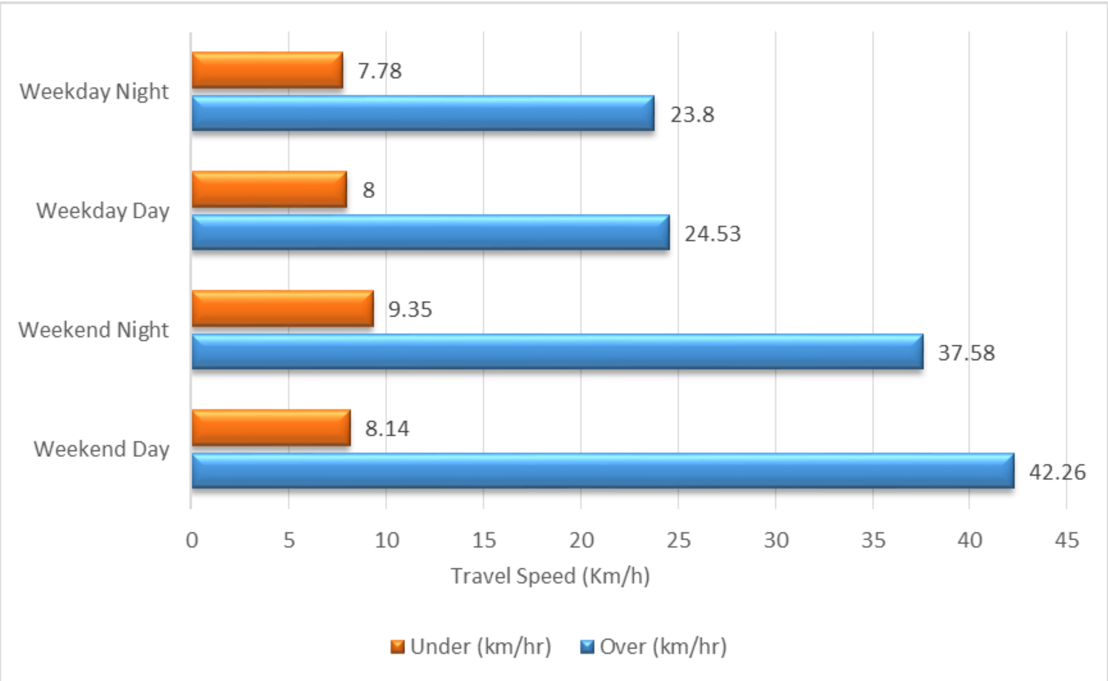


Figure 4.18: Temporal Comparison of Average Vehicle Travel Speed at Mohakhali Flyover

It is observed that the maximum travel speed was recorded in Mohakhali Flyover at above-grade during weekend, day (42.26 km/h) while the slowest was recorded in weekday, night (7.78 km/h) at-grade road of this flyover corridor. This implies that a faster travel speed is observed in this flyover corridor during week-end, day time while the case becomes critical during weekdays and it becomes the worst at week-day, night time at grade.

Vehicle speed at above-grade varies from 42.26 km/h during week-end, day time to 23.8 km/h during week-day, night. While it varies from 9.35 km/h during week-end, night time to 7.78 km/h during week-day, night. Average vehicle speed at above-grade in this flyover corridor is 32.04 km/h while the average vehicle speed at grade is 8.32 km/h which is only a little faster than the average walking speed (5 km/h) [122]. Although on an average vehicles are travelling at above-grade 3.85 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really frustrating. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped to almost at walking speed. The slow speed may be attributed to the observation that buses and mini-buses use the road space to drop off and pick up passengers. In addition, frequent access points close to the intersection reduce speed of through vehicles.

4.4.1.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Mohakhali Flyover to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. In this study, Free Flow Speed (FFS) is defined as the average speed of the traffic stream when traffic volumes are sufficiently low that drivers are not influenced by the presence of other vehicles and when intersection traffic control is not present or is sufficiently distant as to have no effect on speed choice. To find the FFS, travel time was measured using intra-frame scene capture based on superimposed image at free-flow conditions both at-grade and above-grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.19.

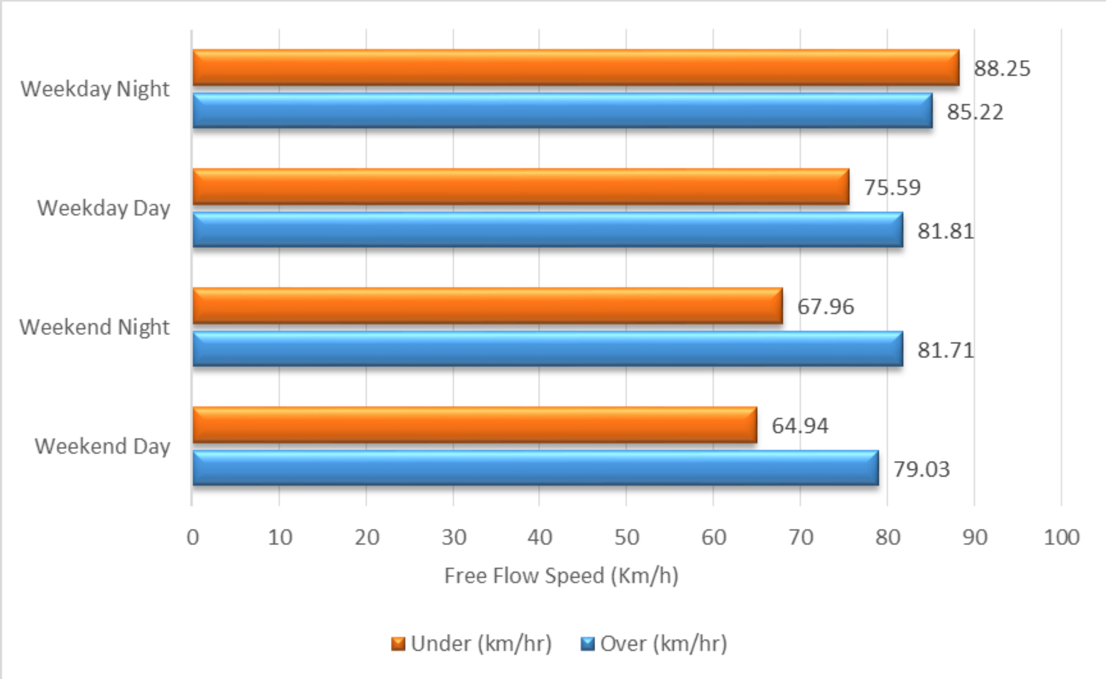


Figure 4.19: Temporal Comparison of Average Vehicle Free Flow Speed at Mohakhali Flyover

It is observed that the maximum free flow speed was recorded in Mohakhali Flyover at at-grade during weekday, night (88.25 km/h) while the slowest was recorded in weekend, day (64.94 km/h) at-grade road of this flyover corridor. Vehicles' free flow speed at above-grade varies from 85.22 km/h during weekday, night time to 79.03 km/h during weekend, day. While it varies from 88.25 km/h during weekend, night time to 64.94 km/h during weekend, day. Average free flow speed at above-grade in this flyover corridor is 84.94 km/h while the average free flow speed at at-grade is 74.16 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.1.3 Delay Due to Variation of Travel Speed and Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., week-day, day; week-day, night; week-end, day; week-end, night. Table 4.19 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Mohakhali Flyover.

Table 4.19: Delay Due to Variation of Travel Speed and Free Flow Speed at Mohakhali Flyover

Mohakhali Flyover	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	1.12	42.26	95.41	79.03	51.02	44.39
Weekend Night, Over	1.12	37.58	107.29	81.71	49.35	57.95
Weekday Day, Over	1.12	24.53	164.37	81.81	49.28	115.09
Weekday Night, Over	1.12	23.8	169.41	85.22	47.31	122.10
Weekend Day,Under	1.33	8.14	588.21	64.94	73.73	514.48
Weekend Night,Under	1.33	9.35	512.09	67.96	70.45	441.63
Weekday Day,Under	1.33	8	598.50	75.59	63.34	535.16
Weekday Night,Under	1.33	7.78	615.42	88.25	54.25	561.17

The analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses.

Table 4.19 shows that significant delay occurs at Mohakhali Flyover corridor in every considered time period. Maximum and minimum delay were found during weekday, night at the at-grade road (561.17 sec/vehicle) and weekend, day at the above-grade road (44.39 sec/vehicle) correspondingly. This implies that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor.

From the light of the analyses performed for checking the mobility condition of the Mohakhali Flyover, it can be concluded that vehicles are operated at low speed both at-grade and above grade of the flyover and a significant delay occurs all the studied time in this flyover corridor.

4.4.2 Khilgaon Flyover

4.4.2.1 Travel Speed

Travel speed of each type of vehicle was measured at Khilgaon Flyover to assess the mobility conditions of vehicles both at-grade and above grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.20.

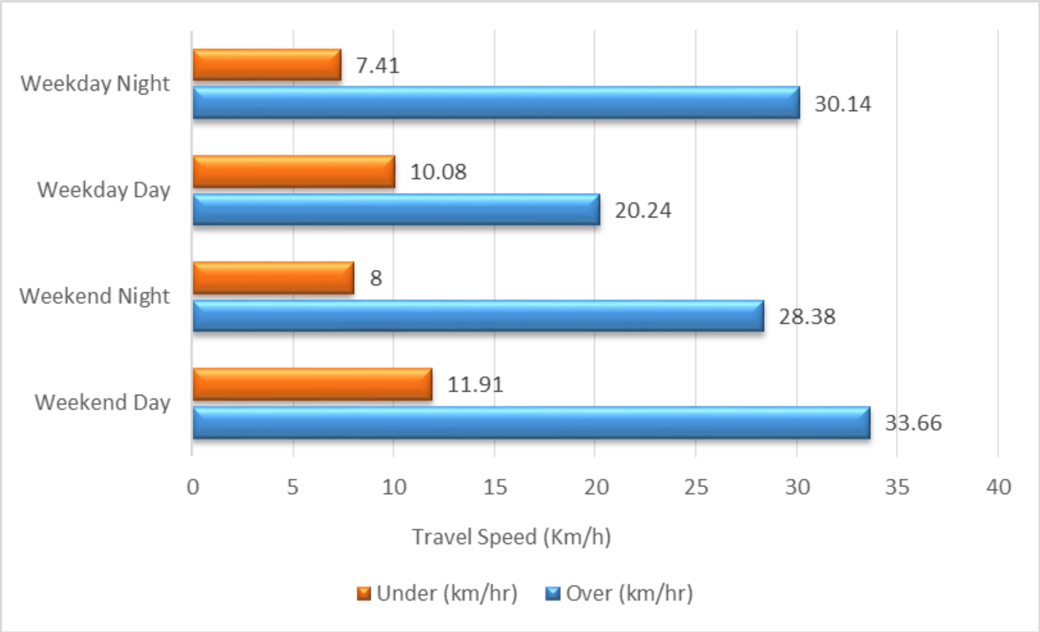


Figure 4.20: Temporal Comparison of Average Vehicle Travel Speed at Khilgaon Flyover

It is observed that the maximum travel speed was recorded in Khilgaon Flyover at above-grade during weekend, day (33.66 km/h) while the slowest was recorded in weekday, night (7.41 km/h) at-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, day time while the case becomes critical during weekdays and it becomes the worst at weekday, night time of the at-grade road of the flyover.

Vehicle speed at above-grade varies from 33.66 km/h during weekend, day time to 20.24 km/h during weekday, night. While it varies from 11.91 km/h during weekend, day time to 7.41 km/h during weekday, night. Average vehicle speed at above-grade in this flyover corridor is 28.10 km/h while the average vehicle speed at at-grade is 9.28 km/h which is really insignificant to maintain the perfect mobility condition at urban roads. Although on an average vehicles are travelling at above-grade 3.03 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really frustrating. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped significantly.

4.4.2.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Khilgaon Flyover to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.21.

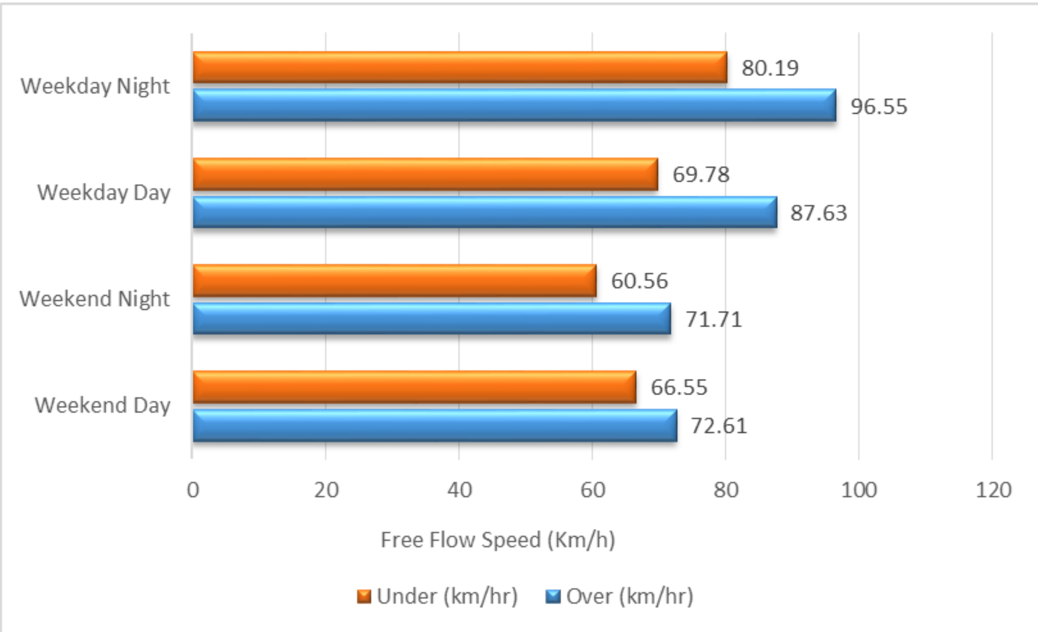


Figure 4.21: Temporal Comparison of Free Flow Speed at Khilgaon Flyover

It is observed that the maximum free flow speed was recorded in Khilgaon Flyover at above-grade during weekday, night (96.55 km/h) while the slowest was recorded in weekend, night (60.56 km/h) at-grade road of this flyover corridor. Vehicles' free flow speed at above-grade varies from 96.55 km/h during weekday, night time to 71.71 km/h during weekend, night. While it varies from 80.19 km/h during weekday, night time to 60.56 km/h during weekend, night. Average free flow speed at above-grade in this flyover corridor is 82.13 km/h while the average free flow speed at at-grade is 69.27 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.2.3 Delay at Travel Speed Compared to Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night.

Analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses. Table 4.20 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Khilgaon Flyover.

Table 4.20: Delay Due to Variation of Travel Speed and Free Flow Speed at Khilgaon Flyover

Khilgaon Flyover	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	1.9	33.66	203.21	72.61	94.20	109.01
Weekend Night, Over	1.9	28.38	241.01	71.71	95.38	145.63
Weekday Day, Over	1.9	20.24	337.94	87.63	78.06	259.89
Weekday Night, Over	1.9	30.14	226.94	96.55	70.84	156.10
Weekend Day,Under	1.48	11.91	447.36	66.55	80.06	367.30
Weekend Night,Under	1.48	8	666.00	60.56	87.98	578.02
Weekday Day,Under	1.48	10.08	528.57	69.78	76.35	452.22
Weekday Night,Under	1.48	7.41	719.03	80.19	66.44	652.59

Table 4.20 shows that significant delay occurs at Khilgaon Flyover corridor in every considered time period. Maximum and minimum delay were found during weekday, night at the at-grade road (652.59 sec/vehicle) and weekend, day at the above-grade road (109.01 sec/vehicle) correspondingly. This implies that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor.

From the light of the analyses performed for checking the mobility condition of the Khilgaon Flyover, it can be concluded that vehicles are operated at very low speed both at-grade and above grade of the flyover and a significant delay occurs all the studied time in this flyover corridor.

4.4.3 Shaheed Ahsanullah Master Flyover

4.4.3.1 Travel Speed

Travel speed of each type of vehicle was measured at Ahsanullah Master Flyover to assess the mobility conditions of vehicles both at-grade and above grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.22.

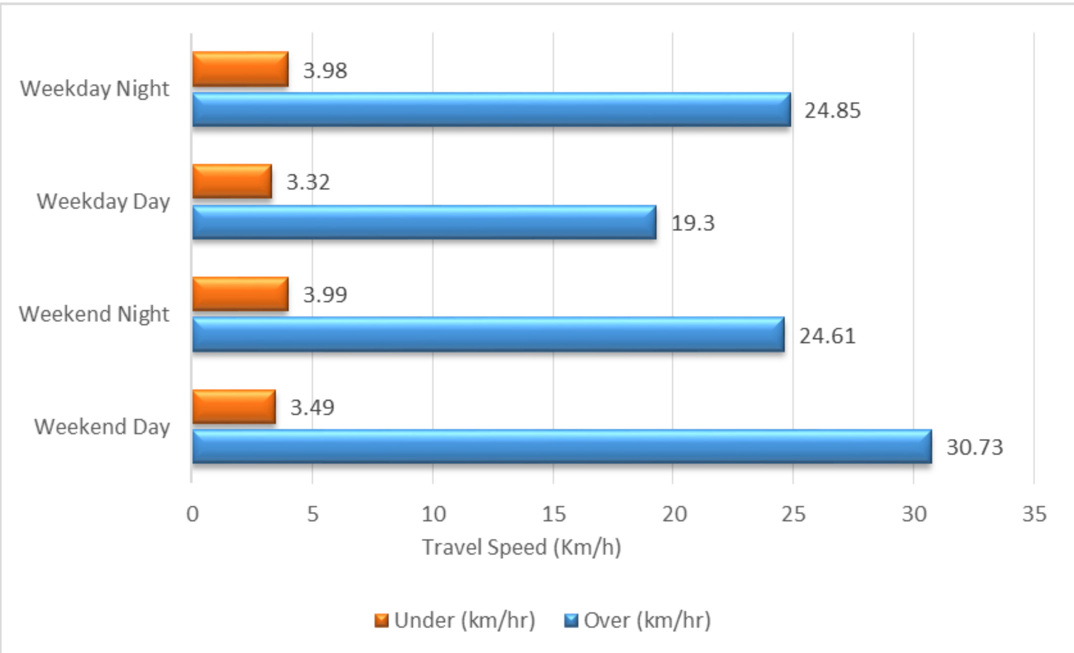


Figure 4.22: Temporal Comparison of Average Vehicle Travel Speed at Ahsanullah Master Flyover

It is observed that the maximum travel speed was recorded in Ahsanullah Master Flyover at above-grade during weekend, day (30.73 km/h) while the slowest was recorded in weekday, day (3.32 km/h) at-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, day time while the case becomes critical during weekdays and it becomes the worst at weekday, day time of the at-grade road of the flyover.

Vehicle speed at above-grade varies from 30.73 km/h during weekend, day time to 19.30 km/h during weekday, day. While it varies from 3.99 km/h during weekend, night time to 3.32 km/h during weekday, day. Average vehicle speed at above-grade in this flyover corridor is 24.87 km/h while the average vehicle speed at at-grade is 3.70 km/h, which is slower than the average walking speed (5 km/h) [122]. Although on an average vehicles are travelling at above-grade 6.73 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really very insignificant to maintain smooth flow in urban cities. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped to less than the walking speed.

4.4.3.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Ahsanullah Master Flyover to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.23.

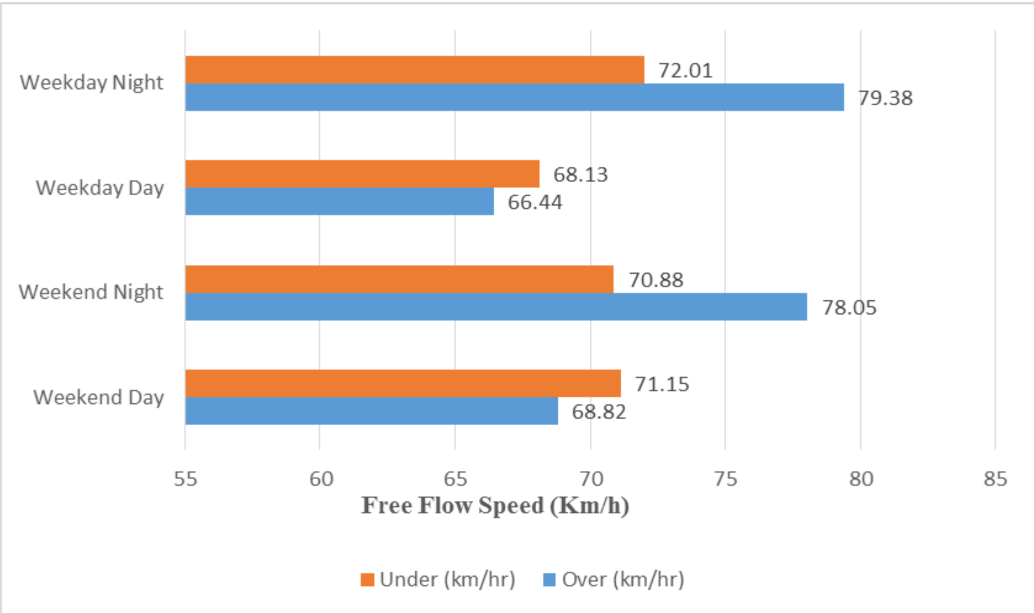


Figure 4.23: Temporal Comparison of Free Flow Speed at Ahsanullah Master Flyover

It is observed that the maximum free flow speed was recorded in Ahsanullah Master Flyover at above-grade during weekday, night (79.38 km/h) while the slowest was recorded in weekday, day (66.44 km/h) above-grade road of this flyover corridor. Vehicles' free flow speed at above-grade varies from 79.38 km/h during weekday, night time to 66.44 km/h during weekday, day. While it varies from 72.01 km/h during weekday, night time to 68.13 km/h during weekday, day. Average free flow speed at above-grade in this flyover corridor is 73.1725 km/h while the average free flow speed at at-grade is 70.54 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.3.3 Delay at Travel Speed Compared to Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night.

Table 4.21: Delay Due to Variation of Travel Speed and Free Flow Speed at Ahsanullah Master Flyover

Ahsanullah Master Flyover	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	0.35	30.73	41.00	68.82	18.31	22.69
Weekend Night, Over	0.35	24.61	51.20	78.05	16.14	35.06
Weekday Day, Over	0.35	19.3	65.28	66.44	18.96	46.32
Weekday Night, Over	0.35	24.85	50.70	79.38	15.87	34.83
Weekend Day,Under	0.74	3.49	763.32	71.15	37.44	725.88
Weekend Night,Under	0.74	3.99	667.67	70.88	37.58	630.08
Weekday Day,Under	0.74	3.32	802.41	68.13	39.10	763.31
Weekday Night,Under	0.74	3.98	669.35	72.01	36.99	632.35

Analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses. Table 4.21 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Ahsanullah Master Flyover.

Table 4.21 shows that significant delay occurs at Ahsanullah Master Flyover corridor in every considered time period. Maximum and minimum delay were found during weekday, day at the at-grade road (763.31 sec/vehicle) and weekend, day at the above-grade road (22.69 sec/vehicle) correspondingly. This implies that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor.

From the light of the analyses performed for checking the mobility condition of the Ahsanullah Master Flyover, it can be concluded that vehicles are operated at very low speed both at-grade and above grade of the flyover, especially vehicles travel speed at at-grade road is less than the walking speed. Also a significant delay occurs all the studied time in this flyover corridor.

4.4.4 Banani Overpass

4.4.4.1 Travel Speed

Travel speed of each type of vehicle was measured at Banani Overpass to assess the mobility conditions of vehicles both at-grade and above grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.24.

It is observed that the maximum travel speed was recorded in Banani Overpass at above-grade during weekend, night (64.51 km/h) while the slowest was recorded in weekday, day (10.62 km/h) above-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, day time while the case becomes critical during weekdays and it becomes the worst at weekday, day time of the at-grade road of the flyover.

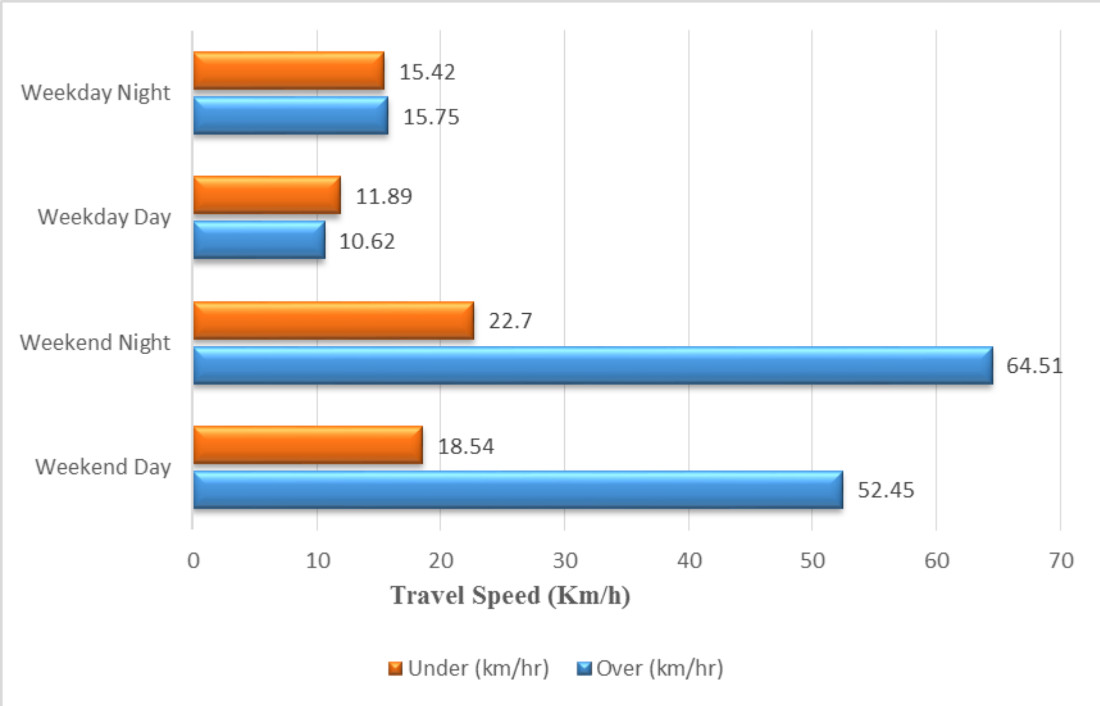


Figure 4.24: Temporal Comparison of Average Vehicle Travel Speed at Banani Overpass

Vehicle speed at above-grade varies from 64.51 km/h during weekend, night time to 10.62 km/h during weekday, day. While it varies from 22.7 km/h during weekend, night time to 11.89 km/h during weekday, day. Average vehicle speed at above-grade in this flyover corridor is 35.83 km/h while the average vehicle speed at at-grade is 17.14 km/h. Although on an average vehicles are travelling at above-grade 2.09 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really very insignificant to maintain smooth flow in urban cities. Particularly, the case is severe at above-grade road during the weekdays. It has been found that during weekdays, travel speed varies from 10.62 km/h to 15.75 km/h at the above grade, which is really insignificant and completely unexpected. This implies this flyover is completely failed to enhance mobility in this corridor. Situation will get worsen with time and increasing trend of motor vehicle growth and in near future, congestion will propagated to flyover and mobility will come to a standstill condition.

4.4.4.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Banani Overpass to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.25.

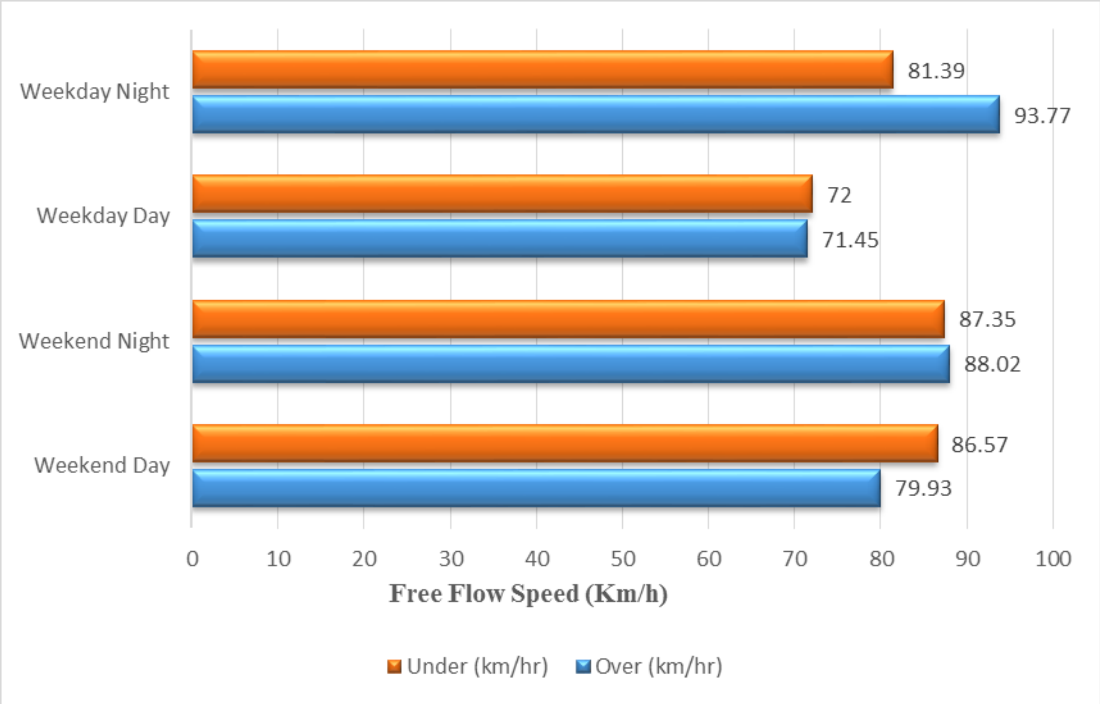


Figure 4.25: Temporal Comparison of Free Flow Speed at Banani Overpass

It is observed that the maximum free flow speed was recorded in Banani Overpass at above-grade during weekday, night (93.77 km/h) while the slowest was recorded in weekday, day (71.45 km/h) above-grade road of this flyover corridor. Vehicles' free flow speed at above-grade varies from 93.77 km/h during weekday, night time to 71.45 km/h during weekday, day. While it varies from 87.35 km/h during weekend, night time to 72 km/h during weekday, day. Average free flow speed at above-grade in this flyover corridor is 83.29 km/h while the average free flow speed at at-grade is 81.83 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.4.3 Delay at Travel Speed Compared to Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night.

Table 4.22: Delay Due to Variation of Travel Speed and Free Flow Speed at Banani Overpass

Banani Overpass	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	0.81	52.45	55.60	79.93	36.48	19.11
Weekend Night, Over	0.81	64.51	45.20	88.02	33.13	12.07
Weekday Day, Over	0.81	10.62	274.58	71.45	40.81	233.76
Weekday Night, Over	0.81	15.75	185.14	93.77	31.10	154.05
Weekend Day,Under	0.92	18.54	178.64	86.57	38.26	140.38
Weekend Night,Under	0.92	22.70	145.90	87.35	37.92	107.99
Weekday Day,Under	0.92	11.89	278.55	72.00	46.00	232.55
Weekday Night,Under	0.92	15.42	214.79	81.39	40.69	174.09

Analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses. Table 4.22 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Banani Overpass.

Table 4.22 shows that significant delay occurs at Banani Overpass corridor in every considered time period. Maximum and minimum delay were found during weekday, day at the above-grade road (233.76 sec/vehicle) and weekend, night at the above-grade road (12.07 sec/vehicle) correspondingly. This implies that severe delays occur at above grade of the flyover during weekdays and hence, construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor.

From the light of the analyses performed for checking the mobility condition of the Banani Overpass, it can be concluded that vehicles are operated at very low speed both at-grade and above grade of the flyover, especially vehicles travel speed at above-grade road is very low during weekdays and significant delay occurs all the studied time in this flyover corridor.

4.4.5 Jatrabari-Gulistan Flyover

4.4.5.1 Travel Speed

Travel Speed of each type of vehicle was measured at Jatrabari-Gulistan Flyover to assess the mobility conditions of vehicles both at-grade and above grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.26.

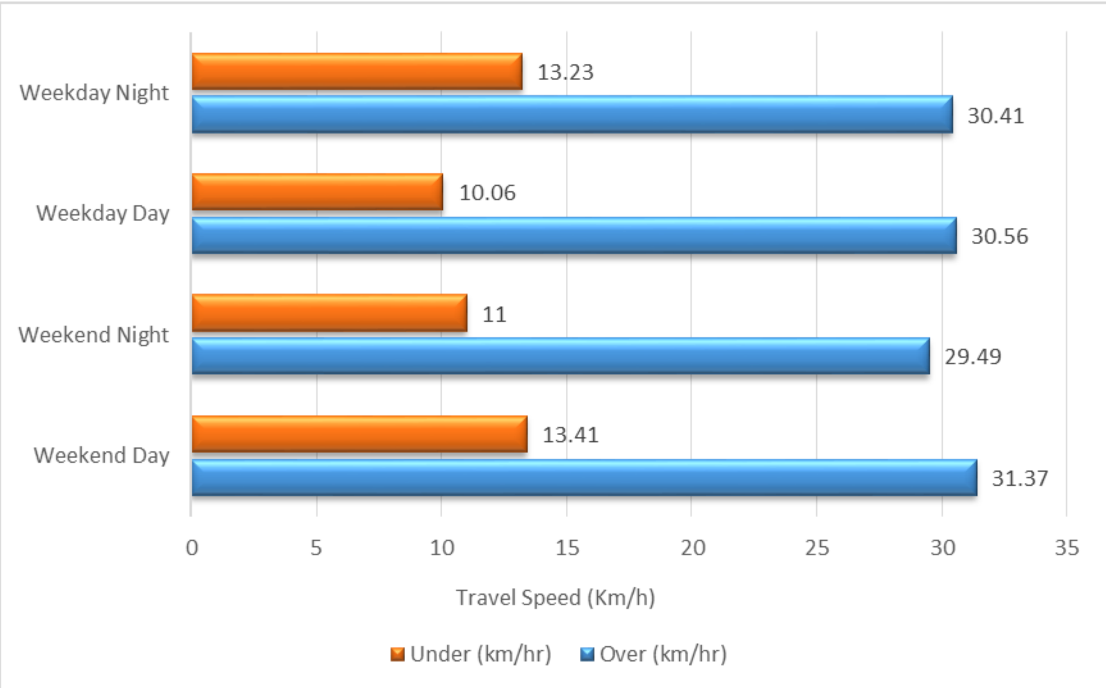


Figure 4.26: Temporal Comparison of Average Vehicle Travel Speed at Jatrabari-Gulistan Flyover

It is observed that the maximum travel speed was recorded in Jatrabari-Gulistan Flyover at above-grade during weekend, day (31.37 km/h) while the slowest was recorded in weekday, day (10.06 km/h) at-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, day time while the case becomes critical during weekdays and it becomes the worst at weekday, day time of the at-grade road of the flyover.

Vehicle speed at above-grade varies from 31.37 km/h during weekend, day time to 29.49 km/h during weekend, night. While it varies from 13.41 km/h during weekend, day time to 10.06 km/h during weekday, day. Average vehicle speed at above-grade in this flyover corridor is 30.46 km/h while the average vehicle speed at at-grade is 12.03 km/h. Although on an average vehicles are travelling at above-grade 2.53 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really very insignificant to maintain smooth flow in urban cities. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped drastically.

4.4.5.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Jatrabari-Gulistan Flyover to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.27.

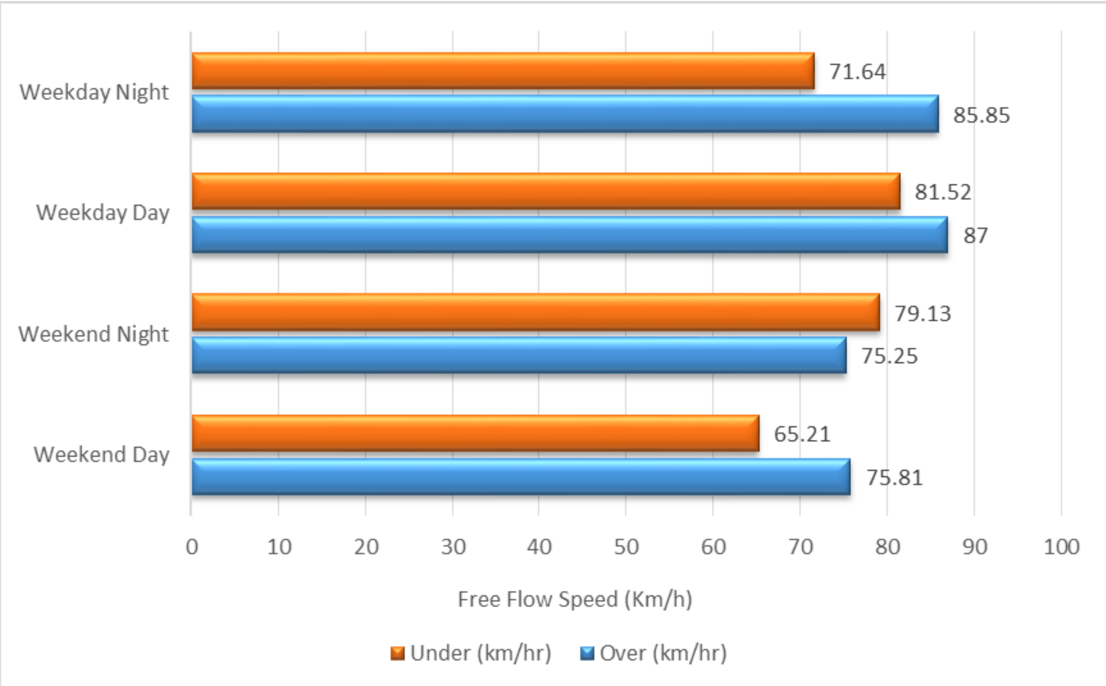


Figure 4.27: Temporal Comparison of Free Flow Speed at Jatrabari-Gulistan Flyover

It is observed that the maximum free flow speed was recorded in Jatrabari-Gulistan Flyover at above-grade during weekday, day (87 km/h) while the slowest was recorded in weekend, day (65.21 km/h) at-grade road of this flyover corridor.

Vehicles' free flow speed at above-grade varies from 87 km/h during weekday, day time to 75.25 km/h during weekend, night. While it varies from 81.52 km/h during weekday, day time to 65.21 km/h during weekend, night. Average free flow speed at above-grade in this flyover corridor is 80.98 km/h while the average free flow speed at at-grade is 74.38 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.5.3 Delay at Travel Speed Compared to Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night.

Table 4.23: Delay Due to Variation of Travel Speed and Free Flow Speed at Jatrabari-Gulistan Flyover

Jatrabari-Gulistan Flyover	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	11.8	31.37	1354.16	75.81	560.35	793.81
Weekend Night, Over	11.8	29.49	1440.49	75.25	564.52	875.97
Weekday Day, Over	11.8	30.56	1390.05	87	488.28	901.78
Weekday Night, Over	11.8	30.41	1396.91	85.85	494.82	902.09
Weekend Day,Under	9.62	13.41	2582.55	65.21	531.08	2051.47
Weekend Night,Under	9.62	11	3148.36	79.13	437.66	2710.70
Weekday Day,Under	9.62	10.06	3442.54	81.52	424.83	3017.72
Weekday Night,Under	9.62	13.23	2617.69	71.64	483.42	2134.27

Analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses. Table 4.23 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Jatrabari-Gulistan Flyover.

Table 4.23 shows that significant delay occurs at Jatrabari-Gulistan Flyover corridor in every considered time period. Maximum and minimum delay were found during weekday, day at the at-grade road (3017.72 sec/vehicle) and weekend, day at the above-grade road (793.81 sec/vehicle) correspondingly. This implies that severe delays occur both at-grade and above-grade road of the flyover and it becomes most critical during weekdays. Hence, it can be evidently concluded that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor, rather becomes a source of severe delays.

From the light of the analyses performed for checking the mobility condition of the Jatrabari-Gulistan Flyover, it can be concluded that vehicles are operated at very low speed both at-grade and above grade of the flyover, especially vehicles travel speed at above-grade road is very low during weekdays and significant delay occurs all the studied time in this flyover corridor

4.4.6 Moghbazar-Mouchak Flyover

4.4.6.1 Travel Speed

Travel speed of each type of vehicle was measured at Moghbazar-Mouchak to assess the mobility conditions of vehicles both at-grade and above grade. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.28.

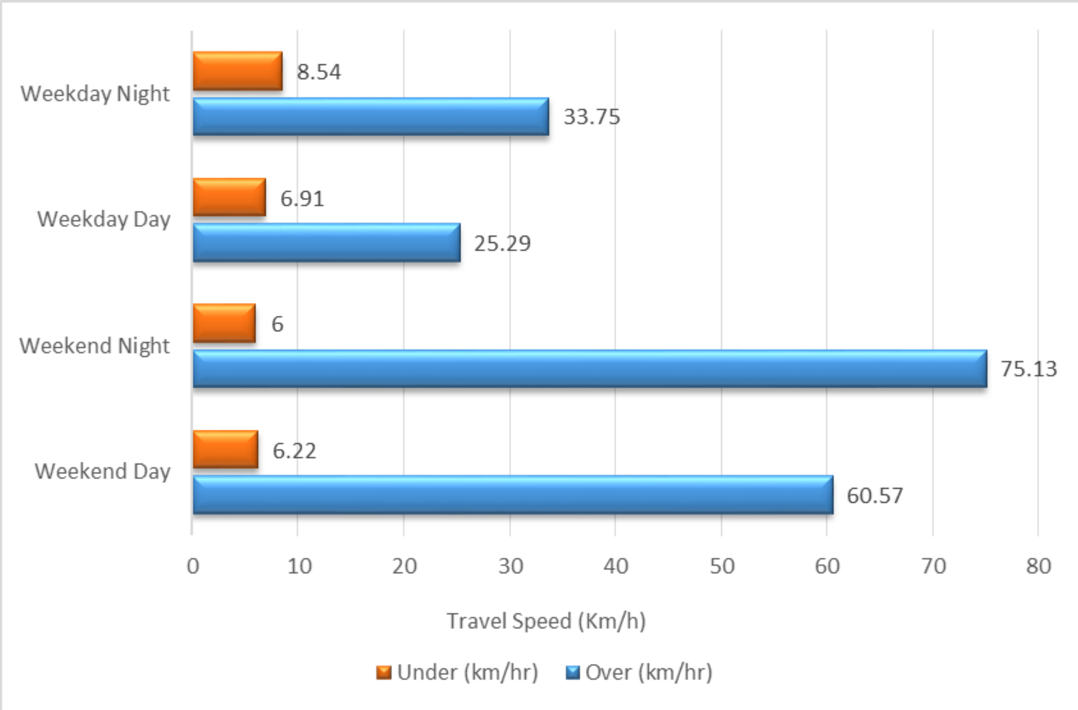


Figure 4.28: Temporal Comparison of Average Vehicle Travel Speed at Moghbazar-Mouchak Flyover

It is observed that the maximum travel speed was recorded in Moghbazar-Mouchak Flyover at above-grade during weekend, night (75.13 km/h) while the slowest was recorded in weekend, night (6 km/h) at-grade road of this flyover corridor. This implies that a better travel speed is observed in this flyover corridor during weekend, night time while the case becomes severe during weekdays and it becomes the worst at weekend, day time of the at-grade road of the flyover.

Vehicle speed at above-grade varies from 75.13 km/h during weekend, night time to 25.29 km/h during weekday, day. While it varies from 8.54 km/h during weekday, night time to 6 km/h during weekend, night. Average vehicle speed at above-grade in this flyover corridor is 48.68 km/h while the average vehicle speed at at-grade is 7.01 km/h, which is a little faster than the average walking speed (5 km/h) [122]. Although on an average vehicles are travelling at above-grade 6.94 times faster compared to at-grade, average vehicle speeds both at-grade and above-grade are really very insignificant to maintain smooth flow in urban cities. Particularly, the case is severe in at-grade road, where the vehicle speed has dropped to almost at walking speed.

4.4.6.2 Free Flow Speed

Free flow speed of each type of vehicle was measured at Moghbazar-Mouchak Flyover to observe how efficient would be the roadway mobility condition in this flyover corridor if vehicles were allowed to be operated under free flow condition. These speeds were measured incorporating temporal variation in weekday, Night; Weekday, Day; Weekend, Night and Weekend, Day and presented in Figure 4.29.

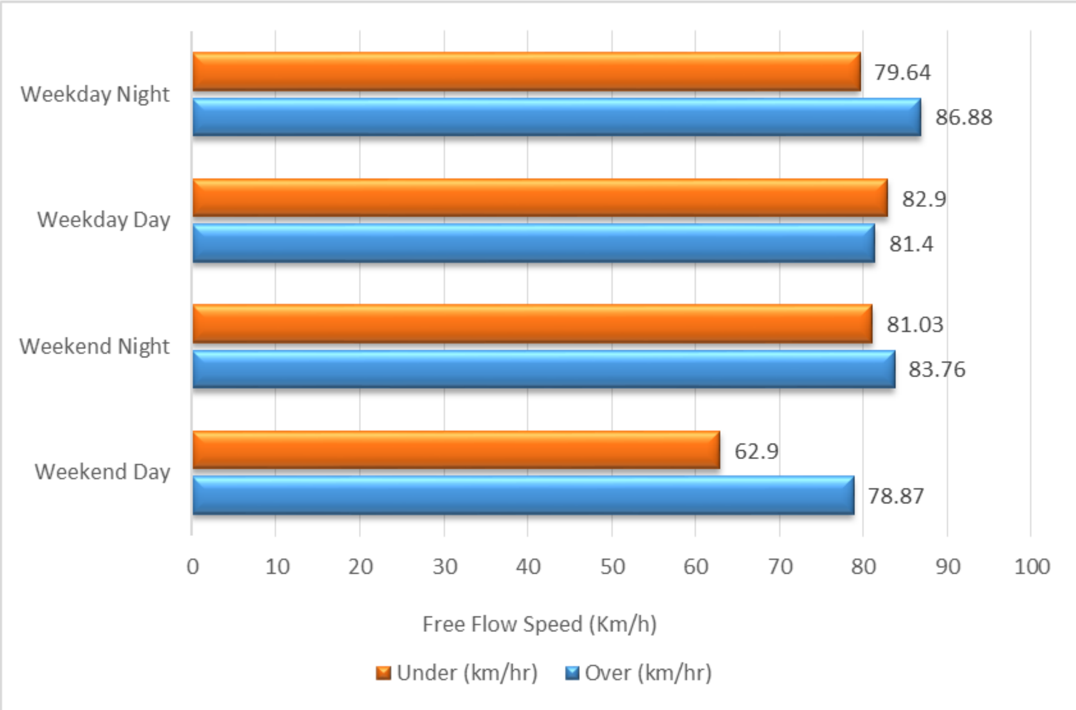


Figure 4.29: Temporal Comparison of Free Flow Speed at Moghbazar-Mouchak Flyover

It is observed that the maximum free flow speed was recorded in Moghbazar-Mouchak Flyover at above-grade during weekday, night (86.88 km/h) while the slowest was recorded in weekend, day (62.9 km/h) at-grade road of this flyover corridor. Vehicles' free flow speed at above-grade varies from 86.88 km/h during weekday, night time to 78.87 km/h during weekend, day. While it varies from 82.9 km/h during weekday, day time to 62.9 km/h during weekend, day. Average free flow speed at above-grade in this flyover corridor is 82.73 km/h while the average free flow speed at at-grade is 76.62 km/h. If uninterrupted, congestion-free vehicle movement were provided, vehicles would travel at such high speed and a smooth road-traffic operation could be ensured. However, the real scenario is different and vehicle travels at travel speed as described in the previous sub-section.

4.4.6.3 Delay at Travel Speed Compared to Free Flow Speed

It has been found that vehicles are operated at travel speed rather than free flow speed in field condition. Speed variation results into variation of time in a particular segment of road. Consequently, author has given an insight to investigate how much delay is commenced due to these speed variation in this flyover corridor during different periods of times i.e., weekday, day; weekday, night; weekend, day; weekend, night.

Table 4.24: Delay Due to Variation of Travel Speed and Free Flow Speed at Moghbazar-Mouchak Flyover

Moghbazar-Mouchak Flyover	Segment Length (km)	Travel Speed (km/h)	Travel Time (sec)	Free Flow Speed (km/h)	Free Flow Time (sec)	Average Delay Per Vehicle (sec)
Weekend Day, Over	8.70	60.57	517.09	78.87	397.11	119.98
Weekend Night, Over	8.70	75.13	416.88	83.76	373.93	42.95
Weekday Day, Over	8.70	25.29	1238.43	81.40	384.77	853.67
Weekday Night, Over	8.70	33.75	928.00	86.88	360.50	567.50
Weekend Day,Under	6.72	6.22	3889.39	62.90	384.61	3504.78
Weekend Night,Under	6.72	6.00	4032.00	81.03	298.56	3733.44
Weekday Day,Under	6.72	6.91	3501.01	82.90	291.82	3209.19
Weekday Night,Under	6.72	8.54	2832.79	79.64	303.77	2529.02

Analyses have been performed to observe how much time is required to pass the flyover segment of a vehicle at free flow condition and at travel speed. During this investigation, it has been found that the length of the flyover at above grade and length of the at-grade segment of the road is not equal. Hence, both at-grade and above grade road length was measured and their corresponding speed was taken into account to conduct these analyses. Table 4.24 shows the calculation steps of delay time due to variation of travel speed and free flow speed at Moghbazar-Mouchak Flyover.

Table 4.24 shows that significant delay occurs at Moghbazar-Mouchak Flyover corridor in every considered time period. Maximum and minimum delay were found during weekend, night at the at-grade road (3733.44 sec/vehicle) and weekend, night at the above-grade road (42.95 sec/vehicle) correspondingly. This implies that severe delays occur at-grade road of the flyover in all the studied night. Hence, it can be evidently concluded that construction of this flyover has failed to enhance the free flow mobility condition in this flyover corridor, rather becomes a source of severe delays.

From the light of the analyses performed for checking the mobility condition of the Moghbazar-Mouchak Flyover, it can be concluded that vehicles are operated at very low speed both at-grade and above grade of the flyover, especially vehicles travel speed at at-grade road is very low and significant delay occurs all the studied time in this flyover corridor.

However, from the perspective of mobility consideration, Jatrabari-Gulistan Flyover can be considered comparatively successful than the other flyovers, However, extensive delays occur in this road segment fade the potentiality of this flyover. Moghbazar-Mouchak flyover also provides good speed at above-grade, however, significant delays occurred at at-grade in this flyover corridor have dropped out of sight its' overall performance. Rest of the flyovers are performing very poorly and Ahsanullah Master Flyover is in the worst operating condition among them.

4.5 Assessment of Congestion Level and Safety

In this study, congestion level has been assessed in terms of queue length, where queue length is defined as the length of the line of motor vehicles that have been stopped at a level crossing in order for the trains to pass. It was measured using video based image processing technique at eight level crossings that was observed to experience significant road traffic operation. In addition to that, how the safer traffic flow has been ensured through the construction of these flyovers have been assessed. Safety has been analyzed in terms accidents occurring at the level crossings underneath the studied flyovers prior to the construction of flyovers and after flyovers. The data for safety analysis have been collected from Accident Research Institute (ARI) and previous literatures regarding rail-road conflict. However, assessment of congestion level and safety of all the level crossings are presented in the following sub-sections in terms of the flyovers, where they are located.

4.5.1 Mohakhali Flyover

4.5.1.1 Assessment of Congestion Level

Because of the presence of Mohakhali Level Crossing underneath the Mohakhali Flyover, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.30 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by [104].

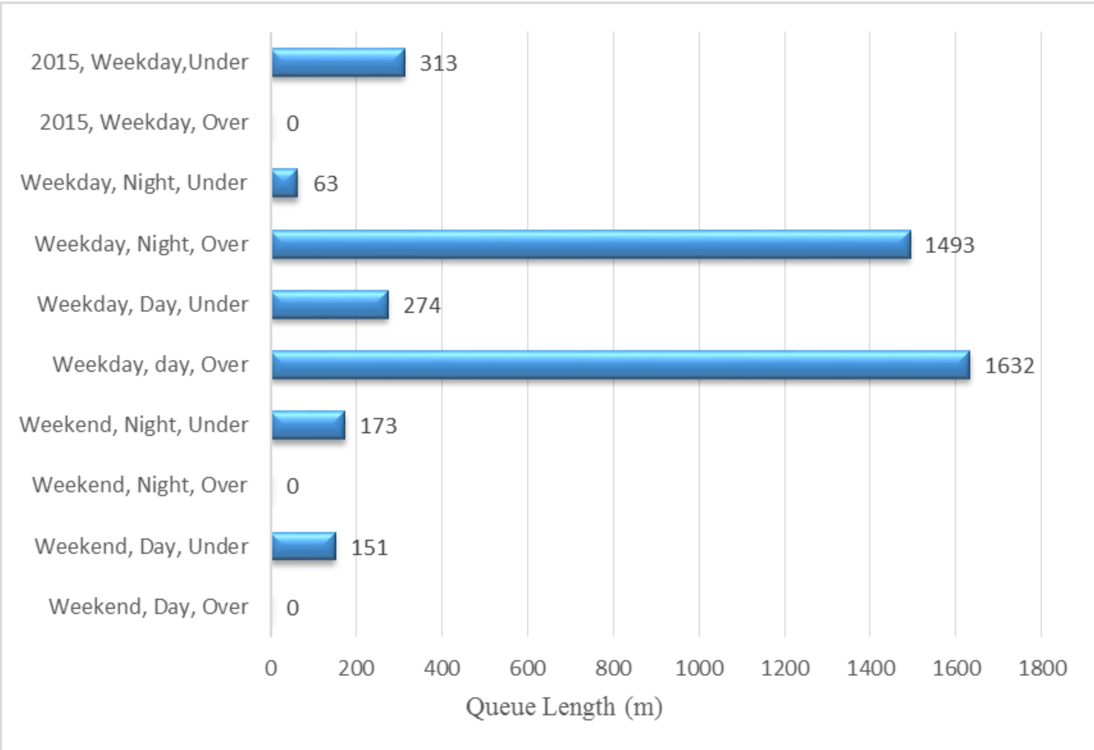


Figure 4.30: Temporal Comparison of Queue Length at Mohakhali Flyover

The longest queue length at grade was recorded at weekday day (373.7 m) while the shortest was recorded at weekday night (62.8 m). Compared to a study in 2015 by Anwari et al. [104], queue length in weekday, day has decreased by 12.46 % in 2017. The fact that queue length has developed at grade along the corridor of Mohakhali

Flyover means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. This comes despite the fact that a larger portion of traffic travelled above grade in 2017 compared to at-grade. In addition, measurement of above grade queue length shows that significant queues have developed at weekday, whereas there was no queue length in 2015. This is surely the worst case and it implies that this flyover corridor has completely failed to fulfill its' demand of traffic and this facility is insufficient to meet this ever increasing traffic demand. With time, the scenario will be getting worsen and this flyover will be proven as completely unwise traffic mitigation measure.

4.5.1.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015), Kamalapur Administration Building (2010-2014) and Haque 2011 [90] informs that one accident has occurred at Mohakhali level crossing back in 2011. From which it may be presumed that Mohakhali Flyover has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Mohakhali Flyover has started operations from 2004, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

4.5.2 Khilgaon Flyover

4.5.2.1 Assessment of Congestion Level

Because of the presence of Khilgaon Level Crossing underneath the Khilgaon Flyover, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.31 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by Anwari, Hoque and Islam (2016).

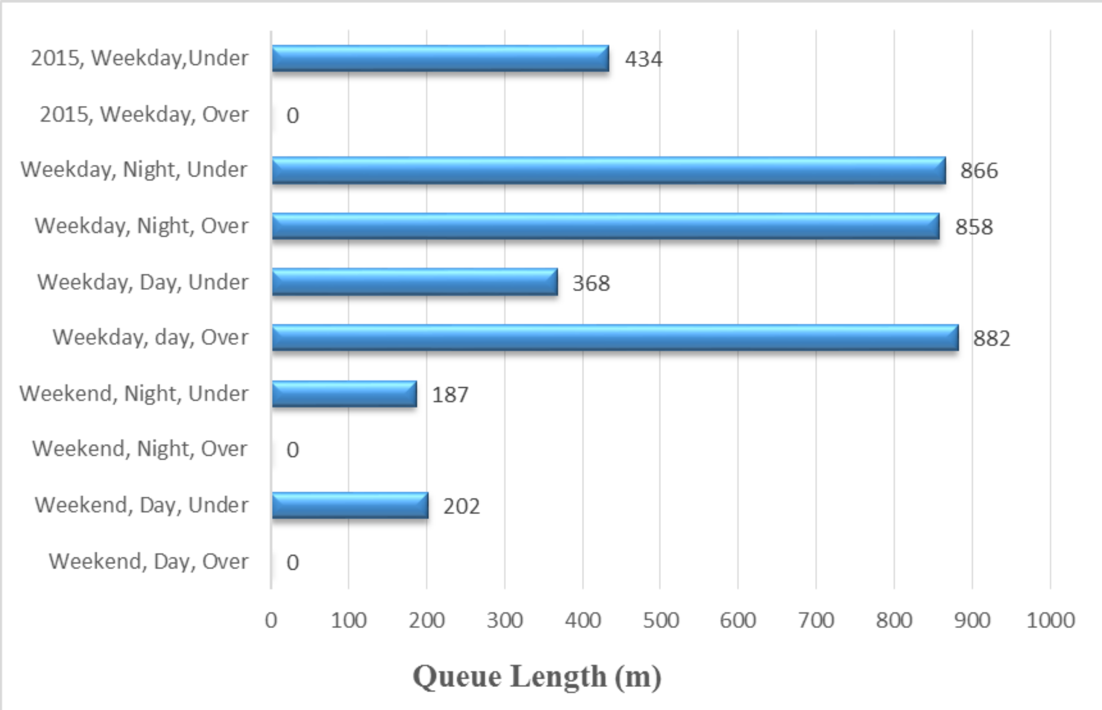


Figure 4.31: Temporal Comparison of Queue Length at Khilgaon Flyover

The longest queue length at above-grade was recorded at weekday day (882 m) while no queue was formed during weekend, day and weekend, night at above-grade. Significant congestion was observed during weekday period both at-grade and above-grade. Compared to a study in 2015 by Anwari et al. [104], queue length in weekday, day has increased by 882% at above-grade and decreased by 15.21% at-grade in 2017. The fact that queue length has developed at grade along the corridor of Khilgaon Flyover means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. This comes despite the fact that a larger portion of traffic travelled above grade in 2017 compared to at-grade. In addition, measurement of above grade queue length shows that queues have developed at weekday, whereas there was no queue length in 2015. This is surely the worst case and it implies that this flyover corridor has completely failed to fulfill its' demand of traffic and this facility is insufficient to meet this ever increasing traffic demand. With time, the scenario will be getting worsen and this flyover will be proven as completely unwise traffic mitigation measure.

4.5.2.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015), Kamalapur Administration Building (2010-2014) and Haque (2011) [90] informs that three accidents have occurred at Khilgaon level crossing in these time period. From which it may be presumed that Khilgaon Flyover has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Khilgaon Flyover has started operations from 2005, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

4.5.3 Shaheed Ahsanullah Master Flyover

4.5.3.1 Assessment of Congestion Level

Because of the presence of Ahsanullah Master (Tongi) Level Crossing underneath the Ahsanullah Master Flyover, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.32 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by Anwari, Hoque and Islam (2016).

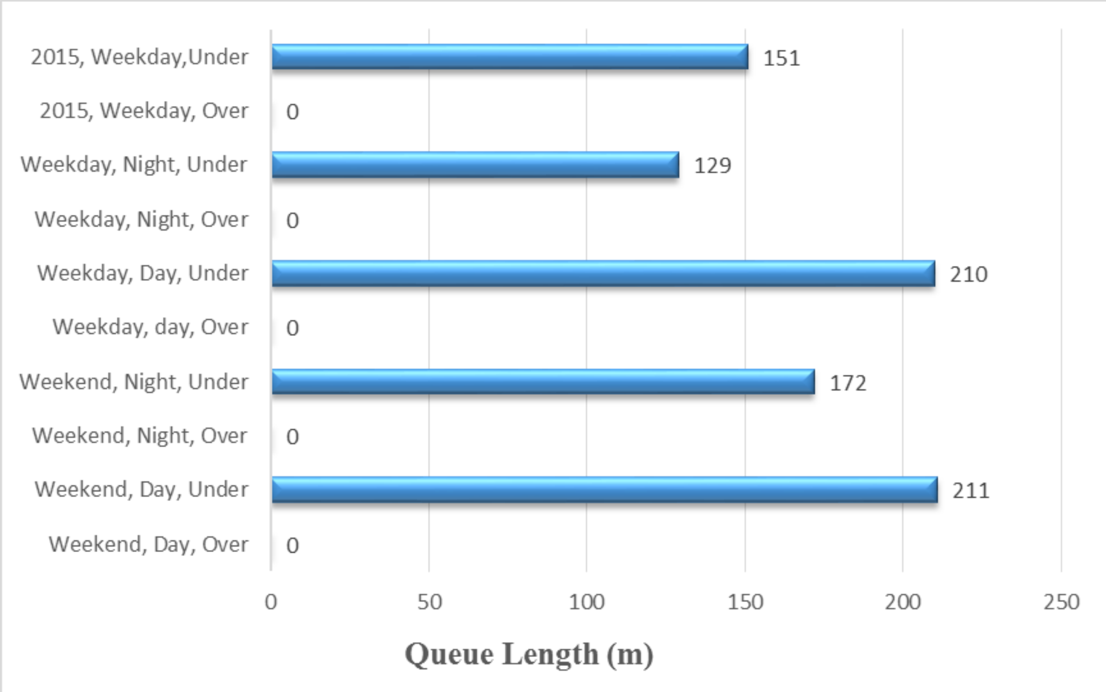


Figure 4.32: Temporal Comparison of Queue Length at Ahsanullah Master Flyover

The longest queue length at at-grade was recorded at weekday day (211 m) and second longest queue was formed during weekday, day under the flyover while no queue was formed during weekend, day; weekend, night; weekday, day; weekday, night at above-grade. Compared to a study in 2015 by Anwari et al. [104], queue length in weekday, day has increased by 39.07% at-grade in 2017. The fact that queue length has developed at grade along the corridor of Ahsanullah Master Flyover means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. Positive sign for this flyover is that no queue has been formed at above-grade during four counted times in this study. Hence, a conclusion can be drawn from the fact that although this flyover is successful in diverting a significant percentage of traffic at-above grade, the flyover is completely failed to reduce the congestion at-grade. Even, the comparison analysis between 2015 data and 2017 data has revealed that congestion has increased 39.07% at-grade within this two years. That indicates that prodigious traffic growth will induce more traffic in this flyover corridor and ultimately, traffic congestion will be propagated at above-grade level.

4.5.3.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015) and Kamalapur Administration Building (2010-2014) informs that no accidents have occurred at Ahsanullah Master (Tongi) level crossing in these time period. From which it may be presumed that Ahsanullah Master Flyover has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Ahsanullah Master Flyover has started operations from 2010, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

4.5.4 Banani Overpass

4.5.4.1 Assessment of Congestion Level

Because of the presence of Banani Level Crossing underneath the Banani Overpass, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.33 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by Anwari, Hoque and Islam (2016).

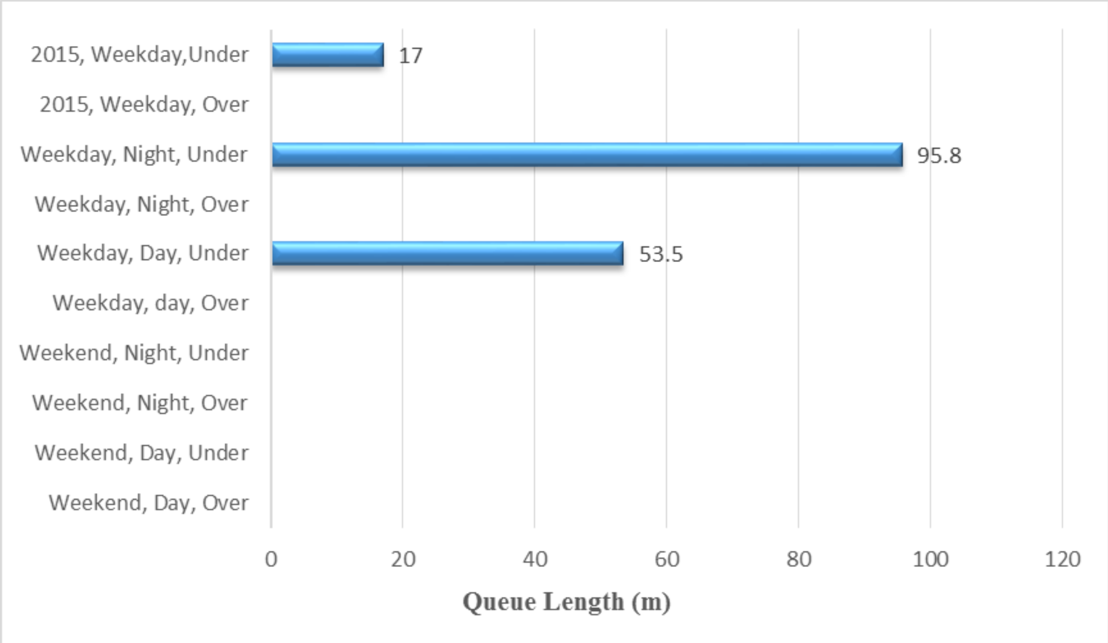


Figure 4.33: Temporal Comparison of Queue Length at Banani Overpass

The longest queue length was recorded 95.8m during weekday night under the overpass and second longest queue was formed during weekday, day (53.5 m) under the flyover while no queue was at above-grade formed during other time period in 2017. Compared to a study in 2015 by Anwari et al. [104], queue length in weekday, day has increased by 214.71% at-grade in 2017. The fact that queue length has developed at grade along the corridor of Banani Overpass means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. Positive sign for this flyover is that no queue has been formed at above-grade during four counted times in this study. Hence, a conclusion can be drawn from the fact that although this flyover is successful in diverting a significant percentage of traffic at-above grade, the flyover is failed to reduce the congestion at-grade during weekdays. Even, the comparison analysis between 2015 data and 2017 data has revealed that congestion has increased 214.71% at-grade within this two years. That indicates that prodigious traffic growth will induce more traffic in this flyover corridor and ultimately, traffic congestion will be propagated at above-grade level.

4.5.4.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015) and Kamalapur Administration Building (2010-2014) informs that one accident has occurred at Banani level crossing back in 2006. From which it may be presumed that Banani Overpass has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Banani Overpass has started operations from 2012, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

4.5.5 Jatrabari-Gulistan Flyover

4.5.5.1 Assessment of Congestion Level

Because of the presence of Saidabad Level Crossing underneath the Jatrabari-Gulistan Flyover, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.34 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by Anwari, Hoque and Islam (2016).

The longest queue length was recorded 620m during weekday night under the flyover and second longest queue was formed during weekday, day (611 m) under the flyover while no queue was formed at above-grade during other time period in 2017. Compared to a study in 2015 by Anwari et al. Anwari, Hoque and Islam (2016), queue length in weekday, day has increased by 167.98% at-grade in 2017. The fact that queue length has developed at grade along the corridor of Jatrabari-Gulistan Flyover means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. Positive sign for this flyover is that no queue has been formed at above-grade during four counted times in this study. Hence, a conclusion can be drawn from the fact that although this flyover is successful in diverting a significant percentage of traffic at-above grade, the flyover is completely failed to reduce the congestion at-grade. Even, the comparison analysis between 2015 data and 2017 data has revealed that congestion has increased 167.98% at-grade within this two years. That indicates that prodigious traffic growth will induce more traffic in this flyover corridor and ultimately, traffic congestion will be propagated at above-grade level.

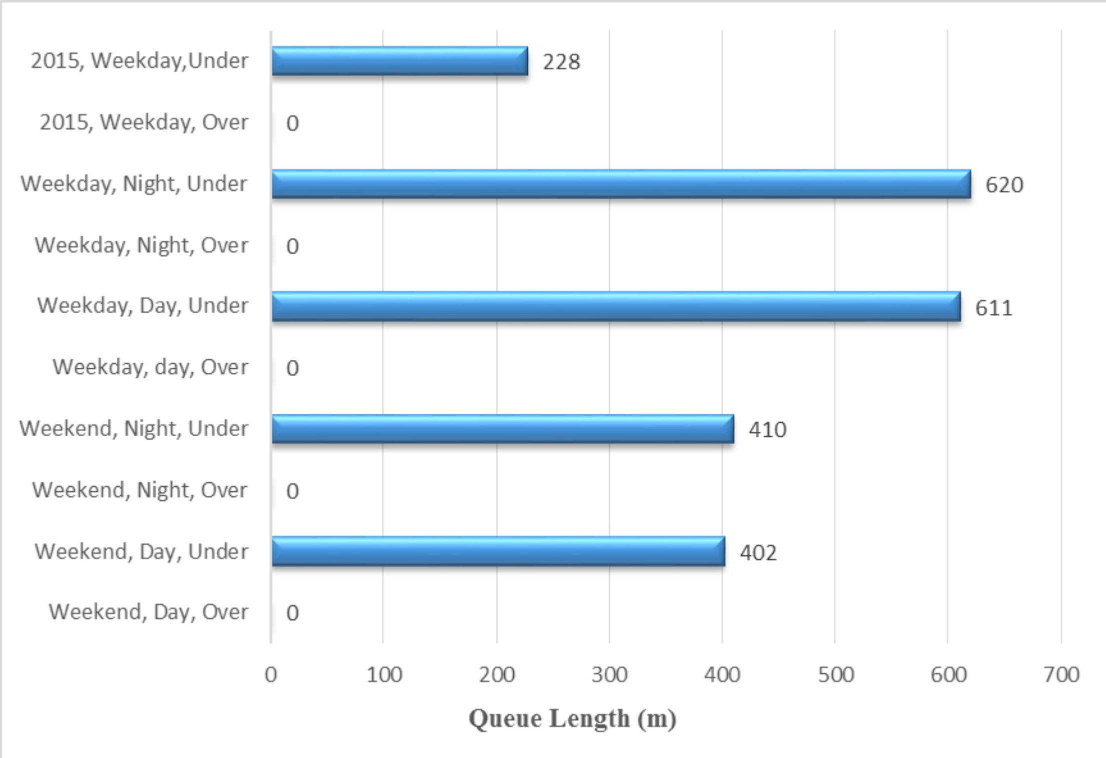


Figure 4.34: Temporal Comparison of Queue Length at Jatrabari-Gulistan Flyover

4.5.5.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015), Kamalapur Administration Building (2010-2014) and Haque(2011) [90] informs that four accidents have occurred at Saidabad level crossing back in 2007, 2008 and 2011. From which it may be presumed that Jatrabari-Gulistan Flyover has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Jatrabari-Gulistan Flyover has started operations from 2013, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

4.5.6 Moghbazar-Mouchak Flyover

4.5.6.1 Assessment of Congestion Level

Because of the presence of three Level Crossings, namely, FDC Level Crossing, Moghbazar Level Crossing and Malibagh Rail-gate Level Crossing underneath the Moghbazar-Mouchak Flyover, a full stop of the traffic flow occurs underneath this flyover frequently as such, the train passes this level crossing. Consequently, queue forms and propagates depending on the time taken by the train to pass completely this level crossing, how much traffic the flyover is segregating from at-grade to above-grade, vehicular flow variation in this flyover corridor with respect to time and vice versa. In the present analysis for this flyover, level of congestion has been assessed in terms of queue length to apprehend whether the flyover is successful in mitigating traffic congestion or not. Figure 4.35 shows the comparison among the data collected in 2017 during four time period: weekend, day, weekend, night; weekday, day; and weekday, night and also compare this data with the data collected by Anwari, Hoque and Islam (2016).

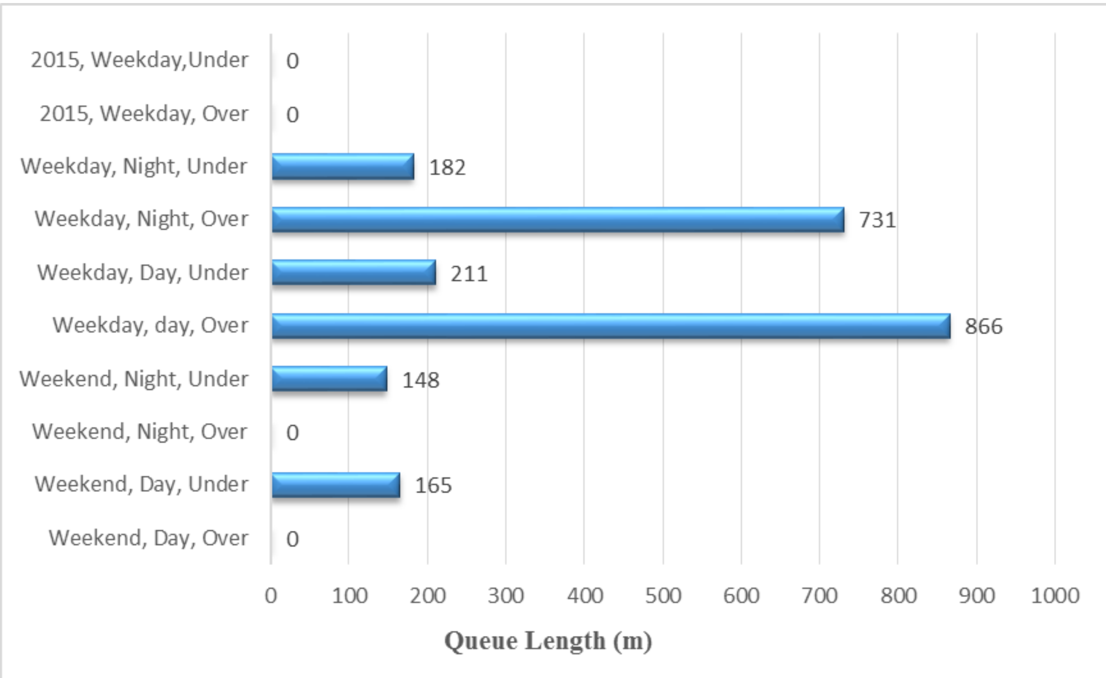


Figure 4.35: Temporal Comparison of Queue Length at Moghbazar-Mouchak Flyover

The longest queue length was recorded at above-grade during weekday, day (866 m) and second longest queue was formed at-above grade during weekday, night time period of this flyover while no queue was formed during weekend, day and weekend, night at above-grade. Significant congestion was observed during weekday period both at-grade and above-grade, and weekend, day and night period at-grade of the flyover. No comparison has been drawn with Anwari et al. Anwari, Hoque and Islam (2016), since this flyover has been constructed after this time period. The fact that queue length has developed at-grade and above-grade along the corridor of Moghbazar-Mouchak Flyover means that the flyover has failed to reduce congestion, even after having facilities to divert through traffic above grade. This comes despite the fact that a larger portion of traffic travelled above grade in 2017 compared to at-grade. In addition, measurement of above grade queue length shows that queues have developed at weekday. This is surely the worst case and it implies that this flyover corridor has completely failed to fulfill its' demand of traffic and this facility is insufficient to meet this ever increasing traffic demand. With time, the scenario will be getting worsen and this flyover will be proven as completely unwise traffic mitigation measure.

4.5.6.2 Assessment of Safety

Examination of the raw accident data collected from Accident Research Institute (2006-2015), Kamalapur Administration Building (2010-2014) and Haque (2011) [90] informs that four accidents have occurred at FDC level crossing, Moghbazar Level Crossing and Malibagh Rail Gate Level Crossing in 2008, 2009, 2010. From which it may be presumed that Moghbazar-Mouchak Flyover has been successful at maintaining safety in this level crossings. However, ARI has confirmed that they have very insignificant collection of level crossings accident data of Dhaka city. In addition to that, Jatrabari-Gulistan Flyover has started operations from 2017, it can be reasoned that the existing accident data are insufficient to draw any reasonable conclusions.

However, from the light of the aforementioned analyses it can be evidently concluded that almost all the flyovers constructed over rail-road level crossing in Dhaka city has failed to mitigate congestion to a significant level. Rather, it has induced more traffic along the flyover corridor and hence, traffic congestion are increasing prodigiously with time. In addition to that the analyses have shown that no rigid conclusion can be drawn from safety point of view since there has only a small collection of level crossing accident data by the responsible authorities. Detailed and extensive level crossing accident data collection, storage and monitoring system is required to draw a fair conclusion on safety issue at this flyover corridor.

4.6 Special Investigation

Some special phenomena observed during reconnaissance survey and data collection time have persuaded author to go for further in-depth investigation. These are described clearly in the flowing sub-sections.

4.6.1 Carriageway Deduction Because of Flyover Geometry

During the reconnaissance survey and data collection at Jatrabari-Gulistan Flyover, a special observation has persuaded the author to go for further in-depth investigation. It has been observed that, along the corridor of this flyover, it contains three piers at each transverse alignment of the roadway. At first observation, it seemed like that the piers of the flyovers have deducted at-grade roadway width significantly. Hence, width of the piers and its surrounding median width, and effective roadway width were measured to obtain the actual scenario and understand the phenomenon clearly.

Figure 4.36: At-grade Lane width reduction at the backbone of Jatrabari-Gulistan Flyover

From the field investigation, it was found that the at-grade roadway has been divided into four separate lanes by the three flyover piers at each transverse section. With reference to Figure 4.36, it has been observed that the left roadway width is 33.96 ft, after that a median has been constructed and its' width was found 16.845 ft. Then a one lane non-functional roadway was observed and its' width was found 14.65 ft. One lane road is termed as non-functional road since no overtaking is possible in this road. In addition to that, of one vehicle goes out of order, a significant traffic congestion initiates and propagates to infinity in a form of back-shockwave. In addition to that, lane changing behavior is not also possible at-grade road of this flyover corridor since every lane is separated by large width median along with barrier or guard rail. In the right side of this one lane non-functional roadway, the most wide median was observed and its' width was found 22.86 ft. Then the most right effective roadway width was found 22.58 ft and rest 12.56 ft space was consumed by the another pier of the flyover and rest of the roadway was encroached by the vendors. Hence, from the observation, it has been found that total at-grade road way width is 123.455 ft, while the effective roadway width for vehicle movement was found to be 71.1 ft. That analysis reveals that 42.41 % road way has been deducted or reduced at at-grade road due to the construction of flyovers.

To investigate how much additional space has been added by flyover at above-grade road, the width of the above-grade road was measured. It was found that, the existing above-grade roadway width is 73.63'. Hence, currently in this existing flyover corridor, total effective width both combining the both at-grade and above-grade is 144.73 ft, whereas, before the construction of flyover, the effective at-grade road width was 123.455 ft. Hence, the construction of this capital intensive mega-structure has increased total effective roadway width only 17.24 %, combining at-grade and above-grade effective roadway width.

Although the flyover is adding only 17.24% additional carriage-way, it is inducing an enormous number of vehicles from the adjacent and other corridors and routes. In addition to that, traffic movements through these four spitted carriageways has made junction operation more complicated. It has reduced the functionality and capacity of at-grade road drastically. On top of that, private and small sized vehicles are increasing at a prodigious rate. They are basically using this flyover. The public vehicles still now use at-grade road, even if congestion level is at its' maximum at at-grade road. The rationale for this incident may be justified by the fact that two major bus terminals of Dhaka city, Saidabad bus terminals and Jatrabari bus terminals, are located along in this flyover corridor. Public vehicles need to pick-up passengers from at-grade terminals and counter points. Hence, they rarely use flyover. In addition to that, critical observations of the proposed layout configuration revealed that the flyover is planned giving minimum attention to the at-grade road users and most importantly layout is arranged in such a way that the motorists are forced to use the flyover even at off-peak period. The overall layout planning of the flyover shows that instead of being a true flyover it would merely be a road-overpass i.e. it will augment roadway capacity by deducting the capacity of existing at-grade road. Too wide medians around the piers of the flyover has facilitated the encroachments to block traffic movements. Consequently, the key road below the flyover does not facilitate free traffic flow as it should have because it has been choked by illegal structures built by encroachers. The field study and interview with the locals reveal that, the medians' widths were deliberately designed to encourage drivers to use the flyover to increase toll collection. Commercial need and greed of the flyover implementing authority has persuaded them to technically destroy the functional and operational effectiveness and level of service of at-grade road. Another hidden consequence of such policy is that, since public transport will use at-grade to pick-up more passengers, these vehicles will have to face tremendous traffic congestion and undefined delay. These will lead the public transport to an unpopular mode of transport and eventually, people will shift to small size vehicles i.e., motocycle, private car, CNG and vice versa. Thus, construction of flyovers is destroying the future scope of sustainable public transport and inviting more unsustainable private vehicles, which will eventually make the situation worse.

4.6.2 Shifting Congestion Rather Mitigating

Further Investigation was conducted to observe how flyovers have deducted the road-way width at touchdown point of the ramps of the flyover. To investigate this phenomenon, chankharpool ramp of Jatrabari-Gulistan flyover was chosen. During this investigation, significant findings have been marked. Field scenario has been depicted in Figure 4.37.

Figure 4.37: At-Grade Lane Width Reduction at the Touchdown Point of Jatrabari-Gulistan Flyover

It is observed from the geometric dimension of the touchdown point of Jatrabari-Gulistan Flyover that, total effective roadway width for moving the vehicles who don’t need to use flyovers is 48.75 ft. Whereas, flyover ramp is reducing 26.67 ft of the at-grade road, which was supposed to use by the at-grade traffic. The percentage of reduction of at-grade road-way width is 35.36 %. Despite this fact, the flyover is attracting enormous amount of small size and private vehicles and existing them at these ramps. The field investigation reveals that chankharpool ramp is finished just before an intersection and hence, it is generating a tremendous congestion at this point and becomes a bottleneck. Similar scenario has been observed at all the ramps of all the flyovers. To this end, it can be concluded that touchdown point is the main point which is dictating the whole corridor capacity and flyovers are not eventually mitigating traffic congestion, rather they are shifting congestion from one point or location to another point or location. Consequently, construction of these flyovers will merely migrate congestion at one location to another location with greater magnitude (due to incompatible connection, toll payment, signal, force convergence, discharge problems) and eventually, it can never be a sustainable solution.

4.6.3 No Pedestrian Facility

In consideration of high pedestrian traffic flow, provision of 1.5m footpath was found absent in most of the flyovers which is near to the requirement. In addition to that, due to headroom restriction (5.5m), in future no grade-separated pedestrian crossing facility in the form of foot-over-bridge along the corridor of these studied flyovers would be possible. Rather, the construction of these flyovers required demolition of the important and widely used foot bridge those were along the alignment of the flyover corridor prior to construction. In addition to that, since the studied flyovers are partially grade-separated facility and no restriction on turning movements at at-grade level would be possible, at the at-grade road there would still be a number of directional turning movements from different approaches. In consequence, pedestrian crossings at at-grade level would be difficult and hazardous. Hence, it can be concluded that during the construction of these partially grade-separated flyovers at the heart of the Dhaka city, pedestrian safety consideration has evidently neglected and hence, it can be said, the construction of flyovers in Dhaka city has made the pedestrian vulnerable to traffic and reduced their safety significantly.

4.6.4 Diminishing Future Scope of Public Transit Oriented Development

In future, introduction of organized at-grade transit system, like bus rapid transit (BRT) system, as recommended in the STP report, would not be possible along Jatrabari-Gulistan Flyover and Moghbazar-Mouchak Flyover corridor as well as along its branch roads due to the presence of ramp landings and at-grade large sized toll plazas.

From Figure 4.38, it is clear that Moghbazar-Mouchak Flyover and Jatrabari-Gulistan Flyover will make foul with the STP recommended bus rapid transit (BRT1, BRT2 & BRT3) and mass rapid transit (MRT4, MRT5 and MRT6) oriented projects. Actually these two flyovers have been constructed in the BRT and MRT alignment. From the STP recommended BRT and MRT alignment, it is observed that BRT 3 line has completely stopped due to the construction of Jatrabari-Gulistan Flyover and Moghbazar-Mouchak Flyover. In addition to that, MRT 6 implementation will require to change its' original alignment as recommended by STP. Construction of MRT 4 and MRT 5 will seriously be affected by these two flyovers. To this end, with the construction of these flyovers, future scope for initiating public mass oriented transport system which have enormous potential to ensure more rider comfort, enhance mobility and increase productivity and bring overall sustainability, has been diminished. Most importantly, it has eliminated the future possibility of integrated transport system. Consequently, these flyovers are leading us to a temporary solution instead of sustainable solution.

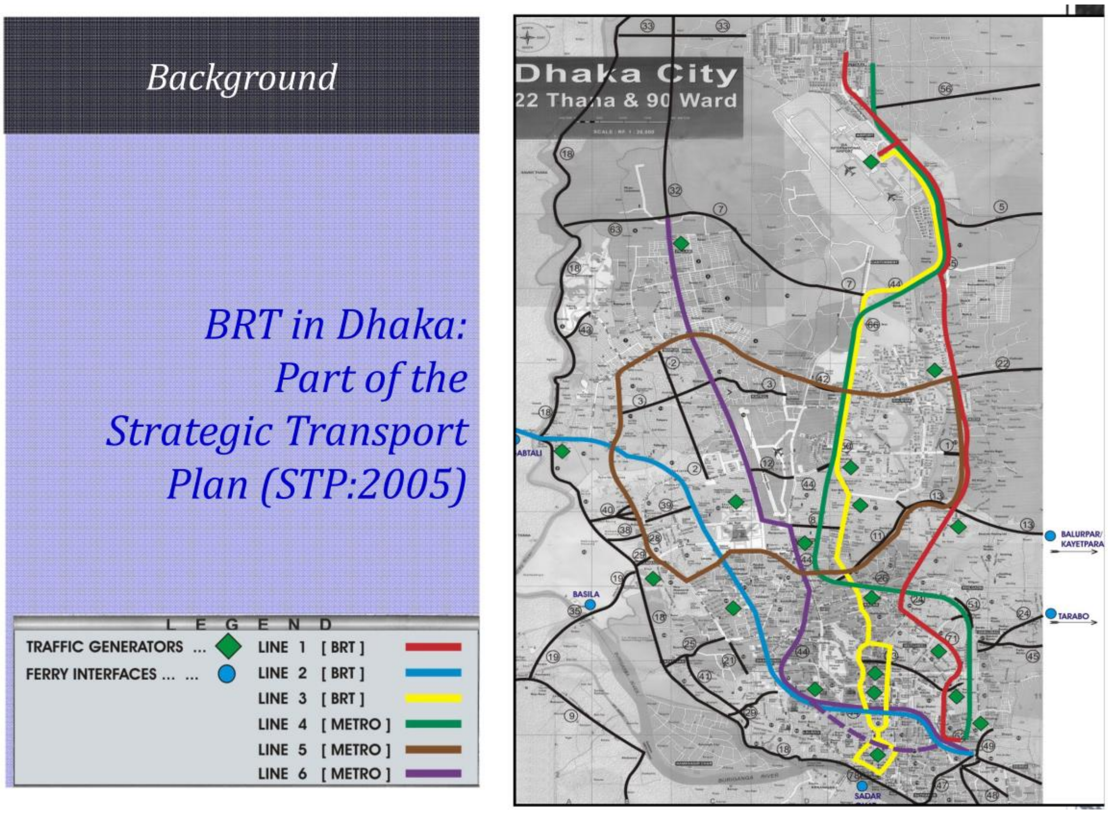


Figure 4.38: Proposed BRT and MRT Routes in Dhaka City

From the light of the above discussion it can be concluded that, the impact of flyovers on at-grade roadway capacity because of reduction of road carriageway is significant, however, the impacts seem to be more acute because of poor configuration of the flyovers constructed over rail-road level crossing in Bangladesh. As a whole, construction of the partially grade-separated flyovers with their present layout configuration would not solve traffic problems of along their respective corridor at all instead it would do more harm than good. It is clearly evident that the construction of this capital intensive irreversible capacity augmentation measure will create another built-in/permanent traffic operational problem in Dhaka city. In addition, impact analyses from operation aspects have shown that instead of mitigating traffic congestion, and enhancing mobility and safety, these flyovers will invite more small size vehicles, shift congestion from one location to another location, provide no facility to pedestrians, act as a counter-product to make public transport an unpopular mode of transport and eventually diminish the scope of public transport oriented development.

4.7 Overview

This chapter has briefly presented the data required to fulfill the objectives of the study and analyzed them to observe how far the objectives have been met through the construction of flyovers over rail-road level crossings of Dhaka city. Assessment of the relative level of usage of road space under and over the flyover has shown that almost all the flyovers are segregating a large percentage of vehicles from at-grade to above-grade, yet, a significant portion of vehicles are left to be exposed at rail-road level crossing of the at-grade road. Assessment of flyovers usage by non-motorized vehicles compared to motorized vehicles has shown that motorized vehicles are the main beneficiaries of the construction of flyovers and constructed flyovers are inducing more traffic whereas, no facilities have been provided for non-motorized vehicles. Assessment of mobility and road accessibility conditions of vehicles both at-grade and above-grade of the flyover has shown that vehicle speed at both at-grade and above-grade are significantly lower and it has been come to almost at walking at the at-grade road. Assessment of congestion level analyses have shown that flyovers have failed to mitigate the traffic congestion along the flyover corridor and significant delays occur both at-grade and above-grade road of the flyover corridor especially during weekdays. Finally, the chapter ends with special investigation on some unusual phenomena observed by the author during conducting the study. Next chapter summarizes the findings of the study and proposes some recommendation for the improvement of the present scenario.

CHAPTER 5
CONCLUSIONS AND SUGGESTIONS

5.1 Findings of the Study

In brief, this study has- (i) assessed the relative level of usage of road space under and over the flyovers, (ii) assessed the usage of flyovers by non-motorized vehicles and public transport, (iii) evaluated the mobility and road accessibility conditions of vehicles both at-grade and above-grade road, and (iv) measured the effectiveness of flyovers in terms of reducing traffic congestion levels and improving safety at level crossings. Hence, it can be evidently concluded that this research has accomplished the four objectives of the thesis.

5.1.1 Findings Related to First Objective

The first objective was to assess the relative level of usage of road space under and over the flyovers. To attain this objective, an extensive effort had been put together to collect and synthesize classified vehicle count data at all the partially grade-separated flyovers constructed over rail-road level crossing in Dhaka city during four time periods: weekday, day; weekday, night; weekend, day; weekend, night by field survey performed on several days by a group of surveyors. The analyses have been performed to check how much at-grade traffic is segregated by the partially grade separated flyovers to above grade and also to observe what percentage of vehicles are exposed to rail-road conflict point even though grade separated facilities have been provided.

Analyses of combined classified vehicle count data (Table A.2) has shown that along the corridor of Mohakhali Flyover, the overall ratio of above-grade to at-grade flow is only 2.12:1. This implies that 67.91 % of total flow at Mohakhali Flyover corridor are using this grade-separated facility and rest 32.09 % vehicles are exposed to the rail-road conflict point.

The case is more severe in Khilgaon Flyover, where it has been found that the overall ratio of above-grade to at-grade flow is only 1.24:1. This implies that 55.29 % of total flow at Khilgaon Flyover corridor are using this grade-separated facility and rest 44.71 % vehicles are exposed to the road-rail conflict point.

The worst case has been found for Ahsanullah Master Flyover, where it has been found that the overall ratio of above-grade to at-grade flow is only 0.44:1. This implies that only 30.57 % of total flow at Ahsanullah Master Flyover corridor are using this grade-separated facility and rest 69.43 % vehicles are exposed to the rail-road conflict point.

From the analyses it has been found that Banani Overpass is most successful in segregating at-grade flow to above-grade and hence, in reducing the rail-road conflict. The overall ratio of above-grade to at-grade flow is 6.17:1, which implies that 86 % of total flow at Banani Overpass corridor are using this grade-separated facility and only 13.94 % vehicles are exposed to the rail-road conflict point.

Jatrabari-Gulistan Flyover has shown a better performance than Mohakhali Flyover and it has been found that the overall ratio of above-grade to at-grade flow is 2.42:1, which implies that 70.75 % of total flow at Jatrabari-Gulistan Flyover corridor are using this grade-separated facility and rest 29.25 % vehicles are exposed to the rail-road conflict point.

Moghbazar-Mouchak Flyover is performing better than Mohakhali Flyover but performance is poor compared to Jatrabari-Gulistan Flyover. The overall ratio of above-grade to at-grade flow is 2.32:1, which implies that 69.86 % of total flow at Moghbazar-Mouchak Flyover corridor are using this grade-separated facility and rest 30.14 % vehicles are exposed to the rail-road conflict point.

However, from the light of the above discussion it can be concluded that from the perspective of segregating traffic from at-grade to above-grade, Banani Overpass has been proved to be most successful and rest of the flyovers are performing very poorly and the worst case has been found for Ahsanullah Master Flyover.

5.1.2 Findings Related to Second Objective

The second objective was to assess the usage of flyovers by non-motorized vehicles and public transport. To attain this objective, an extensive effort had been put together to collect and synthesize classified vehicle count data at all the partially grade-separated flyovers constructed over rail-road level crossing in Dhaka city during four time periods: weekday, day; weekday, night, weekend, day; weekend, night by field survey performed on several days by a group of surveyors. Then, the classified count data were analyzed to obtain the percentage of different types of vehicles both at-grade and above-grade of the studied six partially grade separated flyovers. Analyses have been performed to observe which types of facility (at-grade or above-grade) are used by what types of vehicles (non-motorized or public transport).

Analyses of combined vehicle percentage data (Table A.3) has shown that along the Mohakhali Flyover corridor, Car (66 %) and CNG (15 %) are the most dominating vehicles at above-grade road whereas, Car (50 %), Bus (16 %) and CNG (11 %) are dominating at-grade road. Presence of Non-motorized vehicles are 4% at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to private vehicles and it is inducing more private vehicles to use this facility. However, Public transport i.e., bus, are rarely using this flyover and it has completely failed to provide any facility to non-motorized vehicles.

Along the Khilgaon Flyover corridor, Car (50 %) and Bus (30 %) are the most dominating vehicles at above-grade road whereas, Rickshaw/Van (94 %) are solely dominating at-grade road. Presence of Non-motorized vehicles are 95% at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to private vehicles and a significant portion of public transport are also using this facility. However, the flyover has completely failed to provide any facility to non-motorized vehicles.

Along the Ahsanullah Master Flyover corridor, Human Hauler (25 %), Truck (23 %) and Car (18 %) are the most dominating vehicles at-above grade road whereas, Rickshaw/Van (84 %) are solely dominating at-grade road. Presence of Non-motorized vehicles are 85% at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to commercial vehicles and private vehicles. A significant portion of public transport are also using this facility. However, the flyover has completely failed to provide any facility to non-motorized vehicles.

Along the Banani Overpass corridor, Car (61 %), Bus (15 %) and CNG (11 %) are the most dominating vehicles at above-grade road whereas, Car (79 %) and Motor-cycle (11 %) are dominating at-grade road. Presence of Non-motorized vehicles are 5% at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to private vehicles and is inducing more private vehicles to use this facility. Also a significant portion of Public transport are using this flyover. However, this flyover has completely failed to provide any facility to non-motorized vehicles.

Along the Jatrabari-Gulistan Flyover corridor, Bus (48 %), Car (20 %) and CNG (8 %) are the most dominating vehicles at above-grade road whereas, Rickshaw/Van (51 %) and Bus (34 %) are dominating at-grade road. Presence of Non-motorized vehicles are 51% at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to public transport. Also a significant percentage of private transport and small sized vehicles are also using this flyover. However, this flyover has completely failed to provide any facility to non-motorized vehicles.

Along the Moghbazar-Mouchak Flyover corridor, Car (48 %), Bus (20 %), and CNG (17 %) are the most dominating vehicles at-above grade road whereas, Car (40 %) and Rickshaw/Van (35 %) are dominating at-grade road. Presence of Non-motorized vehicles are 35 % at-grade road and 0% at above-grade road respectively. This statistics implies that this flyover is providing facility basically to private vehicles and has become a source of inducing more private vehicles to use this flyover. Although a significant portion of public transport are using this flyover, it has completely failed to provide any facility to non-motorized vehicles.

However, from the light of the above discussion it can be concluded that from the perspective of providing facilities to non-motorized vehicles, all the flyovers have evidently failed to provide any facilities to non-motorized vehicles. Rather, the NMVs are using at-grade road as before, deteriorating the level of service of the at-road by prolonging traffic congestion. In addition to that, at the touch-down points of the flyover at at-grade road, they are creating hindrance to above-grade flow and hence, disturbing smooth flow at the above-grade. From the perspective of public transport, it can be concluded that Jatrabari-Gulistan Flyover has been proved to provide maximum usage of public transport on flyover and Moghbazar-Mouchak Flyover also shares a significant portion of flyover space with public transport. However, rest of the flyovers are performing very poorly to provide facilities for public transport.

5.1.3 *Findings Related to Third Objective*

The third objective was to evaluate the mobility and road accessibility conditions of vehicles both at-grade and above-grade road. To attain this objective, an extensive effort had been put together to collect and synthesize travel speed and free flow speed data at all the partially grade-separated flyovers constructed over rail-road level crossing in Dhaka city during four time periods: weekday, day; weekday, night; weekend, day; weekend, night by field survey performed on several days by a group of surveyors. The analyses have been performed to observe vehicle mobility condition both at-grade and above-grade at each of the studied flyover corridors and also to find out the delay caused due to travelling at travel speed instead of free flow speed.

Average vehicle speed at above-grade in Mohakhali flyover corridor is 32.04 km/h while the average vehicle speed at at-grade is 8.32 km/h which is only a little faster than the average walking speed (5 km/h). In addition to that, significant delays were observed at the flyover corridor varying from 561.17 seconds to 44.39 seconds.

While, travel speed has been decreased at above-grade (28.10 km/h) and increased at at-grade (9.28 km/h) in Khilgaon flyover corridor compared to Mohakhali Flyover corridor. In addition to that, delays were significantly higher at the Khilgaon flyover corridor varying from 652.59 seconds to 109.01 seconds compared to Mohakhali Flyover corridor.

Worst case has been found for Ahsanullah Master Flyover. Here, the average vehicle speed is 24.87 km/h at above-grade while 3.70 km/h at at-grade road which is lower than the average walking speed (5 km/h). In addition to that, significant delays were observed at the flyover corridor varying from 763.31 seconds to 22.69 seconds.

A better travel speed has been observed at Banani Overpass both at-grade and above-grade. The average vehicle speed at Banani Overpass is 35.83 km/h at above-grade while 17.14 km/h at at-grade road. Compared to aforementioned flyovers, a less delay occurred in this flyover corridor. Maximum and minimum delays is recorded as 233.76 seconds and 12.07 seconds respectively.

Jatrabari-Gulistan flyover was performing better compared to Mohakhali Flyover and Khilgaon Flyover. Average vehicle speed at above-grade in this flyover corridor is

30.46 km/h while the average vehicle speed at at-grade is 12.03 km/h. However, excessive delays were observed in this flyover corridor varying from 3017.16 seconds to 793.81 seconds.

Moghbazar-Mouchak Flyover has showed the maximum above grade speed (48.68 km/h) among all the flyovers while the at-grade travel speed is recorded at 7.01 km/h, which is just close to walking speed. Like Jatrabari-Gulistan Flyover, this flyover has also showed an extensive delay in this corridor varying from maximum 3733.44 seconds to 42.95 seconds.

However, from the perspective of mobility consideration, Jatrabari-Gulistan Flyover can be considered comparatively successful than other flyovers, However, extensive delays occur in this road segment fade the potentiality of this flyover. Moghbazar-Mouchak flyover also provides good speed at above-grade, however, significant delays occurred at at-grade road along the flyover corridor have dropped out of sight its' overall performance. Rest of the flyovers are performing very poorly and Ahsanullah Master Flyover is in the worst operating condition among them.

5.1.4 Findings Related to Fourth Objective

The fourth objective was to measure the effectiveness of flyovers in terms of reducing traffic congestion levels and improving safety at level crossings. To attain this objective, an extensive effort had been put together to collect and synthesize congestion level data at all the partially grade-separated flyovers constructed over rail-road level crossing in Dhaka city during four time periods: weekday, day; weekday, night, weekend, day; weekend, night by field survey performed on several days by a group of surveyors. Level crossing accident data were collected from ARI, Komlapur Railway Administration and Haque (2011) [90]. The analyses have been performed to observe how traffic congestion level has been decreased or mitigated and safety has been ensured through the construction of these partially grade separated flyovers.

In Mohakhali Flyover, maximum congestion level is recorded at 373.7 m and comparison with previous data has revealed that congestion has increased 19.40 % within two years.

Khilgaon Flyover performance is worse compared to Mohakhali Flyover. Here, maximum congestion level is recorded at 882 m and congestion has increased 15.21 % within two years.

In Ahsanullah Master Flyover, maximum congestion level is recorded at 211 m and comparison with previous data has revealed that congestion has increased 39.07 % within two years.

Banani Overpass has showed a minimum congestion level (95.8 m). However, congestion has increased tremendously in this flyover corridor and it is 214.71 % from 2015 to 2017.

Jatrabari-Gulistan Flyover performance is worse than Mohakhali Flyover. Here, maximum congestion level is recorded at 611 m and congestion has increased 167.98 % within two years.

Second maximum queue length is observed at Moghbazar-Mouchak Flyover and it is 866 m. No reasonable conclusion can be drawn from safety point of view due to insufficient data.

However, from these discussion it can be said that Khilgaon flyover has shown the maximum queue length and compared to previous data, Jatrabari-Gulistan Flyover has shown highest congestion increasing rate.

In addition to that, special investigation reveals that construction of these partially grade-separated flyovers in the heart of the city is

- ✓ Significantly deducting the at-grade carriage way
- ✓ deteriorating the operational and functional capacity of at-grade road
- ✓ attracting small size private vehicles
- ✓ making public transport unpopular to general people
- ✓ shifting traffic congestion from one location to another rather than mitigating it
- ✓ inducing more smaller size traffic

- ✓ not giving any facility to the pedestrian
- ✓ And eventually diminishing the future scope of public transit oriented development.

To this end, it can evidently be said that this research has accomplished the four objectives of the thesis and evaluated performance of all the studied flyovers.

5.2 Research Contributions

This thesis presents several novel findings regarding performance evaluation of the partially grade separated flyovers constructed over rail-road level crossing in Dhaka city. These findings have the potential to provide new insights into the planning and decision-making stage whether flyovers are capable of mitigating perennial traffic congestion and minimizing rail-road conflict at these locations. The following are the main contributions of this research:

i) Assess the relative level of usage of at-grade and above-grade road along the corridor of the partially grade-separated flyovers constructed over rail-road level crossings in Dhaka city. Also identify the flyovers those are performing well and which are at their worst operating condition. In addition to that a relative ranking of the flyovers from road space usage perspective have been done so that improvement plan can easily be applied based on the underlying problems of that particular flyover ;

ii) Assess the usage of flyovers by non-motorized vehicles and public transport along the corridor of the partially grade-separated flyovers constructed over rail-road level crossings in Dhaka city. The findings of the analyses imply that no facility has been provided to non-motorized vehicles in those flyovers, rather, they are exposed to rail-road conflict. In addition to them, flyovers are constructed at such locations where public transport are unwilling to use above-grade road and to get more passengers, they normally use at-grade road. Hence, most of the flyovers have failed to provide any facility to public transport. They are also exposed to rail-road conflict.

iii) Evaluate the mobility and road accessibility conditions of the vehicles both at-grade and above-grade of the partially grade-separated flyovers constructed over rail-road level crossings in Dhaka city. The findings of the analyses reveal that vehicles are operated at very low speed both at-grade and above-grade. Particularly, travel speed has dropped drastically at at-grade and somewhere it has reported to be less than walking speed. In addition to that, significant delay has been observed both at-grade and above-grade of all the flyovers. Hence, it can be concluded that construction of these mega-expensive flyovers have failed to enhance mobility in the urban heart.

iv) Assess the queue length and accident rate prior to the construction and after the construction of these partially grade-separated flyovers constructed over rail-road level crossings in Dhaka city. Results from these analyses reveal that significant queue forms at almost all the flyovers and it can evidently be said that construction of these flyovers have failed to reduce traffic congestion. No reasonable conclusions can be drawn from the safety point of view due to inadequate and very small volume of accident data.

To this end, this research has successfully evaluated the performance of all the partially grade-separated flyovers constructed over rail-road level crossing and the findings of the analyses are significant and crucial for further adopting this grade-separated facility to any traffic congestion and rail-road conflict prone area.

5.3 Suggestions

In consideration of the study findings revelations, following suggestions are presented for future considerations:

- ✓ From the overall study findings, it has been evidently proved that the constructed flyovers have failed to fulfil their objectives. Hence, it is recommended that flyovers may be constructed after all the other conventional traffic engineering measures are implemented and these measures have failed to resolve the capacity and traffic congestion problem. Otherwise, it is strongly recommended not to construct this capital intensive structure.

- ✓ From the findings of first objective of this thesis,

- It is recommended to gradually implement low cost effective traffic engineering measures with an aim to minimize conflicts among vehicle-vehicle, vehicle-pedestrian, vehicle-rail and pedestrian-rail, and then shift to expensive measures if required. In addition, if flyovers are to be constructed, they must be constructed with full grade-separation facility. Full grade separation has the potential to resolve rail-road conflict.

- Where partially grade-separated flyovers have already been constructed, it is recommended to limit the public transport flow at-grade road. Rather, public transport should be encouraged to use above-grade road. To ensure accessibility of the passengers to public transport at above-grade, several intermittent accelerators or lifts (not stairs, it will be land hungry and will provide minimum facility to the disabled and handicapped people). These accelerators or lifts will be constructed in the mid-portion of carriageway or in between existing guard-rails position (where there is unused empty space created by piers of the flyovers). At above-grade, bus bay will be provided in between the mid portion of opposite directional traffic as like it is done in BRT or MRT. Passengers will come at at-grade road, use footpath to reach the accelerator location, then will come to mid-portion of the road via signal-controlled pedestrian crossing to pin-point accelerator and then use accelerator to go to above-grade road. Accelerators or lifts will carry passengers from at-grade to above-grade and passengers will get exit at these bus-bay portions at above-grade so that they can easily use public transport facility.

- Flyovers should be made tolled free for public transport. So that it will encourage more public transport to use the flyover space. Whereas, for the existing flyovers, high charge or toll should be imposed on private and small sized vehicles, if they wish to use flyover space.

- Considering the distinctive traffic flow imbalance between weekday and weekend as well as between day-time and night-time, there is a need to explore the possibility of introducing tidal flow regulation as a rush hour traffic management measure.

- ✓ From the findings of second objective of this thesis,

  - Private cars are increasing at a prodigious rate and they are the main user of these flyovers, hence, it is recommended to set rules and regulations to limit the purchasing of private cars.

  - In addition, limit usage of above-grade road by the private car and small sized vehicles. This will force them to use at-grade road and consequently, they will face tremendous traffic congestion. While, public transport will travel at free-flow speed at above-grade road. Eventually, this will lead the private transport users to shift to public transport strategically. However, the precondition to implement this strategy as described earlier is to provide sufficient facilities to the passengers so that they can use this public transport facility comfortably. More strategic tips to ensure this strategy have been described in the later portion of the recommendations section.

  - At first, ameliorate the public transport condition. It must be made more user friendly. Fitness check of the vehicles should be done on regular basis. The boarding-alighting ramp of the public vehicles will at the same level with bus-bay or footpath so that passenger can get in and out comfortably.

  - Bus bay are to be built at a significant distance before and after the starting ramps and ending ramps of the flyovers. So that Passengers can easily and safely board and alight onto the public transport. If the length of the flyover is sufficiently long, several above-grade bus-bays and passengers' boarding-alighting stations should be provided with special consideration to disabled people as described earlier.

  - Dedicated bi-cycle lane, pedestrian walk-way and safe pedestrian crossing should be provided at-grade road.

  - Separate bi-cycle lane should be provided at above-grade also.

- Banning and segregating non-motorized vehicles (except bi-cycles) in primary and secondary urban roads. Their presence should be limited to local roads.

- Access control from the side roads and local roads should be imposed to minimize the effects of local traffic.

✓ From the findings of the third objective of this thesis,

- It has been found that flyovers have failed to enhance mobility along their road corridor. Prior to go for capital intensive measures, geometric design layout should be modified in traffic congestion prone areas/ intersections as such, junction corner widening, widening of approach to accommodate islands/channels and exclusive left/right turning lanes and vice versa.

- To get uninterrupted flow, whole-sale markets, shopping mall, fuel pump, bus terminal, truck terminal, pick-up terminal, CNG terminal, fruit-shops, educational institutions, religious establishments observed at the surrounding of rail-road conflict point and closest intersections of the studied flyovers must be relocated.

- To get uninterrupted flow with large volume of passenger transportation, it is recommended to introduce Bus Rapid Transit (BRT) and Mass Rapid Transit (MRT) to serve overly populous urban city like Dhaka.

✓ From the findings of the fourth objective of this thesis,

- It has been found that flyovers have also failed to mitigate traffic congestion and a significant level of congestion occurred at each of the studied flyovers. Hence, to mitigate traffic the aforementioned low-cost traffic engineering measures may be effective. In addition to that, traffic congestion-prone areas where flyovers are not constructed yet, it strongly recommended to introduce dedicated public bus lane at-grade road along with the aforementioned strategies.

- To improve safety, level crossings need to be authorized and monitored 24 hours/day. In addition to that, safety features including gates, whistles, signs and adequate number of gateman are needed to ensure safe operation round the clock at all approach roads.

- To limit the transverse crossing movement of people over railway crossing, adequate footbridges and pedestrian walkways should be provided.
- In addition to that, after constructing walkways, continuous guard-rail or median barrier should be provided to guide pedestrian in a designated way and ensure their safety.
- Automatic and artificial intelligence based traffic control devices should be introduced to regulate the traffic strictly and ensure safety to the road-users.

✓ From the findings of special investigation,

- Impact of MRT flyover is much smaller than the road-based flyover from the perspective of reducing effective and key road width since it has no up/down ramp. That is why, within the heart of the city always recommended to build public-transport oriented infrastructure, which has the potential to add capacity significantly with minimum influence on the at-grade road. Rather road traffic is off-loaded by deducting from its' own carriageway to metro.

✓ To implement the aforementioned strategies, co-ordination among RHD, LGED, DNCC, DSCC, RAJUK and the Ministry of Railways is required. In addition to that, the study recommends highly to involve the researchers, traffic professionals and experts in this field prior to take any decision or make any new policy. Feasible Master plan should be made incorporating all the aforementioned organizations and experts to cope up with the future difficulties and proceeds to a sustainable solution.

✓ The study does not recommend to demolish the existing partially grade-separated flyovers as country will have to go through huge economic loss. However, the study recommends to improve the existing condition though adopting the aforementioned strategic measures for sustainable movement of people and goods and continue smooth flow through the heart of urban city. In addition to that, the study highly recommends to implement various traditional low cost but very effective traffic control and roadway capacity augmentation measures to ensure mobility as well as the functionality of the urban road before advocating any expensive measure including construction of flyover.

- ✓ The study strongly recommends not to construct flyovers further in any of the urban areas of the country. If more flyovers are constructed without understanding the root causes of the problem, there is a strong possibility that instead of solving the problem it might be a permanent hindrance for implementing future transportation projects along this corridor.
- ✓ Finally, it can be concluded that urban traffic management is a very intricate issue. It needs to be dealt with very prudently and pragmatically otherwise in the future one structural measure like flyover could be a constraint for a better sustainable solution like introduction of organized public transport and other modes of elevated rapid mass transit system.

5.4 Limitations

This study was limited to the analyses of partially grade separated flyovers constructed over level crossings in Dhaka city only. A number of flyovers have already been constructed throughout the country and several are under construction. Government has already decided to construct more flyovers throughout the country. Performance evaluation of these flyovers are required to provide message to the GOB that construction of those flyovers will merely improve the situation.

The study deals only with the at-grade and above-grade road along the corridor of the studied flyovers. No consideration was given for analyzing the impact of those flyovers on the surrounding roads those are connected with these flyovers. To obtain the real impact of the constructed flyovers, it is required to analyze the impact of these flyovers on the adjacent roads.

Classified traffic count data at different time periods were collected by observing peak flow found from field observations. It would be better if classified vehicles count data were collected at peak-periods obtained by 24 hours traffic flow analyses along the respective corridor of the studied segments.

Economic and financial evaluation of constructing those partially grade separated flyovers have not been assessed. It is required to perform cost-benefit analysis along with financial and economic evaluation of these flyovers.

No analyses were done incorporating how to use the underneath flyover spaces. The space underneath the flyovers can be utilized many purposes such as, parking lot, recreation space, coffee house and vice versa. These sorts of analyses were excluded from the current research.

This research contains an insignificant amount of accident data. Authors have tried to collect data from authorized sources as such, Accident Research Institute and Bangladesh Railway. However, they have a poor collection of yearly accident data of level crossings. This is one of the major flaws of this study.

In addition to that, a simple analysis has been performed incorporating geometric design flaws perspective and operational aspects of the studied flyovers on a particular focus at Jatrabari-Gulistan Flyover. Several significant flaws were identified by the author during data collection at the other studied flyovers also. These sorts of analyses would have enriched the thesis.

However, all of these considerations merit further investigation or research, but those were beyond the scope of this study. Despite having these limitations, the researcher believes that the research still holds a very good degree of validity and almost similar results would be obtained if others wish to replicate the study.

5.5 Future Research

This research was intended to evaluate the performance of flyovers constructed over rail-road level crossings in Dhaka city. Although the study provides some valuable information regarding the performance of these flyovers, there is a huge scope to proceed with this study in a wider scale, encompassing as many flyovers as possible. Classified traffic flow data should collected at peak periods by analyzing the 24 hours traffic flow data along the respective corridors of the studied segments. At the same time, analyses should be added incorporating the influence of these flyovers on the corresponding adjacent area. Economic and financial evaluation of such flyovers should be done to enrich the research content. The researchers who are willing to proceed with this research can add more level crossings accident data to make a reasonable conclusion regarding the safety condition through the construction of these flyovers. In addition to that, detailed analyses on geometric design flaws of the other flyovers have the potential to contribute to the state of art of transportation engineering with revelations.

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APPENDIX A

Table A.1: PCE of Different Types of Vehicles

Vehicle	PCE	Vehicle	PCE
Rickshaw/Van	2	Tempo	0.75
Motorcycle	0.75	Bus	3
Bicycle	0.5	Utility	1
Car	1	Truck	3
CNG	0.75	Bullock Carts	4

Source: [118]

Table A.2: Analysis of Combined Classified Vehicle Count Data (PCU/hr)

Name of Flyover	Over/ Under	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total (with phf = 0.92)	Percentage of Total (%)	Ratio of Vehicles Passing Over to those Under
Ahsanullah Master	Over	0	293	0	721	221	999	375	445	905	3960	30.57	0.44
	Under	7522	91	48	213	221	367	0	309	221	8992	69.43	
Banani Overpass	Over	0	1054	4	17145	3124	3	4217	1100	1358	28006	86.06	6.17
	Under	96	243	127	3566	174	3	166	74	88	4536	13.94	
Mohakhali Flyover	Over	0	836	0	11412	2572	36	1811	475	177	17318	67.91	2.12
	Under	162	552	132	4063	872	726	1303	232	144	8185	32.09	
Khilgaon Flyover	Over	0	3469	2	19938	3577	3	12111	681	110	39891	55.29	1.24
	Under	30205	389	287	523	342	348	66	70	33	32263	44.71	
Jatrabari-Gulistan	Over	15	4157	4	6256	2603	1443	15048	1616	298	31438	70.75	2.42
	Under	6624	254	48	1012	207	108	4471	188	88	13000	29.25	
Moghbazar-Mouchak	Over	0	1212	6	10032	3461	0	4129	651	1214	20705	69.86	2.32
	Under	3143	381	7	3584	599	75	828	162	155	8933	30.14	

Table A.3: Analysis of Combined Vehicle Percentage Data (PCU/hr)

Name of Flyover	Rickshaw/ Van	Motorcycle	Bicycle	Car/ Jeep/ Microbus	CNG	Mini-Bus	Bus	Utility	Truck	Total percentage
Ahsanullah Master	58.08	2.96	0.37	7.22	3.41	10.55	2.90	5.82	8.69	100
Banani Overpass	0.29	3.99	0.40	63.65	10.14	0.02	13.47	3.61	4.44	100
Mohakhali Flyover	0.63	5.44	0.52	60.68	13.51	2.99	12.21	2.77	1.26	100
Khilgaon Flyover	41.86	5.35	0.40	28.36	5.43	0.49	16.88	1.04	0.20	100
Jatrabari-Gulistan	14.94	9.93	0.12	16.36	6.32	3.49	43.92	4.06	0.87	100
Moghbazar-Mouchak	10.60	5.37	0.04	45.94	13.70	0.25	16.73	2.74	4.62	100