DEVELOPMENT OF A GIS-BASED MODEL FOR OPTIMUM TRAFFIC FLOW DISTRIBUTION: A CASE STUDY ON SELECTED MAJOR ROUTES OF DHAKA CITY

By

Naila Sharmeen (0411152020)

MASTER OF URBAN AND REGIONAL PLANNING

Department of Urban and Regional Planning

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Dhaka, Bangladesh

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Thesis Acceptance Certificate

The thesis titled "**DEVELOPMENT OF A GIS-BASED MODEL FOR OPTIMUM TRAFFIC FLOW DISTRIBUTION: A CASE STUDY ON SELECTED MAJOR ROUTES OF DHAKA CITY**", Submitted by **Naila Sharmeen**, Roll No: **0411152020**, Session: **April 2011**, has been accepted as satisfactory in partial fulfilment of the requirement for the degree of **MASTER OF URBAN AND REGIONAL PLANNING** on 2nd July, 2014.

BOARD OF EXAMINERS

_____ Chairman (Supervisor)

1. Dr. Meher Nigar Neema
   Associate Professor
   Dept. of URP, BUET, Dhaka

_____ Member (Ex-officio)

2. Dr. Md. Shakil Akther
   Professor and Head
   Dept. of URP, BUET, Dhaka

_____ Member

3. Dr. Roxana Hafiz
   Professor
   Dept. of URP, BUET, Dhaka

_____ Member (External)

4. Md. Anisur Rahman,
   Traffic Engineer, DTCA;
   Project Director, CASE (Clean Air and Sustainable Environment) Project
   Room: 1331, Level: 13-14,
   Nagar Bhaban, 5-Phoenix Road, Fulbaria, Dhaka-1000

CANDIDATE'S DECLARATION

It is hereby declared that this thesis entitled "**Development of a GIS-based Model for Optimum Traffic Flow Distribution: A Case Study on Selected Major Routes of Dhaka city**" has not been, either in whole or in part, previously submitted elsewhere for the award of any degree or diploma.

Naila Sharmeen

Roll no. 0411152020 (P)

Session-April, 2011

DEDICATED TO MY BELOVED PARENTS:
DR. JAFAR AHMAD HAKIM & MRS. FATEMA NAILA TASNEEN,
WHO ARE THE IMMENSE INSPIRATION OF ALL MY WORKS

ABSTRACT

Traffic congestion is a part of daily life routine envisaged in mega city Dhaka. The urban transport system is confronted with a big challenge to cope up with excessive population growth resulting outstripped its capacity. Transport situation in Dhaka is characterized by traffic congestion and delays, poor traffic management and fast growing air pollution problems. Besides, faulty traffic signalling systems, inadequate manpower, narrow road spaces and overtaking tendency of drivers create pro-longed traffic congestions. Due to traffic congestion a substantial portion of working hours have to be left on streets. With rapid urbanization, congestion will only worsen the prevailing situation in the absence of effective planning. Traffic congestion has increased significantly in urban areas of Dhaka city where the growth in volume of motorists has risen faster than the growth in roadway capacity. To develop an optimal transportation system an estimation of optimum traffic flow is necessary.

Optimum traffic flow distribution is defined as traffic rate allocation based on network utility maximization. In this context scenario is somewhat different in Bangladesh, here in Dhaka city vehicular emission and roadway capacity issues are more important than least travel cost and travel time as there are not so many alternative options (both road and vehicle mode) to the road users. Reducing congestion will reduce automobile emissions, and thus urban air pollution, which is currently posing a major health threat in most megacities like Dhaka. However, no study has been conducted yet to develop a traffic flow distribution model considering travel demand. In this context, firstly an attempt has been made to study the existing travel demand along some major routes of Dhaka city. The GIS-based model would be developed to optimize traffic flow in some selected major roads of Dhaka city by keeping pollution level within an acceptable limit (according to ECR, 1997) and not exceeding road type capacity (according to DITS,1994) and also to occupy additional traffic flow along existing alternative route in order to reach the same destination.

To examine the travel demand of vehicle users along the study routes, cordon survey (O-D survey) through direct interview method has been conducted under field work. For the detail analysis the selected major roads have been divided into four major routes viz. 1) Mirpur Road, 2) Pallabi to Gulistan, 3) Kuril to Bijoyshoroni and 4) Kuril to Shegunbagicha. Detail analysis has been conducted and photographs have been provided to portray the scenario. For convenience of analysis total study area has been divided into some Traffic Analysis Zones (TAZs). After thorough analysis of the primary and secondary data some findings have been summarized. Land use demand estimation has been conducted along the major routes of Dhaka city. Through this, existing travel demand has been explored. Roads with excessive vehicular pressure have been identified. A reason behind this excessive congestion has shown to be due to some specific land uses which play predominant role and located along and nearby these routes. From travel demand estimation, dominance of specific TAZ as origin and destination of most of the trips made has been identified. Vehicle mode wise dominance of TAZ has also been identified. Calculation of land use demand for different TAZ has also been performed. From O-D survey findings output matrix has been developed consisting percentage of vehicles starting from an origin and going into particular destination to serve specific purpose along each of the thirty five study links. Besides this, route identification for each category vehicle (% of vehicle classes going into which destination along specific route) has also been done. Also travel behaviour analysis has been conducted under the study. After that, optimum traffic volume has been computed for each route using GIS based Geo processing option (python coding) to depict the ideal number of traffic suitable for each route through satisfying two important criteria: vehicular emission and roadway capacity which are very significant variables in the context of Dhaka city. Finally, as travel demand cannot be neglected and must be satisfied, for this reason alternative route are being used to accommodate additional vehicles to reach their original destination. On the basis of these findings some specific recommendations have been made to reduce traffic congestion and to improve public health through ensuring a smooth travel to the vehicle (both motorized and non-motorized) and road users of Dhaka city.

Abbreviations and Acronyms

CBD: Central Business District
NMT: Non-Motorized Traffic
MT: Motorized Traffic
TAZ: Traffic Analysis Zone
HC: Hydro Carbon
NO_x: Nitrogen Oxide
CO: Carbon Monoxide
KM: Kilometre
Ft: Feet
PCU: Passenger Car Unit
PCE: Passenger Car Equivalent
ADT: Average Daily Traffic
VKT: Vehicle Kilometres Travelled
EF: Emission Factor
CNG: Compressed Natural Gas
DHUTS: Dhaka Urban Transport Network Development Study
DITS: Dhaka Integrated Transport Study
DTCA: Dhaka Transport Coordination Authority
DUTP: Dhaka Urban Transport Project
HCM: Highway Capacity Manual
TDM: Travel Demand Management
TSM; Transportation System Management
TRB: Transportation Research Board
FFT: Fuel Free Transport

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Destination of the trip	Purpose of the trip												
	Missing value	Embassy	Business	Education	Home based trip	Medical	Office	Return trip	Shopping	Travel	Visit	Work	Total
													100.0%
Abdullahpur	100.0%												100.0%
Aftabnogor											33.3%	66.7%	100.0%
Agargaon	12.5%											87.5%	100.0%
Amtoli			66.7%				33.3%						100.0%
Arambagh												100.0%	100.0%
Asadgate												100.0%	100.0%
Azimpur	76.9%			15.4%							7.7%		100.0%
Badda	25.0%		12.5%								12.5%	50.0%	100.0%
Banani	8.3%			8.3%				8.3%				75.0%	100.0%
Banglamotor			12.5%									87.5%	100.0%
Bijoynogor								50.0%				50.0%	100.0%
Bonosree					33.3%						33.3%	33.3%	100.0%
Brac, Mohakhali							100.0%						100.0%
Dhaka medical						100.0%							100.0%
Dhanmondi				75.0%				8.3%			16.7%		100.0%
Dhanmondi 02				100.0%									100.0%
Dhanmondi 27									20.0%		20.0%	60.0%	100.0%
Dhanmondi 32								100.0%					100.0%
Dhanmondi 6				100.0%									100.0%
Doinik bangla				25.0%								75.0%	100.0%
DU				66.7%								33.3%	100.0%
Elephant road												100.0%	100.0%
Eskaton											50.0%	50.0%	100.0%
Farmgate			5.6%	11.1%								83.3%	100.0%
Fokirapul												100.0%	100.0%
Gulistan	62.5%									6.3%		31.3%	100.0%
Gulshan 01	7.1%	7.1%	7.1%				21.4%		7.1%		7.1%	42.9%	100.0%
Gulshan 02	75.0%											25.0%	100.0%
Hatirjheel												100.0%	100.0%
Hatirpool									50.0%			50.0%	100.0%
Highcourt												100.0%	100.0%
IDB											100.0%		100.0%
Jatrabari	57.1%		7.1%								14.3%	21.4%	100.0%
Jhigatola											100.0%		100.0%
Kakoli								100.0%					100.0%
Kakrail				33.3%								66.7%	100.0%
Kallyanpur										100.0%			100.0%
Karwanbazar												100.0%	100.0%
Kathalbagan											50.0%	50.0%	100.0%
Kazipara								20.0%			20.0%	60.0%	100.0%
Khamarbari	50.0%											50.0%	100.0%
Khilgaon	100.0%												100.0%
Kochukhet											100.0%		100.0%
Kolabagan												100.0%	100.0%
Komolapur	71.4%									14.3%		14.3%	100.0%

Lalmatia												100.0%	100.0%
Malibag			12.5%	12.5%				12.5%			12.5%	50.0%	100.0%
Manikdi											100.0%		100.0%
Maoa	100.0%												100.0%
Mirpur 01												100.0%	100.0%
Mirpur 02	20.0%										20.0%	60.0%	100.0%
Mirpur 10	16.7%			11.1%				22.2%			5.6%	44.4%	100.0%
Mirpur 11								28.6%				71.4%	100.0%
Mirpur 12	87.5%											12.5%	100.0%
Mirpur 13				50.0%							50.0%		100.0%
Mirpur 14	50.0%											50.0%	100.0%
Mirpur 02												100.0%	100.0%
Mirpur zoo	100.0%												100.0%
Moghbazar											25.0%	75.0%	100.0%
Mohakhali	29.6%				3.7%		3.7%	7.4%				55.6%	100.0%
Mohammadpur	7.7%			15.4%							53.8%	23.1%	100.0%
Motijheel	45.5%			3.0%								51.5%	100.0%
Motshobhaban												100.0%	100.0%
Mouchak												100.0%	100.0%
Mymensingh	100.0%												100.0%
Nabisco												100.0%	100.0%
Nazimuddin road											100.0%		100.0%
New market	12.5%			12.5%					12.5%			62.5%	100.0%
Niketon								100.0%					100.0%
Nilkhet												100.0%	100.0%
Nobabgonj												100.0%	100.0%
Pallabi											100.0%		100.0%
Panthopath									8.3%		8.3%	83.3%	100.0%
Polton	6.7%						6.7%					86.7%	100.0%
Poribagh												100.0%	100.0%
Postogola	80.0%											20.0%	100.0%
Pressclub												100.0%	100.0%
Rajarbagh												100.0%	100.0%
Rampura												100.0%	100.0%
Sadarghat	63.6%									18.2%		18.2%	100.0%
Savar	100.0%												100.0%
Science lab												100.0%	100.0%
Shahbagh				7.7%								92.3%	100.0%
Shamoly						33.3%						66.7%	100.0%
Shantibag											100.0%		100.0%
Shantinogor				70.0%							10.0%	20.0%	100.0%
Shaorapara				20.0%							20.0%	60.0%	100.0%
Shegunbagicha								7.1%				92.9%	100.0%
Shiddeshwari				100.0%									100.0%
Taltola								25.0%			25.0%	50.0%	100.0%
Tangail	100.0%												100.0%
Tejgaon												100.0%	100.0%
Uttora	25.0%							25.0%				50.0%	100.0%

**Abdullahpur, Khilgaon, Maoa, Mirpur zoo, Mymemsingh, Savar, Tangail show missing value for trip purpose as public vehicles specially bus has been found to go into these destinations while doing O-D survey.*

CHAPTER 1

Introduction

1.1 Background of the Study

Dhaka, the capital of Bangladesh is the most densely populated city in the world. Day by day, the population is escalating and most part of the city is badly affected by huge traffic jam. It is said that during the Mughal times (1608-1765), Capital Dhaka stretched in south-north direction from the River Buriganga to the Tongi Bridge or Tongi River. The physical expansion of Dhaka City over the last few decades was mainly due to rapid population growth; the highest rate of population growth and physical expansion took place during 1981–1991 when population was doubled (Ahmed and Mohuya, 2013).

The urban transport system is confronted with this unprecedented population growth resulting outstripped its capacity. Getting locked in traffic jam for even hours is a daily experience. The city streets remain congested for 10 to 12 hours during any given weekday (Siddiquee, 2010). The resultant loss is just impossible to measure in terms of money. Traffic congestion is a part of daily life in Dhaka. In addition, traffic congestion causes serious air pollution and thus worsens the overall environmental condition. Vehicle related air pollution is growing at an alarming rate, and traffic delays have tripled in the last three years in the mega city Dhaka. Traffic congestion and delays, poor traffic management and fast growing air pollution problems characterize the transport situation in Dhaka. Uninhibited emissions from motor vehicles constitute the dominant source of air pollution in Dhaka (Ahmed and Alam, 2012). Besides, faulty traffic signaling systems, inadequate manpower, narrow road spaces and overtaking tendency of drivers create pro-longed traffic congestions. Due to traffic jam a substantial portion of working hours have to be left on streets. Basic problem of the city's traffic system is that the existing road network is incapable of holding the ever increasing number of motor vehicles. At present motor vehicles have become inseparable parts of urban life. Besides providing needed mobility they cause serious environmental problems, notably air pollution and also cause traffic congestion. With rapid urbanization, congestion will only worsen in the absence of effective planning (Hai, 1998). With the ever-growing

population and chaotic traffic on the roads, commuting in the Dhaka city is certainly a public misery. The city's traffic problems and ambient air pollution condition has reached to such a crisis proportion that, these shortcomings seriously compromised the ability of the transport sector in Dhaka to sustain economic growth and reasonable quality of life.

Main source of outdoor air pollution is Vehicular Air Pollution (VAP), 45 to 48 percent of pollution is generated from vehicles (Chowdhury and Imran, 2010). The emitted amounts are highly dependent on vehicle speed changes through the interaction between the various vehicles in the traffic flow. A homogeneous traffic flow with a minimum of transient movements gives reduction of vehicle emissions as well as higher capacity and less delay (Hoglund and Niittymaki, 1999). It is also time to think about restriction on private car use or small occupancy vehicle and also to reduce dependency on fuel use by promoting NMT (Non-Motorized Transport) and reduce vehicle emissions and air pollutions by introducing improved transport systems. A sustainable transport system must provide mobility and accessibility to all urban residents in a safe and environment friendly mode of transport. This is a complex and difficult task in a megacity like Dhaka because the needs of people belonging to various groups are not only different, but also often conflicting in nature. However, because of functional constraints of speed and capacity, NMPT (Non-Motorized Public Transport) is not a substitute in real sense for motorized public transport.

In developing countries, the majority of people do not drive automobiles, yet the majority of street space is reserved for automobiles. Despite the problems of congestion and long commute times, the desire for personal vehicles ownership remains high. There is little modal integration in developing countries, on links and nodes that helps to increase mobility by public transit (Klineman, Subba and Suzuki, 1998). Non-motorized transportation (NMT) serves a major role in serving the mobility needs of citizens in developing countries. But NMT is being increasingly marginalized by government officials and transportation planners in these countries in favor of capital intensive automobile and transit projects. Non-motorized vehicles (NMVs) offer low cost private transport, emit no pollution, use renewable energy, emphasize use of labor rather than capital for mobility, offering an alternative to motorized transport for many short trips.

NMVs account for 25 to 80 percent of vehicle trips in many Asian cities, more than anywhere else in the world. Impacts of motorization on CO2 and other greenhouse gas emissions are severe and NMV encouragement might reduce growth of transport related contributions to global climate change and air pollution (Replogle, 1991). Developed countries have implemented alternate strategies to combat pollution caused by motor vehicles but due to lack of resources and expertise the developing countries have failed miserably to cope with the situation (Ahmed and Alam, 2012).

Traffic congestion has increased rapidly in urban areas where the growth in volume of motorists has risen faster than the growth in roadway capacity (Wahrman, 1998). The USA Highway capacity manual defines capacity of a facility as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a roadway (TRB, 1998). The expanding urban traffic growth in developing countries has become a major concern to city planners, transportation professionals and policy makers. Although travel demand analysis is an important component of any urban transportation planning exercise it seems to have been neglected in transportation planning activities in the cities of the developing world (Hasan and Hoque, nd).

Limited resources which have been invested for the development of transport facilities such as infrastructure and vehicles coupled with the rapid rise in transport demand and the lack of application of adequate and proper traffic management schemes are producing severe transport problems in almost all the urban areas of Bangladesh (Hoque, 2004 and Quiam, 1994). High traffic congestion in the streets and the sufferings of the inhabitants from vehicle emissions demand alternative strategies to solve those problems. In fact, nearly 80,000 people live per square kilometer of land in Dhaka. In addition, a large number of people commute from nearby districts to work in Dhaka every day. Yet Dhaka has failed to develop a network of public transport systems both for commuters and for people living within the city (Islam & Hadi, 2003; Quazi, 2003). This is a major cause for the rising level of transportation problems in Dhaka city. Traffic mismanagement in cities in Bangladesh is a major cause for traffic jams and also air pollution (Mahmood, Bashar and Akhter, 2009).

Transportation is a vital infrastructure facility for the economic development of a country. The movement of men or materials i.e., transport, as a service, is a derived demand. Between the two basic components of transport demand, freight and passenger traffic, there exists a serious dilemma for the planner to develop an optimal transportation system for the nation. Efficient land and location planning can help in optimization of transport effort to the effect that it promotes dispersal of economic activities and residential opportunities to reduce the movements. For any transportation planning process, the first stage is a survey and analysis, which establishes the present demand for travel and a relationship to explain that in terms of causal variables. The estimation of accurate trip generation is imperative for a realistic planning program (Mini, Soosan and Rema, 2013). To develop an optimal transportation system estimation of optimum traffic flow is necessary.

Optimum traffic flow distribution can be defined as traffic rate allocation based on network utility maximization and the expected distribution of vehicles is based on the assumption that most favorable routes which minimizes travel cost and travel time are chosen among all possible routes in an optimum traffic flow distribution (Hande, Zhang and Chiang, 2007; Braess, Nagurney and Wakolbinger, 2005). In Bangladesh context scenario is somewhat different, here in Dhaka city vehicular emission and roadway capacity issues are more important than least travel cost and travel time as there are not so many alternative options (both road and vehicle mode) to the road users. Reducing congestion will reduce automobile emissions, and thus urban air pollution, which is currently a major health problem in most megacities like Dhaka (TRB, 2006).

Many researchers have studied on transportation scenario and ineffectiveness of present transport situation of Dhaka (Mahmud, Gope and Chowdhury, 2012; Habib, Ahmed and Siddiquee, 2002; Habib, 2002; URL: 1). However, no study has been conducted yet to develop a traffic flow distribution model considering travel demand. In this context, firstly an attempt has been made to study the existing travel demand along some major routes of Dhaka city. As GIS (geographic information systems) is an interactive system for real world modeling which can handle, process, analyze and build models for all types of geographic data, this study uses GIS to construct GIS-based transportation modeling.

The GIS-based model would be developed to optimize traffic flow in some selected major roads of Dhaka city by keeping pollution level within acceptable limit (according to ECR, 1997) and not exceeding road type capacity (according to DITS,1994) and also to occupy additional traffic flow along existing alternative route in order to reach the same destination. This study would provide a new model for transport planners to distribute traffic flow by minimizing environmental pollution and to ensure a smooth travel.

1.2 Objectives of the Study

The objectives of the study are:

- To study the existing travel demand along some major routes of Dhaka city.
- To develop a GIS-based traffic flow distribution model by keeping pollution level within acceptable limit and not exceeding road type capacity.
- To shift additional traffic flow to existing alternative route in order to reach the same destination.

1.3 Scope of the Study

The main goal of the research is to develop a GIS-based traffic flow distribution model considering existing travel demand which will optimize traffic flow by keeping pollution level within acceptable limit and by not exceeding road type capacity along some selected major routes of Dhaka city. This study would provide a new traffic flow distribution model satisfying two criteria: 1) keeping pollution level within acceptable limit and 2) keeping traffic volume within capacity of a particular type of road. The developed model would provide transport planners an efficient distribution of traffic thereby reducing traffic congestion and environmental pollution in consideration with travel demand. Travel demand calculation/analysis of travel behavior gives indication on proper land use planning. After travel behavior analysis it can be easily understood that

which specific land uses play predominant role in creating excessive vehicular pressure because of their location along and nearby the most congested routes. Also most traffic congested links because of specific land uses have been identified after travel demand calculation.

This traffic flow distribution model can be applied to other study areas of other countries as well to identify and calculate the optimum number of traffic flow along a major arterial route satisfying the same criteria or some other criteria also.

1.4 Limitation of the Study

Every research and study has to conduct under some limitations and constraints. The present study is no exception. The limitations and constraints of the study are as follows:

The present annual growth rate of motorized vehicle (7.6%) according to STP, 2005 has been used for calculating the traffic volume for present year (2014), which is not sufficient. Because, growth rate of vehicle can vary every year for different factors like income level and socio-economic status of people, road capacity, safety, security etc. Another limitation is that, in this study traffic volume data for motorized traffic (MT) along major study routes has been collected from a volume study (field survey, 2013) but traffic volume data along associated secondary roads have been collected from Dhaka Urban Transport Network Development Study (DHUTS, 2009) conducted by Dhaka Transport Coordination Board (DTCB) and Japan International Cooperation Agency (JICA) joint team. On the other hand, traffic volume data for NMT has been collected through field survey for the present year 2014. It is assumed that, the growth rate of 2013 remains the same as the growth rate of 2009, the possibility of which is very low. Besides that, the same growth rate has been used in case of all kind of vehicles. But, rate of growing of each vehicle can be different. Beside that due to budget constraints and limited manpower traffic volume survey and O-D survey could not be conducted on the same day and same time along all the study links. Traffic volume survey and O-D survey for different links of road has been conducted on consecutive weekdays for specific time

period due to limited manpower. Since the data of whole week is not collected, data of only one or two weekdays have been considered.

While conducting Origin-Destination survey to achieve the first objective of the study, problems are faced by the surveyors to take interview from running vehicles. Also in case of public transport, question on trip purpose, preferred alternative route etc. is not always appropriate especially for public bus. Same problem happens with the question regarding intermediate stop of the journey.

To achieve the second objective of the research, total effective capacity for each study link has to be calculated. As in Dhaka most of the major arterial roads possess huge carriageway width, value of effective capacity is also higher in case of these arterial roads. But in the real scenario it has been observed that huge portions of carriageway of the road are occupied by unauthorized use, parking etc. For this reason traffic congestion occurs as running vehicles may not always be able to use the road space with full capacity. Proper measurement of these types of illegal use of road space is not possible within such a short span of time for research and also with limited manpower. If true effective capacity can be measured for major arterial roads and that capacity can be set as one of the criteria then the study result will be more realistic and better understanding of the traffic congestion situation can be achieved.

Problems and complexities can be arise while fulfilling the 3rd objective of the research which focus on shifting additional traffic flow to existing alternative route in order to reach the same destination. As we have not enough alternative parallel roads to a major route so after data processing and analysis in case of too much congested routes (if the existing volume exceeds the optimum volume by a huge margin), it cannot be surely said that the researcher will be able to accommodate all the additional vehicles to reach their destination using alternative routes because each alternative route also has to maintain its respective optimum volume.

In context of a developing world mega city like Dhaka, achievement of practical implication of this particular research can be very much difficult as there is very limited practice of efficient TDM (Travel Demand Management) and TSM (Transportation

System Management) measures here. Traffic Prioritization on the basis of pollution, fuel rating and high occupancy is not being considered within the total transport planning process of our country. Fixation of optimum volume along each major arterial route may not be sustained in the long run as strict mechanized system must be developed to regulate and control traffic flow along specific routes.

1.5 Organization of the Study

This dissertation comprises of eleven chapters. The first chapter presents an introduction with the background of the study. The second chapter gives an idea to develop a clear understanding of the concepts of optimum traffic flow distribution and to examine the present travel pattern and traffic flow scenario of Dhaka City. The third chapter provides the outline of the methodology for determining optimum traffic flow along major routes of Dhaka city. The fourth chapter provides an overview of the selected study routes (link wise). General profile of the four major study routes (Mirpur road, Pallabi to Anandabazar, Kuril to Bijoyshoroni and Kuril to Shegunbagicha) and also some other secondary associated roads which can act as an alternative route if needed have been elaborately described in this chapter. Four major routes are subdivided into thirty five links based on major intersections on those roads. These links are described thoroughly along with their respective lengths in Chapter Four. The fifth chapter comprises the detail process of data collection and survey findings from cordon (O-D) survey, traffic volume survey and carriageway width survey. This chapter mainly focuses on giving direction for analyzing the survey data to achieve the objectives of the research. Estimation of land uses demand and travel behavior analysis of vehicle users have been conducted in the following chapter, Chapter Six. Computation of optimum traffic volume along all the study routes satisfying two criteria separately (vehicular emission standard and roadway capacity standard) has been explored in Chapter Seven. In Chapter Eight model developments and calibration using GIS has been executed for different traffic flow distribution along the major study routes to distribute traffic flow in an optimum way. Python based algorithm has been developed in this chapter to compute both optimum and additional traffic flow for each study links among all the routes. In the next chapter,

Chapter Nine additional traffic flows has been assigned along alternative routes (if possible) through satisfying their original travel demand. Chapter Ten summarizes the major findings of the study. On the basis of these findings in Chapter Eleven some recommendations have been given regarding the benefits of maintaining an optimum traffic flow along major routes of Dhaka city and finally concluding remarks have been drawn.

CHAPTER 2

Literature Review and Conceptual Framework

2.1 Introduction

Literature review is important to collect background information on study topic and gather knowledge about the past studies of the same topics which help the study to be more informational. This section has been done to come up with clear conception about the research objectives and to get a specific idea to prepare a methodology to achieve those objectives. No study has been conducted yet to develop a traffic flow distribution model considering travel demand in the context of Bangladesh from the planning aspect. Yet an earnest attempt has been made to make a review of the relevant researches, reports, books and articles etc. that are available. An extensive literature review has been conducted to develop a clear understanding of the concepts of optimum traffic flow distribution and to examine the present travel pattern and traffic flow scenario of Dhaka City. In this section review has been done on relevant general information, different methods of estimating travel demand in different studies, methods of developing traffic flow distribution model in different countries, various methods of trip assignment and relevant researches and studies in home and abroad. Review has also been done about the traffic environment related rules and policies and road capacity standards in Bangladesh.

2.2 History of Transport Plan in Dhaka

Urbanization in Dhaka is essentially a process of migration from rural and smaller towns. After the liberation of Bangladesh in 1971, the development processes of Dhaka City rapidly increased. Dhaka City has also been witnessing a tremendous growth in population and physical expansion. The population of Dhaka has grown from only 3.4 million in 1951 to 10.71 million in 2001 – a growth of 7.31 million in 50 years (GOB, 2001). As per future prediction, this population will further grow to about 20 million by the year 2020 and to 25 million by 2025 (STP, 2004). The city experiences the proliferation of scattered development without appropriate guidance

which resulted in huge urban system difficulties. In 1959, a partial master plan was prepared for the city but the city has been developed with the minimum assistance of that plan. Even, the fringe areas of the city are progressing without any guidance, control and regulation yet which will be one of the main integral parts of the city in the near future. At present, Dhaka city is axially expanding in the north-south direction, mainly north direction for the causes of marshy land in east-west fringe area and riverine flood flow land in the south. Sporadic residential, commercial and other socio-economic infrastructures like super markets, high- rise buildings or apartments/complexes, garments factories etc. are being constructed at various parts of the city without appropriate consideration of planning principles, resulting indiscipline trip generation. Unplanned mixed land use pattern, presence of cantonment, BDR, airport within the core area of capital city, heavily centralized government frame structure are directly and indirectly affecting the entire transportation system of the Dhaka city. Inefficient and malfunctioning traffic management is also one of the major problems of Dhaka city transportation system, which is highly responsible for making the existing system more unproductive. Indeed, for the causes of unplanned and non- integrated road network development, there have very limited scope to apply traditional low cost but very cost-effective traffic management measures (Mahmud, Hoque and Qazi, nd).

According to the 1959 Master Plan, Dhaka did not have much scope to expand to the south, east or west; so the plan therefore proposed that the northern boundary should be extended to include all the land in Tongi suitable for building and concluded that this should be sufficient to accommodate the growth of Dhaka until 1978. The plan also recommended taking control on the land on the south bank of the Buriganga River. The plan detailed out the strategic location of these sites. For example, since Tongi is located far to the north and did not have good transport links with Dhaka, it was suggested to be developed as a self-contained new town having a balanced community of houses and a nucleus of industry. Mirpur, on the other hand, was suggested as a residential satellite having good commuting options to the main city (Kabir and Parolin, nd).

Prior to 1864 the roads of Dhaka had no names. Only mohallas had names, such as Kasaitoli, Patuatoli and Mughaltoli. It was only with the establishment of the Municipality in 1846 that the roads in this town began to be named. In 1961-62, there

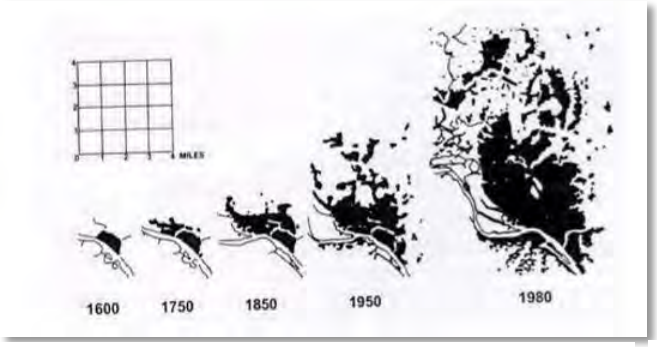


Figure 2.1: Urban Growth of Dhaka
Source: Shankland Cox Partners and Others, 1981

Figure 2.2: Road network map of DCC area (year 2008) with major rivers
Source: URL 02

Figure 2.3: Road network map of Dhaka city with major rivers
Source: URL 03

Figure 2.4: Road network map of Dhaka city showing both major arterial and secondary/connecter roads
Source: URL 03

Figure 2.5: Present road network map of DCC area

was a total of 110 miles of municipal roads of which 44 miles were tarred or cemented, and 50 miles brick metalled, and 16 miles kutcha fair weather roads. After the partition in 1947, Dhaka became the provincial capital of East Pakistan. Size and population of the city increased rapidly. Thus a faster vehicle, rickshaws, was introduced. Through some motorcars were available at that time, they were few in numbers. Privately owned bus system was introduced in the city in 1950. This was insignificant to meet the demand of the people. Thus the government introduced EPRTC (East Pakistan Road Transport Corporation) in 1961. The combined fleets of EPRTC and private buses were operating in the following routes, Sadarghat-Rampura, Gulistari-Banani, Gulistan- Mirpur, Gulistan -Deinra, Gulistan-Mohammadpur. Later routes like Gulistan-Adamjee and Gulistan-Agargaun were introduced. The war of Liberation in 1971 caused huge damage to the fleet. After the independence, city size and population grew in an unprecedented speed. Numbers of buses could not keep pace with the increased demand of the increased population. All types of vehicles increased very rapidly. Transport system gradually turn on road based and demand on road network increases rapidly. But with the increasing demand, planed road network was not expanded to fulfil the requirement (Mahmud and Haque, nd).

2.3 Definition of key terms

2.3.1 Travel Demand Management (TDM)

Travel demand management (TDM) has come out as a policy choice for solving transportation and traffic congestion problems by reducing and restricting travel demand instead of increasing the transportation facilities. Policy makers and transportation experts have opined that strategies to manage the travel demand will be more effective to solve the transportation problems rather than strategies to increase capacity (supply) of the facilities. In addition, the inability of the transport infrastructure to respond quickly to the changing travel needs coupled with the growth in passenger and freight travel may also have diverted the idea of placing more emphasis on the demand management techniques instead of solving the problems by increasing the supply side avenues or increasing the capacity of the transportation system (Mahmood, Bashar and Akhter, 2009). The objectives of variable demand

management are to address the need for transport and to suppress generation of additional travel due to creation of any extra space for individualized transport. The measures fall into three basic categories, as follows: reduction of the need for travel, rescheduling the time of journey and use of more efficient modes of travel.

2.3.2 Transportation System Management (TSM)

Transportation System Management (TSM) is a package of short term measures to make the most productive and cost-effective use of existing transportation facilities, services and modes. For the implementation of such well recognized, cost-effective management tools in a city area demand assessment of the potentiality and the fulfilment of implementation pre-requirements (Mahmud and Hoque, 2012).

The basic objective of TSM is to create more efficient use of existing facilities through improved management and operation of vehicles and the roadway. TSM refers to all strategies that contribute to the efficient use of existing highway facilities, both on the supply side (changing the facility itself) and, on the demand side (changing the way people travel).

The TSM strategies on the supply side (i.e., changing the facility itself) can be classified into the following categories: creating efficient use of road space, and providing and improving transit services. The actions in this group are intended to improve the flow of traffic, usually without altering the total number of vehicles that use the roadway during an average day. Techniques used include: Traffic operations improvements, Traffic signalization improvements, Improvements for pedestrians and bicycles, Special roadway designations (priorities in roadway assignments, for example, HOV lanes), Parking management and Intermodal coordination.

2.3.3 Cordon survey

To ensure that all travel-pattern and land-use data relating to the transportation planning process is collected in an efficient and economic manner the area to be studied is defined by a boundary known as an external cordon. Travel pattern data is required for four basic movements (External-External or through movements, External-Internal, Internal-External and Internal movements) along the external cordon area. For this purpose cordon survey will be done through direct interview

method. The only satisfactory method of determining the origin and destination of through movements and external-internal movements across the external cordon is to question the persons actually making the movement. In transportation studies this is normally done by direct interview, or issuing prepaid business reply postcards at the roadside (Bruton, 1970).

2.3.3.1 Road traffic movement (direct interview method)

In the direct interview method, a sample of road users are stopped at the external cordon survey point, and questioned by an interviewer, who records the answers on specially prepared forms. Questions are put to the driver of the vehicle about the origin and destination of his journey. The size of sample interviewed varies with the accuracy required in grossing up, and the volume of traffic on a particular route (Bruton, 1970).

2.3.3.2 Sample selection at cordon surveys (Variable rate sampling)

Three main types of sampling procedure can be employed on a cordon survey. These are: time cluster sampling, volume cluster sampling and variable rate sampling. Among the three, variable rate sampling is the method normally used at cordon surveys and was developed by the Road Research Laboratory. Interviewers are employed at a constant rate, and the size of sample selected varies with the volume of traffic flow. Depending on the characteristics of the stream, sample rates are calculated for either half-hour or one-hour periods. To reduce bias different sample rates are usually calculated for different classes of vehicle (Bruton, 1970).

2.3.4 Capacity

Each country has its own method of measuring traffic capacity that slightly varies across the border, but the definition of traffic capacity uses a similar concept. The U.S.A. Highway Capacity Manual defines capacity of a facility as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a roadway (TRB, 1998).

Capacity is defined on the basis of _reasonable expectancy‘. That is, a stated capacity for a given facility is a rate of flow that can be repeatedly achieved during peak

periods for which sufficient demand exists and that can be achieved on facilities with similar characteristics throughout North America. It is not the absolute maximum rate of flow ever observed on such a facility type. Driver characteristics vary from region to region and the absolute maximum rate of flow may vary from day to day and from location to location. Occasionally, measured rates of flow at some locations will exceed the defined capacity of the facility type. Such rates, however, are usually not sustainable or cannot be achieved repeatedly.

Traffic engineers raise the following three points in their study of capacity. First, the quantitative method to determine the reasonably expected and repeatedly achieved maximum flow rate for a point on the road should be proposed based on a distribution of observed flow rates. Second, when flow rates entail statistical distribution, the question raised is what percentage on this statistical distribution can become the rational capacity. Third, when analysing traffic capacity under prevailing non-ideal conditions, adjustment factors are independently multiplied to the capacity of ideal conditions, but it is questionable that this independent multiplicative adjustment of capacity is truly rational (Chang and Kim, nd).

2.3.5 Optimum traffic flow distribution

The distribution of traffic flow on the roads of a traffic network is of interest to traffic planners and traffic controllers. Optimum traffic flow distribution can be defined as traffic rate allocation based on network utility maximization and the expected distribution of vehicles is based on the assumption that most favourable routes which minimizes travel cost and travel time are chosen among all possible routes in an optimum traffic flow distribution (Braess, Nagurney and Wakolbinger, 2005; Hande, Zhang and Chiang, 2007).

2.3.6 Vehicular emission

Vehicular emissions are the gasses released through an exhaust system of vehicles (URL: 4). Motor vehicle emissions are composed of the by-products that come out of the exhaust systems or other emissions such as gasoline combustion. Carbon monoxide, hydro-carbons and sulfur-oxide along with nitrogen-oxides and particulates are all harmful vehicle emissions that discharge out of the exhaust gasses

of an internal combustion engine. These emissions contribute to air pollution and are a major ingredient in the creation of smog in cities (URL: 5).

2.3.7 Vehicular speed

The third basic measurement of traffic is that of average, or mean, speed. Speed of travel is simple and widely used measure of the quality of traffic flow. Basically speed is the total travelled distance divided by the time of travel. Travel time is its reciprocal value. The problem of when, where and how to take speed measurements that are representative of the traffic stream is not trivial. For example, the speed of successive vehicles may be taken at a single point of the roadway over a long period of time. These speeds are also known as spot speeds. Alternatively, the speeds of all the vehicles occupying a length of highway may be taken at the same instant. In general we distinguish between three basic classes of speed of travel: a) spot speed b) overall speed c) running speed. All speeds vary with time, location, environmental and traffic conditions. Speeds vary also with the quality of traffic services, being generally higher along motorways and expressways as well as during times when traffic congestions are not a factor. Today the most important factor impacting speed is traffic density and problem of traffic congestions. At a given time and location, speeds are widely dispersed and can generally be represented by a normal probability distribution. The range of speeds decreases with increase in traffic volume (Valentin, nd).

2.3.8 Traffic volume

Number of vehicles passing a particular section of road in per unit time at a specified period is called traffic volume. In cities the maximum traffic occurs just before and after college and office hours, i.e. peak hour. Traffic survey carrying out during these peak hours will almost cover the required information (Singh, 2001).

2.3.9 Vehicle Kilometres Travelled (VKT)

Vehicle Kilometres Travelled (VKT) is the total kilometres travelled by motor vehicles at any particular road systems during a given period of time. It is used as an indicator to measure road safety performance in a particular country and as an indicator for international traffic safety comparison purposes. It also indicates about

the activity of vehicles and roadway use (URL: 6). Traffic congestion, transportation greenhouse gas (GHG) emissions and air quality calculations can be estimated using Vehicle Kilometre Travelled as an important indicator (The City of Calgary, 2010).

2.3.10 Network planning and Traffic assignment

The network planning stage of the transportation planning process aims to develop alternative highway and public transport networks for the selected land use plans. Traffic assignment is that part of transportation planning process which allocates a given set of trip interchanges to a specific transport network or system. It can be used to estimate the volume of traffic on various links of the system for any future year, or to simulate present conditions. The traffic assignment process requires as input a complete description of either the proposed or existing transportation system, and a matrix of interzonal trip movements. The output of the process is an estimate of the traffic volumes on each link of the transportation system (Bruton, 1970).

2.3.10.1 All or nothing assignments

All or nothing assignments are based on the assumption that the path taken by vehicles travelling from zone of origin to zone of destination will be the one with least travel resistance or travel time. The basic procedure in all or nothing assignments involves: the description and coding of the network into links and nodes, the determination of minimum path time from each zone with originating traffic to all other zones and the assignment of all traffic flows from each zone to every other zone by the appropriate minimum path, and the aggregation of total flows on each link in the defined network.

Criticisms of the 'all or nothing' assignment technique

The technique takes no account of increasing congestion associated with increased volumes and assigns too many vehicles to the better routes as travel time on these routes will be better than on the multi-purpose streets. Small differences in journey times by different routes between the same origin and destination can bring about unrealistic journey paths when the all or nothing assignment is used (Bruton, 1970).

2.3.10.2 Capacity restraint assignments

A capacity restraint assignment is an alternative method of dealing with overloaded links in the network. It is carried out entirely by the computer and is completely automatic. The input required by this assignment technique is similar in many ways to that required by _all or nothing‘ assignments. The practical capacity of each link of the network is fed into the computer as well as journey time. The first stage involves the building of minimum path trees. Traffic is then assigned to these minimum paths but as the assigned volume on each link approaches the practical capacity the computer, through an iterative procedure in which loaded link information is used as a feedback to the tree-building process, automatically lowers the assumed speeds on the affected links thereby making these links less attractive to traffic (Bruton, 1970).

2.3.11 Traffic Analysis Zone (TAZ)

Traffic analysis zones act as the origins and destinations of all traffic movements. Trips enter the network from TAZs and move along link connectors. The study area of Dhaka Strategic Transport Model (DSTM) is subdivided into 102 TAZs. Of these 102 TAZs, 90 are located within the DCC, 1 under cantonment board and 11 external TAZs cover the urbanized surrounding of the study area (STP, 2005).

2.3.12 Road network

Dhaka‘s transport network is mainly based on roads. Roads have been divided into four groups: 1) Major road (principal arterial), 2) Secondary road (minor arterial), 3) Collector road and 4) Outer network. Among the arterial roads, major known corridors are considered as principal arterials (STP, 2005).

2.4 Travel demand analysis

The travel forecasting process is at the heart of urban transportation planning. Travel forecasting models are used to project future traffic and are the basis for the determination of the need for new road capacity, transit service changes and changes in land use policies and patterns. Travel demand modelling involves a series of mathematical models that attempt to simulate human behaviour while traveling. The

models are done in a sequence of steps that answer a series of questions about traveller decisions. Attempts are made to simulate all choices that travellers make in response to a given system of highways, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react in a particular transportation alternative (Ahmed, 2012).

2.4.1 Techniques for Travel demand analysis

Kato, Kaneko and Inoue (2005) in their article ―Empirical analysis on relationship between types of Travel demand techniques and estimated user‘s benefit stemming from transportation investment" analysed empirically the impact of selecting travel demand forecast techniques on estimation of user‘s benefit stemming from transportation investment. Three techniques are discussed in the paper: the multinominal logit (MNL), user equilibrium (UE) and all-or-nothing (AON). These three techniques are compared in the empirical analysis of the urban railway project in Tokyo based on the same data set. Consequently, it is found that the user‘s benefit estimated by the MNL is largest, whereas the benefit by the UE is smaller than the benefit estimated by the MNL by about 10 % and the benefit estimated by the AON is smaller than the MNL by about 20%. Finally, some policy implications related to choosing the travel demand forecast techniques in transportation planning are discussed.

2.4.2 Factors influencing travel demand

Analysing the factors that have influenced travel demand in the past is a crucial first step in finding effective and lasting solutions to managing the expected increases in future travel demand in urban areas. A report on urban travel and sustainable development attributes the following six factors to the growth in travel demand: Economic growth, increasing income levels, rising car ownership, transport system improvements, competition between public and private transport and demographic changes (ECMT/OECD, 1995).

2.4.3 Measurement of existing travel demand

Chatterjee and Venigalla (nd) in their book titled ―Travel demand forecasting for Urban Transportation Planning" stated that detailed information on existing travel is

needed for two purposes – 1) analysing existing problems, and 2) developing mathematical models for forecasting travel. A variety of surveys can be performed for gathering information related to existing travel demand. However, travel surveys are expensive, and, therefore, care must be taken to identify the types of information that really would be useful for specific purposes, and then the most suitable procedures should be selected for gathering the information. Sampling techniques are useful, and adequate time and care must be devoted to developing sampling procedures. There are several different types of survey techniques, some of which are suitable for automobile travel, some for transit travel, and some for general passenger movement. Survey procedures for freight vehicles and commodity movements may be very different in certain respects from those of passenger travel.

Time Frame for Travel Surveys

Since travel demand varies during a given year according to the season (or month of year) and day of week, a decision must be made carefully to select a specific time frame of reference for surveys. For urban transportation studies it is a common practice to develop travel demand information for an average weekday in the _fall' season. However, the time can be different based on the nature of the problem to be analysed. For example, in the case of a tourist oriented urban area the major concern may be traffic problems during weekend days or holidays, and surveys may be done to capture information for one of those days. A few major types of surveys are discussed in the following sections.

2.4.3.1 Origin-Destination (O-D) Surveys

The classification of trips into the three classes of internal, external-internal (and vice-versa), and through trips is useful for _meso' scale and metropolitan level as well as small area studies. This classification scheme is useful for developing forecasting procedures/models as well as policies and strategies for accommodating travel because strategies for each of these classes of travel would be different. For example, through trips may require a by-pass facility. External-internal trips may have to be intercepted before they reach a heavily congested area such as the central business district (CBD). The origins and destinations of trips along with some other

characteristics such as trip purpose and mode of travel can be determined in different ways:

a. Home interviews (for internal travel)

b. Roadside interviews at cordon stations (for external-internal and through trips)

c. On-board survey on transit vehicles.

All of these three techniques involve ‗sampling‘ and require careful planning before their execution. The reliability of the results of an O-D survey depends on its sampling scheme and sample size, and this issue was examined by Makowski, Chatterjee and Sinha (1974).

2.4.3.2 Traffic Volume and Passenger Counts

For determining the use of various roadway facilities and assessing their level of service, vehicle counts are taken at selected locations along roadways. Short-count techniques are useful provided appropriate expansion factors are developed based on previous or on-going research on fluctuations of traffic by hour, by weekday, and by month. All state Departments of Transportation (DOTs) has extensive programs for gathering traffic volume data on an annual basis. These vehicle counts usually are taken with machines. For urban transportation studies ‗screen lines‘ and ‗cut-lines‘ are established in the study area to select traffic count locations and take counts in an organized manner so that the major travel movements can be measured and analysed. These counts are also used for checking the results of travel forecasting models. Similarly traffic counts are taken at special traffic generators such as an airport and a large college/university to capture their unique travel generating characteristics. For analysing the use of a transit service, passenger counts are taken on-board transit vehicles and/or at selected stops or stations. These passenger counts usually are taken by observers who are assigned to specific transit vehicles and/or transit stops/stations according to a survey plan (Chatterjee and Venigalla, nd).

2.4.4 Travel demand model

The development of mathematical models capable of simulating existing traffic patterns and projecting future travel demand is one of the most important phases of

the transportation planning process. When transportation planning was in its infancy, simple trend-line analysis was performed to forecast traffic demands. However, such methods were based on the existing relationships between land uses and intensities of land uses. If land development patterns changed over time (and most do), forecasts were seldom reliable. Historical trend analysis also failed to account for the impact of construction of new transportation facilities, or even the improvement of existing facilities. To obtain reliable estimates of future travel patterns, both the travel simulation models and the projected land use data must be sensitive to the many quantitative and qualitative parameters influencing the generation and distribution of trips. These characteristics and patterns depend largely on the following factors:

1. Socioeconomic conditions affecting trip production and attraction;

2. The land-use pattern, including the location and intensity of use; and,

3. The type, extent, and quality of transportation facilities.

With these factors as input to travel demand models, forecasts of future travel patterns are made and used to test the adequacy of any proposed transportation system improvements to serve projected traffic demands.

The development of travel demand models can be divided into three basic steps—trip generation, trip distribution, and traffic assignment. The first step, trip generation, involves estimating the number of trip ends generated in (productions) and attracted to (attractions) each traffic analysis zone. Each trip on the regional highway system has both an origin and a destination. In this fashion, each trip is defined by two trip ends, one being a production and one being an attraction. The second step, trip distribution, involves the distribution of the trip ends between all possible zones, which is accomplished by a mathematical trip distribution (gravity) model. The gravity model is so named because its basic form follows the mathematical formula Isaac Newton developed to approximate the pull of gravity. In general terms, this model suggests that the frequency of trip interchange between zone pairs is directly related to the number of productions and attractions in each zone, and inversely related to the travel time between them. The third step, traffic assignment, is the assignment of vehicle trips to the roadway network, which is accomplished by selecting the route with the lowest travel time. The travel demand models have two primary data elements:

demographic characteristics (by TAZ) and a transportation network description (URL: 7).

2.4.4.1 Activity based travel demand modelling

According to Bowman and Ben-Akiva (2000), the most important elements of activity-based travel theory can be summarized in two basic ideas. First, the demand for travel is derived from the demand for activities. Travel causes disutility and is only undertaken when the net utility of the activity and travel exceeds the utility available from activities involving no travel. Second, humans face temporal-spatial constraints, functioning in different locations at different points in time by experiencing the time and cost of movement between the locations. They are also generally constrained to return to a home base for rest and personal maintenance. In the paper titled ―Activity-based disaggregate travel demand model system with activity schedules" they presented an integrated activity-based discrete choice model system of an individual‘s activity and travel schedule, for forecasting urban passenger travel demand. A prototype demonstrates the system concept using a 1991 Boston travel survey and transportation system level of service data. The model system represents a person‘s choice of activities and associated travel as an activity pattern overarching a set of tours. A tour is defined as the travel from home to one or more activity locations and back home again. The activity pattern consists of important decisions that provide overall structure for the day‘s activities and travel. In the prototype the activity pattern includes (a) the primary most important activity of the day, with one alternative being to remain at home for all the day‘s activities; (b) the type of tour for the primary activity, including the number, purpose and sequence of activity stops; and (c) the number and purpose of secondary additional tours. Tour models include the choice of time of day, destination and mode of travel, and are conditioned by the choice of activity pattern. The choice of activity pattern is influenced by the expected maximum utility derived from the available tour alternatives.

2.4.4.2 Comparison of trip based and activity based approach

Since the beginning of civilization, the viability and economic success of communities have been, to a major extent, determined by the efficiency of the

transportation infrastructure. To make informed transportation infrastructure planning decisions, planners and engineers have to be able to forecast the response of transportation demand to changes in the attributes of the transportation system and changes in the attributes of the people using the transportation system. Travel demand models are used for this purpose; specifically, travel demand models are used to predict travel characteristics and usage of transport services under alternative socio-economic scenarios, and for alternative transport service and land-use configurations (Bowman and Ben-Akiva, 2000).

The Trip-Based Approach

The trip based approach uses individual trips as the unit of analysis and usually includes four sequential steps. The first, trip generation, step involves the estimation of the number of home-based and non-home based person-trips produced from, and attracted to, each zone in the study area. The second, trip distribution, step determines the trip-interchanges (i.e., number of trips from each zone to each other zone). The third, mode choice, step splits the person-trips between each pair of zones by travel mode obtaining both the number of vehicle trips and number of transit trips between zones. The fourth, assignment, step assigns the vehicle trips to the roadway network to obtain link volumes and travel times and the person trips to the transit network. Time-of-day of trips is either not modelled or is modelled in only a limited way, in the trip-based approach. Most commonly, time is introduced by applying time-of-day factors to 24-hour travel volumes at the end of the traffic assignment step or at the end of the trip generation step.

A fundamental conceptual problem with the trip-based approach is the use of trips as the unit of analysis. Separate models are developed for home-based trips and non-home based trips, without consideration of dependence among such trips. Further, the organization (scheduling) of trips is not considered; that is, there is no distinction between home-based trips made as part of a single-stop sojourn from home and those made as part of a multiple-stop sojourn from home. Similarly, there is no distinction between non-home based trips made during the morning commute, evening commute, from work, and as part of pursuing multiple stops in a single sojourn from home. Thus, the organization of trips and the resulting inter-relationship in the attributes of multiple trips is ignored in all steps of the trip-based method. This is difficult to

justify from a behavioural standpoint. It is unlikely that households will determine the number of home- based trips and the number of non-home based trips separately. Rather, the needs of the households are likely to be translated into a certain number of total activity stops by purpose followed by (or jointly with) decisions regarding how the stops are best organized. Similarly, the location of a stop in a multistop sojourn (or tour) is likely to be affected by the location of other stops on the tour. Also, in a multistop tour from home consisting of, say, a grocery shopping stop and a social visit, the trip-based approach fails to recognize that the travel mode for all three trips (home to shop, shop to visit, and visit to home) will be the same. The travel mode chosen will depend on various characteristics of all three trips (and not any one single trip) and, consequently, these trips cannot be studied independently.

The behavioural inadequacy of the trip-based approach, and the consequent limitations of the approach in evaluating demand management policies, has led to the emergence of the activity-based approach to demand analysis (URL: 8).

The Activity-Based Approach

The activity-based approach to travel demand analysis views travel as a derived demand; derived from the need to pursue activities distributed in space. The approach adopts a holistic framework that recognizes the complex interactions in activity and travel behaviour. The conceptual appeal of this approach originates from the realization that the need and desire to participate in activities is more basic than the travel that some of these participations may entail. By placing primary emphasis on activity participation and focusing on sequences or patterns of activity behaviour (using the whole day or longer periods of time as the unit of analysis), such an approach can address congestion-management issues through an examination of how people modify their activity participations (for example, will individuals substitute more out-of-home activities for in-home activities in the evening if they arrived early from work due to a work-schedule change) (URL: 8).

2.5 Traffic flow distribution model

2.5.1 Advantages of GIS based transportation model development in compare to other transportation software based model

As network distances are based on the actual shape of the road network, GIS makes it possible for planning models more accurately. Whole modelling process based on GIS is more efficient. Data preparation is greatly facilitated and the database and visualization capabilities catch errors before any modelling problem occurs. Less staff time is needed to implement and maintain GIS based travel models. In a GIS-based modelling system GIS itself and GIS-derived measurements are used directly in the modelling process. There are significant advantages to deploying a GIS-based mapping solution for the presentation and dissemination of roadway and traffic condition information as real time traffic information for all major roadways in an urban area is one of the most important pieces of information necessary to produce a dynamic route guidance system (Nual, Wlodyka and Phiu-Nual, nd).

Real-time traffic information for all major roadways in an urban area is one of the most important pieces of information necessary to produce a dynamic route guidance system. Recent GIS development has included many new capabilities for traffic engineering applications. Nual, Wlodyka, and Phiu-Nual (nd) in their paper described work using the latest GIS technology along with advanced traffic analysis and simulation models to produce real-time traffic information. The overall experience has been that GIS has provided great benefit for all phases of development and that new GIS technology has made the presentation and dissemination of real-time traffic information easier and more effective than ever before. Geographic Information Systems (GIS) have been used extensively in the field of transportation facility and asset management for quite some time now. However, given that GIS can both model transportation networks and incorporate associated network characteristics directly into the database, it is likely that the next major GIS application for transportation will be advanced transportation network analysis tools that take advantage of GIS-based datasets. Coupled with vehicle and order scheduling, GPS tracking, and logistics support systems, there exists the capability for real-time traffic responsive fleet and mobile workforce management not far on the horizon. It is just recently that GIS has

been used with traffic and transportation models for the purposes of area-wide transportation system analysis, forecasting, and evaluation.

Difficulties encountered in modelling large urban network using PTV-VISION (VISSIM) include: • Utilization of several tools required throughout the study. Practitioners needed to be proficient in several traffic analysis tools and be aware of some common problems that crop up while using them. It was observed that the same data has to be entered into different programs, as the format of input data is different from program to program. • Data requirements for large-scale models are extensive. • Gathering field data for such models is a laborious and time consuming process. • The process of manual data entry for large networks is error prone, very time consuming and laborious. • Although computing power has improved during the past few decades, model convergence still takes substantial time for large-scale transportation networks. A computer with a P4 3.4 GHz processor and 3 GB of RAM was used to perform simulations. An additional 3GB of virtual memory was solely provided for the Dynamic Traffic Assignment (DTA) process. Overall, the DTA procedure required approximately 720 hours to achieve convergence. • Coding intersections from scratch in VISSIM is time consuming (intersections are not modelled in detail in the regional model). • O/D-matrices were taken unchanged and, therefore, link flows matched reality much better than turning flows. However, for micro-simulation, turning flows are very important to get queues and spillbacks right (Hourdos and Michalopoulos, 2008).

Planning model software like Tranplan, and TransCAD models are suitable to use for large-scale planning-level applications where specific, detailed traffic analysis results are not the primary need. Typically, these models perform the four-step planning process (trip generation, distribution, modal split, and assignment) and can be used both at the regional and local levels (Veeregowda and Weeks, nd).

2.5.2 Simulation of traffic flow

Fellendorf and Vortisch in their book titled ―Fundamentals of Traffic Simulation" under the chapter: Microscopic Traffic Flow Simulator VISSIM defines Traffic simulation as an indispensable instrument for transport planners and traffic engineers. VISSIM is a microscopic, behaviour-based multi-purpose traffic simulation to analyse

and optimize traffic flows. It offers a wide variety of urban and highway applications, integrating public and private transportation. Complex traffic conditions are visualized in high level of detail supported by realistic traffic models.

2.5.2.1 Fixed Route Modelling

A route is a fixed sequence of links and connectors: A route may have any length – from a turning movement at a single junction to a route that stretches throughout an entire simulation network. A route starts at a routing decision and ends at destination point. Each routing decision point may have multiple destinations resembling a tree with multiple branches. A routing decision affects all or a subset of vehicles types. Vehicles usually travel on one route before entering a new route. However, partial routes are available allowing distributing vehicles on alternative subsets of routes. Managed lanes for high occupancy traffic are typically modelled with partial routes using a user-definable toll pricing model. If vehicles travel on fixed or partial routes they are aware of downstream turning movements if the visibility distance (lane selection distance) reaches upstream to the particular point; thus the combination of visibility distance and predefined routes is a crucial element to model lane selection realistically. Both routing decisions and lane selection distance can be defined for all vehicles or sub- sets of vehicles. Quite often the set of driver-vehicle units is subdivided in a class of drivers familiar with the area and another class following street signs. This feature is widely used to model complex situations where some drivers tend to select appropriate lanes several intersections ahead, while others are decide and manoeuvre late (Barceló, 2010).

2.5.2.2 External Emission Modelling

In order to calculate traffic-related emissions a number of modelling options are available. In German-speaking countries calculations are usually based on the HBEFA (Handbook Emissions Factors Road Traffic), which provides emission values for a set of predefined representative driving cycles and vehicle fleets. Also other emission models were developed in the past such as the European COPERT model. Emission measurements and calculations have been supported by the European project ARTEMIS. The COPERT/CORINAIR methodology allows calculating different pollutants based on measured driving cycles matched with average cycle

speeds. Based on intensive measurements on engine test beds, Hausberger (2003) described a detailed instantaneous emission model (PHEM – Passenger car and Heavy duty vehicle Emissions Model). A variety of vehicle and engine types has been embedded by specific engine maps. Driving cycles and engine specifications (Car/lorry, EURO 0 to EURO 4, diesel/gasoline, power, cubic capacity, weight, transmission) are required as input data. Based on a driving cycle, respectively, trajectories with speed and location over time, PHEM calculates engine power required as a result of the driving resistance. Losses in the transmission system and road gradient are being considered. The actual engine speed is simulated by transmission ratios and a gear shift model. VISSIM provides simulated driving cycles as trajectory data for PHEM, which is calculating the emissions as if the driving cycles are taken from a dynamometer. The toolbox is supplemented by adding various traffic responsive signal control strategies. A study is being conducted comparing the impact of different signal control strategies on traffic-related emissions using the adaptive signal control system MOTION (Barceló, 2010).

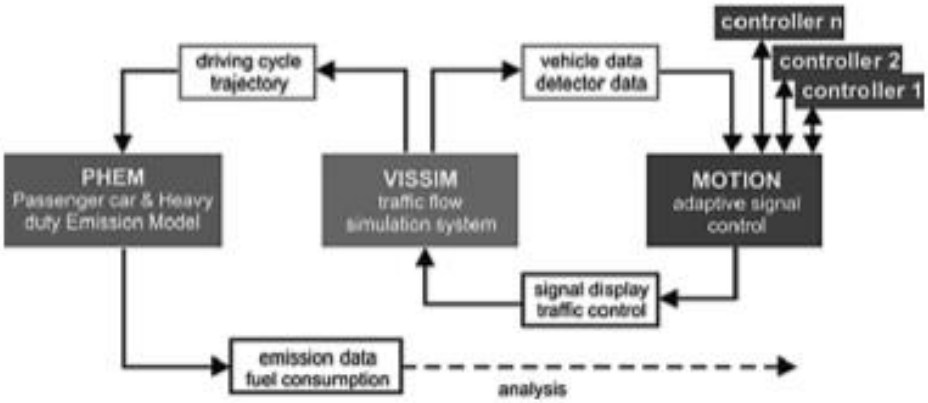


Figure 2.6: Toolbox for modelling traffic-related emissions in urban environments

2.5.2.3 Traffic Congestion Modelling

Miller, Wu and Hung in their work titled ―GIS-based dynamic traffic congestion modelling to support Time-Critical Logistics" reported on a GIS-based decision support system for dynamic congestion modelling and shortest path routing in TCL. The system predicts network flow at detailed temporal resolutions and solves for the combined departure time and shortest path required for a shipment to reach its destination by a given deadline. The GIS provides effective decision support through

its database management capabilities, graphical user interfaces and cartographic visualization. Data requirements for the congestion network model fall into two general areas: i) static transportation network data, including link performance functions; and ii) temporal origin-destination trip departure data which indicate the traffic flow heading during each time period. Network data include the traditional node-arc data model representing the transportation network in the study area. Each arc must have necessary information in order to calculate the link performance function that relates the level of flow to the travel time required to traverse the link. The major flow data required is a time-specific O-D departure matrix. Ideally, the O-D flow data should be ―tagged" with the time of day when each trip occurs. These data can be aggregated to the discrete time intervals of the DUO model. Since the DUO model specifics a dynamic equilibrium for flows departing within the same time interval, the critical ―time stamp" is the departure time of each trip (although the arrival times can also be used for model validation). Adding a departure time question to the O-D surveys commonly conducted by metropolitan planning organizations can derive these data.

In the absence of detailed time-stamped flow data, another option is to temporally disaggregate a daily O-D flow matrix. The simplest method is to divide the daily O- D flow equally into discrete time intervals implied by the specified time duration. However, the approach is crude since O-D flows typically exhibit within-day variation rather than an even distribution. Alternatively, the daily O-D matrix can be disaggregated using a daily flow profile curve that indicates the distribution of peak flows during the day.

The key component of the DTA procedure is to find a shortest path tree from each origin to all other destinations based on the projected link impedance in the current and future time intervals. The shortest path algorithm used is the well-known Dijkstra algorithm. The search routine finds shortest paths based on link impedances as projected during the time intervals in which they will be traversed. To minimize array space allocation, each projected link volume and link impedance can be calculated as it is needed in the shortest path routine. The main computational increase of this routine over a "static" shortest path routine is that the time interval in which each tree uses each link must be recorded. For each link, the current and projected link volumes

are estimated as weighted combinations of the final volume assigned to that link in the previous interval (t - 1) and the volume assigned thus far in the current interval t.

Link impedances are measured in terms of travel time. In the current implementation, we use the standard "BPR" performance functions that relate capacity, current volume and free-flow traversal time to estimate travel time as a function of current flow:

Travel time (T) = T_0 [1+a_1 (Q/C_s) a_2]

where:

T = link travel time in minutes, T_0= link free-flow travel time in minutes

Q = link flow rate in vehicles per time interval, C_s = steady state link capacity in vehicles per time interval and a_1, a_2 = empirical parameters.

Some metropolitan planning organizations estimate the required empirical parameters for their local areas. If these are not available, researchers can use the estimated parameters developed by (Branston, 1976) for Winnepeg, Canada:

Speed limit (mph)	**a_1**	**a_2**
0-30	1.50	4.42
31-40	1.03	5.52
41-50	1.01	6.59
50+	1.15	6.87

Since these parameters are related to different functional road classes (in terms of posted speed limits), they provide reasonable results without the expense of calibrating the flow cost functions for each study area. However, they cannot capture regional or local differences in driver behaviours.

2.5.3 Traffic assignment models using GIS based maps

Traftools has developed the Traffic Information Engine (TIE)™ to make use of existing real-time traffic data sources in order to simulate and predict both current and future traffic conditions and for the presentation of the resulting traffic information on GIS-based maps. TIE™ includes a complete set of traffic system analysis functions that can be used to evaluate and forecast changing traffic conditions whether due to

modified traffic lane usage, intersection controls, accidents, special control circumstances, circulation systems, land use, or any other factor affecting the transportation network. Since TIE™ can forecast traffic conditions in real-time, it is particularly useful for many applications related to Traveller Information Systems (TIS).

TIE™ is a software package that operates in cooperation with the GIS, extracting and requesting data as necessary and providing results for presentation purposes. TIE™ utilizes a GIS-based transportation network and requires as data input real-time traffic data and trip matrices representing travel patterns. Analysis and simulation are performed independently of the GIS to produce traffic information such as travel time and speed along major roadways, traffic flow, average delay, and queue length at major intersections or bottlenecks, and dynamic route guidance that provides the shortest time path between any origin and destination based upon optimized travel times between all possible routes.

The results produced by TIE™ are incorporated into the database and presented on GIS-based maps. By choosing GIS, the maps are interactive and multiple datasets can be linked, related, and presented in real-time. The traffic information is constantly being updated as conditions change; therefore, presentation of the real-time information on static base maps would limit the value of the information and make further use of the data difficult. In contrast, the real-time GIS-based data store allows for many other applications such as the transfer of real-time data directly into fleet and mobile workforce management models to compute new assignments, schedules, and routes, or the provision of real-time traffic information to in-vehicle navigation systems for both every day and emergency evacuation use. Nual, Wlodyka, & Phiu-Nual in their paper titled ―Real-Time Traffic Information Production and Presentation Using GIS-Based Maps" discussed the use of GIS technology with transportation analysis and simulation models for the production and presentation of real-time traffic information.

Traffic assignment is the process of allocating vehicle trips from the matrices estimated above onto highway and public transit networks. The basic premise in traffic assignment is the assumption of a rational traveller, i.e. one who chooses the route that offers the least perceived (and anticipated) individual cost. A number of

factors are thought to influence the choice of route when driving between two points, including travel time, distance, cost (fuel and other), congestion and queue length, type of roads, scenery, road work, accidents, and delays. In general, it is not practical to try to model all factors and therefore approximation is inevitable. The most common approximation is to consider only two factors: time and cost.

TIE™ allows tree building based on both time and cost. Tree building is a process to find the shortest path (a set of links) between a point of origin and destination. There are many algorithms that may be used for tree building. TIE™ adopted Dijkstra‘s algorithm, one of the most commonly used tree building algorithms found in many assignment models.

TIE™ employs two assignment techniques for assigning vehicle trips onto a highway network and transit network simultaneously: Wardrop‘s equilibrium assignment and proportional stochastic assignment. Equilibrium assignment attempts to approximate equilibrium conditions of traffic assuming that traffic arranges itself in congested networks in such a way that all routes between any O-D (origin-destination) pair have equal and minimal costs while all unused routes have greater or equal costs. This is generally referred to as Wardrop‘s first principal. Wardrop also suggested the second principal as an alternative way of assigning traffic onto a network as follows: Under equilibrium conditions, traffic should be arranged in congested networks in such a way that the average (or total) travel cost is minimized.

Stochastic assignment emphasizes the variability in driver‘s perceptions of costs and the composite measure they seek to minimize (travel time, generalized costs). Stochastic methods need to consider second-best routes. Several methods have been proposed to incorporate these aspects, but only two have relatively widespread acceptance: simulation- based and proportional-based methods.

Transit assignment is somewhat more complicated than private vehicle assignment in that it requires important simplifying assumptions and computational requirements tend to be much heavier. The present version of TIE™ provides only for transit vehicle assignment without further consideration related to passenger trips. Transit assignment is useful when the mode of transit uses the same right-of-way as other vehicles. TIE™ allows for all classes of vehicle assignments to be carried out

simultaneously, eliminating the need for a separate process devoted to transit alone (Nual, Wlodyka, and Phiu-Nual, nd).

2.5.4 Spatial network model of traffic flow

A quantity of practical importance in the design of an infrastructure network is the amount of traffic along different parts in the network. Traffic patterns primarily depend on the users‘ preference for short paths through the network and spatial constraints for building the necessary connections. Gastner (nd) in his study examined the traffic distribution in a spatial network model which takes both of these considerations into account. Assuming users always travel along the shortest path available, the appropriate measure for traffic flow along the links is a generalization of the usual concept of ”edge between ness”. He found that for networks with a minimal total maintenance cost, a small number of connections must handle a disproportionate amount of traffic. However, if users can travel more directly between different points in the network, the maximum traffic can be greatly reduced.

In that paper he studied the traffic distribution in a spatial network model. The model is based on the optimization of maintenance costs measured by the length of all edges and the ease of travel measured by the sum of all distances between vertex pairs. A single parameter γ determines the relative weight of both considerations. If users prefer short geometric distances, more edges are added to the network. On the other hand, if the user prefers short graph distances, a hub-and-spoke network emerges with only few additional edges. The traffic along one edge can be measured as it‘s ~~b~~etween ness” which is the number of shortest paths in the network using this edge. The cheapest network to maintain has a small number of edges with very high between ness. If more weight is given to user-friendliness, the highest between ness in the network decreases. The effect, however, is stronger if minimize geometric rather than graph distance. In the first case, the additional edges can reduce the traffic by a large extent, whereas in the second case, the connections between the hubs still carry a substantial amount of traffic. In the model, it is assumed that all edges can in principle handle infinitely much traffic. For future work, one could consider edges with finite capacities so that some edges along the shortest path might become congested and hence unavailable. This problem, however, possesses some non-trivial features requiring a more careful analysis of the users‘ strategies (Gastner, nd).

2.6 Methods of Trip assignment

The fourth and the final step of the travel demand forecasting process is Traffic Assignment. The trip matrices (O-D) developed during generation, distribution, and mode choice phases are used as inputs for this step. The outputs are the traffic volumes on the street network of the study area. Traffic Assignment is the procedure by which the planner predicts the paths the trips will use. For example, if a trip goes from a residential area to the university area, the model predicts the specific streets or transit routes to be used to complete that trip. Traffic assignment process begins by constructing a map representing the vehicle and transit networks in the study area, because the model assigns traffic on these networks. There are mainly two types of traffic assignment procedures: All-or-Nothing assignment, and Capacity Restrained assignment %Both of these assignment procedures consist of two steps: 1) Determination of the minimum path and 2) Assign/load trips onto the minimum path.

Determination of Minimum Path:

It is assumed that the travellers want to use the minimum impedance route between two points. *f* Impedance can be time, distance, cost, etc. *f* The basic rule is that the ―users choose the route that minimizes their own travel time".

All-or-Nothing assignment technique allocates the entire volume interchanging between pairs of zones to the minimum path calculated on the basis of free-flow link impedances (usually travel times). %After all interchange volumes are assigned, the flow on a particular link is computed by summing all interzonal flows that happens to include that link on their minimum paths.

Capacity-Restrained Assignment:

We know that as flow increases toward capacity, the average stream speed decreases from the free-flow speed to the speed at capacity. %In all-or-nothing assignment, the interzonal flows are assigned to the minimum paths computed on the basis of free-flow link impedances (usually travel times). But if the link flows were at the levels dictated by the assignment, the link speeds would be lower and the link travel times would be higher than those corresponding to free-flow conditions. As a result, the minimum paths computed prior to trip assignment may not be the minimum paths

after the trips are assigned. In capacity-restrained assignment technique, the interzonal trips are assigned to the minimum paths in increments and link travel times are updated before each incremental loading of trips onto the network. The travel time, T_Q on a particular link at a traffic flow, Q can be calculated using the following equation developed by the Bureau of Public Roads:

$T_Q = T_O\ [1+.15(Q/Q_{max})^4]$

Where, T_Q= travel time at traffic flow Q T_0= free-flow travel time Q = link flow Q_{max}= capacity of the link.

2.7 Road capacity and vehicular emission related regulation

2.7.1 Dhaka Integrated Transport Study (DITS, 1994)

In DITS: Traffic management manual, Part C: Section 4; some guidelines were given on road classification. A four level road classification has been proposed for greater Dhaka: Primary roads, Secondary roads, Connector roads and Local roads. Freeways have been excluded as they are not relevant in the short term.

Primary Roads: serving high volume through traffic and inter-regional needs, they are designed for maximum capacity with separation of pedestrian and non-motorized traffic. They are the highest level of urban roads and will have limited junctions and restricted access.

Secondary roads: while of lesser importance than primary roads, their main role is to serve inter-district through traffic and non-motorized vehicles may be restricted on certain segments. Access restrictions will be less than on primary roads.

Connector roads: function as a bridge between local roads and secondary roads with traffic near start or end of trip. Through traffic is to be minimized and heavy trucks may be banned. Access and parking control will be limited to critical locations.

Local roads: represent primarily residential areas with access to adjacent property as main priority. Pedestrian and slow moving vehicles are the main users, with buses and tempos restricted. Heavy trucks will be discouraged but permitted for such services as

garbage collection. Table 2 gives STOP sign sight distance guidelines with major road speed, Table 7 lists the main characteristics of each road class, Table 8 summarizes recommended cross-section design criteria for roads in Dhaka including no. of lanes in each direction, Table 9 summarizes recommended lane widths for urban situations, Table 10 shows speed and sight parameters (see appendix F). Also road classification example is given in Figure 20 and the suggested classified road network for Dhaka is proposed in Figure 21 (see appendix F again).

2.7.2 Environmental Conservation Rule (ECR, 1997)

The Government of the People‘s Republic of Bangladesh (1997) has mentioned Rule 4, subsequent Rule 7A and 7B, and Rule 12 which state about vehicle emission and emission standard oriented rules and regulations which need to be followed. Rule 4 states that:

4. Vehicles emitting smoke injurious to health and otherwise harmful. - (1) The owner of a vehicle using petrol, diesel and gas as fuel shall, before registration of the vehicle or renewal of its fitness certificate under the Motor Vehicles Ordinance, 1983 (LV of 1983), hereinafter referred to as the said Ordinance, ensure that a catalytic converter or a diesel particulate filter is fitted in the vehicle. (2) If a vehicle is not fitted with the apparatus mentioned in sub-rule (1) and if it violates the standards specified in schedule 6 or, as the case may be, 7, the vehicle shall be deemed to be a vehicle emitting smoke harmful to the environment or injurious to health.

Collection of _Pollution under Control Certificate‘ and approval of diesel oriented issues have given importance in the rule 7A and 7B considering the environmental aspects.

7A. Procedure for issuance of Pollution under Control Certificate.- The owner of a vehicle shall, after causing the vehicle to be fitted with the apparatus mentioned in sub-rule (1) of rule 4 and before registration of the vehicle under the said Ordinance, or, as the case may be, before renewal of the fitness certificate, collect the Pollution under Control Certificate in accordance with Form-4 (see appendix F).

7B. Restriction on importation etc. of catalytic converter and diesel particulate filter.-

The importer of catalytic converters or diesel particulate filters shall, before importation and marketing thereof, take written approval of the Director General by demonstrating and proving its effectiveness."

12. Determination of environmental standards.– For carrying out the purposes of clause (a) of sub-section (2) of section 20, the standards for air, water, sound, odor and other components of the environment shall be determined in accordance with the standards specified in Schedules - 2, 3, 4, 5, 6,7 and 8 (see appendix F).

2.8 Relevant studies and researches in home and abroad

2.8.1 Relevant studies and researches in Bangladesh

No study has been conducted yet to develop a traffic flow distribution model considering travel demand. Many researchers have studied on transportation scenario and ineffectiveness of present transport situation of Dhaka.

Mahmud and Hoque (2012) in their study titled ―Transportation system management: An assessment for implementation of general tools in Dhaka city" explained Transportation System Management (TSM) as a package of short term measures to make the most productive and cost-effective use of existing transportation facilities, services and modes. For the implementation of such well recognized, cost-effective management tools in a city area demand assessment of the potentiality and the fulfilment of implementation pre-requirements. In that study, an attempt has been made to assess the possibilities and inherent weakness for implementation of different transportation system management tools in Dhaka city. At present, in Dhaka city, there are only about 4 km one-way road which is only 0.31 % of total road network of DCC. There are very little options to introduce the one way operation in other road for the lack of alternative or twin road in the city. The city has not any tidal flow operational road and it is almost impossible to introduce such tool for the mixed land use of the entire city. For the lack of well orientation of road network as well as alternative road, there have very few options to restrict right-turn of an intersection by accommodating the vehicle in alternative road in Dhaka city. About 86 % of major X-junction are 4 phases and about 90 % of T-junction are 3 phases. Among the newly

signalized 59 intersections, 47 (80%) intersections phases are equal to its approaches. For the lack of alternative road, or link road or for the lack of east-west connectivity there is very few opportunity of reducing signal phases of the major busy intersections. It is also difficult to provide coordinated signal in the intersection of the city. For the lack of interconnection between the side roads or for the absence of service road it is also difficult to close the side street. At present condition, it is nearly impossible to construct bus bay on road side, as most of the side of the road are fully build up without sufficient setback. Providing exclusive bus-lane for the implementation of BRT is an apprehension issue in Dhaka city. There is also minimum scope to provide exclusive bus lane in present road network. The underlying reasons behind this failure are found in that study as the inherent weakness in the land use and transportation planning and the consequent haphazard uncontrolled development. This is a built in problem for the mega city of Dhaka and the city is detriment such a cost effective modern traffic management tool everlasting. There is no coordinated signal system in the intersection of the city. There are very little options to introduce such tools for the huge lack of implementation requirements in the present development condition. Corresponding data has been collected from the field observation, road inventory and land use survey and tried to justify with the prerequisite for the implementation of the tools. At the very outset, the prevailing transport and travel scenario and existing road network which is foundation of the implementation of TSM has discussed.

According to Mahmud, Gope and Chowdhury (2012), 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. 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. Dhaka City is the capital of Bangladesh which is a least developed country. It is very important for this City to take vital role in the economy of Bangladesh. But now due to traffic jam, this City is causing the major loss in the economy of Bangladesh. By reducing traffic jam, this city can play a very important role for the country and at the same it can also bring relief and peace for the citizens by ensuring healthy environment free from noise and

pollution. To ensure a healthy generation, traffic jam must be reduced. There are lots of solutions. Some short term strategies that can be taken care of – i. Increasing pedestrian facilities, ii. Maximum use of road width, iii. Controlling road side activities, iv. Modern signalling system, v. Speed wise dedicated road for vehicles, vi. Car free days, vii. High Parking charge, viii. Discourage private cars, ix. Time rescheduling, x. TIA (Traffic Impact Assessment) before plan pass of any construction, xi. Increase the number of public vehicle, and xii. Training of traffic polices. Similarly some midterm strategies, which can be taken care of within 5 to 10 years, are given below: i. BRT (Bus Rapid Transit), ii. Central authority to control traffic of Dhaka City, iii. Construction of roads through East-West, iv. Adequate parking facilities, v. Circular embankment-cum-road along periphery of Dhaka City, vi. Connecting the missing links of important roads, and vii. Improving the efficiency of railways and river ferries. Some long term solutions are - 1) Environment sustainable transport, 2) MRT (Mass Rapid Transit), and 3) Grade separated road network.

Khan, Hoque and Huq (2011) in their study focused on Traffic management as a vital tool for improving the roadway capacity. This study is intended to explore the prospect of introducing three most common traffic supply control management measures - Tidal Flow, One-Way Operation and Signal Coordination in Dhaka city. The study is undertaken for Dhan- mondi R/A bounded by Mirpur road, Satmosjid road, Dhanmondi Road no. 2 and Road no. 27. Volume surveys are conducted at the two end points with Mirpur road to find out the distinctive flow imbalance during the determined peak hour in the morning. The resulting directional flows are found to be 21%, 79% and 46%, 54% respectively leading to absence of tidal flow. Implementation requirements of other two regulations are also investigated. The pre-requisites are not met and the underlying reasons behind this failure are found in this study as the inherent weakness in the planning of road network and the consequent mixed type of land-use pattern. Dhaka is an overly populated city with minimum usage of land for its road network. Consequently, the traffic demand frequently exceeds the supply with severely congested conditions in most of the routes where expansion of facilities and roads is difficult and expensive requiring low-cost traffic management tools to improve the existing roadway capacity. Of the many types of management regulations, Tidal Flow Operation, One- way Operation and Signal

Coordination are very common low cost traffic management techniques. But the implementation of such management tools has some certain pre-requisites to be fulfilled in order to be war- ranted. To apply these management measures in the roads of Dhaka, the potentiality or the implementation requirements need to be investigated to check whether they are warranted or not in the context of Dhaka. The major finding of that study is that the traffic management tools stated in the study cannot be implemented as effective measures to accomplish the objective of reducing traffic congestion in Dhaka city within the existing system capacity. The findings of that study have been discussed in two parts – Problems in Implementation and Hypothetical Solution.

In that study the specific problems that are identified in implementing the three management tools are– tidal flow, one-way operation and signal coordination can be summarized as below: Not obtaining a dominant direction of flow, Minimum number of primary roads and non-availability of grid-iron pattern road network in the main roads and of parallel alternate route with same O-D, Excessive lateral movements and Indiscipline traffic stream and rapid flow. All these problems are the consequences of the combined effect of unplanned road network and uncontrolled land use which are again interlinked with each other and these are in fact the problems that will be faced in implementing any management regulation in Dhaka city under prevailing road network. Hence, the land use pattern is also disorganized making a mix up of residential and commercial purposes. Grid pattern road net- work in the local roads, cause disturbance to main road traffic flow by excessive lateral movements, scattered commercial activities, rapid or random flow, weak intersection operation and low directional imbalance during the peak periods of the day. Also the absence of parallel alternate routes with same O-D for the main roads, cause concentrated traffic load on the single primary road serving the area and do not allow one-way operation. So, it is clear that the roads in Dhaka have been constructed on the basis of short-term demand without considering for the future demand and expansions of different activities. It is a planning failure which is responsible for such irreversible damage. No management regulations can be actually successful under the prevailing condition. So, before forcing the well-established traffic management measures of the developed world in Dhaka city to control the alarming situation of traffic congestion, it is to be realized that neither the roads nor the existing traffic flow condition is in a state to cope up

with these new regulations. Rather, first, this requires some alternative well-planned and sustainable solution to achieve a control over the present land- uses and trip distribution. After this preparatory treatment, the management regulations can be attempted.

Some Hypothetical solutions have been given under that study as follows: 1) By limiting or confining the non-residential trips towards Dhanmondi, a sufficient number of trips would be avoided reducing the lateral movements, 2) Control of planned land-use pattern can be readily accomplished through planned road network. An ideal residential area‘s road should contain a cul-de-sac discouraging the through traffic. If Dhanmondi had to be planned and maintained as a residential area, then the internal road network should not have been of grid pattern. Then the land use control would be also easier with control over the generation and destina- tion of trips, 3) Maintaining fixed type of use for a particular area, i.e. a fixed CBD, a distinctive, predictable significant flow imbalance would be obtained during an easily identifiable peak hour, 4) Mirpur road is wide enough (8-lanes) to provide central two lanes as tidal flow lanes and the outer three lanes on each side of the central lanes, provided lane-based movements, could be used as permanent one- way for the particular direction

At last some recommendations have been formulated under that study as: although Dhaka has already become a city of disorganized road network and mixed land-use pattern due to faulty planning, still some corrective measures may be taken by a strong regulation authority like RAJUK through strict control of the land-use for existing or for any new residential or commercial area to prevent in- disciplined trip generation, attraction and distribution. For Dhanmondi area, some of the particular non-residential uses, i.e. schools, colleges, offices etc. can be shifted to some other places with proper planning and considerations over the short and long-term consequences and other effects. Most importantly, while planning some new town-project, responsible efforts must be taken so that this type of irreversible damage and mistake do not occur in future. Town planner should concentrate on the potentiality of the road network not only on the basis of the capability to meet the current demand, but also for future expansions and overall management actions (Khan, Hoque and Huq, 2011).

Anwar (2010) in his article titled ―A Study on Factors for Travel Time Variability in Dhaka City Corporation Area" stated that knowledge of travel time variability is valuable for improving the reliability of traffic information services and increasing the accuracy of travel time predictions. The paper attempts to explore the travel time variability in Dhaka city with the data collected by the probe vehicle. A comprehensive investigation of travel time distribution was conducted in terms of various time windows. With respect to travel time variability, approximately each mean travel time level has a certain variability associated with it. It has been observed that the higher travel times in the morning off-peak and afternoon peak have the lower coefficient of variance but the smaller mean travel time in the morning peak has the higher variability than other times of the day. The travel time variability has also been investigated by multiplicative nonlinear regression model. To establish the model, delay time (delay), volume-capacity (V/C) ratio and congestion index (CI), which is actual travel time divided by free flow time, were considered as explanatory variables while logarithm of travel time was used as dependent variable. The intention of that article is to develop an econometric model that predicts travel time variability. Prior to the discussion on econometric models, some general information about travel time variability has been assessed. The results presented in that paper gave insights in the empirical relationship between travel time variability and mean travel times as well as other variables, such as delay, congestion index, volume-capacity ratio etc. A reliable traffic system indicates that travellers can anticipate their travel times accurately before their trip, based on the experience gained from the past trips. In that sense, the measurement of reliability is how stable rather than severe the congestion is from day to day. Therefore, travel time variability can be used for evaluating the reliability of transportation systems.

Hasan and Hoque (nd) in their paper titled ―A Simplified Travel Demand Modeling Framework: in the Context of a Developing Country City" presented a simplified travel demand modelling framework to determine the modal flows on urban transport network of Dhaka, the capital of a developing country, Bangladesh. The framework consists of a system of models and is developed based on a number of principles such as having strategic perspective, addressing heterogeneous demand characteristics, following disaggregate and simplified modelling approach and capturing the multi-modal nature of Dhaka‘s transport system. That paper also discusses the modelling

issues related to Dhaka‘s transport context and the principles followed in modelling framework to handle those issues. The structure of the framework is based on four-step modelling process with some modifications in different steps in order to make it suitable for the context. According to that study, the critical issues for developing a travel demand model for Dhaka city are the heterogeneous socio-economic structure; the existing mixed transportation system and heterogeneous travel demand behaviours; and the lack of information of people‘s travel behaviour and zonal employment and population forecasting.

In that paper, a comprehensive travel demand modelling framework is presented in order to handle the critical modelling issues for Dhaka city. The framework attempts to develop a system of models which can determine the complex travel demand applying the four-step modelling process. It follows a simple modular structure so that individual model elements can be updated, implemented and applied easily. Different modelling issues and modelling processes have been discussed. This framework has achieved some important features: segmentation of demand market with a multi-stage modal split procedure; implementation of multi-modal nature of Dhaka‘s transport system; integration with land use features; and capturing congestion effects of the mixed traffic system. The simplified approach, followed in that study, can be used in similar developing country cities where information is not available for sophisticated analysis without ignoring the heterogeneous socioeconomic nature of these cities.

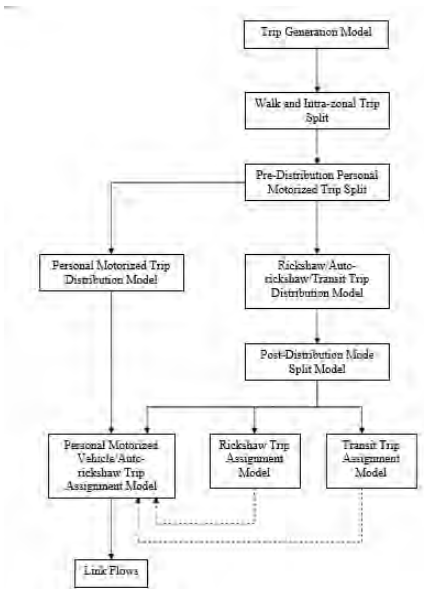


Figure 2.7: Structure of the Modelling Framework Dhaka Strategic Transport Model (DSTM)

2.8.2 Relevant studies and researches in abroad

In order to move toward better understanding of freeway congestion mitigation and emissions reduction strategies, Bigazzi and Figliozzi (2011) in their study titled –An Analysis of the Relative Efficiency of Freeway Congestion Mitigation as an Emissions Reduction Strategy" explores the effects of traffic speeds, freeway capacity, travel demand, and alternative efficiency strategies on freeway emissions. Emissions from a homogenous freeway section with typical fleet and traffic characteristics are modelled and analysed utilizing widely established emission models and macroscopic speed-flow relationships. Assuming an inelastic travel demand function, it is observed that the potential for marginal emissions rate reductions through average travel speed adjustments between 30 and 65 mph is small – though larger rate reductions are possible by moderating speeds that are outside this range. If elastic travel demands functions are assumed, then it is observed that capacity expansions that reduce marginal emissions rates by increasing travel speeds are likely to increase total emissions for initial Level of Service E or above. Finally, it is also shown that alternative emissions reduction strategies that do not rely on increasing freeway speed or capacity may be more effective, even assuming an inelastic demand function.

According to Vergel, *et al.* (1999), in Metro Manila, major atmospheric pollutants such as total particulate matter (TPM) and nitrogen dioxide (NO_2) come mostly from motor vehicle emission. The purpose of their paper is to analyse the relationship between traffic flow and air pollution. Traffic survey and environmental survey of TPM and NO_2 are conducted in 1998 at 22 roadside locations in Metro Manila. The roadside TPM and NO_2 concentration are modelled by multiple linear regression of traffic volume of various vehicle types including buses and Para transit vehicles. The emission mass rate is then estimated from the Plume model where the roadside concentration model is incorporated. The problem of road traffic congestion and the corresponding pollution from motor vehicles it brings have become an important issue in developing metropolitan areas lacking a railway network and urban expressway network like Metro Manila. The Metro Manila Urban Transport Integration Study (MMUTIS) reported in 1997 that the source of major atmospheric pollutants comes mostly from motor vehicle exhaust emission and it was determined that the suspended

particulate matter (SPM) and oxides of nitrogen (NO_x) were found to be the major pollutants. Several air pollution monitoring studies conducted since 1990 support the increasing trend in total suspended particulates (TSP) exceeding the pollution standards, mainly attributed to Para transit vehicles such as buses and some taxicabs. The purpose of that study is to analyse air pollution traffic flow characteristics that affect the traffic environment specifically around signalized intersections and mid-block sections using macroscopic traffic flow variables such as traffic volume classified according to different vehicle classes including buses and trucks.

That study has implemented an environmental survey in Metro Manila measuring and understanding the actual conditions of pollutant levels such as roadside TPM concentration and NO_2 concentration. A special traffic flow characteristic such as the presence of Para transit vehicles and its relationship with the air pollution is analysed and roadside pollutant concentration is modelled. The pollutant emission mass rate generated by the vehicle traffic is calculated from the measured roadside pollutant mass concentration.

Hoglund and Niittymaki (1999) in their paper deals with the methodological aspects and the difficulties of surveying environmental effects, especially air pollution, from speed changes and traffic calming. It describes the complexity of interpreting surveying and study results in terms of a best-worst alternative. Results from a case study with two specific streets within the central and semi- central urban area in Gothenburg, Sweden, are presented in the paper.

The methodology used is traffic simulation and calculations of emissions related to singular vehicles‘ driving patterns, using a specially developed computer programme. The aggregated results of total emissions, for various substances depending on certain ”real” traffic situations for different times of the day, give the possibility for a comparison of different alternatives. The results show the complexity of finding such a ~~b~~est alternative” to be feasibly implemented. The emitted amounts are highly dependent on vehicle speed changes through the interaction between the various vehicles in the traffic flow.

That paper also explained the used methodology of estimating single vehicle‘s emissions from specific driving patterns, measured, simulated or calculated with

kinematic methods. In combination with instant emission data from three-dimensional emission matrixes it is possible to create continuous emission profiles for the specific vehicles. The method gives today amounts for emitted substances of CO2, CO, NO_x, HC, particles and fuel consumption. The aggregated results from single vehicle‘s emissions can then give the comparisons of total emission amounts over a certain street length and time unit for various infrastructural design alternatives such as traffic calming devices. Also different traffic management options and traffic signal control strategies could be handled by this method in combination with traffic simulation.

Mini, Soosan and Rema (2013) in their study titled ―Estimation of Travel demand from the city commuter region of Muvattupuzha municipal area” stated Transportation as a vital infrastructure facility for the economic development of a country. The estimation of accurate trip generation is imperative for a realistic planning programme. The idea in that paper is to prepare a trip generation model to explain the travel demand from settlements falling under commuting distance of an urban area. The commuter region of Muvattupuzha has been chosen as the study area. Trip generation includes both production and attraction. Following are the usual methods of trip generation models: Zonal regression method, Household regression method, Category analysis and Person trip models. In that study category analysis for predicting trip production from the city commuter region and household level regression model for predicting trips attracted to city centre are recommended.

The main objective of that research was to develop a procedure for estimating trip generations from settlements falling under commuting distance of an urban area. For this purpose, the commuting region of Muvattupuzha urban area was chosen as the test bed. A survey was conducted in local buses and based on the surveys conducted the commuter region of Muvattupuzha Home interview surveys were conducted in the delineated area. From category analysis curves developed it was found that for high income group, work trip rates are higher followed by education trips. For low income class, on the other hand, educational trips are higher. Scooter owners have been found to make more trips than others. Category analysis, which bases its predictions on the assumption that the trip generation rates exhibited today by different classes of households will hold good in the future was found to give a fair degree of accuracy in short-term estimates of future trip generation. Five sets of mathematical models have

been built in this study to explain the trips attracted to Muvattupuzha centre. In all the models developed, the R2 value was found to be between 0.67 and 0.83. Based on the models developed, a deficiency estimate of the number of bus trips as at present has been prepared. From this it has been noticed that many of the settlements in the commuter region of Muvattupuzha centre are deficient in the number of bus trips. Analysis of this nature using category analysis technique leading to the development of trip production models has been carried out for the first time for Muvattupuzha and it is hoped that the findings of the study would be useful to Road Transport Corporation.

Chang and Kim (nd) in their study titled ―Development of Capacity Estimation Method from Statistical Distribution of Observed Traffic Flow" presented a quantitative method for highway capacity determination by evaluating alternative approaches in developing capacity from the statistical distribution of observed traffic flow. Extremely long headways are considered to be unreasonable for sufficient demand and for the maximum flow rate defining capacity. Therefore, the longer headways are removed from measured data. The objective of that study is to define capacity in a quantitative form and to express capacity as a certain percentage found on a distribution of observed flow rate. Then, it can resolve the two problems of the subjectivity of capacity definition and underestimation or overestimation of capacity that has been calculated by using adjustment factors, the previous method of capacity adjustment under non-ideal conditions. It is derived from the collective consideration of three criteria of capacity determination which are maximum observed field data, derived value from traffic stream model among speed, flow rate, and density, and the average headway of passenger car only traffic. That study analysed the quantitative method to define capacity by evaluating the headway and volume distribution from observed traffic flow.

According to Huang *et al.* (2003), the travel demands generated in cities can be regarded as the result of people trying to hold activities in different places under the constraints of time and space. If the analysis process didn‘t contain the previous idea, the influences to individuals‘ decisions and travel behaviour in time-space constraints could not be accounted for and could not support policy analysis effectively when activity patterns had changed. That study sampled residents in metropolitan Tainan

and recorded a weekday and a weekend travel-activity schedule by using an ―activity diary surveys”. For the weekday aspect, that study has constructed a two stage choice model with ―activity patterns choices” and ―locations choices. For the weekend aspect, that study has constructed a four stage choice model with ―beginning time choices of primary activity ―, ―content choices of primary activity”, ―travel-activity pattern choices”, and ―location choices”. The results showed that there is strong connection between travel and activity, and time-space limitations would also influence the choice behaviour of people.

Modi *et al.* (2011), in their paper presented an overview of the travel demand modelling for transportation planning. Mainly there are four stages model that is trip generation, trip distribution, modal split and trip assignment. The choice of routes in the development of transportation planning depends upon certain parameters like journey time, distance, cost, comfort, and safety. The scope of that study includes the literature review and logical arrangement of various models used in Urban Transportation Planning.

According to that study, trip generation gives an idea about the total number of trips generated to and attracted from different zones in the study area. In trip distribution, growth factor modelling and in trip generation, regression methods can be used to predict the trips. Trip matrix can be used to represent the trip pattern of a study area. Growth factor methods and gravity model are used for computing the trip matrix. Transportation planning involves so many iterative techniques, and large road networks, which is not possible to solve manually. But the computer programmers are created readymade soft wares available for solved the transportation planning problems. Trip assignment is the last phase of four stage transportation planning. Multipath route assignment technique seems to be the most realistic among all those techniques. The basic steps in Transportation Planning Models are: 1) Assessment of the existing road network, traffic and travel characteristics of the study area. 2) Forecast travel demand up to the horizon year 2021 and identify transport system requirements. 3) Digitization of road network. 4) Conducting sample surveys for trip rates, mode choice and O-D. 5) Preparing trip generation models and O-D matrices. 6) Traffic assignment on selected network and assessment of vehicle/capacity ratio. 7) Creating transportation scenario for future.

The purpose of a report (2006) titled ―Travel Demand Model Documentation & User Guide, Des Moines Area" was to describe in detail the trip based travel demand model developed for the Des Moines metropolitan area. Travel demand models are used for simulating current travel conditions and for forecasting future travel patterns and conditions. Once travel demand is known, the planner can assess the performance of alternative transportation systems and identify various impacts that the system will have on the urban area, such as delay and emission. With information on how transportation systems perform, and the magnitude of their impacts, planners can provide decision-makers with some of the information they need to evaluate alternative methods of supplying a community with transportation services.

That travel demand model was developed by staff of the Des Moines Area Metropolitan Planning Organization (MPO), Iowa, and using Caliper's TransCAD software. An important, essential use of the 2001 National Household Travel Survey (NHTS) Add-on data in the Des Moines metropolitan area is the survey‘s input in the Des Moines Area MPO‘s travel demand model. The Des Moines Area MPO used the traditional modelling process of trip generation, trip distribution, and trip assignment to develop the travel demand model. The Des Moines Area MPO does not conduct mode choice modelling. The 2001 NHTS Add-on data was able to assist the Des Moines Area MPO in determining whether mode choice modelling would be a valuable use of time and resources. Transit usage accounted for less than 1% of the total trips, according to the 2001 NHTS Add-on data. Based on the 2001 NHTS Add-on survey data, it was decided that at the present time transit usage was not a large enough percentage of total trips to warrant the creation of a mode choice model.

In that report it is stated that trip generation forecasts the number of trips from urban activity. For example, the number of trips that are generated by a shopping centre is quite different from the number of trips generated by an industrial complex that takes up about the same amount of space. In trip generation, the planner attempts to quantify the relationship between urban activity and travel. The output of the trip generation model is a table of trip ends: the number of trips that are produced and the number that are attracted. The 2001 NHTS Add-on data, the 2000 U.S. Census data, and the 2000 Census Transportation Planning Package (CTPP) were the main input data for trip generation analysis of Des Moines Area MPO‘s travel demand model.

Trip distribution procedures determine where the trips produced in each zone will go and how they will be divided among all other zones in the study area. The trip distribution analysis used the gravity model which is based on travel time as measures of trip impedance. The output of trip distribution is a set of tables that show the travel flow between each pair of zones. The trip assignment model predicts the paths that the trips will take. For example, if a trip goes from a suburb to downtown, the model predicts which specific roads are used. The trip assignment process begins by constructing a network map. The network maps show the possible paths that trips can take. The output of the trip assignment model shows the paths that include the flow of traffic.

Mcnally (2007) in his chapter of a book titled ―Handbook of Transport Modelling" explored that the basic structure introduced by Manheim (1979) and expanded by Florian et al. (1988) provides a comprehensive paradigm in which to examine the four-step model (FSM). In this representation (Figure 2.3), the transportation system T, defined as all elements of transportation infrastructure and services, and the activity system A, defined as essentially everything else (the spatial distributions of land use and the demographic and/or economic activity that occurs in those land uses), serve as exogenous inputs to performance procedures P and demand procedures D, respectively. It is such demand and performance procedures that comprise the basic FSM. While some form of location procedure L is required, it has typically been executed independent of the FSM and rarely integrated in any formal manner within the basic equilibration procedure. Similarly, formal supply procedures S are virtually non-existent. Florian et al. characterizes formal analysis as involving the choice of analysis perspective (effectively, time frame and spatial definition) and the definition of procedures, and thus variables, which are to be specified endogenously or exogenously.

Of critical importance to this approach is an understanding of the units of analysis for these procedures, defined spatially and temporally. Demand procedure D typically produces person trips, defined as the travel required from an origin location to access a destination for the purpose of performing some activity. These trips reflect units of time and space (such as daily person trips per household or peak-hour person trips per zone). Performance procedure P nearly always reflects mode-specific trips (person or

vehicle) defined as a link volume (e.g., freeway vehicle trips per hour or boarding per hour for a particular transit route segment). The equilibration process must resolve demand and performance procedures defined at different spatial levels. Demand procedures defined at the zonal level and performance procedures defined at the link level are interconnected by the path level: paths comprise sequences of links that connect O-D pairs.

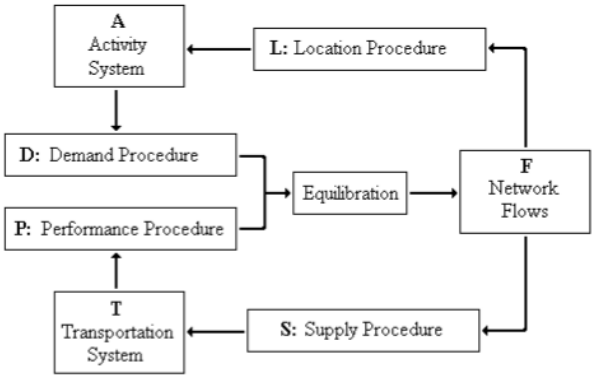


Figure 2.8: The Manheim/Florian Transportation Systems Analysis Framework

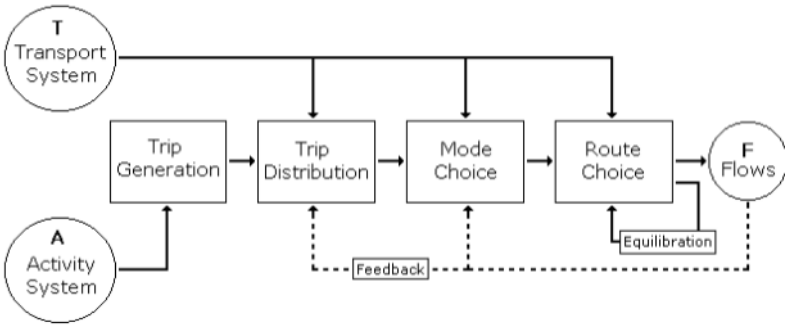


Figure 2.9: The Four Step Model

2.9 Summary

The literature review shows that, traffic flow model development and travel demand forecasting are conducted through different methodologies in abroad. Since, no traffic flow distribution model has been developed based on the Bangladeshi data; this study seeks to apply the traffic flow distribution process to the Bangladeshi data. The results of this study would go some way to establish the usefulness of the optimum traffic flow distribution in the Bangladeshi transportation system. On the basis of the concepts and techniques illustrated in the literature review the following chapter presents analytical methodology of the study.

CHAPTER 3

Methodology and Study Design

3.1 Introduction

To achieve the objectives of the study, it is necessary to develop a methodology for the study. The methodology used for developing a GIS-based traffic flow distribution model in consideration with travel demand is described in this chapter. The collection procedure of data, the application procedure of different mathematical theories to calculate travel demand, to develop the GIS based model and also to assign traffic along the study route is portrayed in the following sections. This chapter describes about how the research has been carried out. The research has been conducted in a systematic process. The detail discussion about the stages has been made follow. The summary of the works to obtain the research objective has been shown with a flow chart.

3.2 Methodology of the Study

The preliminary step of the study starts with extensive literature survey and review to develop clear understanding of the concept of optimum traffic flow distribution and its application along the major routes of Dhaka city. An extensive literature review has been conducted to examine the present travel pattern and traffic flow scenario of Dhaka City. The objectives have been fixed. Then the study area has been selected. In this study, the proposed study area will be confined to four major routes namely Mirpur road, Pallabi to Anandabazar at Gulistan, Kuril to Bijoyshoronee and Kuril to Shegunbagicha. The Mirpur Road (from Technical Morh to Azimpur), Mirpur road (from Pallabi to Mirpur-10 roundabout), Rokeya Shoroni (from Mirpur 10 to Bijoy Shoroni), Airport Road (from Kuril to Anandabazar, Gulistan via Mohakhali, Farmgate, Karwan Bazar, Shahbagh, Motshobhobon Kodom Foara), Progoti Shoroni, DIT, Mouchak to Kodom foara has been selected for the study. Some other secondary roads which act as connector or link road or parallel road to the above major four routes have been also taken under study area. These secondary associated roads can play important role as an alternative route to the vehicle users if needed. The data

needed for conducting the research have been collected from both primary and secondary sources. The main steps of methodology of the study are as follows:

Step 1- Data Collection: Primary and Secondary data has been collected in order to conduct the research.

a) Primary data: To attain the first objective of the study, travel pattern data along the study area is required. For this purpose cordon survey has been done through direct interview method. Variable rate sampling method has been used to get the origin-destination data. Non-motorized traffic volume data along primary arterial roads has been collected through volume survey. Both motorized and non-motorized traffic volume data for some selected secondary alternative roads have been collected from field survey. Data on effective carriageway width of road has been collected from field survey to attain the second objective.

b) Secondary data: Link wise traffic volume data for motorized vehicles along major arterial roads of Dhaka city has been collected from an unpublished MURP thesis (Jahan, 2013). Traffic volume (both MT and NMT) along some alternative secondary roads have been collected from DHUTS, 2009. To convert the traffic volume data (both year 2009 and 2013 data) into current year (2014) data, present annual growth rate of motorized vehicle (7.6%) has been used (STP, 2005). Soft copy of Detail Area Plan (DAP) Map has been collected from RAJUK which provides the data on detail road network map. Standard for emission from motor vehicles has been collected from ECR, 1997. Road capacity standard (PCU/lane/hour) has been collected from DITS (1994). Past relative contribution data by different travel modes in air pollution of Dhaka city have been collected from previous researches (Ahmed and Alam, 2012; Chowdhury and Imran, 2010; ADB, 2006). Data on vehicular emission inventory of Dhaka city, emission factors and vehicle usage in Dhaka and emission rate of motorized vehicles have been collected from secondary source (Rabbani and Sharif, 2005). Revised ambient air quality standards for Bangladesh of numerous pollutants have been collected from secondary source (Hasan *et al*, 2013). Updated (2005) Bangladesh national air quality standard, WHO guideline values and US EPA standards have also been collected (ADB, 2006). Also for calculation of emission, vehicle composition data on the basis of fuel type have been collected from previous research (Kadir, Sen and Hasan, 2012).

Step 2- Data Processing: The traffic volume data, vehicular emission data and road capacity data have been recorded and processed using geographic information system. Major roads of Dhaka city will be identified and have been extracted from road network of Dhaka city. Traffic volume data at cross section of certain roads have been recorded. The whole transport network have been abstracted in three layers: node layers, network layers and traffic zone level.

Step 3- Data Analysis: After data processing, a GIS-based model of traffic flow distribution has been developed. Using GIS, traffic flow have been distributed in such a way that would not exceed the acceptable limit of pollution level and the capacity of a particular road type. The following variables have been used for GIS-based traffic flow modeling:

A) Traffic volume
B) Vehicular emission
C) Capacity of a particular type of road

The model has been executed for different traffic flow distribution. After each traffic flow distribution, the model has checked whether it will exceed both the acceptable limit of vehicular emission and the road capacity. The modeling result which has fulfilled the two criteria is the optimum traffic flow distribution. The obtained data on optimum traffic flow distribution has been analyzed using GIS. After that difference between actual (existing) and optimized traffic flow for each study route has been calculated and additional traffic flow has been distributed along existing alternative route in accordance with travel demand not exceeding the optimum traffic volume for that alternative route.

Step 4- Recommendations: Finally, on the basis of findings, some recommendations have been made to reduce traffic congestion and to improve public health.

The steps followed for the study have been shown using a flow chart in Figure 3.1.

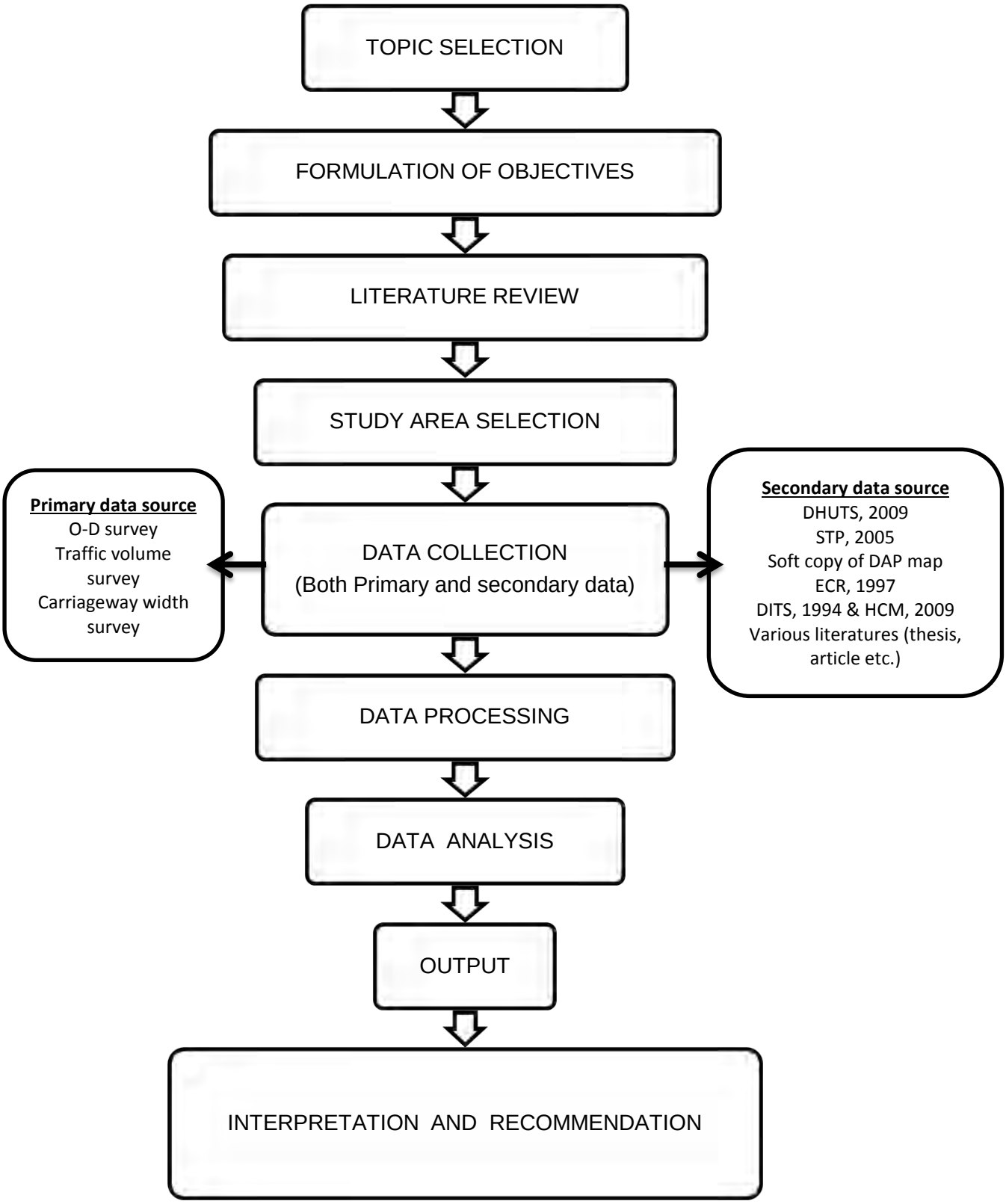


Figure 3.1: Methodological Framework of the Study

3.3 Study Design

3.3.1 Fixation of Objectives

To achieve the aim of the research, three objectives have been fixed. Objectives help to carry out the research in more organized and systematic way. These have been fixed based on focus of the research and from background of the study.

3.3.2 Literature Review

Following fixation of objectives literature survey has been carried out to find out the means to achieve those objectives. A number of international journals, thesis reports, researches and studies which are relevant with this research have been reviewed to conceptualize the objectives. Theses about fuel economy, fuel consumption pattern, and daily activity of motorized traffic of Dhaka city have been reviewed. International journals, articles and project reports on estimation of vehicular emission have been reviewed. Journal articles, features in the internet in different websites and research papers on methods of pollutant mitigation by trees have also been reviewed. Relevant environmental policies and transportation laws practiced in Bangladesh have been reviewed.

3.3.3 Development of Conceptual Framework (Co-ordination schema)

Conceptual framework is the shortest form to describe the objective wise specific methodology. It provides a skeleton to the research activity. The variables of the objective, data source, data collection method have been identified through developing the framework. Co-ordination schema of the research is attached within appendix A.

3.3.4 Preparation of Checklist

A checklist for traffic volume survey has been prepared mentioning three different categories of non-motorized vehicles that run on the major roads of Dhaka. To prepare the checklist with these three categories (Rickshaw, Rickshaw van and Bi-cycle) of non-motorized vehicles a preliminary observation on those roads has been carried out. The finalized checklist with which traffic volume survey have been carried out has attached in appendix A. Another checklist has also been prepared to

conduct the Origin-Destination (O-D) survey through direct interview method. Two types of cordon survey checklist have been prepared for each link to cover both direction (incoming and outgoing) vehicles. Data on no. of occupants, origin, destination, purpose of trip, intermediate stop (both precise stop address and stop purpose), preferred alternative route and preferred alternative mode against eleven categories of both motorized and non-motorized vehicles have been collected through the cordon interview survey. To select the vehicle categories for O-D survey, a preliminary observation on those roads has been carried out earlier before the survey started. One other checklist consisting data on carriageway width (both sides), footpath width (both sides) and median width along all four major study routes (link wise) and also along seven other secondary alternative roads which can be used as an alternative route to reach the road user's original destination has been prepared. All the checklists have been attached in appendix A.

3.4 Field work

Field work for the research includes non-motorized traffic volume survey in the selected major roads, traffic volume survey (both MT and NMT) along some associated secondary roads and collection of carriageway width data of all selected major roads and those secondary roads which can be used as alternative routes. To examine/study the travel demand of vehicle users along the study routes is the first objective of the research and to satisfy this objective, cordon survey (O-D survey) through direct interview method will also be conducted under field work.

3.4.1 Traffic volume survey

Traffic volume surveys (only NMT) in peak hour on weekdays have been conducted on the selected major road links. A survey team has been involved to collect data of all the links. At first major roads of Dhaka have been selected for the study, and then the roads have been categorized in to four routes. These routes are then divided into total 35 links based on the major intersections and traffic signals on them. Also traffic volume survey on both Motorized and Non-motorized transport (MT and NMT) along five selected secondary alternative roads (volume data for those roads not available in

DHUTS by DTCB, 2009) has been conducted during congested morning and evening peak hours.

3.4.2 Cordon survey

In the direct interview method, a sample of road users are stopped at the external cordon survey point, and questioned by a surveyor, who will record the answers on specially prepared forms (checklists). The information recorded includes general information like: date, time, location of the survey point and surveyor identification etc. This information is normally recorded as the vehicle approaches the survey point. Questions are put to the driver of the vehicle about the origin and destination of his journey. The origin and destination of a trip must never be recorded as the same point. For round trips the farthest point reached from one end of the journey should be recorded as either the origin or destination of the trip. The driver is next questioned about the purposes of his journey. For study convenience subdivision/coding of journey purposes and origin-destination land uses will be done along specific route (link wise). In certain cases additional questions concerning a possible intermediate stop within the area under study and the reasons for it are asked of people making through trips. The size of sample interviewed varies with the accuracy required in grossing up, and the volume of traffic on a particular route. Three main types of sampling procedure can be employed on a cordon survey. Among the three, variable rate sampling is the method will be used at cordon surveys for this study. Surveyors are employed at a constant rate, and the size of sample selected varies with the volume of traffic flow. Depending on the characteristics of the stream, sample rates are calculated for either half-hour or one-hour periods. To reduce bias different sample rates are usually calculated for different classes of vehicle. Using sample size calculator by Raosoft, Inc.htm; (see appendix B). assuming 95 % confidence level and with margin of error (5%) recommended sample size has been calculated for each category vehicle along each link for the four major study routes. Population size is the existing traffic volume for each category vehicle along different study links (see appendix B). The number of surveyors required to operate the cordon survey station depends on traffic volume, the number of questions asked and sample size selected. As a rule of thumb it is estimated that one interviewer should be able to cope with approximately 80 vehicles per hour.

Photo 3.1: Conducting Origin-Destination survey along Route 03 (Kuril to Bijoyshoroni)
Source: Field survey, 2014

3.4.3 Carriageway width survey

With the help of a measurement tape (large in length size) data on carriageway width (both left and right sides), footpath width (both sides) and median width along all four major study routes (link wise) and also along seven other secondary alternative roads will be collected through field survey by the survey team. This measurement better is done on weak end or off peak hours when vehicle pressure is less than usual time along the busiest routes.

Photo 3.2 and 3.3: Measuring footpath width under carriageway width survey along Route 04 (Kuril to Shegunbagicha)
Source: Field survey, 2014

3.5 Data Processing

After collection of data from primary source through checklist survey, data has been processed through qualitative and quantitative techniques. The traffic volume data, vehicular emission data and road capacity data for particular road links have been

recorded in ArcGIS interface. Major roads of Dhaka city have been identified and extracted from road network of Dhaka city. Traffic volume data at cross section of certain roads have been recorded. The whole transport network will be abstracted in three layers: node layers, network layers and traffic zone level. Microsoft Excel and Statistical Package for Social Service (SPSS) have also been used for data processing. Data format have been prepared and after completion of data input and plotting of optimum traffic volume along each route in GIS interface it has been made ready for analysis.

3.6 Data Analysis

Data has been analysed to estimate or calculate travel demand, optimum traffic volume along major study routes (link wise) according to emission standard and road capacity standard and finally to calculate the difference between existing and optimum volume along each route so that additional traffic flow can be distributed along existing alternative route in accordance with travel demand not exceeding the optimum traffic volume for that alternative route.

3.6.1 Travel Demand Calculation

From the origin-destination data collected from direct interview method (cordon survey) land use demand can be calculated for different category vehicles. After demand calculation percentage of vehicles (mode wise) going into which direction had been found. Output matrixes of O-D survey for four major routes (link wise) are attached within appendix C.

3.6.2 Conversion of 2009 and 2013 traffic volume data to present year (2014) data

Data on registered number of motor vehicles in Bangladesh and Dhaka city upto May, 2013 has been collected from BRTA (Bangladesh Road Transport Authority) which can be used to get the growth rate of traffic for calculation of traffic volume for present year 2014. In this regard also data on GDP, per capita income and population of Dhaka city will be collected from Population census, BBS to establish Elasticity

model (Linear regression: estimating demand elasticity) for calculating traffic growth factor. In case of complexity arising through this procedure of growth rate calculation, present annual growth rate of motorized vehicle in Dhaka (7.6%) will be considered for calculation (STP, 2005).

Elasticity model (for calculation of traffic growth factor)

- Dependent Variable: Number of vehicle
- Independent Variables: GDP, Per capita income, population

- Assumptions:

1. GDP relates to freight movement (truck, small truck)
2. Per capita income relates to private car, taxi, auto rickshaw, station wagon, micro/minibus, motorcycle, jeep
3. Population relates to public bus (Large bus, mini bus)

- Model:

$Y = \alpha + \beta X$
$\log Y = \log\alpha + \log\beta X$
$d/dx(\log Y) = d/dx(\log\alpha + \log\beta X)$
$\beta = (X/Y)*dy/dx$
Here $dy = (dy2-dy1)$
$dx = (dx2-dx1)$

For example: (Calculation of growth rate for private car)

$\beta = (X/Y)*dy/dx$

Here X = per capita income (2011) (BBS)
Y = No of registered Private car (2011) (BRTA)
x2 , y2 corresponds to 2011 data
x1 , y1 corresponds to both 2009 and 2013 data

In case of complexity arising through this procedure of growth rate calculation, present annual growth rate of motorized vehicle in Dhaka (7.6%) will be considered for calculation.

$ADT_f = ADT_i$ (1+Growth rate) (F-I)

Here, ADT_f = Average daily traffic for future year (2014)
ADT_i = Average daily traffic for initial year (both 2009 and 2013)
F = Future year for ADT (2014), I = Initial year for ADT (both 2009 and 2013)

Source: Virginia Dept. of Transportation, 2000

3.6.3 Calculation of optimum traffic volume according to vehicular emission standard

Vehicular emission of particular road link has been determined using traffic volume plying on that road link. Emission can be calculated in numerous ways. Two of the most effective equations for calculating emission are as follows:

Based on distance and cold start emission

Emission = $\Sigma_{i,j,k,l,m}$ (Distance*Emission factor $_{i,j,k,l,m}$) + Σ C $_{i,j,k,l,m}$

Here, C = cold start emission
i = fuel type
j = vehicle type
k = pollutant type
l = operating condition
m = emission control technology

- Distance can be expressed also as Vehicle Kilometers Travelled (VKT/day)
- Emission factor in kg/unit of distance
- Number of vehicles along a selected link/road network can be multiplied with the total Emission value.

Based on Speed and Travel time

Emission = {Emission rate of motorized vehicles (mg/min)*Travel time}

Travel time = Length of link (Total Kilometers Travelled) / Speed of vehicle (km/min)

Travel time (T) can also be calculated in the following way:

$$T = T0\ [1+a1\ (Q/Cs)\ a2]$$

Here, T0 = link free flow travel time in min (Link free flow speed 70-80 km/hr)

Source: Al-Azzawi, nd

Q = link flow rate in vehicles/time interval
Cs = Steady state link capacity in vehicles/time interval
a1, a2 = empirical parameters

Source: Branston, 1976

In this study, first equation based on distance and cold start emission has been used to calculate optimum traffic volume according to emission standard (standard amount of

particulate). Here cold start emission (c) considered to be zero in context of avg. temperature and average speed range of our country.

Equation can be modified as follows:

Standard wise emission for specific pollutant type and vehicle type (fuel wise) along a particular link of a given route = Length of that link*Emission Factor (EF)* Optimum Traffic volume

Standards for emission from motor vehicles (according to ECR, 1997) and Updated (2005) Bangladesh national air quality standard & WHO guideline values have been given within appendix D. Also emission factor for each category vehicle according to fuel type has been collected from secondary sources (Rabbani and Sharif, 2005 and Jahan, 2013) and included within appendix D. Link wise length of major routes and other secondary alternative routes have been given in the following chapter titled as Study area profile.

3.6.4 Calculation of optimum traffic volume according to road capacity standard

Table 3.1: Road capacity standard

Category of Roads	Design Speed (km/hr)	Number of lanes in each direction
Urban Arterial road (Primary road)	90-70	3
Secondary road	60-50	2
Connector road	50-40	2
Local road	40-20	1

Source: DITS (1994)

Capacity is calculated by using a standard. The capacity of 12 feet lane is 1200 PCU/hour as recommended in Highway Capacity Manual (Douglas county HCM, 2009). On the other hand, the standard capacities for the sections are calculated with 1400 PCU/hour/lane as recommended in DITS (1994). It is to be noted that the capacity calculated is the effective capacity (capacity excluding encroachment) of the study sections. In general, the design capacity of urban arterial road is 1400 PCU/lane/hour according to DITS (1994). But in context of our country as on street parking and other unauthorized encroachment along arterial roads has been practiced,

so it is more feasible for us to accept the lower standard provided by Highway Capacity Manual (capacity 1200 PCU/lane/hour).

For example in case of Mirpur Road (Science lab- New Market section/link):

Name of the section	**Effective Carriage way width (ft)**	**Effective no. of lanes (assuming 12' per lane width)**	**Standard capacity/lane (PCU/hour)**	**Total Effective Capacity (PCU/hr)**
Science lab signal to New market signal (Link 10 of Route 01: R10)	36.25	3.021	1200	3625

Effective carriageway width data has been calculated from data collected through carriageway width survey. Total effective capacity of a link along major route has been calculated through multiplying effective number of lanes with standard capacity/lane. Standard capacity varies with category of roads. For this link along Mirpur Road, optimum traffic volume must be equal or less than 3625 PCU/hour. From Jahan, 2013 total motorized traffic volume for the year 2013 along this specific link has been found as 1481 (both direction). Total NMT for this specific link has been found from volume survey, 2014 as 12052/hour (695 PCU/hour). After applying STP growth factor (7.6%), motorized traffic volume for present year (2014) has been found as 1594 (1614 PCU/hour). After converting into PCU, traffic volume (both MT and NMT) has been found as 2309 PCU/hour which is far below the total effective capacity calculated (3625 PCU/hour) for this link along Mirpur Road (Route 01).

Conversion of traffic volume into PCU

Passenger Car Unit (PCU) is the present and most popular technique to determine the road way capacity. The basic concept behind this practice is that different types of vehicle offer different degree of interference to other traffic and it is necessary to bring an analysis all types to a common unit. The common unit adopted is the PCU. While traffic is composed of a variety of vehicles, the passenger car equivalence (PCE) is used to convert the volume of each vehicle type into PCU-that represents the equivalent traffic impedance value of each vehicle type in the flow based on a value of 1.0 for a passenger car; the flow is then expressed as PCU/hour or PCU/day.

Table 3.2: PCE values by Vehicle type for Dhaka City

Mode	PCE
Bus	2.0
Mini bus	1.5
Micro bus	1.0
CNG/Auto rickshaw	0.7
Passenger car/Jeep/Taxi	1.0
Motor Cycle	0.3
Human Hauler	0.5
Bicycle	0.2
Rickshaw	0.4
Pushcart	4.0
Truck	2.0

Source: DITS, 1994 and STP, 2005

As volume of traffic was found through summing various kinds of vehicle number so an equivalent factor is needed for comparison. For this reason vehicle number has been multiplied with their corresponding PCE and an equivalent number suitable for comparison among different vehicles are found. For Dhaka city DITS (1994) and then DUTP (1998) have calculated the PCE values for intersections. The DITS values are recognized as more acceptable and rational of the two and thus widely used in different traffic studies. In this context DITS recommended PCE values and STP recommended values (for Bus, Truck and Rickshaw) are used for this study as well.

Calculation of total effective capacity of each link along the four major routes and associated some other secondary roads are being shown within appendix E. Conversion of existing current year traffic volume into PCU has been included within appendix B. Two types of initial year traffic volume (2009 and 2013) and NMT volume for the present year (2014) all are included within appendix B where sample size calculation for O-D survey has been shown.

3.6.5 GIS based traffic flow distribution model development

After calculating optimum traffic volume according to both vehicular emission standard and roadway capacity standard, standard or optimum volume has been found for four major routes (link wise) and other associated secondary roads. Lower traffic volume between the two volumes (one found after applying standardized emission

value for particulates and other found from effective road capacity PCU value calculation) along each road has been selected as the optimum volume for that particular road. Using Python based coding under Geo processing option of ArcGIS interface, traffic flow has been distributed in such a way that could not exceed the acceptable limit of pollution level and the capacity of a particular road type. Three types of variables have been used for GIS-based traffic flow modelling: existing traffic volume, traffic volume with acceptable limit of vehicular emission (acceptable amount of particulates emitted) and capacity of a particular type of road. The model would be executed for different traffic flow distribution. After each traffic flow distribution, the model has checked whether it will exceed both the acceptable limit of vehicular emission and the road capacity. The modelling result which would fulfil the two criteria and the traffic volume which is less or equal to both the traffic volume calculated according to emission and road capacity is the optimum traffic flow distribution and the optimum number of traffic for each road. The obtained data on optimum traffic flow distribution has been analysed using GIS.

3.6.6 Traffic assignment along alternative routes

After finding out the optimum volume along each route difference between actual (existing) and optimized traffic flow for each study route has been calculated. For those routes which possess additional traffic flow (optimum volume < existing volume), has been assigned/shifted along existing alternative route in accordance with travel demand not exceeding the optimum traffic volume for that alternative route. After fulfilling 1st objective (demand calculation) percentage of vehicles going into which direction had been found. So, these additional vehicles can be shifted according to their destination along existing alternative routes if possible. Because there are lack of alternative routes to major routes in Dhaka city and people are not always willing to use alternative route rather than use the most common route which directly approaches to the destination land use. While shifting traffic volume external-external (Through movements) movements have been given first priority. Through movements are those with an origin and a destination outside the area defined by the external cordon. It has been tried to keep internal movements (with both their origin and destination inside the area bounded by the external cordon) along their original route. But it must be ensured that those alternative routes should not exceed their

respective optimum volume. At the initial period of this study it was assumed that additional traffic flow will be assigned along alternative routes following Capacity Restraint assignment technique as All or nothing assignment technique takes no account of increasing congestion associated with increased volumes and assigns too many vehicles to the routes with shortest travel time. In Capacity Restraint assignment, practical capacity of each link of the network is fed into the computer as well as journey time. The first stage involves the building of minimum path trees. Traffic is then assigned to these minimum paths but as the assigned volume on each link approaches the practical capacity the computer, through an iterative procedure in which loaded link information is used as a feedback to the tree-building process, automatically lowers the assumed speeds on the affected links thereby making these links less attractive to traffic. But after going through the work it is being observed that as there are lack of sufficient alternative routes and in most of the cases there is only one choice for shifting the additional traffic flow to alternative route, all or nothing assignment technique will be followed to assign the trips along alternative roads.

3.7 Findings and Recommendation

Detail analysis has been done and photographs have been provided to portray the scenario. After thorough analysis of the primary and secondary data some findings have been summarized. Land use demand estimation has been conducted along the major routes of Dhaka city. Through this, existing travel demand has been explored. Roads with excessive vehicular pressure have been identified. A reason behind this excessive congestion is because of some specific land uses which play predominant role and located along and nearby these routes. After that, optimum traffic volume has been computed for each route to depict the ideal number of traffic suitable for each route through satisfying two important criteria: vehicular emission and roadway capacity which are very significant variables in Dhaka city context. Finally as travel demand cannot be neglected and must be satisfied, for this reason alternative route are being used to accommodate additional vehicles to reach their original destination. On the basis of these findings some recommendations have been made to reduce traffic

congestion and to improve public health through ensuring a smooth travel to the vehicle (both motorized and non-motorized) and road users of Dhaka city.

3.8 Summary

This chapter has given an overview of the procedure which has been used to develop an optimum traffic flow distribution model for Dhaka city. Mirpur road, Pallabi to Anandabazar at Gulistan, Kuril to Bijoyshoronee and Kuril to Shegunbagicha had been selected as the four major study routes of this research which is described link wise in the following chapter. Some other secondary roads which are parallel/connector/link road to the major study routes and can play important role as an alternative route are also showed in the next chapter.

CHAPTER 4

Study Area Profile

4.1 Introduction

Major arterial roads of Dhaka city has been considered as study area for the research. These roads have been divided into links based on major intersections on those roads. The major roads are Mirpur road, Pallabi to Anandabazar (via Agargaon, Bijoyshoroni, Karwan bazaar, Shahbagh, Shegunbagicha, Gulistan), Kuril to Bijoyshoroni (via Mohakhali, Jahangirgate) and Kuril to Shegunbagicha (via DIT, Mouchak, Kakrail). Figure 4.1 shows the selected major roads of the study which latter have been categorized into four major routes, shown in Figure 4.2 and 4.4. The divided links of these major four routes have been shown in Figure 4.3 and 4.5.

4.2 Selected major roads

Roads have been selected focusing the fact that these can reflect the overall traffic environment scenario of Dhaka city. Major arterial roads of Dhaka have been selected for research purpose. The Mirpur Road (from Technical Morh to Azimpur), Mirpur road (from Pallabi to Mirpur-10 roundabout), Rokeya Shoroni (from Mirpur 10 to Bijoy Shoroni), Airport Road (from Kuril to Anandabazar, Gulistan via Mohakhali, Farmgate, Karwan Bazar, Shahbagh, Motshobhobon Kodom Foara), Progoti Shoroni, DIT, Mouchak to Kodom foara have been selected for the study. To make detail analysis and get better traffic-environment scenario these major roads have been divided into links with major signals on those. At those major signals, traffic flow merges or diverges into or from the selected roads. The major roads have been considered into four major routes. The divided links of these selected routes are listed in Table 4.1.

Photo 4.1: Link 10 (Science lab signal to New market signal) along Route 01 (Mirpur Road)
Source: Field survey, 2014

Photo 4.2: Link 9 (Russel square signal to Science lab signal) along Route 01
Source: Field survey, 2014

Photo 4.3 and 4.4: Link 7 (Karwan bazaar_SAARC foara to Shahbagh) along Route 02 (Pallabi to Anandabazar)
Source: Field survey, 2014

Photo 4.5: Link 2 (Banani rail crossing to Banani DOHS) along Route 03 (Kuril to Bijoyshoroni)
Source: Field survey, 2014

Photo 4.6: Link 3 {Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)} along Route 04 (Kuril to Shegunbagicha)
Source: Field survey, 2014

Table 4.1: Selected Major Roads and Their Divided Links

Selected Major Roads	Divided Links	Length of the Road Links (Km)
Route 1 Mirpur Road From: Technical Morh Via: Shyamoli, Asadgate, Dhanmondi, New market area To: Azimpur Signal	Link 1 (R1): Technical Morh to Shyamoli cinema hall signal	1.60
	Link 2 (R2): Shyamoli cinema hall signal to Agargaon shishumela signal	0.25
	Link 3 (R3): Agargaon shishumela signal to Residential model college corner (north)	0.62
	Link 4 (R4): College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road	0.47
	Link 5 (R5): Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal	0.49
	Link 6 (R6): Asad gate signal to Lalmatia signal infront of Aarong	0.26
	Link 7 (R7): Lalmatia Aarong signal to Dhanmondi 27 signal	0.21
	Link 8 (R8): Dhanmondi 27 signal to Panthapath Russel square signal	0.65
	Link 9 (R9): Russel square signal to Science lab signal	1.5
	Link 10 (R10): Science lab signal to New market signal	0.73
	Link 11 (R11): New market signal to Azimpur signal	0.62
Route 2 Pallabi to Anandabazar at Guslistan Via: Mirpur 10, Agargaon, Bijoyshoroni, Farmgate, Karwan bazaar, Shahbagh, Shegunbagicha	Link 1 (R1): Pallabi Shoronee 11 to Mirpur 10	1.97
	Link 2 (R2): Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school	3.57
	Link 3 (R3): Agargaon to Bijoy shoroni	1.34
	Link 4 (R4): Bijoy shoroni	0.55
	Link 5 (R5): Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal	0.59
	Link 6 (R6): Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara	1.08
	Link 7 (R7): Karwan bazaar_SAARC foara to Shahbagh	1.37
	Link 8 (R8): Shahbagh to Motsho bhaban	1.00
	Link 9 (R9): Motsho bhaban to Kodom foara	0.43
	Link 10 (R10): Kodom foara to Anadabazar_Gulisthan	0.61

Route 3 Kuril to Bijoy Shoroni Via: Mohakhali, Jahangirgate	Link 1 (R1): Kuril to Banani rail crossing	2.43
	Link 2 (R2): Banani rail crossing to Banani DOHS	1.70
	Link 3 (R3): Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)	1.51
	Link 4 (R4): Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate	1.26
	Link 5 (R5): Jahangir gate to Bijoy shoronee_Novo theatre signal	1.21
Route 4 Kuril to Shegunbagicha Via: DIT, Mouchak Morh, Shantinagar, Kakrail	Link 1 (R1): Kuril to Bashundhara residential area entrance	0.096
	Link 2 (R2): Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)	2.60
	Link 3 (R3): Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)	2.04
	Link 4 (R4): Rampura TV Bhaban to Hatirjheel connecting road point	1.35
	Link 5 (R5): DIT (Hatirjheel connecting road point to Malibagh rail crossing)	2.27
	Link 6 (R6): Malibagh rail crossing to Mouchak Morh	0.45
	Link 7 (R7): Mouchak Morh to infront of Polwel gas station at Outer circular road	0.27
	Link 8 (R8): Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road	0.91
	Link 9 (R9): Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha	0.88

Source: Jahan, J. (2013)

4.3 Selected secondary roads

Some other secondary roads which act as connector or link road or parallel road to the above major four routes have been also taken under study area. These secondary associated roads can play important role as an alternative route to the vehicle users if needed namely Sat Masjid Road (parallel to Mirpur road), Panthapath (connector/link road to Mirpur road), Farmgate – Manikmia Avenue (parallel to Mirpur road),

Agargaon-Prime Minister Office Link Road (parallel/connector to Pallabi-Anandabazar route), New Eskaton Road (parallel/connector to Pallabi-Anandabazar route), Tongi diversion road (parallel to both the routes; Kuril-Bijoy Shoroni and Kuril-Shegunbagicha), Sayad Mahbub Moreshed Avenue (IDB-Shymoli), Green Road (parallel to Mirpur road), Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco), Hatirjheel Link road (parallel to Kuril-Shegunbagicha) and Matikata road (infront of Banani, Raddison to Pallabi, Mirpur) / Mirpur flyover (parallel/connector to Kuril-Bijoy Shoroni) etc. Also it can be said that both route 01 and 02; Mirpur Road and Pallabi-Anandabazar route are alternative routes to each other. Figure 4.6 shows the location of selected alternative secondary roads with four major study routes.

Table 4.2: List of alternative roads

Study Route	Name of Alternative Road	Length of alternative road (km)
Parallel to Route 01	Sat Masjid Road	5.029
Connector between Route 01 & 02	Panthapath	1.62
Connector between Route 01 & 02	Farmgate – Manikmia Avenue	1.64
Connector between Route 02 & 03	Agargaon-Prime Minister Office Link Road	2.91
Connector to Route 02	New Eskaton Road	1.96
Parallel to Route 03 & 04	Tongi diversion road	4.77
Connector between Route 01 & 02	Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	1.43
Connector between Route 01 & 02	Green Road	2.12
Connector to Route 02	Bijoy sharani- Tejgaon link road (Rangs Bhaban-Nabisco)	0.75
Parallel to Route 03 & 04	Hatirjheel Link road	5.00
Connector between Route 02 & Route 03	Matikata road (infront of Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]	4.5
Route 1 can be used as alternative road of Route 2 and vice versa		

Source: Road length calculated using GIS

Photo 4.7: Access/connector road to Route 01 with Green road at Dhanmondi 03
Source: Field survey, 2014

Photo 4.8: Meeting point of Green road with Route 01 (Mirpur road) at Science lab
Source: Field survey, 2014

Photo 4.9: Panthopath act as a connector road between Route 01 and 02 (Pallabi to Gulistan)
Source: Field survey, 2014

Photo 4.10: Access/connector road to Mirpur road with secondary alternative road Saat Masjid road at Dhanmondi 27
Source: Field survey, 2014

4.4 Divided Traffic Analysis Zones

For convenience in data handling and analysis total study area has been divided into eight traffic analysis zones (TAZ). These are namely Mirpur, Mohammadpur, Dhanmondi, Old Dhaka, Motijheel, Tejgaon/Farmgate, Banani/Gulshan, Uttara/Tongi and others. Detail description has been given on TAZ in the following chapter.

4.5 Summary

This chapter carries out brief description of the study routes. Mirpur road, Pallabi to Anandabazar at Gulistan, Kuril to Bijoyshoronee and Kuril to Shegunbagicha were selected as the major study routes for this research. The next chapter gives direction for data analysis through giving details about data collection and survey findings.

Figure 4.4: Selected Four Major Study Routes within DCC Area

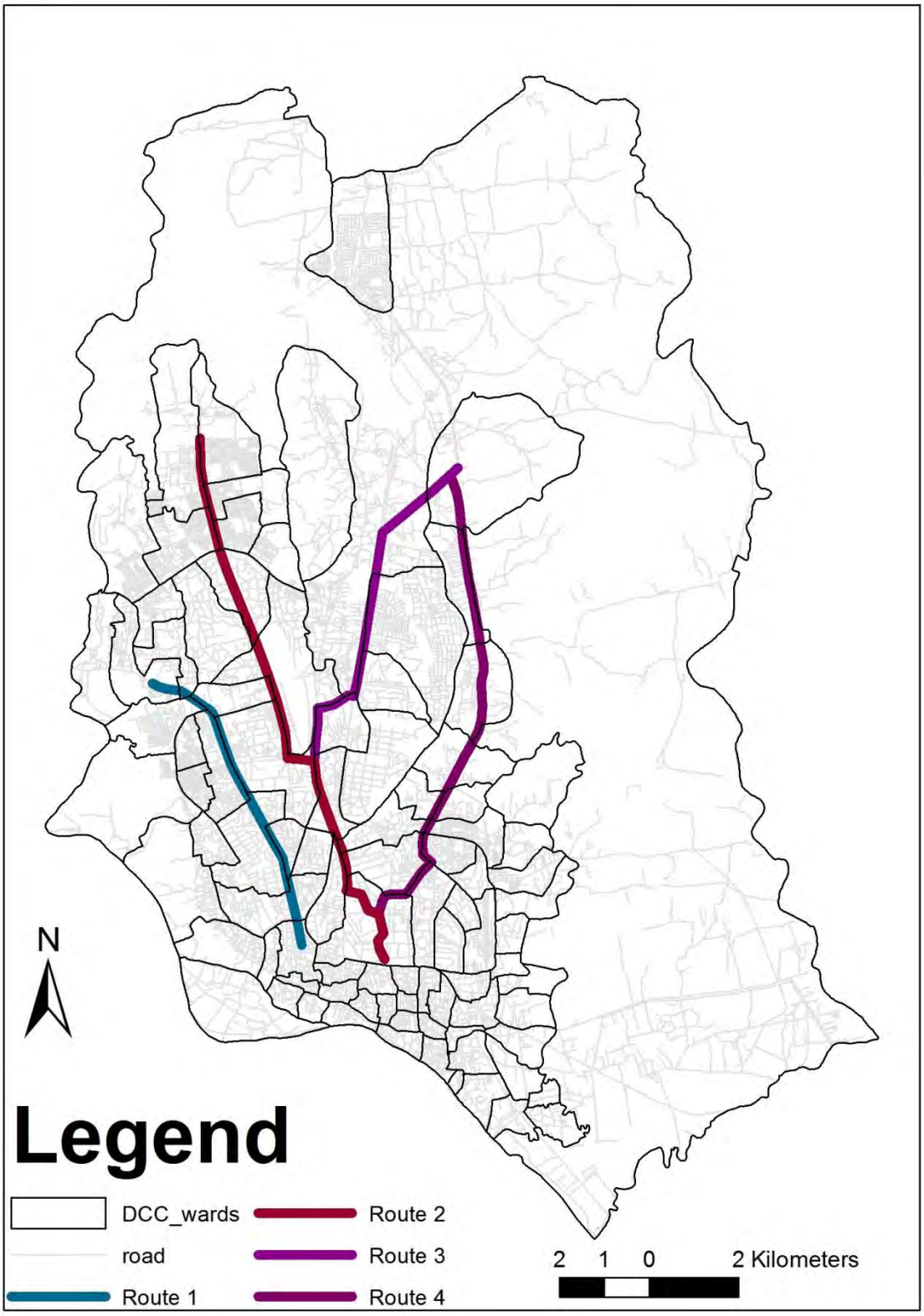


Figure 4.5: Selected 35 Links along Four Major Study Routes

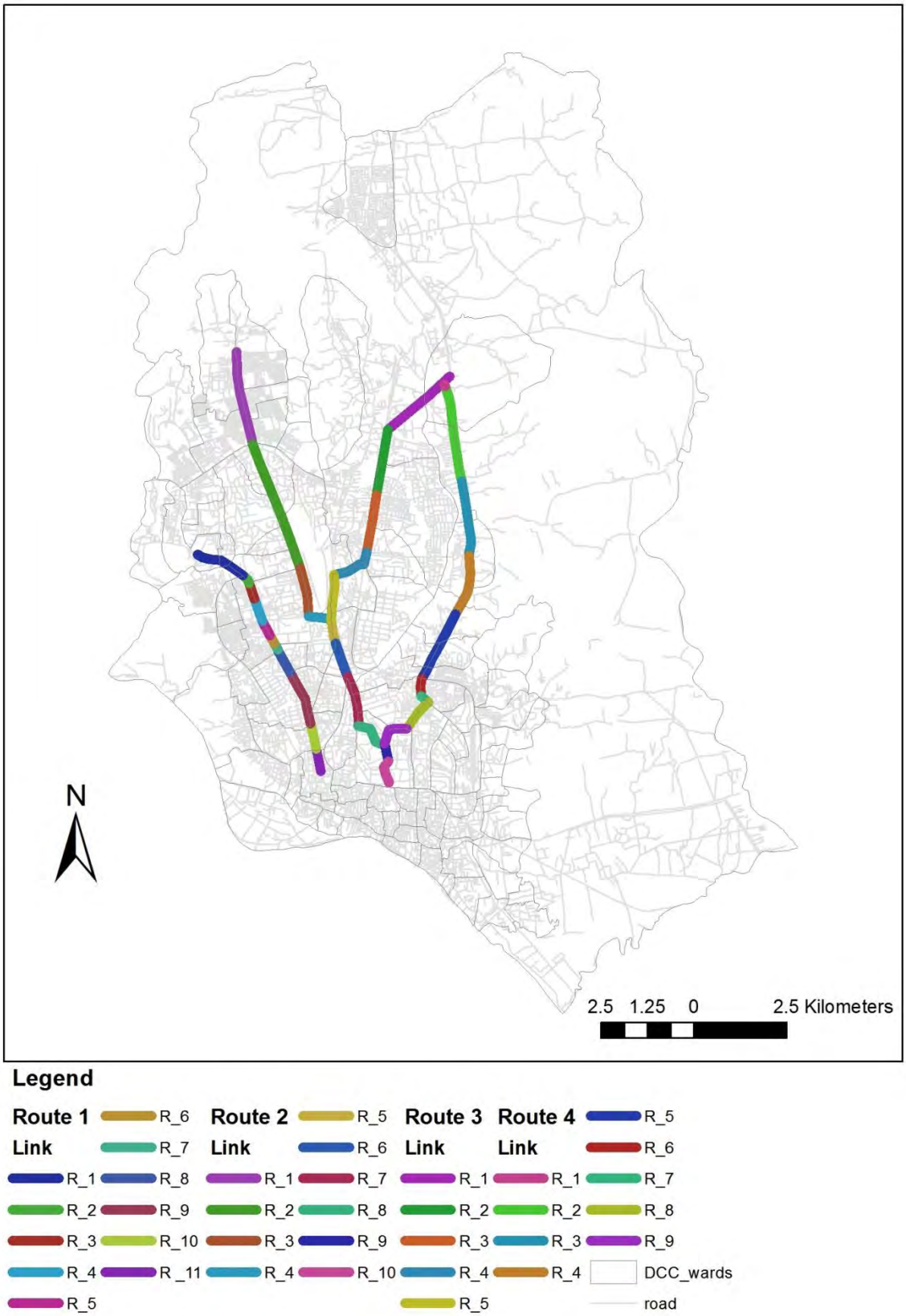
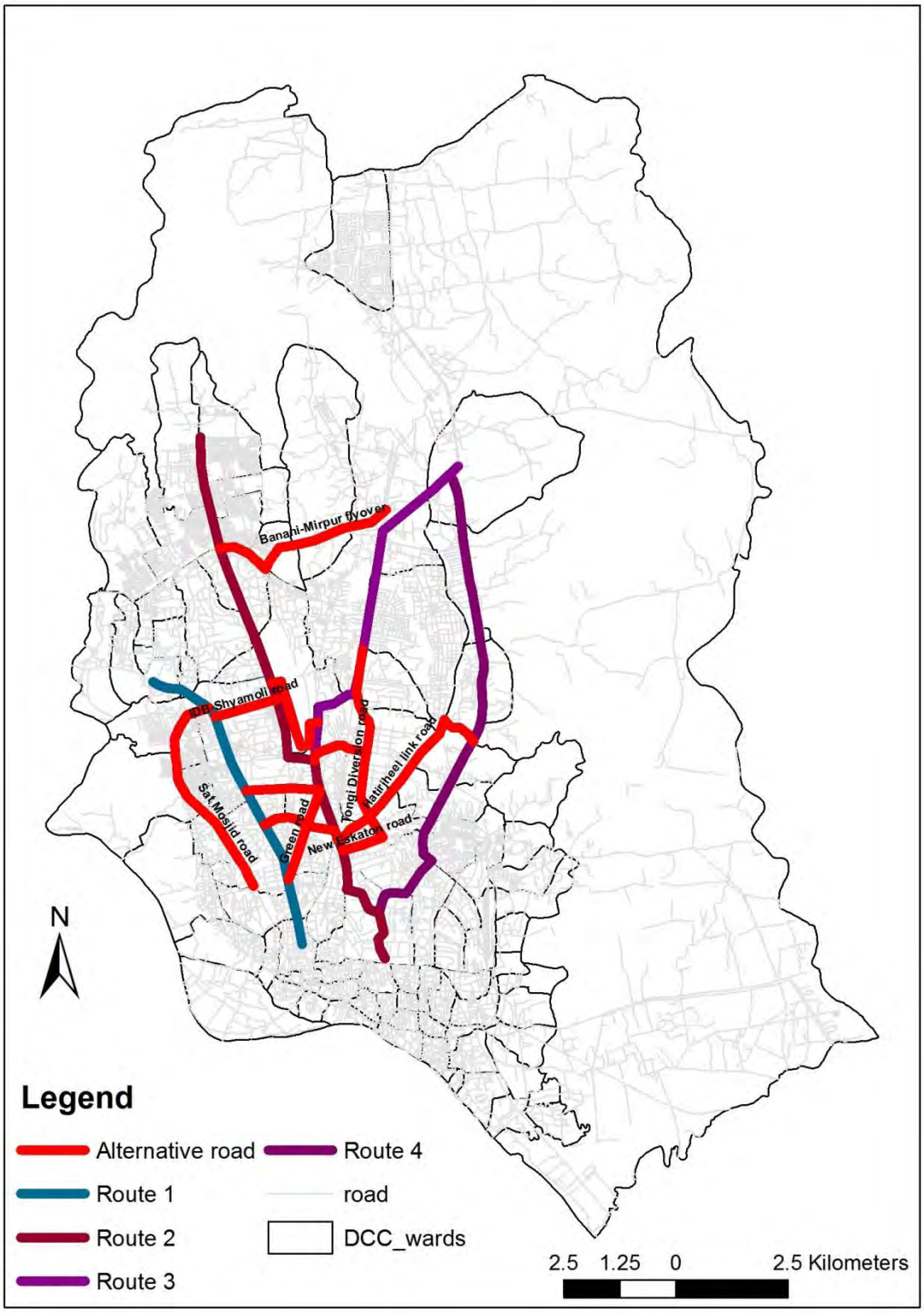


Figure 4.6: Selected Alternative Secondary Roads along with Major Study Routes



CHAPTER 5

Data Collection and Processing

5.1 Introduction

This chapter comprises the detail process of data collection and survey findings from cordon (O-D) survey, traffic volume survey and carriageway width survey. This chapter mainly focuses on giving direction for analysing the survey data to achieve the objectives of the research.

5.2 Detail process of data collection

Data types and data sources which are needed for accomplishing this research has already been discussed in the third chapter titled "Methodology and Study design". Both primary and secondary data are needed for this study. Detail process of only primary data collected from Origin-Destination survey which is the most prominent field work of this research has been discussed here in this section.

5.2.1 Origin and Destination surveys

Through origin and destination travel surveys, data on the origin and destination of all trips, trip purpose, travel time and length of trip, mode of travel, and the land use at the points of origin and destination. This information serves as the basis for predicting the demand levels and flow patterns of future travel. O-D survey measures a representative sample of the trips that originate with or pass through along four major arterial study routes of DMA (Dhaka Metropolitan Area). For convenience total study area has been divided into seven Traffic Analysis Zones (TAZs).

Table 5.1: Divided Traffic Analysis Zones

Name of TAZ
Mirpur
Mohammadpur
Dhanmondi
University or Old Dhaka
Motijheel
Tejgaon/Farmgate
Banani/Gulshan
Tongi/Uttora

Three types of vehicular trips: 1) trips made by commercial vehicles from outside the area (external trips), 2) those made by commercial vehicles within the area (internal commercial) and 3) those made by vehicles occupied by persons who reside in the area (internal residential).

5.2.2 Types of travel survey: Cordon survey

The cordon survey has been conducted as one of the typology of travel survey to inventory external travel in this study. At the first step in this survey, a cordon line is drawn about the study area. All roads which cross the cordon line are listed. Traffic volume data for these roads were collected from secondary source. According to principle of cordon survey, the most heavily travelled roads are interviewed for a 24 hour period, less heavily travelled roads for 16 hours and minor roads for some 8 to 12 hours. Generally a sufficient volume must pass through the interviewing stations to equal about 90 to 95 % of the total average daily traffic crossing into the study area. Only a representative sample of the vehicles (20 to 35 %) that cross through the cordon need be interviewed for trip data (Dickey, 1980). Due to limited man power and shortage of time, variable rate sampling method has been employed in this study to conduct survey and only during peak hour (both morning and evening) data for 8 hours daily have been collected. As evening peak hour data was found to be mainly for return trip for this reason only morning peak hour vehicle trip has been considered for further analysis. Details have already been discussed in Methodology chapter. Vehicles are stopped at the interviewing station and the drivers questioned as to their origin, destination, and trip purpose, land use at origin and destination, and number of occupants inside the vehicle.

5.3 Survey findings

Exact primary (field) survey findings from Cordon (O-D) survey, Traffic volume survey (only NMT along major roads and all vehicle classes along some (five) secondary alternative roads) and Carriageway width survey have been attached within appendix B. Output matrix from O-D survey has been attached within appendix C. Other secondary survey findings: traffic volume along major roads (only MT) and

traffic volume along some (six) secondary roads (both MT and NMT) are also being attached within appendix B.

5.4 Direction for analysing the survey data/data processing

From cordon (O-D) survey data vehicle class wise data on number of occupants, zone of origin with specific land use, zone of destination with specific land use, trip purpose , intermediate stop with stop address, preferred alternative mode and route (if any) have been retrieved along the study routes (link wise). As travel behaviour analysis and travel/land use demand calculation is the main task to achieve the first objective of the study, the following aspects can be important for analysing O-D survey data.

- Land use demand calculation: demand of specific land use/dominance of specific kind of land use/zone with specific purpose (highest number of trip making to specific destination zone/land use with specific trip purpose)
- Percentage of vehicles (mode wise) going into which direction (both origin and destination: zone wise)
- Travel behaviour analysis of vehicle users

Some hypothesis can be formulated under travel behaviour analysis of different vehicle modes:

- Private car users are satisfied with their present mode, not interested to shift any other mode.
- Bus, CNG, Taxi and other public transports are running along a specific route every day, not interested to shift to other alternative route to reach their original destination.
- Most of the trips are work based trip and some are education based trips, trip made with visit and travel purpose are found occasionally.
- Most of the private cars are found to make return trip from destination.
- Passenger occupancy of private cars is low in most of the time.
- Most of the NMT (Rickshaw) trips are intra zonal trip (short distance trip). Rickshaw trip both starts and ends within particular route.

- Most of the private cars are going into specific zone like Dhanmondi, Bonani, Gulshan and Uttora zone.
- Most of the public vehicles (especially buses) are serving along specific routes like Route 01 (Mirpur road) and Route 02 (Pallabi to Anandabazar at Gulistan).
- Most favourite route for private car is Route no. 03 (Kuril to Bijoyshoroni).
- Most favourite route for public bus is Route no. 02 (Pallabi to Anandabazar at Gulistan) especially link no. 1 & 2 of route 02 (Rokeya shoronee Mirpur 10, Pallabi shoronee 11 etc.).
- Link no. 02 (Banani rail crossing to Banani DOHS) of Route 03 (Kuril to Bijoyshoroni) face congestion because of excessive no. of cars.
- Leguna/Tempo/HH are mainly found on the later part of Route no. 04 (Kuril to Shegunbagicha) (Link of Malibagh rail crossing to Mouchak Morh, DIT etc.: Link no. 5, 6, 7).
- Private car is increasing in number from Hatirjheel connecting road point to Kuril (from Link 1-5) along Route no. 04 (Kuril to Shegunbagicha).
- Route 03 totally emphasizes private car ownership and there is complete ban of NMT along all the links.
- NMT is seen running on some parts of Route 01, 02 and 04.
- Missing value for intermediate stop related information for all the modes especially public transport modes.
- Willingness to shift to alternative other modes and other routes (for each category vehicles)

From the traffic volume data through applying emission factor and emission standard according to ECR, 1997; emission wise optimum traffic volume and additional traffic volume for each link along four major arterial routes can be computed. Also from field survey carriageway width data has been collected. Then data can be analysed as follows:

- Route wise comparison of total pollution traffic flow and non-polluting traffic flow
- Link wise inter comparison between traffic flow along specific route considering emission standard

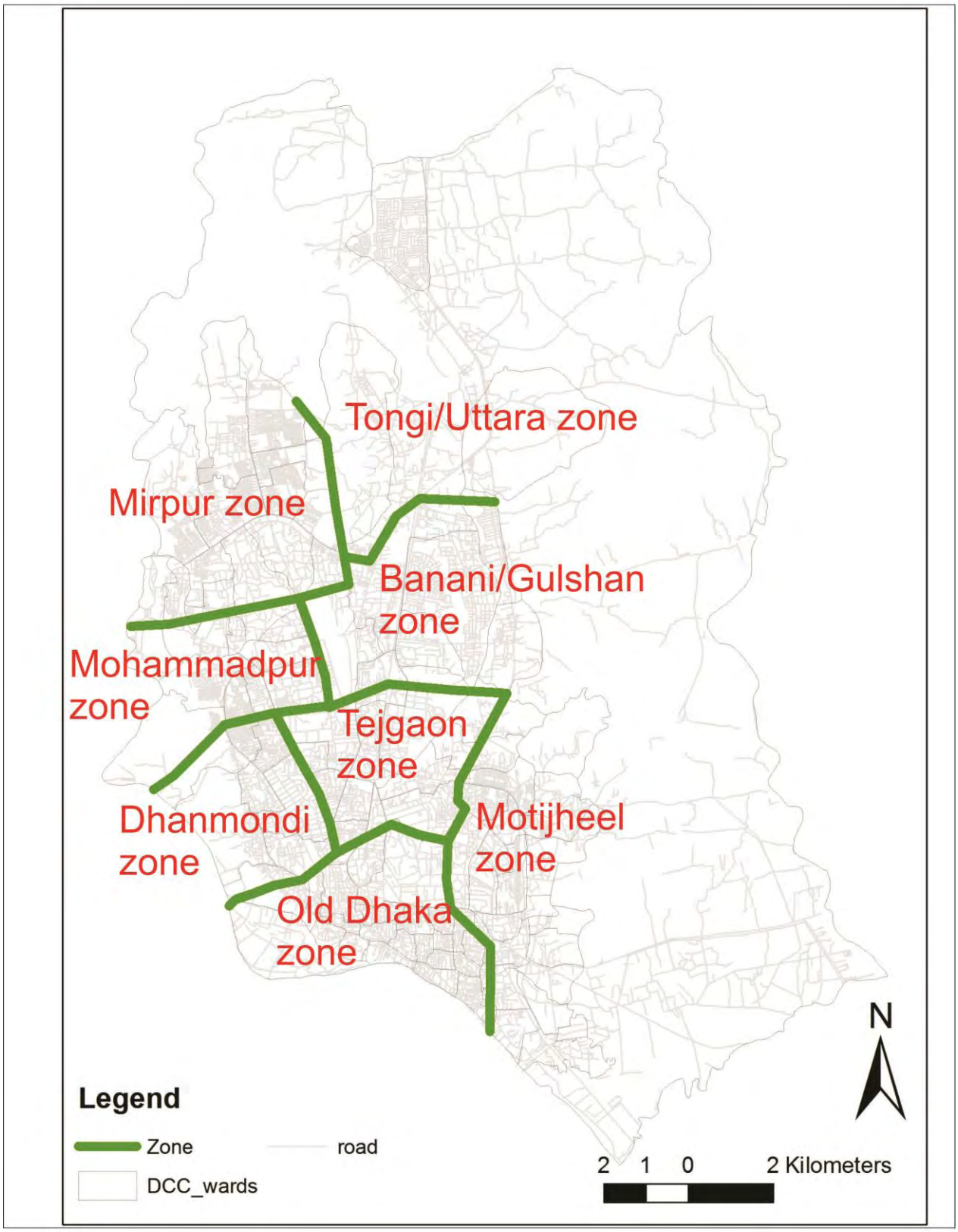
- Route wise deviation of total effective capacity from original capacity provided
- Link wise total effective capacity along each study route
- Analysis of existing traffic flow and effective roadway capacity
- Comparative scenario building for existing traffic flow in consideration with both criteria (both link and route wise)
- Final optimum traffic flow and additional (shifting) traffic flow satisfying both criteria

  In a similar way, from traffic volume data and carriageway width survey, determination of optimum traffic volume for secondary alternative roads can be done.

5.5 Summary

In this chapter mainly various aspects and scopes for analysing the dataset collected from both primary and secondary sources have been discussed. Already in the methodology chapter data processing tools and soft wares have been mentioned broadly. From the following chapter data analysis portion of the study will be started and the immediate following chapter explores travel demand and travel behaviour of both vehicle modes and vehicle users which is one of the major parts of the study.

Figure 5.1: Divided Traffic Analysis Zones (TAZ) for the Study



CHAPTER 6

Estimation of Travel Demand and Travel Behaviour Analysis

6.1 Introduction

Land use demand estimation and travel behaviour analysis of vehicle users have been conducted in this chapter. Existing travel demand along four major arterial routes within Dhaka City Corporation (DCC) area has been explored through conducting Cordon survey (Origin-Destination survey) along these routes. From travel demand estimation, dominance of specific Traffic Analysis Zones (TAZ) as origin and destination of most of the trips made has been identified. Vehicle mode wise dominance of TAZ has also been identified. Calculation of land use demand for different TAZ has also been done. From O-D survey findings output matrix has been developed consisting percentage of vehicles starting from which origin and going into which destination to serve specific purpose along each of the thirty five study links. Besides this, route identification for each category vehicle (% of vehicle classes going into which destination along specific route) has also been shown in this chapter. Also travel behaviour analysis has been conducted under the study. Some hypothesis has been formulated on both travel demand estimation and travel behaviour of vehicle users. Some of the null hypotheses are rejected after the analysis and some are proved as true null hypothesis. Under travel behaviour analysis; trip purpose analysis, analysis on vehicle occupancy rate, evaluation of preferred alternative routes and alternative travel modes has been conducted. Some route wise discrimination among different vehicle modes were also being found after the analysis.

6.2 Estimation of travel demand

For convenience we have divided the total study area into eight traffic analysis zones (TAZ). These are namely Mirpur, Mohammadpur, Dhanmondi, Old Dhaka, Motijheel, Tejgaon/Farmgate, Banani/Gulshan, Uttara/Tongi and others. These are some broader zones to conduct zone wise analysis and to identify predominance of TAZs as vehicle trip origin and vehicle trip destination both. But while collecting data, specific area/address for origin and

destination has also been asked by the interviewers so that with the help of area wise origin-destination data and purpose of each trip, reasons behind dominance of a particular area/zone can be identified. From this analysis demand of particular area because of specific land use category has been identified. Also the reasons of excessive pressure of vehicle trips along some routes and within some areas with highly demanding land uses have been explored in this section of the chapter.

6.2.1 Identification of dominant Traffic Analysis Zones

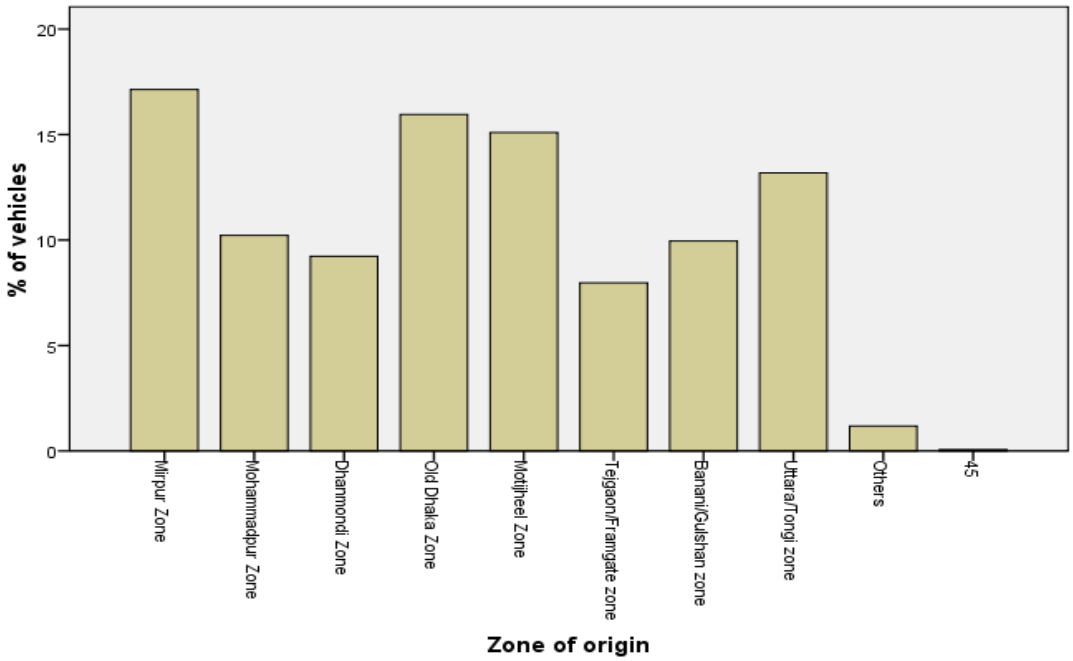


Figure 6.1: Distribution of Traffic Analysis Zones as place of origin of trip

From the two figures (6.1 and 6.2) distribution of TAZs can be seen as both places of origin and destination of the trips made along four major arterial study routes. As place of origin Mirpur zone plays most dominant role and on the other hand, Motijheel zone is found as the most prominent zone as place of destination. One of the basic reasons of this finding can be explained with the notion that huge number of offices and commercial establishment existed within Motijheel zone and most of the trips were found to be as work based trip in the peak congested traffic hours. Besides Motijheel zone also considered as CBD (Central Business District) area for Dhaka city, so it's very obvious that most of the work based trips choose this particular zone as destination zone. In the other side though Mirpur is a mixed use zone but mostly used as residential purpose. Also as a place of origin among all the trips considered under this study

Tejgaon/Farmgate zone shows the lowest value and as destination, Mohammadpur zone shows the lowest value. As Tejgaon zone was at the initial period was recognized as an industrial area and Mohammadpur zone is predominantly a residential area so this findings can be said as appropriate though in present day Dhaka city's growth pattern context, both the zones are mixed use zones.

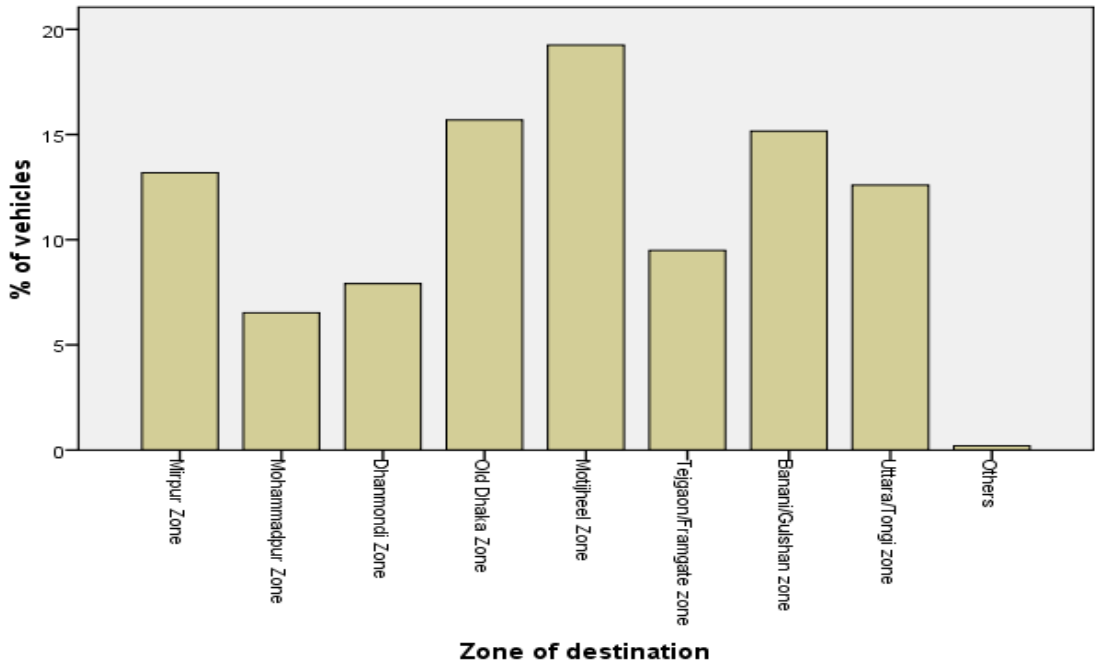


Figure 6.2: Distribution of Traffic Analysis Zones as place of destination of trip

6.2.2 Mode wise dominance of traffic analysis zone

In the previous two figures overall distribution of both place of origin and destination zones have been given. But vehicle wise distribution is more important for exploring travel demand more clearly. In the following figure, number of each category vehicle coming from different origin zones has been depicted running along all four major arterial routes. For private car, Old Dhaka zone is most prominent as a place of origin and Tejgaon/Farmgate zone originates least number of trips made by car. Dhanmondi and Motijheel zone hold the second highest share as origin for trips made by car. Uttara zone also found to play important role as a place of origin for private car. Surprisingly Banani/Gulshan zone lags by a little margin from the abovementioned zones as a place of origin for trips made by car.

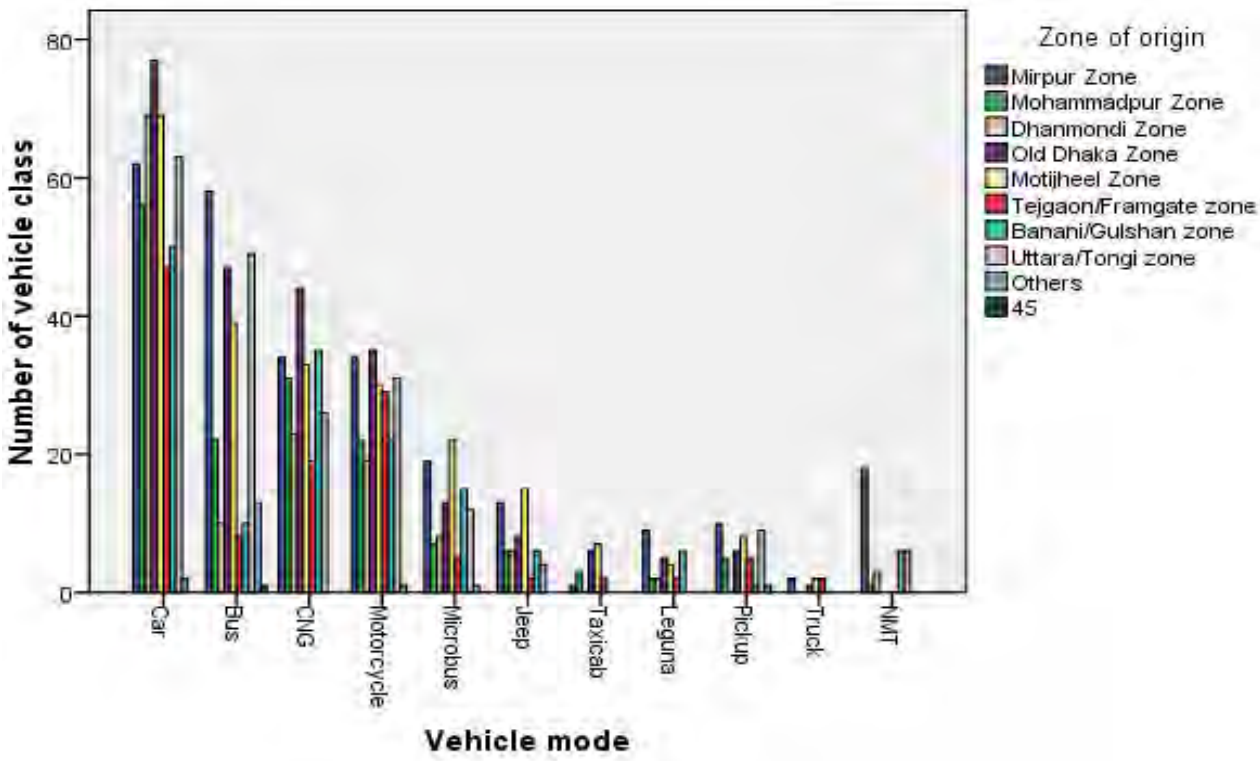


Figure 6.3: Mode wise Vehicle trip distribution of origin zone

Highest number of Public bus trips originates from Mirpur zone and lowest number of trips by bus originates from Tejgaon/Farmgate. We all know that Mirpur zone possess a very good quality public bus service and originate a huge number of buses from here every day, it's quite natural to have Mirpur as originating highest number of bus trips from here. Old Dhaka and Motijheel zone was found to receive highest bus trips as destination. For Non-motorized traffic (NMT), vehicle share is very low in compare to some other vehicle modes as some of the study links and routes are totally banned for NMT. For NMT, Mirpur zone contribute highest number of trips as both origin and destination (in figure 6.3). From the following figure (fig. 6.4), we can see Dhanmondi and Uttora zone as destination zone contributes nil to NMT trips. Mohammadpur and Old Dhaka surprisingly contribute very little as destination zones for trips made by NMT whereas Banani/Gulshan zone found as destination zone for a few number of trips made by NMT.

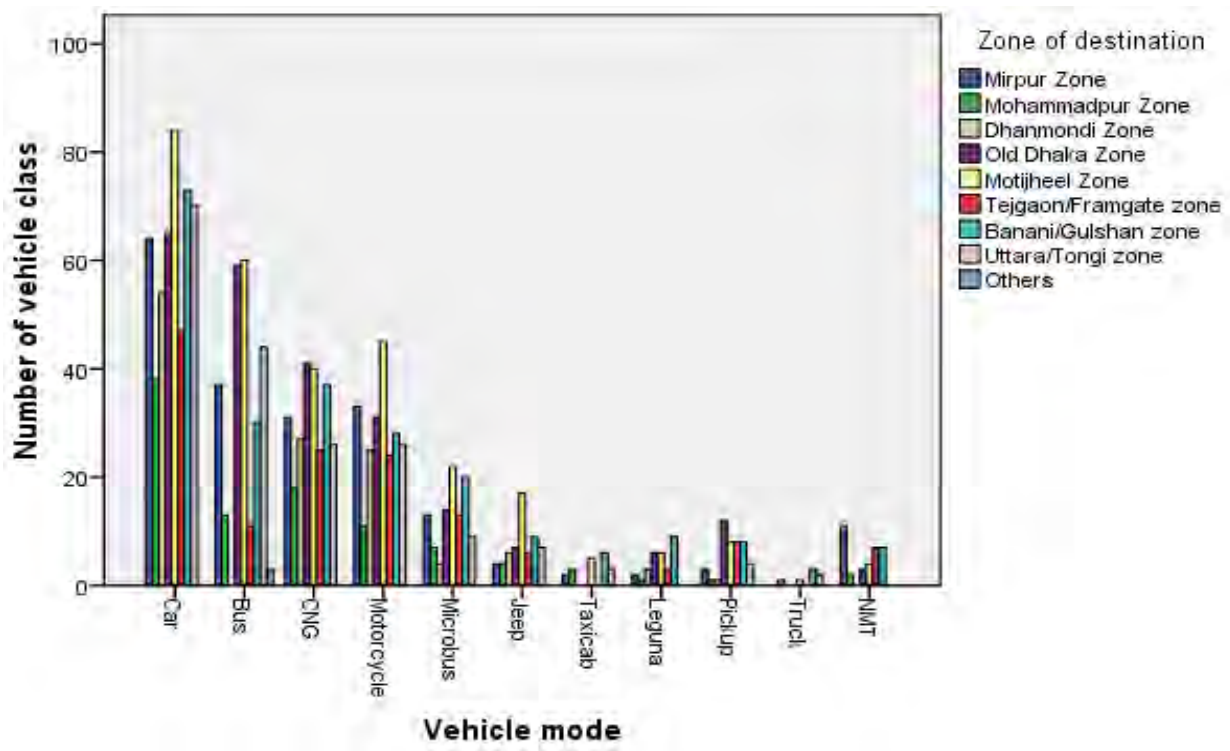


Figure 6.4: Mode wise Vehicle trip distribution of destination zone

As previously said we have assumed some hypothesis before analysing travel demand. In this chapter, with relevance to each figure, hypothesis is mentioned one by one. In this context our first hypothesis was as follows:

Null hypothesis 01: Most of the private cars are going into specific zone like Dhanmondi, Banani, Gulshan and Uttara zone.

From the abovementioned figure it can be said that Null hypothesis is rejected as most of the cars have their destination zone as Motijheel. But if we analyse further as destination zone of trips made by car the next two positions are hold by Banani/Gulshan and Uttara/Tongi zone. So it can be said that Null hypothesis is not fully rejected but partially accepted.

For Public bus Motijheel zone contributes highest as a place of destination. In parallel Old Dhaka, Uttara/Tongi and Mirpur zone also serves well as a destination zone for trips made by bus. As Mirpur zone is a potential zone for both origin and destination place for bus, so this outcome is expected. Another hypothesis for the study was as follows:

Null hypothesis 02: Most of the public vehicles (especially buses) are serving along specific routes like Route 01 (Mirpur road). It can be said that this hypothesis may be true/partially true as Mirpur zone contributes highly as both places of origin and destination for trips made by bus. But that does not mean always that public bus mostly run along Mirpur road. When analysis can be solely done on identification of favourite route of Bus among four major routes then the actual scenario will be depicted (see section 6.5 of this chapter).

Except CNG Auto rickshaw and Motorcycle, other vehicle classes are not found in a significant amount from volume survey along the study routes so that sample size for O-D survey is also small for those vehicle classes. Though NMT is found in a significant amount along some specific links of the study routes but as NMT is banned within some links with complete ban along route 03, for this reason overall share of NMT in sample size also is poor in compare to bus, car and some other vehicle modes.

6.2.3 Demarcation of land use demand for different TAZ

From the above analysis we can see vehicle mode wise zonal contribution/dominance as origin and destination places. But actual demand of any zones as destination place cannot be assessed in this way. Major reason of choosing a particular zone as destination by a vehicle is mainly because of its trip purpose.

Table 6.1 (A): Destination zone wise distribution of trip purpose

Destination zone	Trip purpose									Total
	Work Trip	Educational purpose	Visit	Medical	Travel	Return trip	Shopping	Recreation	Others	
Mirpur Zone	61.6%	15.9%	10.4%	.6%	.6%	7.9%	1.2%	1.8%		100%
Mohammadpur Zone	54.0%	13.8%	17.2%	3.4%	5.7%	3.4%	2.3%			100%
Dhanmondi Zone	54.4%	27.2%	9.6%	.9%	.9%	2.6%	4.4%			100%
Old Dhaka Zone	57.7%	22.3%	10.3%	5.7%	1.7%	1.1%	1.1%			100%
Motijheel Zone	77.5%	13.1%	4.7%		2.1%	1.7%			.8%	100%
Tejgaon/ Farmgate zone	84.4%	5.9%	5.2%	.7%	.7%	2.2%			.7%	100%
Banani/ Gulshan zone	74.9%	9.9%	7.4%		1.0%	5.4%	1.0%	.5%		100%
Uttara/Tongi zone	62.8%	14.1%	9.6%	1.9%	.6%	7.1%	1.9%	1.9%		100%

**colour percentage vehicle trips show destination zone wise highest and lowest no. of trips with specific purpose*

From the above table (6.1: A) it can be clearly understood that almost all destination zones got most of the vehicles for work purpose as this trip purpose shows dominant share for all the zones. As survey was done in congested morning peak hour of weak days so this result was expected. But from the findings it can be said that if office, industry and other work areas are not distributed in a scattered way along all the zones and if specific areas/zones are built as work zones then definitely travel demand can be reduced and for work purpose vehicles don't have to go to all the zones but only a few zones (work zone) receive dominant share form vehicles for work trip. Among all the vehicle trips Mirpur zone receives, highest trip for work purpose (61.6%) and lowest trip share (0.6%) for both medical and travel purposes are being found. Mohammadpur zone also receives highest percentage of trip for work purpose (54%) and lowest vehicle trips (2.3%) for shopping purpose. Dhanmondi zone receives a significant portion of education based trip also as many educational institutes are built up here within the zone breaking the initial residential character of that zone. Motijheel zone receives a very limited number of vehicle trips with return purpose as it's a CBD area and return trip mainly ends at residential zone. After work trips (57.7%) Old Dhaka zone receives huge amount of traffic (22.3%) with education purpose as some renowned public universities and schools are located here within the zone. In the figure below the similar findings has been shown through graphical representation. Within each zone percentage distribution of various trip purposes has been shown. From this, prominent land use category within a zone has been identified and land use demand demarcation separately for each TAZ has been achieved.

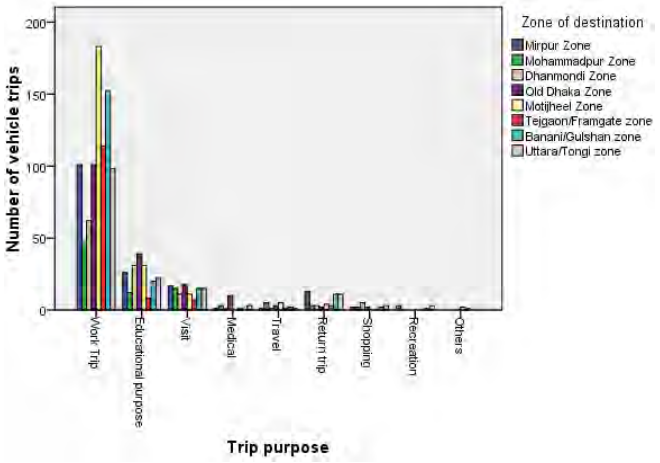


Figure 6.5: TAZ wise demand demarcation according to trip purpose

Table 6.1 (B): Determination of priority land use among all TAZs

Trip purpose	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Work Trip	11.8%	5.5%	7.2%	11.8%	21.3%	13.3%	17.7%	11.4%	100.0%
Educational purpose	13.8%	6.3%	16.4%	20.6%	16.4%	4.2%	10.6%	11.6%	100.0%
Visit	15.6%	13.8%	10.1%	16.5%	10.1%	6.4%	13.8%	13.8%	100.0%
Medical	5.3%	15.8%	5.3%	52.6%		5.3%		15.8%	100.0%
Travel	5.3%	26.3%	5.3%	15.8%	26.3%	5.3%	10.5%	5.3%	100.0%
Return trip	26.0%	6.0%	6.0%	4.0%	8.0%	6.0%	22.0%	22.0%	100.0%
Shopping	12.5%	12.5%	31.3%	12.5%			12.5%	18.8%	100.0%
Recreation	42.9%						14.3%	42.9%	100.0%
Others					66.7%	33.3%			100.0%
	12.9%	6.9%	9.0%	13.8%	18.6%	10.6%	16.0%	12.3%	100.0%

**Highlighted vehicle trips denote highest demand of specific land use category for each zone among all the TAZs*

From the table (6.1: B) above it can be interpreted that among all the vehicle trips going into all destinations for work purpose, Motijheel zone receives highest amount of vehicle trips (21.3%). This finding is very much expected as Motijheel is the central business zone or CBD area for Dhaka city. Dhanmondi and Motijheel zone receives the second highest percentage (16.4%) of education based vehicle trip. As predominantly Dhanmondi was developed as a residential area but with the time being haphazard mixed use development completely changed its character and now it is fully a mixed use zone. This finding on Dhanmondi zone with significant number of vehicle trips for education purpose definitely proves the above statement. On the other hand Motijheel is the central commercial area of the city. But because of unplanned development many educational institutes constructed within the zone. For this significant vehicle trips have to make to Motijheel for education purposes. Old Dhaka zone receives the highest portion of vehicle trip (20.6%) for education purpose. As some renowned public university like Dhaka University, BUET etc. are located within this zone so that this zone faces huge amount of traffic for education purpose. Many private universities, schools, colleges etc. are located within Dhanmondi zone which change its residential character and due to this reason huge number of additional traffic has come to Dhanmondi every day. For medical purpose highest number of vehicles (52.6%) goes to Old Dhaka zone as Dhaka Medical College located here. For travel

purpose most of the vehicle trips go to Mohammadpur and Motijheel zone. Return trip is one of the causes of traffic congestion. From the analysis it has been revealed that among all the return trips made to different destination zones, Mirpur zone receives highest percentage (26%) of return trip. Uttara/Tongi and Banani/Gulshan zone hold the second position jointly to receive return trip (22%). Dhanmondi zone receives highest number of shopping trips (31.3%) among all the shopping trips made by vehicles to all zones and this is a very expected finding as currently huge number of shopping mall and shopping complexes are located within Dhanmondi zone. Uttara/Tongi zone and Mirpur zone receive highest number of vehicle trips (42.9%) for recreation purpose among all recreation trips has been made to all TAZs.

If we conduct an analysis incorporating both destination area and purpose of a specific vehicle trip then distribution of specific trip purpose at exact destination address has been found. Missing values in the database (attached within appendix C) are for public vehicle like bus, HH etc. where specific one trip purpose could not be found. Each row in the database consist data on one vehicle trip. Vehicle mode is not important for this particular analysis.

Under trip purpose variable nine categories (work, educational, visit, medical, travel, return trip/home based trip, shopping, recreation and others) have been included in this study. It is noticeable that every category of trip purpose can be considered as a land use category also or somewhat indicates to specific land use prominence in that particular destination zone.

From table 6.2 particular land use dominance on specific destination address can be identified. Each row of the table indicates percentage of vehicle trips with specific purpose coming into that destination area/address.

From table 6.2 for convenience of understanding following table has been constructed showing land use dominance for those areas which receives highest vehicle trips running for those particular purposes (land use) in compare to other areas.

Table 6.3: Prominent Land use influencing travel demand to specific areas

Area	Dominant Trip purpose (Land use category)
Amtoli	Business (Commercial)
Arambagh	Work (Commercial)
Asadgate	Work (Commercial)
Bonosree	Home based trip (Residential)
Brac, Mohakhali	Office (Commercial)
Dhaka medical	Medical (Hospital)
Dhanmondi 02	Education (School/College/University)
Dhanmondi 32	Return trip (Residential)
Dhanmondi 6	Education (School/College/University)
Elephant road	Work (Commercial)
Fokirapul	Work (Commercial)
Gulshan 01	Embassy
Hatirjheel	Work (Commercial)
Hatirpool	Shopping (Commercial)
Highcourt	Work (Commercial)
IDB	Visit (Residential)
Jhigatola	Visit (Residential)
Kakoli	Return trip (Residential)
Kallyanpur	Travel (Recreation)
Karwanbazar	Work (Commercial)
Kochukhet	Visit (Residential)
Kolabagan	Work (Commercial)
Lalmatia	Work (Commercial)
Manikdi	Visit (Residential)
Mirpur 01	Work (Commercial)
Mirpur 02	Work (Commercial)
Motshobhaban	Work (Commercial)
Mouchak	Work (Commercial)
Nabisco	Work (Commercial)
Nazimuddin road	Visit (Residential)
Niketon	Return trip (Residential)
Nilkhet	Work (Commercial)
Nobabgonj	Work (Commercial)
Pallabi	Visit (Residential)
Poribagh	Work (Commercial)
Pressclub	Work (Commercial)
Rajarbagh	Work (Commercial)
Rampura	Work (Commercial)
Science lab	Work (Commercial)
Shantibag	Visit (Residential)
Shiddeshwari	Education (School/College/University)
Tejgaon	Work (Commercial)

From the table it can be said that most of the areas are dominated by commercial land uses. Some areas are dominated by educational land uses. Residential land uses holds third position in determining trip pattern of vehicles. Some other land uses like recreational land use, hospital, embassy etc. are seen to dominate the travel pattern of vehicles to a specific zone in a very limited manner. Commercial land uses are found as major influencing land use category to direct vehicle trips into specific destination areas. Commercial land uses includes office, industry, shopping mall etc. which are liable for the majority vehicle trips in Dhaka city. If these dominating land uses are located within specific zones instead of scattered establishment of these land uses, then travel demand can be reduced to a significant level and traffic congestion can definitely be lessened up to a tolerable limit.

6.3 Development of Origin-Destination Matrix for route identification of vehicular trip

Besides travel demand analysis, route identification for vehicle trips is very much important for this research as determination of optimum traffic volume and assignment of additional traffic along alternative routes are another two objectives of this study. In this context it is very essential to explore the route through calculating percentage of vehicle trips with both origin and destination zone along all the study links (appendix C) and along four major routes (see from table 6.8-6.12). Also calculation of percentage of different category vehicle trips going into which destination along four major routes (see from table 6.4-6.7) are also important for vehicle mode wise route identification. After identifying the route it will be very much easier to assign additional traffic volume along alternative routes in order to make reach those vehicles to their original destination.

6.3.1 Vehicle mode wise route identification

Under section 6.2.2 of this chapter overall vehicle mode wise distribution to destination zone along all the routes has been observed. Here percentage of vehicle classes going into which destination along different routes has been analysed.

Table 6.4: Percentage distribution of vehicle trip (mode wise) to destination zone along Route 01

Vehicle mode	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	**Total**
Car	17.8%	15.8%	21.8%	23.8%	5.9%	7.9%	4.0%	3.0%	100.0%
Bus	28.3%	7.5%		34.0%	20.8%		3.8%	5.7%	100.0%
CNG	22.0%	11.9%	16.9%	27.1%	10.2%	6.8%	3.4%	1.7%	100.0%
Motor cycle	21.1%	10.5%	26.3%	33.3%	1.8%	5.3%	1.8%		100.0%
Microbus	26.1%		4.3%	34.8%	21.7%	8.7%	4.3%		100.0%
Jeep		20.0%	33.3%	33.3%	6.7%		6.7%		100.0%
Taxicab		75.0%					25.0%		100.0%
Leguna			40.0%			60.0%			100.0%
Pickup		8.3%	8.3%	50.0%	16.7%	16.7%			100.0%
Truck					100.0%				100.0%
NMT		40.0%		60.0%					100.0%
	19.1%	12.5%	16.7%	29.6%	9.9%	6.6%	3.6%	2.1%	100.0%

Table 6.5: Percentage distribution of vehicle trip (mode wise) to destination zone along Route 02

Vehicle mode	Zone of destination									
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others	**Total**
Car	18.2%	9.8%	13.6%	15.2%	22.0%	12.9%	6.1%	2.3%		100.0%
Bus	21.7%	8.7%		23.2%	31.9%	4.3%	5.8%	2.9%	1.4%	100.0%
CNG	13.6%	12.1%	12.1%	18.2%	21.2%	13.6%	7.6%	1.5%		100.0%
Motor Cycle	18.2%	6.8%	15.9%	11.4%	29.5%	15.9%	2.3%			100.0%
Micro bus	14.3%	10.7%	3.6%	7.1%	25.0%	21.4%	17.9%			100.0%
Jeep	4.8%	4.8%	4.8%	9.5%	47.6%	28.6%				100.0%
Taxicab					66.7%		33.3%			100.0%
Leguna	33.3%	16.7%	16.7%		33.3%					100.0%
Pickup	15.4%			30.8%	30.8%	23.1%				100.0%
Truck		100.0%								100.0%
NMT	64.7%					35.3%				100.0%
	19.0%	9.0%	9.0%	15.3%	25.8%	14.3%	6.0%	1.5%	.3%	100.0%

Table 6.6: Percentage distribution of vehicle trip (mode wise) to destination zone along Route 03

Vehicle mode	Zone of destination									Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others	
Car	13.0%	5.1%	6.5%	6.5%	8.7%	8.7%	21.0%	30.4%		100.0%
Bus	8.5%	1.4%		11.3%	15.5%	8.5%	21.1%	31.0%	2.8%	100.0%
CNG	10.2%	1.7%	10.2%	8.5%	10.2%	11.9%	27.1%	20.3%		100.0%
Motor Cycle	12.0%	2.0%	4.0%	4.0%	16.0%	16.0%	24.0%	22.0%		100.0%
Micro bus	4.2%	8.3%	8.3%	12.5%	4.2%	8.3%	33.3%	20.8%		100.0%
Jeep	11.1%						77.8%	11.1%		100.0%
Taxicab	20.0%						40.0%	40.0%		100.0%
Leguna							100.0%			100.0%
Pickup						28.6%	42.9%	28.6%		100.0%
Truck							33.3%	66.7%		100.0%
	10.5%	3.2%	5.1%	7.2%	10.2%	9.9%	26.8%	26.5%	.5%	100.0%

Table 6.7: Percentage distribution of vehicle trip (mode wise) to destination zone along Route 04

Vehicle mode	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Car	3.2%	1.6%	4.0%	9.7%	29.8%	8.1%	25.8%	17.7%	100.0%
Bus	1.6%	3.1%		26.6%	25.0%	3.1%	14.1%	26.6%	100.0%
CNG	4.9%	3.3%	4.9%	13.1%	23.0%	8.2%	23.0%	19.7%	100.0%
Motor Cycle	9.7%	1.4%	1.4%	6.9%	31.9%	8.3%	19.4%	20.8%	100.0%
Microb us	7.4%	7.4%		3.7%	33.3%	11.1%	22.2%	14.8%	100.0%
Jeep	13.3%				40.0%		6.7%	40.0%	100.0%
Taxicab	14.3%				42.9%		28.6%	14.3%	100.0%
Leguna				50.0%	33.3%		16.7%		100.0%
Pickup	7.7%			15.4%	15.4%	7.7%	38.5%	15.4%	100.0%
Truck							100.0%		100.0%
NMT					33.3%	8.3%	58.3%		100.0%
	5.1%	2.2%	2.2%	12.5%	28.9%	6.8%	23.0%	19.3%	100.0%

From the following figure it has been observed that maximum private car (23.8%) along route 01 go into Old Dhaka zone. Minimum vehicle trip by car (3%) end their trip in Uttara/Tongi zone. Maximum bus trips (34%) also go into Old Dhaka zone and

second position as favourite destination of bus held by Mirpur zone (28.3%) along Mirpur Road. NMT running along Mirpur Road end their trip mainly old Dhaka zone (60%) and Mohammadpur zone (40%).

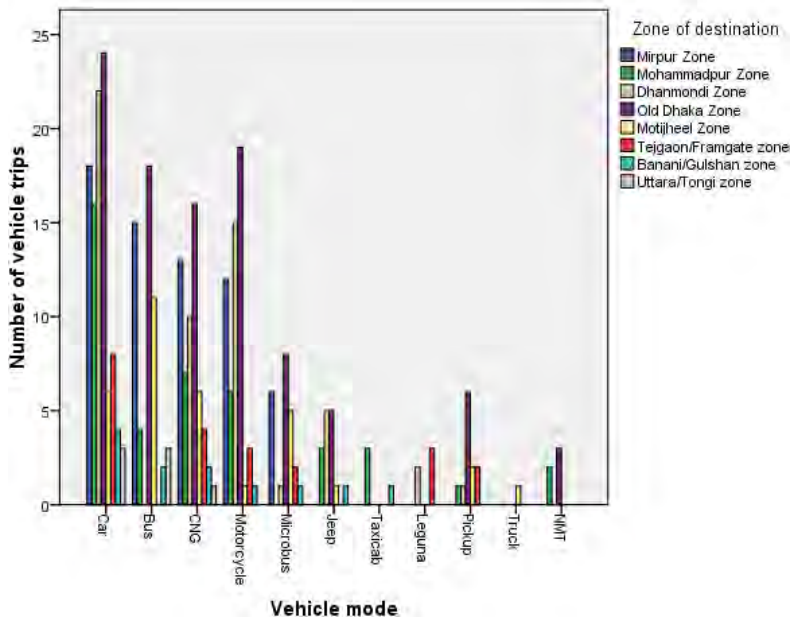


Figure 6.6: Distribution of vehicle trip (mode wise) to destination zone along Route 01 (output of Table 6.4)

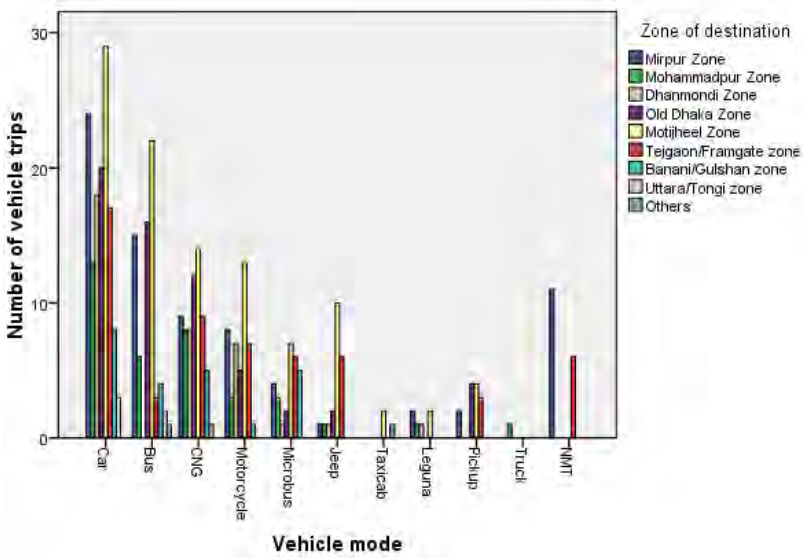


Figure 6.7: Distribution of vehicle trip (mode wise) to destination zone along Route 02 (output of Table 6.5)

Along Pallabi to Anandabazar, Gulistan route (route 02) most of the car trips go into Motijheel zone (22%) as destination and second highest number of car (18.2%) end their trip in Mirpur zone. In case of bus trips along this route, most of the trips go for Motijheel (31.9%), Old Dhaka (23.2%) and Mirpur zone (21.7%). NMT use this route

to reach Mirpur (64.7%) and Tejgaon/Farmgate zone (35.3%). Leguna/HH etc. use this route to go Mirpur, Mohammadpur, Dhanmondi and Motijheel zone.

Using route 03 (Kuril to Bijoyshoroni), private cars go mostly to Uttara/Tongi (30.4%) and Banani/Gulshan zone (21%). Most of the Bus trips also use this route to go to similar destination zones (31% and 21.1%). 100 % trips made by Tempo/Leguna/HH use this route to go only Banani/Gulshan zone.

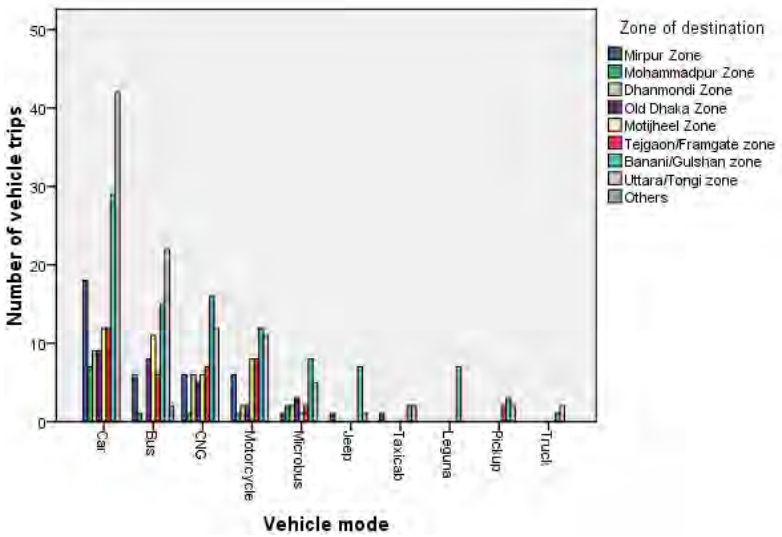


Figure 6.8: Distribution of vehicle trip (mode wise) to destination zone along Route 03 (output of Table 6.6)

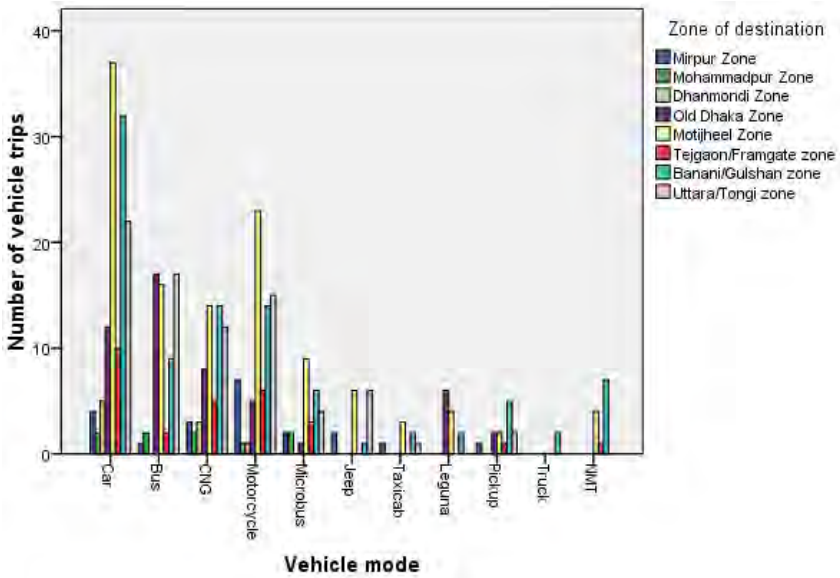


Figure 6.9: Distribution of vehicle trip (mode wise) to destination zone along Route 04 (output of Table 6.7)

Private car trips which go into destination zones like Motijheel zone (29.8%) and Banani/Gulshan zone (25.8%) use route no. 04 (Kuril to Shegunbagicha). Bus trips

use this route to reach mainly Old Dhaka, Uttara/Tongi, Motijheel and Banana/Gulshan zone. Least number of bus trips (1.6%) among all the bus trips along route 04 go Mirpur zone.

6.3.2 Development of Origin-Destination (O-D) matrix

Overall Origin-Destination (O-D) matrix along four major study routes and route wise separate O-D matrix have been developed (from table 6.8-6.12). In table 6.8, O-D matrix has been developed for all vehicle trips. Figure 6.9-6.13 is the graphical explanations of five O-D matrixes.

Table 6.8: O-D matrix developed for all vehicle trips along four major study routes

Zone of origin	**Zone of destination**								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others
Mirpur Zone	4.6%	4.2%	11.9%	31.2%	24.6%	8.8%	9.2%	5.4%	
Mohammadpur Zone	4.5%		9.7%	22.6%	21.3%	12.9%	20.0%	9.0%	
Dhanmondi Zone	20.7%	.7%	3.6%	15.0%	13.6%	7.1%	17.9%	21.4%	
Old Dhaka Zone	28.1%	12.8%	8.3%		4.5%	7.9%	19.8%	18.6%	
Motijheel Zone	18.8%	11.8%	4.4%	1.3%	7.0%	10.9%	21.4%	24.0%	.4%
Tejgaon/ Farmgate zone	16.5%	5.0%	11.6%	9.9%	9.9%	2.5%	24.8%	18.2%	1.7%
Banani/Gulshan zone	6.6%	9.3%	7.9%	18.5%	40.4%	6.0%	4.0%	7.3%	
Uttara/Tongi zone	5.0%	4.0%	6.0%	28.5%	34.5%	13.5%	8.5%		
Others		5.6%	5.6%	5.6%	38.9%	44.4%			
	13.2%	6.5%	7.9%	15.7%	19.2%	9.5%	15.2%	12.6%	.2%

From Mirpur zone maximum number of vehicle trips goes for Old Dhaka zone. We can explore this from the figure below also. From Mohammadpur zone majority vehicle trips go to Old Dhaka, Motijheel and Banani/Gulshan zone etc. Majority vehicle trips originate from Dhanmondi to reach Uttara/Tongi and Mirpur zone. Vehicles originating from Old Dhaka go mainly for Mirpur zone and from Motijheel zone majority vehicles go to reach Uttara/Tongi, Banani/Gulshan and Mirpur zone. From Tejgaon/Farmgate zone majority trips go to Banani/Gulshan zone. Significant portion of vehicle trips (40.4%) originates from Banani/Gulshan zone choose

Motijheel zone as their destination. From Uttara/Tongi zone most of the vehicles go to Motijheel and Old Dhaka zone.

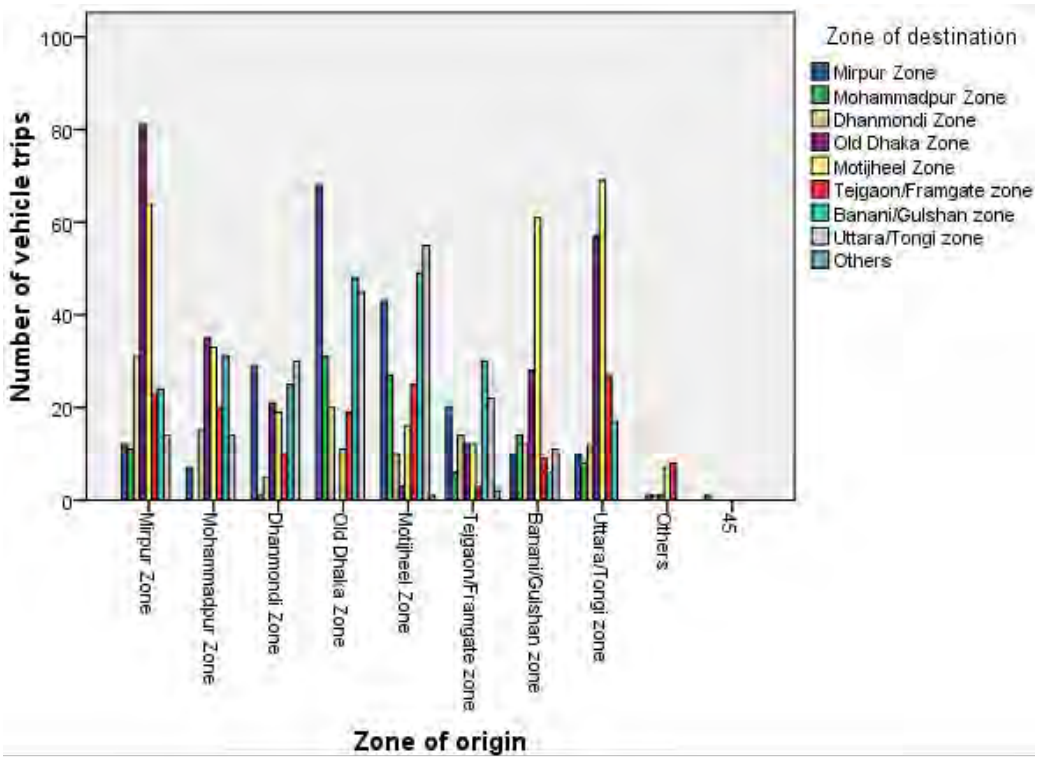


Figure 6.10: Route identification of overall vehicle trips: outcome of O-D matrix (Table 6.8)

6.3.2.1 Route wise development of O-D matrix

Table 6.9: O-D matrix developed for vehicle trips along Route 01 (Mirpur Road)

Zone of origin	**Zone of destination**								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	**Total**
Mirpur Zone		6.1%	24.5%	52.0%	9.2%	7.1%	1.0%		100.0%
Mohammadpur Zone	4.4%		19.1%	38.2%	14.7%	11.8%	8.8%	2.9%	100.0%
Dhanmondi Zone	15.9%	2.3%	6.8%	43.2%	15.9%	6.8%	4.5%	4.5%	100.0%
Old Dhaka Zone	41.9%	26.7%	12.8%		8.1%	4.7%	3.5%	2.3%	100.0%
Motijheel Zone	56.7%	36.7%	3.3%					3.3%	100.0%
Tejgaon/ Farmgate zone			80.0%	20.0%					100.0%
Uttara/Tongi zone				100.0%					100.0%
Others		100.0%							100.0%
	19.1%	12.5%	16.7%	29.6%	9.9%	6.6%	3.6%	2.1%	100.0%

Table 6.10: O-D matrix developed for vehicle trips along Route 02 (Pallabi to Anandabazar at Guslistan)

Zone of origin	**Zone of destination**								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others
Mirpur Zone	9.1%	4.1%	5.8%	22.3%	38.8%	13.2%	5.0%	1.7%	
Mohammadpur Zone	5.5%		3.6%	16.4%	41.8%	20.0%	9.1%	3.6%	
Dhanmondi Zone	35.0%			5.0%	30.0%	17.5%	7.5%	5.0%	
Old Dhaka Zone	33.9%	14.3%	16.1%		7.1%	16.1%	12.5%		
Motijheel Zone	35.4%	27.1%	12.5%	2.1%		16.7%	4.2%		2.1%
Tejgaon/ Farmgate zone	25.7%	14.3%	22.9%	22.9%	8.6%	2.9%	2.9%		
Banani/Gulshan zone	9.5%	14.3%	19.0%	23.8%	28.6%	4.8%			
Uttara/Tongi zone	4.5%	9.1%		40.9%	31.8%	13.6%			
Others					50.0%	50.0%			
	19.0%	9.0%	9.0%	15.3%	25.8%	14.3%	6.0%	1.5%	.3%

Table 6.11: O-D matrix developed for vehicle trips along Route 03 (Kuril to Bijoy Shoroni)

Zone of origin	**Zone of destination**								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others
Mirpur Zone	2.7%			8.1%	13.5%		43.2%	32.4%	
Mohammadpur Zone	3.3%					3.3%	63.3%	30.0%	
Dhanmondi Zone	23.3%						30.0%	46.7%	
Old Dhaka Zone	12.8%					2.6%	30.8%	53.8%	
Motijheel Zone	11.1%					2.8%	36.1%	50.0%	
Tejgaon/ Farmgate zone	13.1%		1.6%		3.3%	3.3%	42.6%	32.8%	3.3%
Banani/ Gulshan zone	7.3%	10.9%	10.9%	18.2%	25.5%	14.5%	3.6%	9.1%	
Uttara/Tongi zone	12.7%	8.5%	15.5%	18.3%	16.9%	23.9%	4.2%		
Others			7.1%	7.1%	35.7%	50.0%			
	10.5%	3.2%	5.1%	7.2%	10.2%	9.9%	26.8%	26.5%	.5%

Table 6.12: O-D matrix developed for vehicle trips along Route 04 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone					75.0%		25.0%		100.0%
Mohammadpur Zone							50.0%	50.0%	100.0%
Dhanmondi Zone	3.8%		7.7%				42.3%	46.2%	100.0%
Old Dhaka Zone	13.1%					8.2%	42.6%	36.1%	100.0%
Motijheel Zone	4.3%	2.6%	2.6%	1.7%	13.9%	13.9%	29.6%	31.3%	100.0%
Tejgaon/ Farmgate zone	15.0%	5.0%	5.0%	15.0%	35.0%		15.0%	10.0%	100.0%
Banani/Gulshan zone	5.3%	6.7%	2.7%	17.3%	54.7%		5.3%	8.0%	100.0%
Uttara/Tongi zone			1.0%	31.4%	47.6%	6.7%	13.3%		100.0%
Others					100.0%				100.0%
	5.1%	2.2%	2.2%	12.5%	28.9%	6.8%	23.0%	19.3%	100.0%

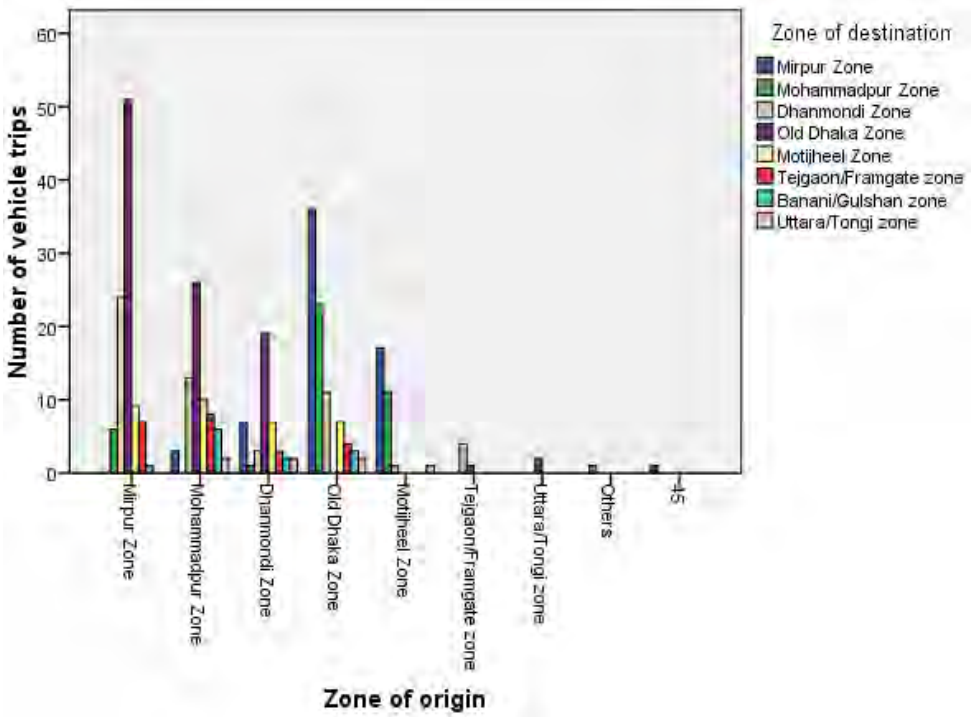


Figure 6.11: Route identification of vehicle trips along route 01: outcome of O-D matrix (Table 6.9)

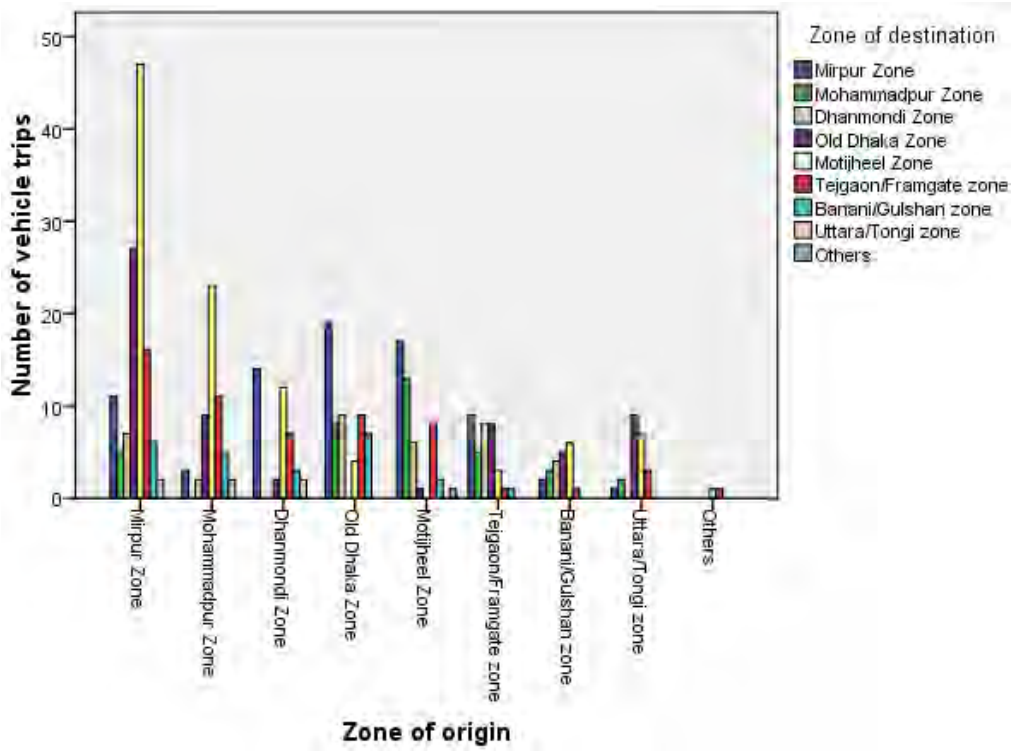


Figure 6.12: Route identification of vehicle trips along route 02: outcome of O-D matrix (Table 6.10)

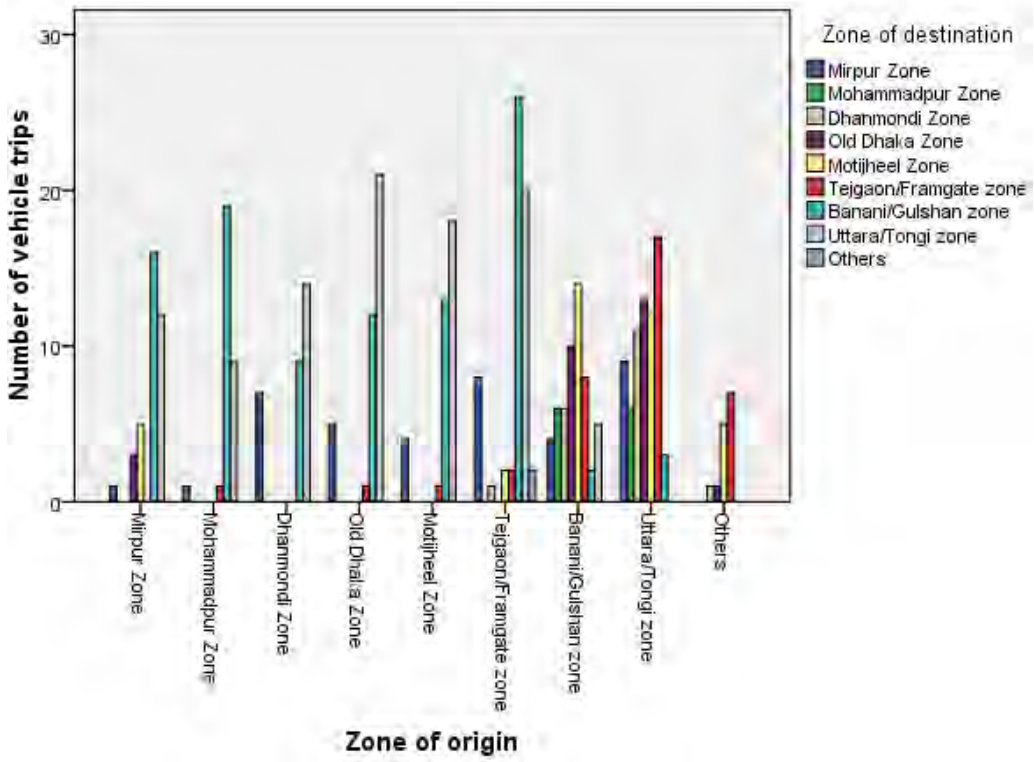


Figure 6.13: Route identification of vehicle trips along route 03: outcome of O-D matrix (Table 6.11)

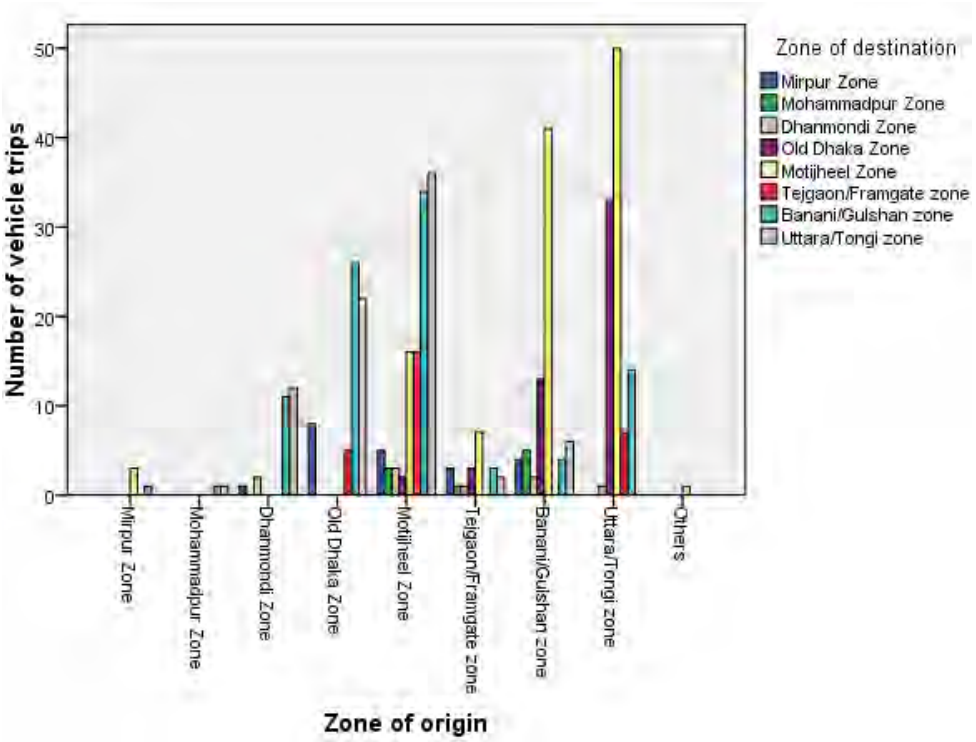


Figure 6.14: Route identification of vehicle trips along route 04: outcome of O-D matrix (Table 6.12)

6.3.2.2 Link wise development of O-D matrix

In the above section under 6.3.2 route wise and overall Origin-Destination matrix has been developed. But link wise O-D matrix develop is the most important part of travel demand estimation as route identification of vehicle trip along each link helps to assign additional vehicle trips to alternative route in order to reach their original destination. Calculation of optimum volume (both vehicular emission wise and road capacity wise) and existing traffic volume all are calculated for the thirty five study links. So it's very essential to identify route for vehicle trips along each link. To satisfy the third objective of the research we have to take help from these 35 O-D matrixes develop from O-D survey to assign additional vehicles from each link to alternative secondary roads through satisfying their original demand (to make reach the vehicle trips to original destination). In the following table O-D matrix for link 01 along Mirpur Road has been given. Other 34 O-D matrixes also have been attached within appendix C (from Matrix 2-Matrix 35).

Matrix 6.1: Origin-Destination Matrix for Link R1 (Technical Morh to Shyamoli Cinema Hall Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination						Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	
Mirpur Zone		28.6%	28.6%	33.3%	4.8%	4.8%	100.0%
Mohammadpur Zone	75.0%		25.0%				100.0%
Dhanmondi Zone	100.0%						100.0%
Old Dhaka Zone	100.0%						100.0%
Motijheel Zone	100.0%						100.0%
Others		100.0%					100.0%
	36.1%	19.4%	19.4%	19.4%	2.8%	2.8%	100.0%

6.4 Travel behaviour analysis of vehicle users

Travel behaviour analysis of vehicle user is an integrated part of any travel behaviour estimation study. Under travel behaviour analysis, trip purpose analysis, analysis on vehicle occupancy rate, evaluation of preferred alternative routes and alternative travel modes has been conducted in this study. As in the earlier section of this chapter, some hypothesis has been formulated on travel behaviour of vehicle users. Some of the null hypotheses are rejected after the analysis and some are proved as true null hypothesis.

6.4.1 Analysis of trip purpose

Null hypothesis 03: Most of the trips are work based trip and some are education based trips, trip made with visit, travel and other purposes are found occasionally.

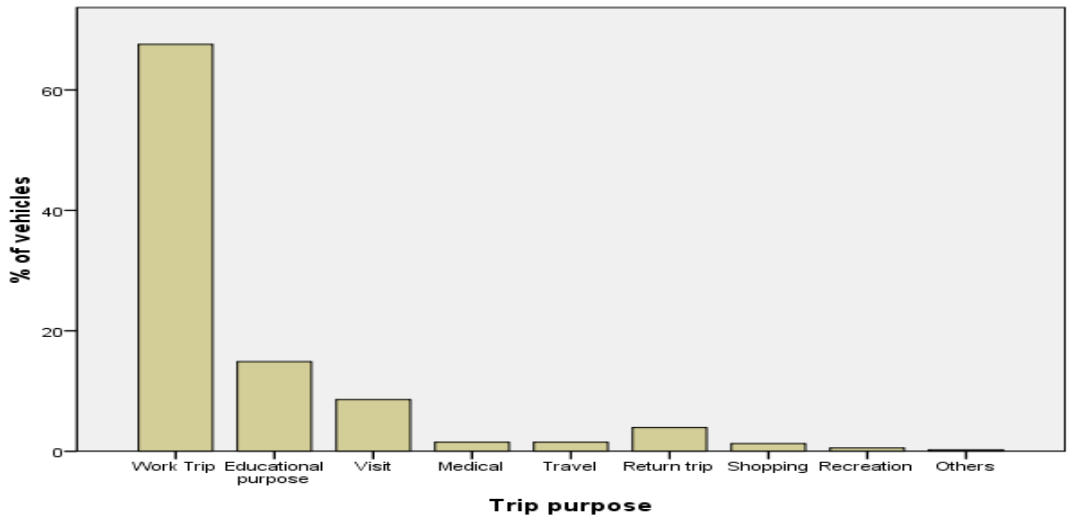


Figure 6.15: Distribution of vehicle trips according to trip purpose

From the above figure it can be easily seen that work trip is the most prominent trip among all the vehicular trips made every day especially in congested morning peak hours. Educational trip also contributes a significant share in trip purpose. Visit and return trip are also being observed while doing O-D survey. Some other purposes like medical, travelling, shopping, recreation etc. are seen contributing a very lower share into trip purpose of vehicles.

Null hypothesis 04: Most of the private cars are found to make return trip from destination (trip purpose of private car).

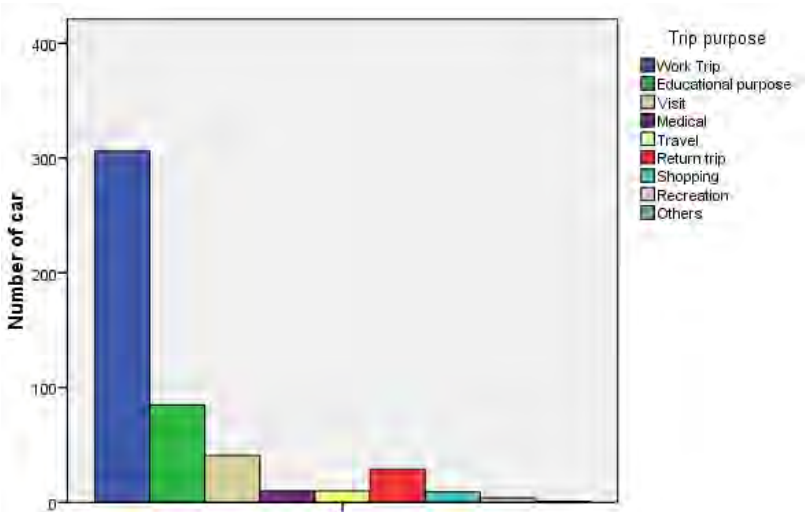


Figure 6.16: Frequency distribution of private car according to trip purpose

As significant number of return trips by private car has been observed during survey, a hypothesis was formulated based on trip purpose of car. After analysis it has been found that like the overall condition most of the trips made by car were for work purpose mainly. So it can be said that hypothesis no. 04 has been rejected. One of the basic reasons of finding more work trip is mainly the survey time. Congested morning peak hours are given preference while doing survey. If evening peak hour, off peak hour and average peak hours could also be considered for analysis then real picture of trip purposes by various modes specially car has been depicted. Because of time and manpower limitation this was not possible.

6.4.2 Analysis of vehicle occupancy rate

Analysing vehicle occupancy rate of different category vehicles is also important to identify travel behaviour of vehicle users. While analysing vehicle occupancy rate private car is the most important mode to explore the occupancy condition as most of the time cars are lower occupants accommodating only one or two persons excluding driver and sometimes drivers are seen alone making return trip from destination.

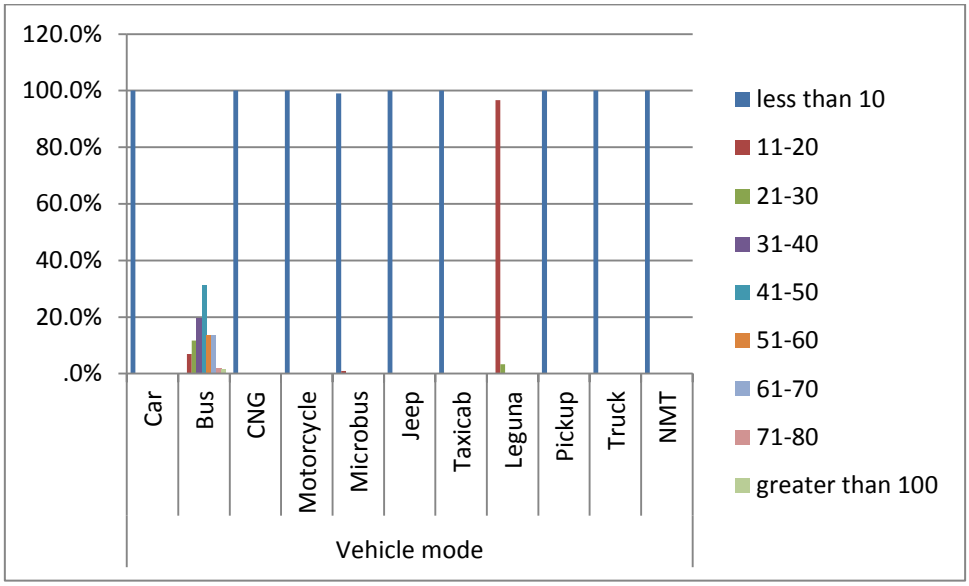


Figure 6.17: Average vehicle occupancy limit for all vehicles along four study routes

<u>Null hypothesis 05</u>: Passenger occupancy of private cars is low in most of the time.

Figure 6.18: Occupancy rate of private car

From the above graphical representation it is clear that most of the private cars possess very low occupancy. Only one passenger (excluding driver) have found in the survey for the dominant share (42.1%) of cars. Almost 37.7% cars are seen to occupy only two passengers. Full occupancy with four passengers has been seen in case of only 2.8% private cars. So it can be said that null hypothesis is true for this particular analysis and this situation really creates a huge problem in existing transportation condition of Dhaka city. As private vehicles (specially car) are increasing in number day by day, taking huge space along the road but only serve a very few number of people.

Photo 6.1: Zero occupancy of private car along Route 03 (Kuril to Bijoyshoroni)
Source: Field survey, 2014

6.4.3 Evaluation of preferred alternative routes and alternative travel modes

During Origin-Destination survey respondents (vehicle users) were asked about whether they have any other preferred alternative route and alternative travel mode which they think is better in compare to their existing route and existing travel mode. Mixed response in this case has been observed from the interviewees. Some hypothesis has been formulated at the initial stage of analysis on vehicle user's perception about alternative travel route and mode. While giving information on alternative route many drivers could not be able to give answer properly because of lack of knowledge on alternative route. Normally they use the route which they are familiar most. They don't want to use alternative any other route which they do not use very often in the fear of any risk. In case of most of the public vehicles especially bus, HH etc. route was fixed already.

6.4.3.1 Preferred alternative mode

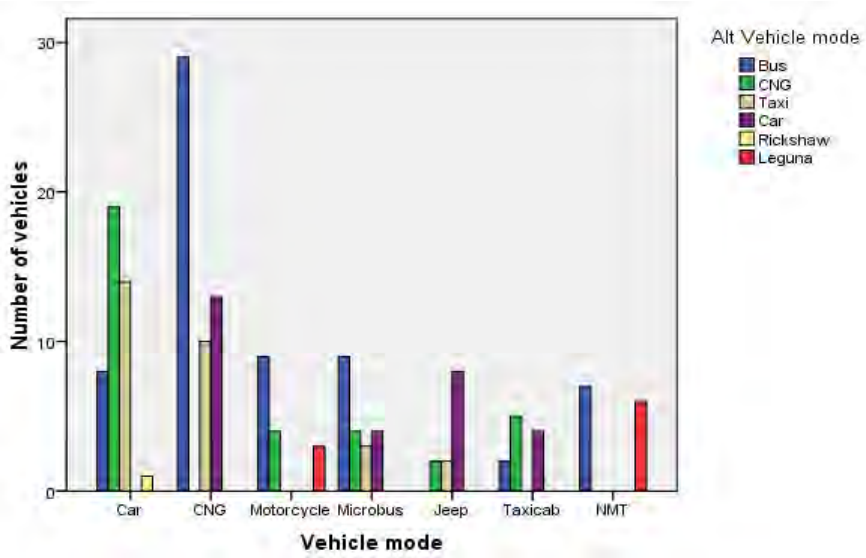


Figure 6.19: Distribution of preferred alternative mode against each category vehicle

<u>Null hypothesis 06</u>: Private car users are satisfied with their present mode, not interested to shift any other mode.

While analysing vehicle user's opinion on alternative vehicle mode above hypothesis is formulated. From the following figure we have to identify whether the above hypothesis is accepted or rejected. From the two figures (fig. 6.7 and fig. 6.8) it can be easily interpreted that the above hypothesis is rejected and alternative hypothesis is true. Private car and other modes also want to shift to alternative mode if proper service facility will be given and availability can be ensured. In case of car, people want to shift to other alternative public transport modes like bus, CNG, Taxi, NMT etc. A huge number of CNG users want to shift to bus as alternative route. They choose bus at the top position. Car and taxi are also on their preference list of alternative mode. Motor cycle, Microbus, Taxi and NMT users also want to use public bus as alternative mode. NMT users are only willing to shift to bus and HH (Leguna etc.). Private car is seen as one of the preferred alternative modes for Micro bus, Jeep and Taxicab. One interesting finding is that some Motorcycle users want to shift to Leguna (HH etc.). Most important finding from the survey in alternative mode aspect is that no bus users are willing to shift any other alternative mode. Missing data is showed for all bus users willing to shift to alternative mode. This gives an indication

that mass people are willing to continue to use bus though public bus service is not at all satisfactory.

Table 6.13: Preferred alternative modes of car

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Bus**	8	1.6	19.0	19.0
	CNG	19	3.8	45.2	64.3
	Taxi	14	2.8	33.3	97.6
	Rickshaw	1	.2	2.4	100.0
	Total	42	8.5	100.0	
Total		496	100.0		

From the above table percentage distribution of cars in willingness to shift to alternative other modes have been seen. It is very obviously found that almost 92% private car users are not willing to shift any other alternative mode as we have not developed our public transport facility up to the level. For this those who can afford car, do not want to bear sufferings as there is a huge lack of demand between public transport demand and supply and transportation mismanagement is seen everywhere in the city. A limited portion of car users want to shift Bus, CNG, Taxi and Rickshaw. From this finding it can be said that null hypothesis 05 has proved to be partially true as most of the car users are not willing to shift any other vehicle mode.

6.4.3.2 Preferred alternative route

Null hypothesis 07: Bus, CNG, Taxi, HH, NMT; all public transports are running along a specific route every day, not interested to shift to other alternative route to reach their original destination.

As it has been discussed earlier in this section that most of the vehicle users are not willing to shift to alternative routes, missing data has been found while doing analysis on preferred alternative route for the study. None of the private car users mentioned about any alternative route. Some bus drivers (for only 18 bus trips) mentioned some alternative route as follows:

Table 6.14: Preferred alternative route by bus

Existing Route	Destination zone	Alternative route
Route 01: Link 10 (R10)	Motijheel	Baily road
Route 01: Link 11 (R11)	Mohammadpur	Mohammadpur
Route 01: Link 11 (R11)	Mohammadpur	Farmgate
Route 03: Link 04 (R4)	Banani/Gulshan	Farmgate
Route 03: Link 04 (R4)	Banani/Gulshan	Dhanmondi
Route 03: Link 04 (R4)	Banani/Gulshan	Dhanmondi
Route 03: Link 04 (R4)	Uttara/Tongi	Farmgate
Route 03: Link 04 (R4)	Banani/Gulshan	Farmgate
Route 03: Link 04 (R4)	Banani/Gulshan	Farmgate
Route 03: Link 04 (R4)	Uttara/Tongi	Farmgate
Route 04: Link 07 (R7)	Mirpur	Baily road
Route 04: Link 07 (R7)	Uttara/Tongi	Kakrail road
Route 04: Link 07 (R7)	Tejgaon/Farmgate	Baily road
Route 04: Link 07 (R7)	Uttara/Tongi	Polton
Route 04: Link 08 (R8)	Banani/Gulshan	Kakrail road
Route 04: Link 08 (R8)	Uttara/Tongi	Baily road
Route 04: Link 09 (R9)	Tejgaon/Farmgate	Kakrail road
Route 04: Link 09 (R9)	Uttara/Tongi	Baily road

Source: O-D survey, 2014

Some other preferred alternative route choice has also been found from a very limited number of vehicle users (for only five vehicle trips).

Table 6.15: Preferred alternative route by some other vehicle modes

Vehicle class	Existing Route	Destination zone	Alternative route
Motorcycle	Route 04: Link 04 (R4)	Tejgaon/Farmgate	Mohakhali
Jeep	Route 04: Link 04 (R4)	Motijheel	Farmgate
Taxicab	Route 01: Link 10 (R10)	Mohammadpur	Jhigatola
Taxicab	Route 01: Link 11 (R11)	Mohammadpur	Dhanmondi
Truck	Route 01: Link 10 (R10)	Motijheel	Farmgate

Source: O-D survey, 2014

From the above two table it can be said that hypothesis 08 is partially proved to be true especially for CNG, HH, NMT. For other public vehicles like Bus and Taxi above hypothesis can be accepted as response to alternative route is found in a very limited number by a few vehicular trip.

6.5 Route wise discrimination among different vehicle modes

In Dhaka city currently route wise discrimination for specific vehicle modes are seen. Especially for non-motorized traffic (NMT) some routes (for example: route 03 of this study: Kuril to Bijoyshoroni) are completely banned and some are partially banned

along some specific links of a whole route. It is now very clear that policy makers are promoting private car ownership and discourage NMT and other pollution free vehicles. Also proper emphasis is not given to public transport modes. For this reason, route wise discrimination among different vehicle classes are seen at present in Dhaka city. Situation discussed below in reference with the data collected from survey.

Null hypothesis 08: Most favourite route for private car is Route no. 03 (Kuril to Bijoyshoroni).

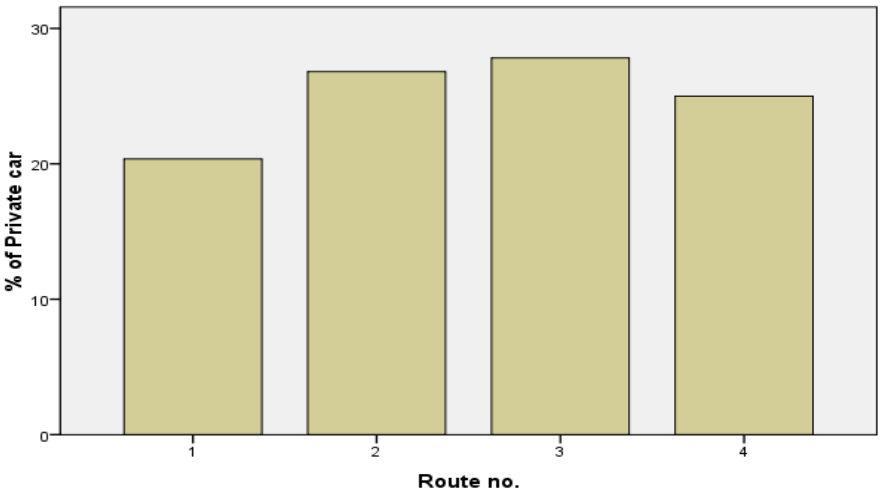


Figure 6.20: Distribution of private car along major study routes

Our preliminary assumption was that route no. 3 (Kuril to Bijoyshoroni) can be the most favourite route used by car as this is the only route which is completely banned for NMT along all the five links of this route. Sample size for survey has been taken under variable rate sampling method applying on the traffic volume along these routes. In volume survey most of the private cars are seen to run along route no. 03. So it can be said that hypothesis is correct and fully accepted. But as all the routes are not of same length so number of car per kilometre length is important to explore the actual scenario. In the following figure we can see route wise variation in number of car/km length of specific route. This figure helps to know the route wise actual distribution of cars and come up with decision about the most car friendly route. While calculating number with respect of route length route 03 remains dominant but route 01 now holds the second position as car friendly route or route with more cars. Route 02 shares lowest number of per km cars and that is 11.

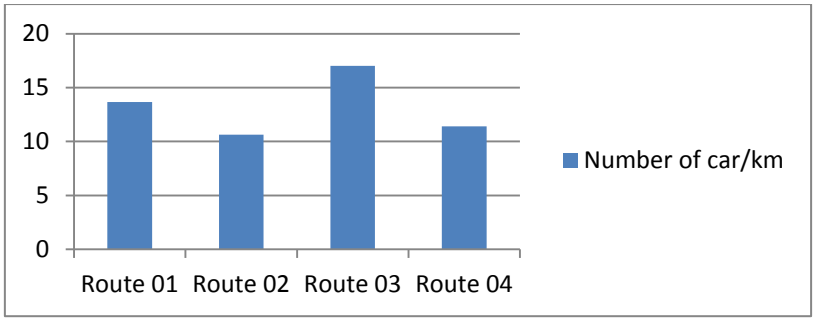


Figure 6.21: Route wise comparison in number of car/km

Photo 6.2: Private car running along Route 01 (Mirpur Road)
Source: Field survey, 2014

Photo 6.3: Dominance of car running along Link 7 (Karwan bazaar_SAARC foara to Shahbagh) Route 02 (Pallabi to Anandabazar)
Source: Field survey, 2014

<u>Null hypothesis 09</u>: Link no. 02 (Banani rail crossing to Banani DOHS) of Route 03 (Kuril to Bijoyshoroni) face congestion because of excessive no. of cars.

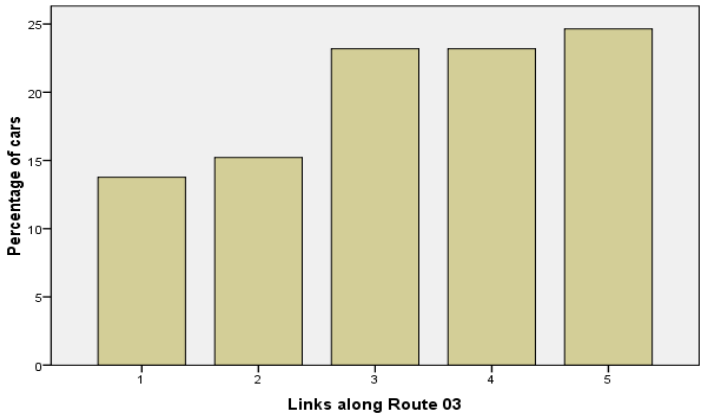


Figure 6.22: Distribution of private car along five study links of Route 03

As route 03 occupy maximum number of private cars so an analysis has been done to identify the most congested link along this route for car. While doing survey it was observed that link no. 02 was most congested. On the basis of that observation above

hypothesis (Null hypothesis 09) was formulated. But after data analysis it can be seen from the above figure that link no. 05 (starting form Jahangir gate to Bijoy shoronee_Novo theatre signal) shares major percentage of car in compare to other links. But link 3 (from Banani DOHS to Mohakhali-Gulshan road intersection) and 4 (Mohakhali-Gulshan road intersection; near Mohakhali flyover starting point to Jahangir gate) also shares many cars in compare to rest two links (link 01 and 02). Increasing number of private cars from link 01 to 05 along route 03 (Kuril to Bijoyshoroni) can be explained in a way that as soon as the route approaches toward city central areas travel demand is also increasing and as a result private car in number is also increasing.

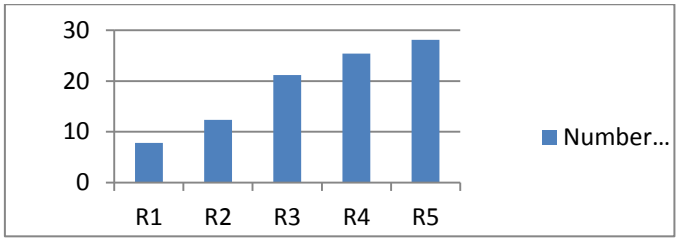


Figure 6.23: Link wise comparison in number of car/km along Route 03

<u>Null hypothesis 10</u>: Private car is increasing in number from Hatirjheel connecting road point to Kuril (from Link 1-5) along Route no. 04 (Kuril to Shegunbagicha).

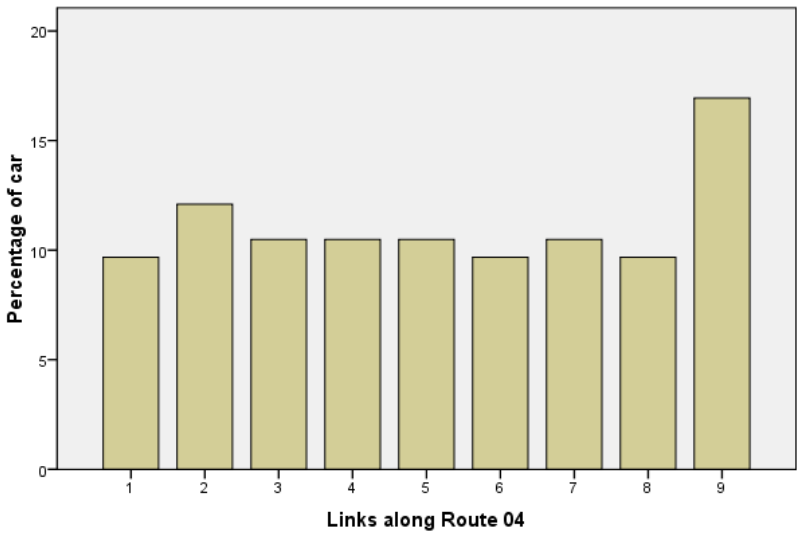


Figure 6.24: Distribution of private car along nine study links of Route 04

From the above figure it is very clear that null hypothesis no. 10 is partially accepted as link no 01 (Kuril to Bashundhara residential area entrance) shares lowest number

of cars and there is a gradual increase in no. of cars from link 1 to other links. Almost similar number of private cars are found from link 1-8 along Kuril to Shegunbagicha route but along link no 09 (Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha) of Route 04 highest number of cars found.

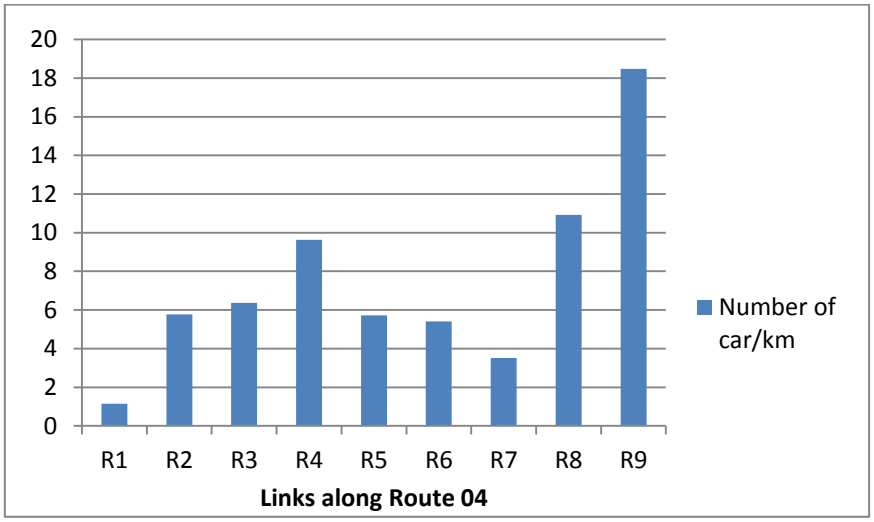


Figure 6.25: Link wise comparison in number of car/km along Route 04

But again if we consider length variation among different links along Route 04 after calculating number of car per kilometre then highest number of car holder link remains the same but link no. 08 (Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road) found to be as with second highest number of cars/km along this route. According to this measurement analysis, the above hypothesis can be considered to be accepted as from link no. 01 to 04, number of car/km is seen to increase. But in link no. 05 (DIT: Hatirjheel connecting road point to Malibagh rail crossing) number of cars/km is decreased.

Null hypothesis 11: Most favourite route for public bus is Route no. 02 (Pallabi to Anandabazar at Gulistan) especially link no. 1 & 2 of route 02 (Rokeya shoronee Mirpur 10, Pallabi shoronee 11 etc.).

Photo 6.4: Huge number of buses observed along Link 4 (Rampura TV Bhaban to Hatirjheel connecting road point) of Route 04
Source: Field survey, 2014

Photo 6.5: Dominant bus route along Link 6 (Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara) of Route 02
Source: URL 1

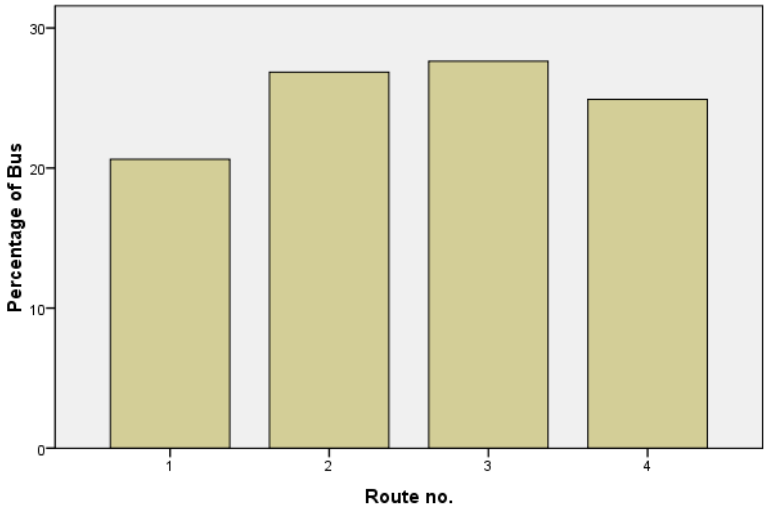


Figure 6.26: Distribution of public bus along major study routes

From the above figure of overall distribution of bus along major study routes it has been found that distribution of bus in total number has been highest for Kuril to Bijoyshoroni route. According to this the above hypothesis can be rejected though route 02 (Pallabi to Anandabazar) holds the second position to occupy bus in frequency distribution. But while calculating number of bus per km length of each route, Mirpur Road (Route 01) shows prominent position. Route 02 in this case stood last position in ranking, so it can be said that above hypothesis is rejected fully.

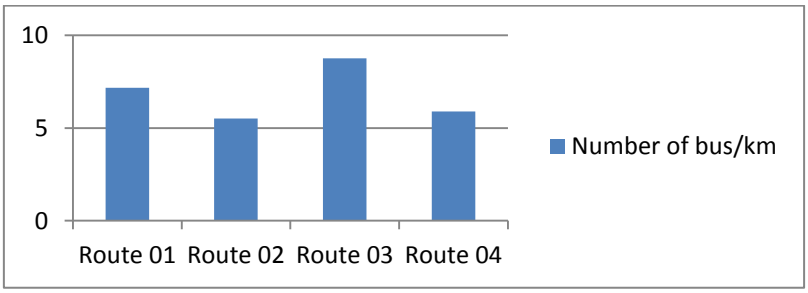


Figure 6.27: Route wise comparison in number of bus/km

Again from the two figures below (percentage distribution of bus and no. of bus per km respectively), it is clear that null hypothesis 11 (see above) is rejected fully as link 01 and 02 of Route 02 shows very minimum value for bus. Link no. 09 (Motsho bhaban to Kodom foara) is proved to occupy the highest number of bus in both the cases. Also link no. 08 (Shahbagh to Motsho bhaban), 03 (Agargaon to Bijoy shoroni) and 07 (Karwan bazaar_SAARC foara to Shahbagh) also found to have a significant number of bus/km length of those links.

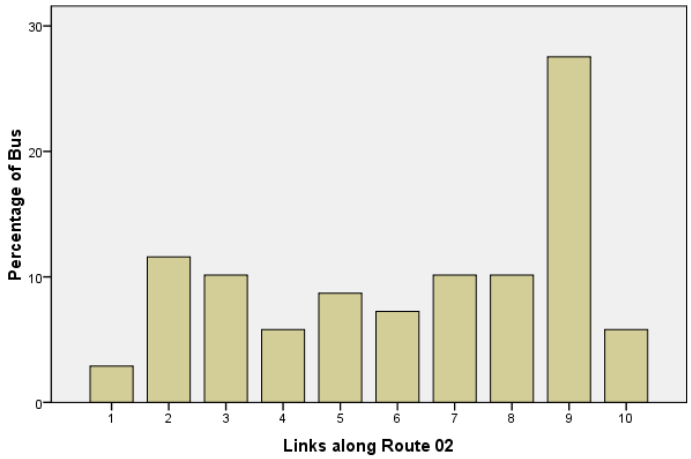


Figure 6.28: Distribution of bus along ten study links of Route 02

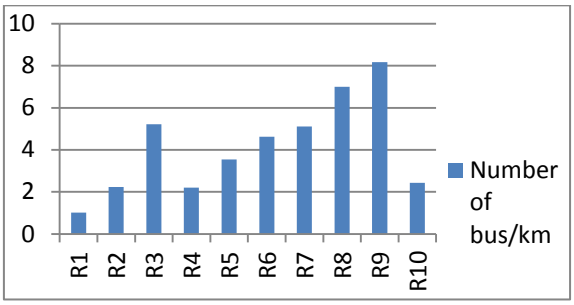


Figure 6.29: Link wise comparison in number of bus/km along Route 02

Behind the formulation of hypothesis 11, reasons like improved bus service facility in Rokeya shoronee Mirpur 10 and Pallabi shoronee 11 areas played a role. But actual scenario is different. Travel demand ultimately control bus routes and the most congested links along route 02 show dominating share in bus number per kilometre length.

Null hypothesis 12: Leguna/Tempo/HH are mainly found on the later part of Route no. 04 (Kuril to Shegunbagicha) (Link of Malibagh rail crossing to Mouchak Morh, DIT etc.: Link no. 5, 6, 7).

From the following two figures it can be clearly interpreted that above hypothesis is rejected and both in overall distribution in number and no. of HH/km analysis it is found that link no. 5 and 6 occupy very minor share of Leguna/Tempo/HH but link no. 7 (Mouchak Morh to infront of Polwel gas station at Outer circular road) occupy significant number of Leguna/Tempo/HH in compare to other links of Route 04.

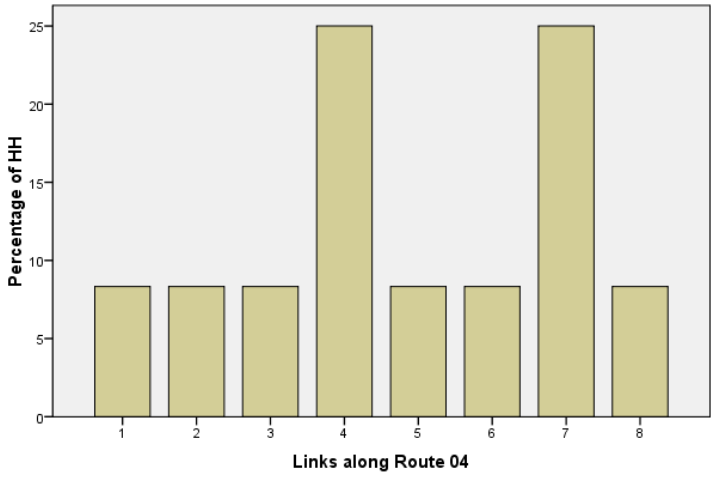


Figure 6.30: Distribution of L/T/HH along nine study links of Route 04

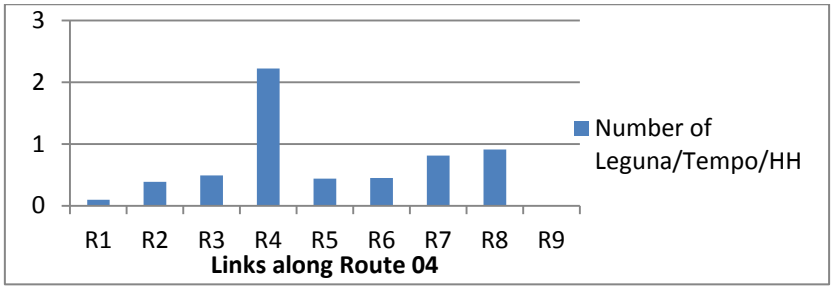


Figure 6.31: Link wise comparison in number of HH/km along Route 04

From the above graph of per kilometre analysis it is found that link no. 4 (Rampura TV Bhaban to Hatirjheel connecting road point) shares maximum number of HH/km length of link.

Null hypothesis 13: Route 03 totally emphasizes private car ownership and NMT is seen running on some parts of Route 01, 02 and 04.

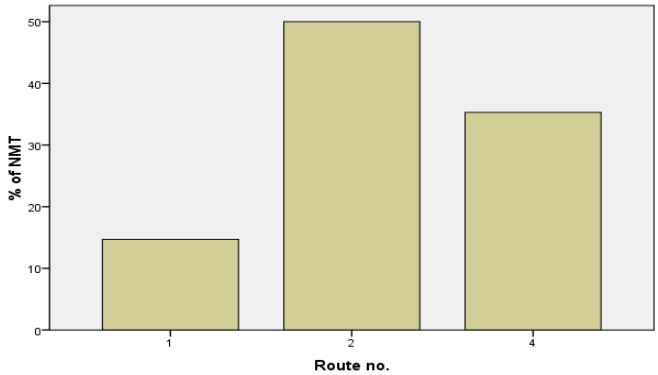


Figure 6.32: Distribution of NMT along major study routes

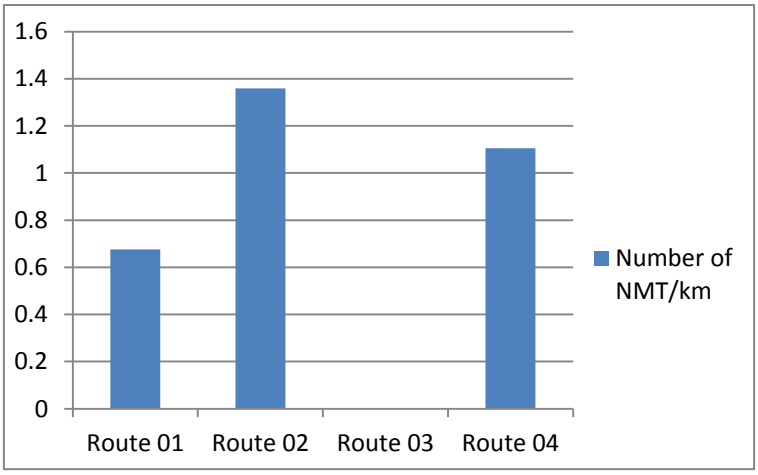


Figure 6.33: Route wise comparison in number of NMT/km

While doing volume survey for Non-motorized traffic along four major routes it has been observed that there is a complete ban of NMT along Route 03. Along many links of route 01 and 02 and for a few links along route 04 also NMT is banned. There are some links where NMT is banned but some rickshaws are seen to run along those links. Based on this observation above hypothesis was formulated and the hypothesis is accepted. From both the analysis, it has been found that Route 02, 04 and 01 possess significant shares of NMT respectively.

Photo 6.6: Separate NMT lane along Link 10 (Science lab signal to New market signal) along Route 01 (Mirpur Road)
Source: Field survey, 2014

Photo 6.7: Huge number of NMT running along Link 4 (Rampura TV Bhaban to Hatirjheel connecting road point) along Route 04 (Kuril to Shegunbagicha)
Source: Field survey, 2014

<u>Null hypothesis 14</u>: Most of the NMT (Rickshaw) trips are intra zonal trip (short distance trip). Rickshaw trip both starts and ends within particular route.

Origin-Destination matrix has been developed for Non-motorized traffic especially for rickshaw trips shown in the following table. From the table it is clearly seen that in case of Mirpur zone 61.1% of NMT trips originates and ends both within the zone. Only 11.1% and 27.8% trips go into Mohammadpur and Tejgaon/Farmgate zone respectively. Also in case of Banani/Gulshan zone 33.3% trips ends within the same zone. As NMT is banned along the major arterial roads of this zone and sample size for O-D survey was also very limited, so many trips found here are intra zonal or short distance trips. Except these two zones in case of other three zones (Mohammadpur, Dhanmondi, Uttara/Tongi etc.) no intra zonal trip has been found. So the above hypothesis is proved to be accepted for only one zone (Mirpur zone) but rejected for all other zones.

Table 6.16: O-D matrix developed for NMT within different TAZs

Zone of origin	**Zone of destination**					
	Mirpur Zone	Mohammadpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Framgate Zone	Banani/ Gulshan zone
Mirpur Zone	61.1%	11.1%			27.8%	
Mohammadpur Zone					100.0%	
Dhanmondi Zone			100.0%			
Banani/Gulshan zone				66.7%		33.3%
Uttara/Tongi zone					16.7%	83.3%
	32.4%	5.9%	8.8%	11.8%	20.6%	20.6%

Photo 6.8 ad 6.9: NMT running along Mirpur road making short distance trip within the same zone
Source: Field survey, 2014

<u>Null hypothesis 15</u>: Most of the public vehicles (especially buses) are serving along specific routes like Route 01 (Mirpur road) and Route 02 (Pallabi to Anandabazar at Gulistan).

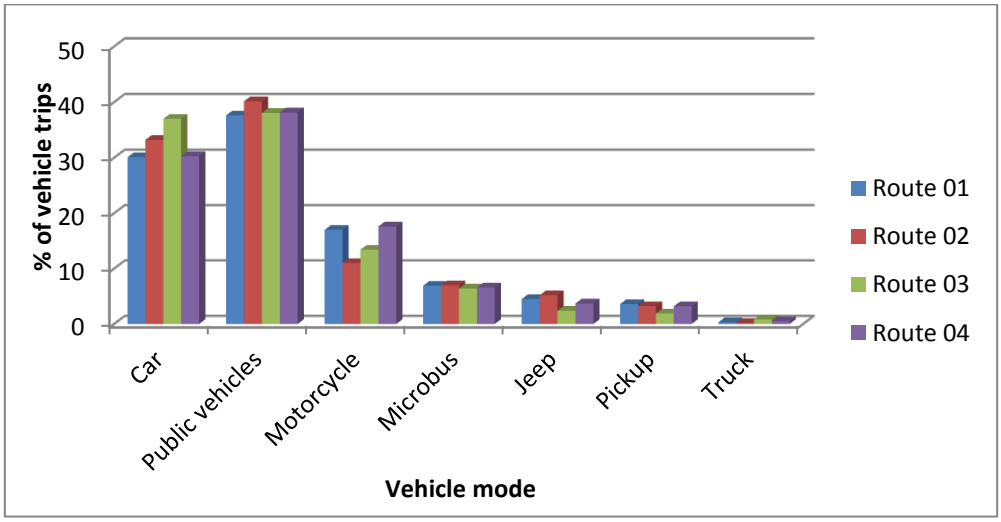


Figure 6.34: Percentage distribution of public vehicles in compare to other vehicle modes along four major routes

Here public vehicles include Bus, CNG, Taxi, Leguna/Tempo/HH and NMT (Rickshaw etc.). From the above figure it has been easily found that not only for route no. 01 and 02 but for all the four major routes public vehicles possess the dominant share in compare to other vehicles. So, it can be said that hypothesis 15 is accepted. From this finding it has been proved that though government or policy makers encourage private vehicles especially car at current days but still majority people use public vehicles and public vehicles occupy dominant share among all vehicular trips in Dhaka city.

6.6 Summary

In this chapter some specific findings have been revealed under travel demand identification of vehicle trips. Work based trip dominate the congested morning peak hours almost all along the major study routes. Dominant land use category has been identified separately for each TAZ. Demand demarcation or dominance of specific TAZ as destination zone among all the zones have been showed in this chapter. Route identification of vehicle trips for both link and route wise have been done. Under travel behaviour analysis, route wise discrimination among different vehicle modes has been analysed through formulating some hypothesis based assumption. While doing O-D survey missing values have been found for intermediate stop related information for all the modes especially public transport modes. In the next chapter, link wise optimum traffic volume has been determined satisfying both criteria which were fixed earlier: vehicular emission and road capacity for four major study routes and some available secondary roads which can be used as alternative roads.

Figure 6.35: Traffic Analysis Zone (TAZ) wise distribution of trip purpose

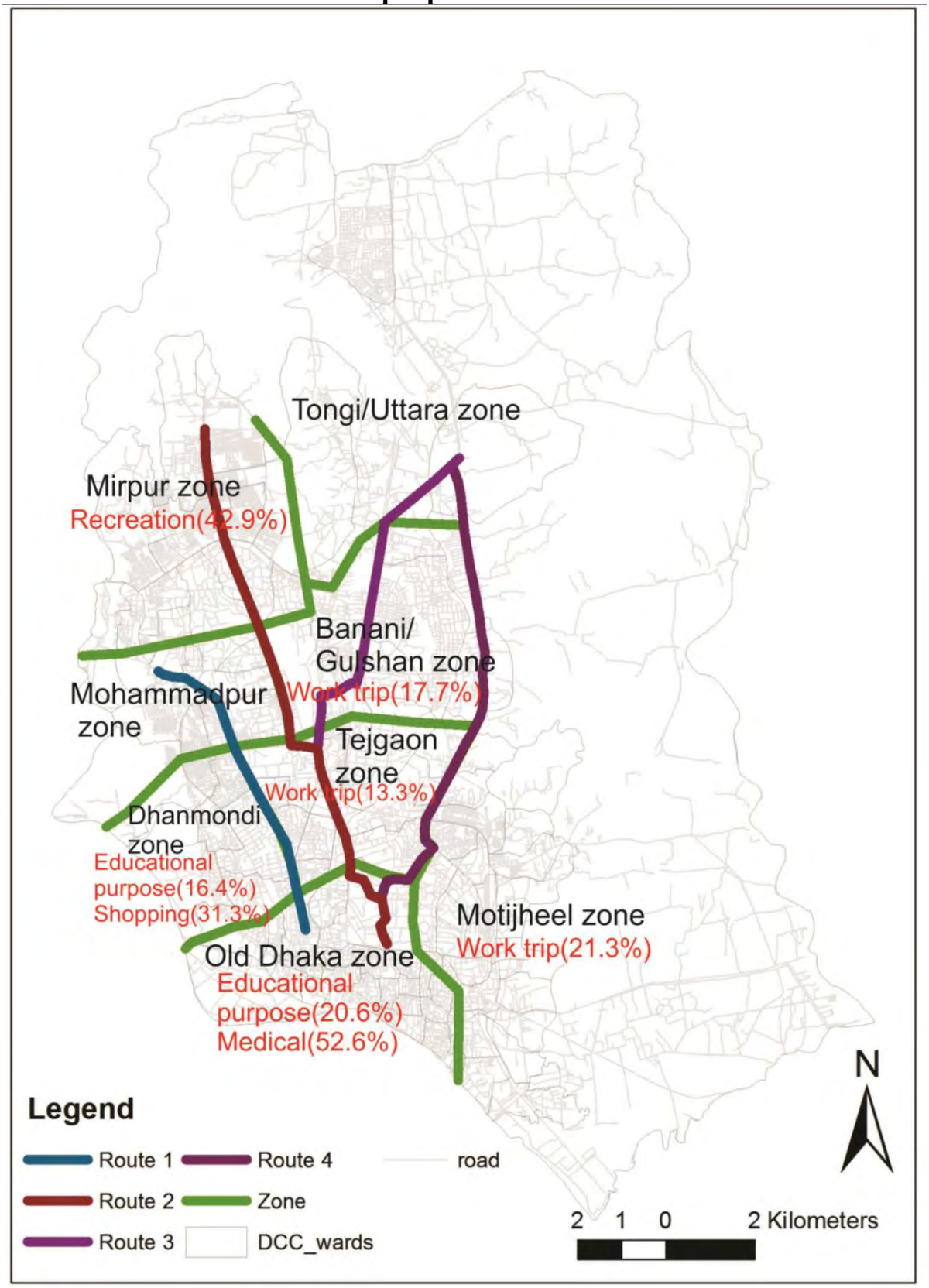


Figure 6.36: Percentage Distribution of Vehicle Trips along Route 01 according to Travel mode and Destination zone

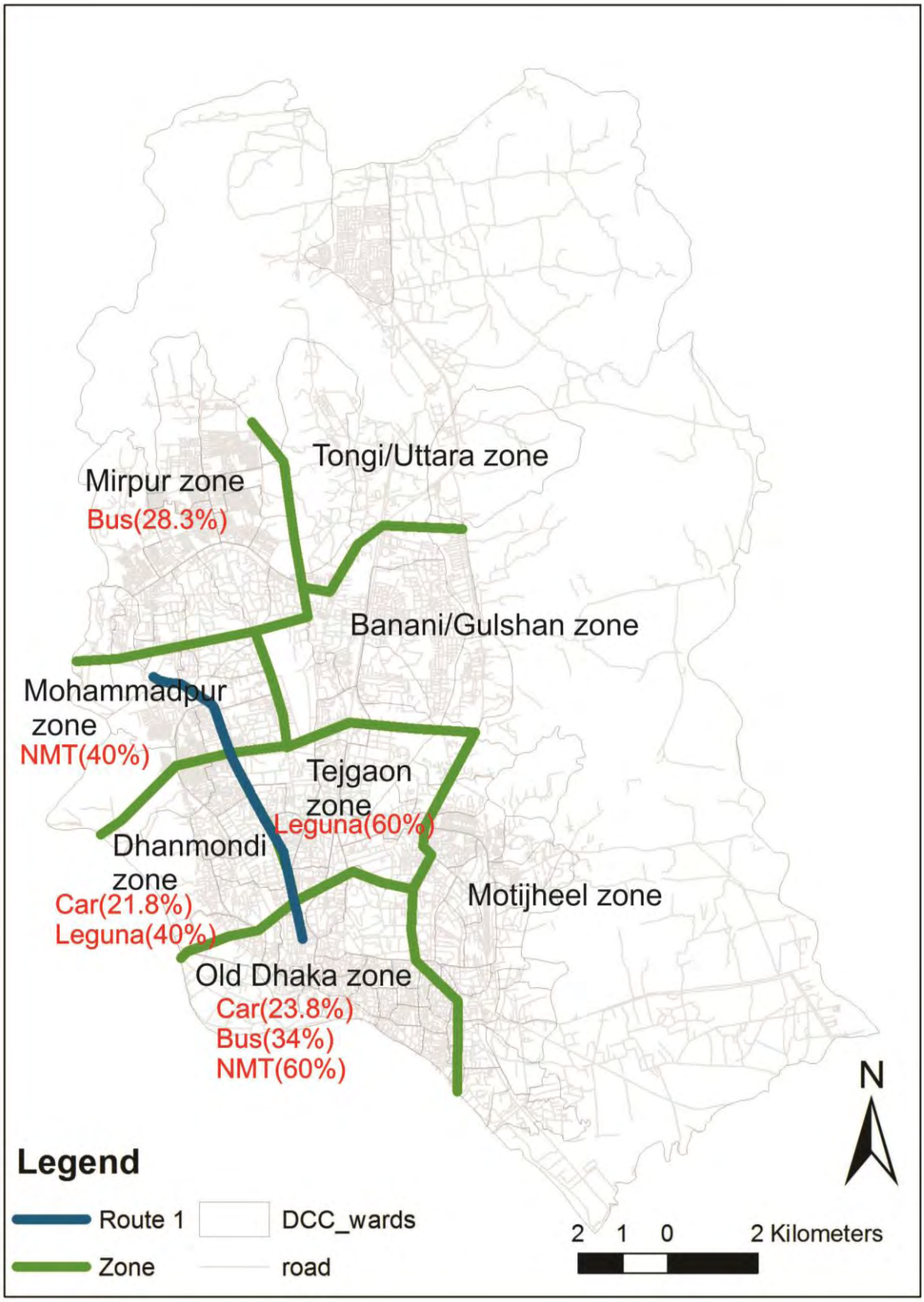


Figure 6.37: Percentage Distribution of Vehicle Trips along Route 02 according to Travel mode and Destination zone

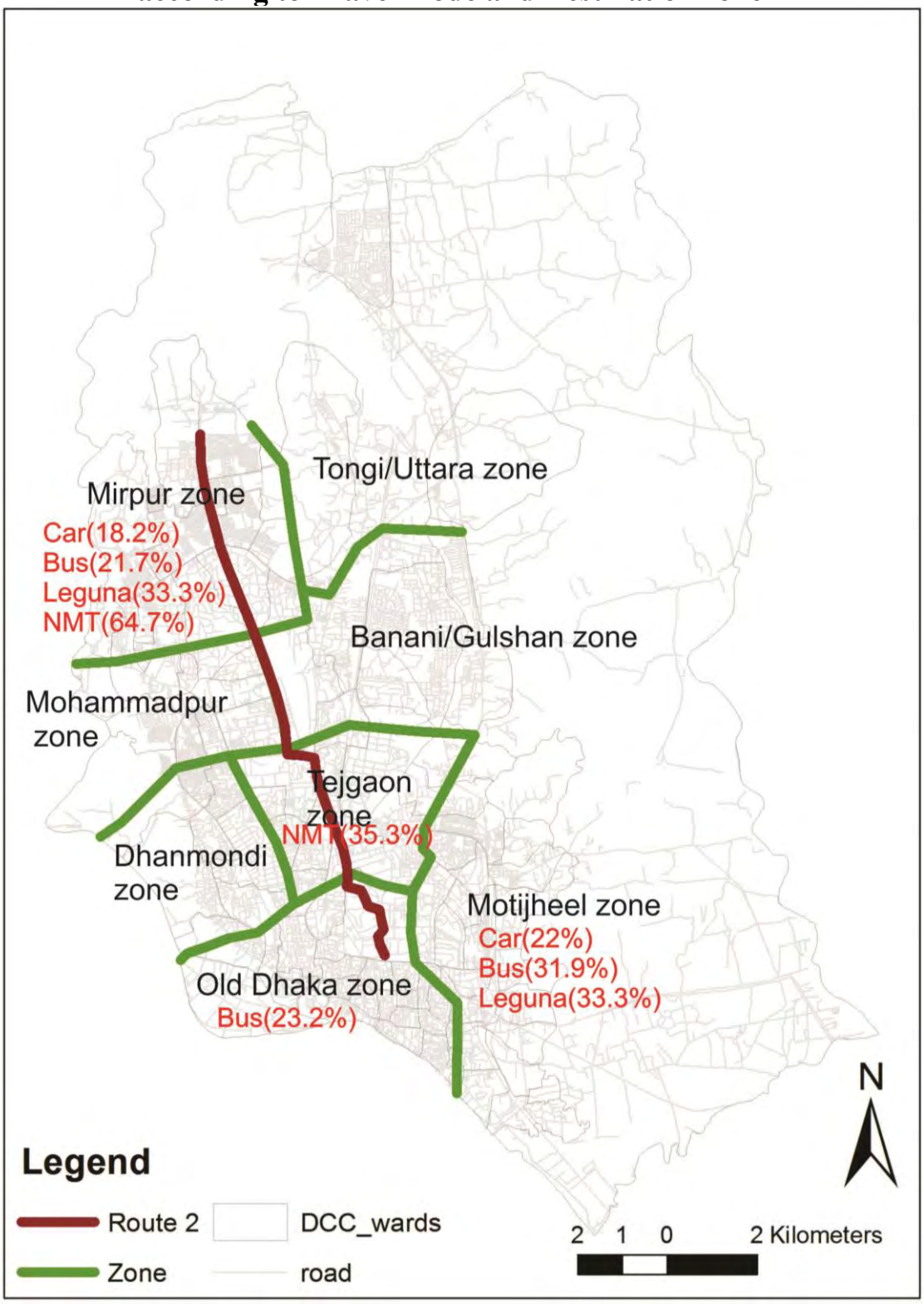


Figure 6.38: Percentage Distribution of Vehicle Trips along Route 03 according to Travel mode and Destination zone

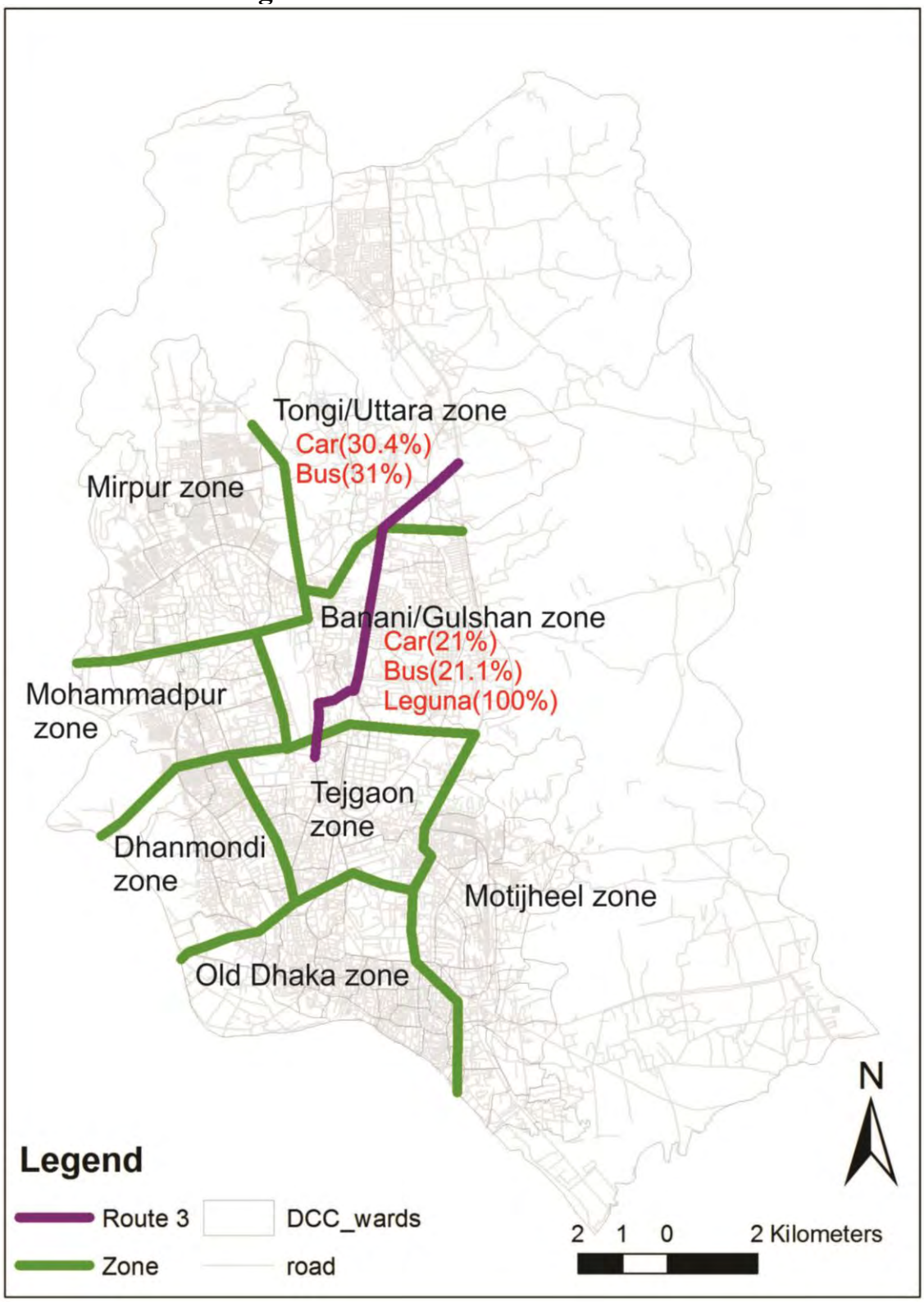


Figure 6.39: Percentage Distribution of Vehicle Trips along Route 04 according to Travel mode and Destination zone

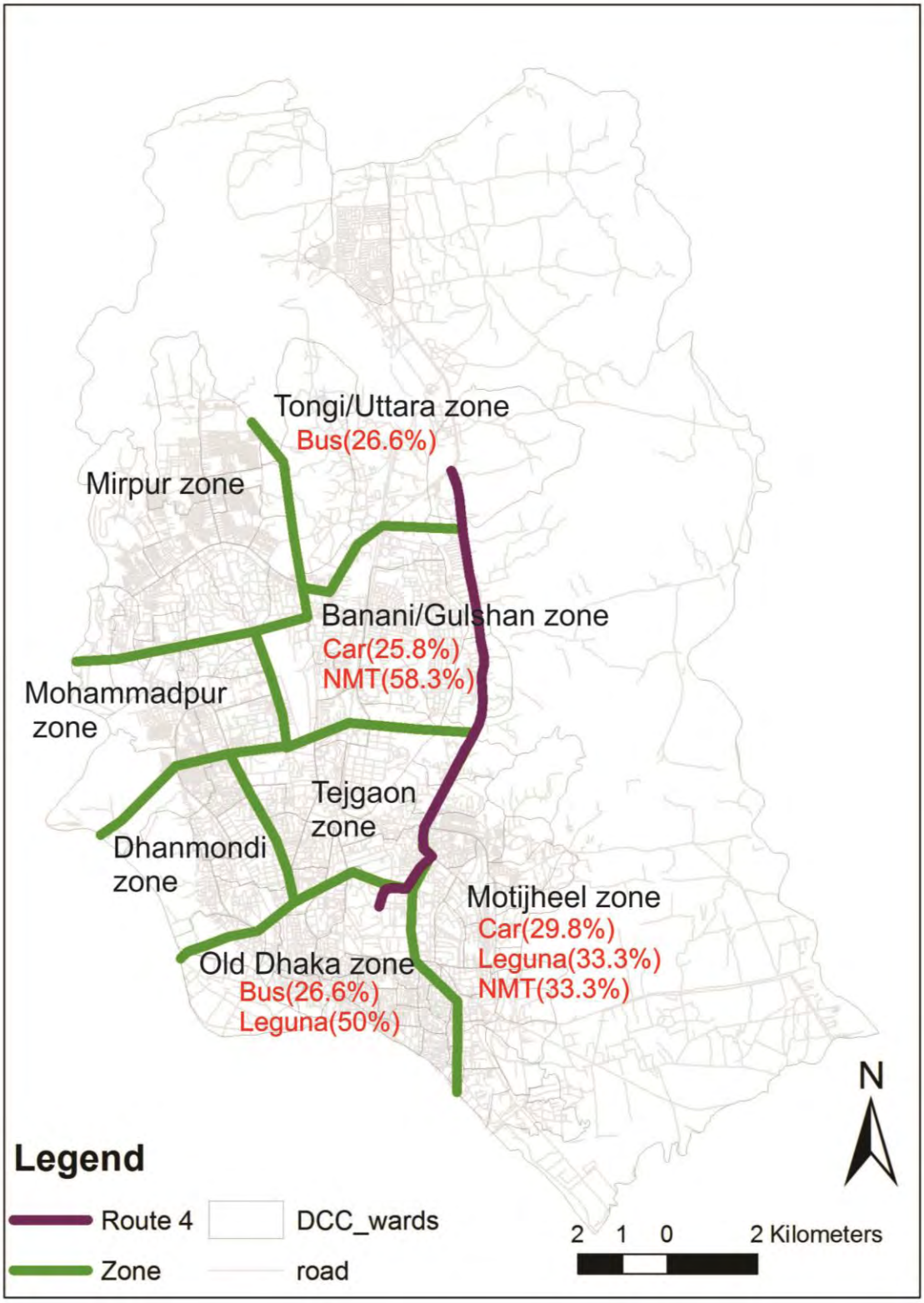


Figure 6.40: Overall Route Identification of all vehicle trips

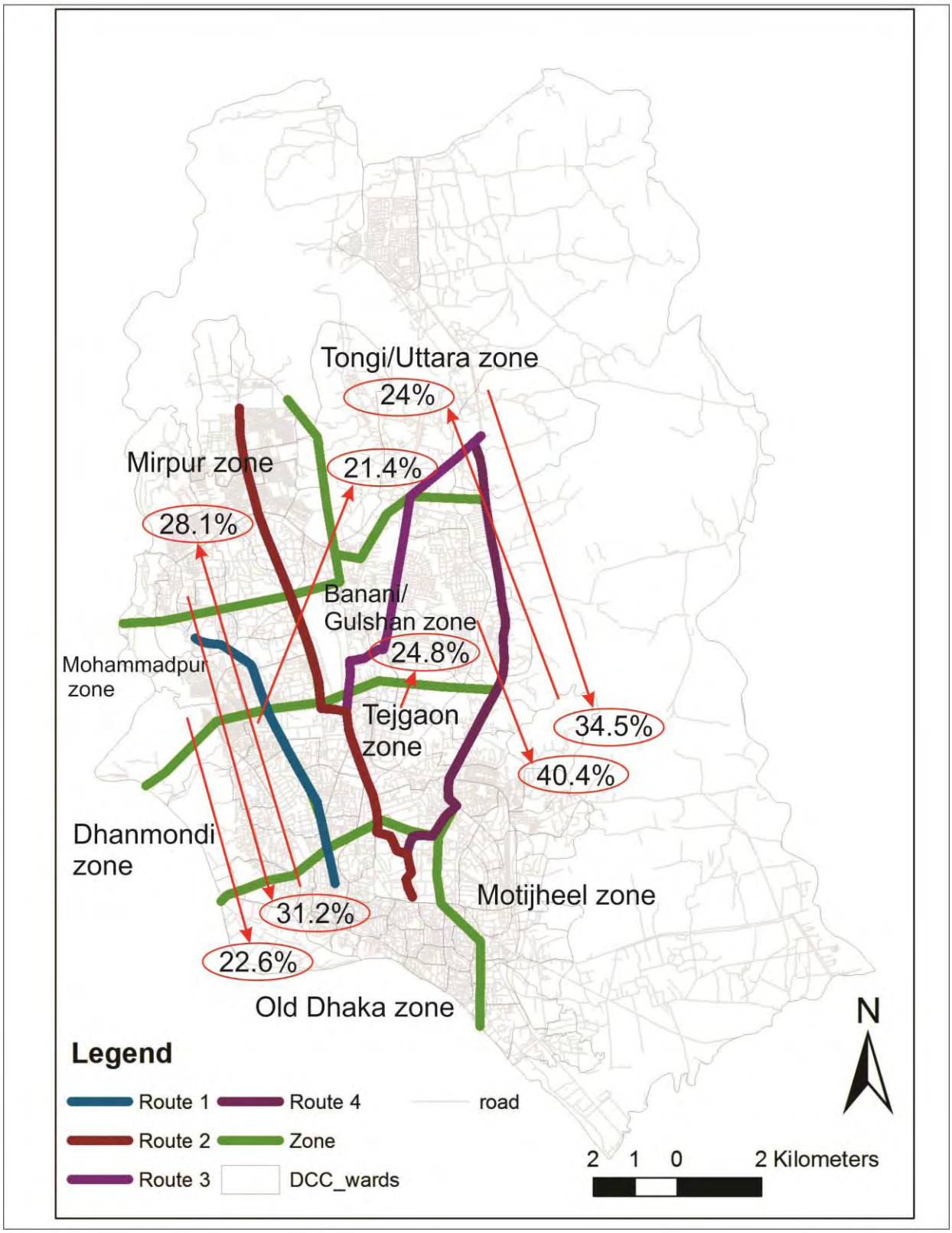


Figure 6.41: Route Identification of vehicle trips running along Route 01

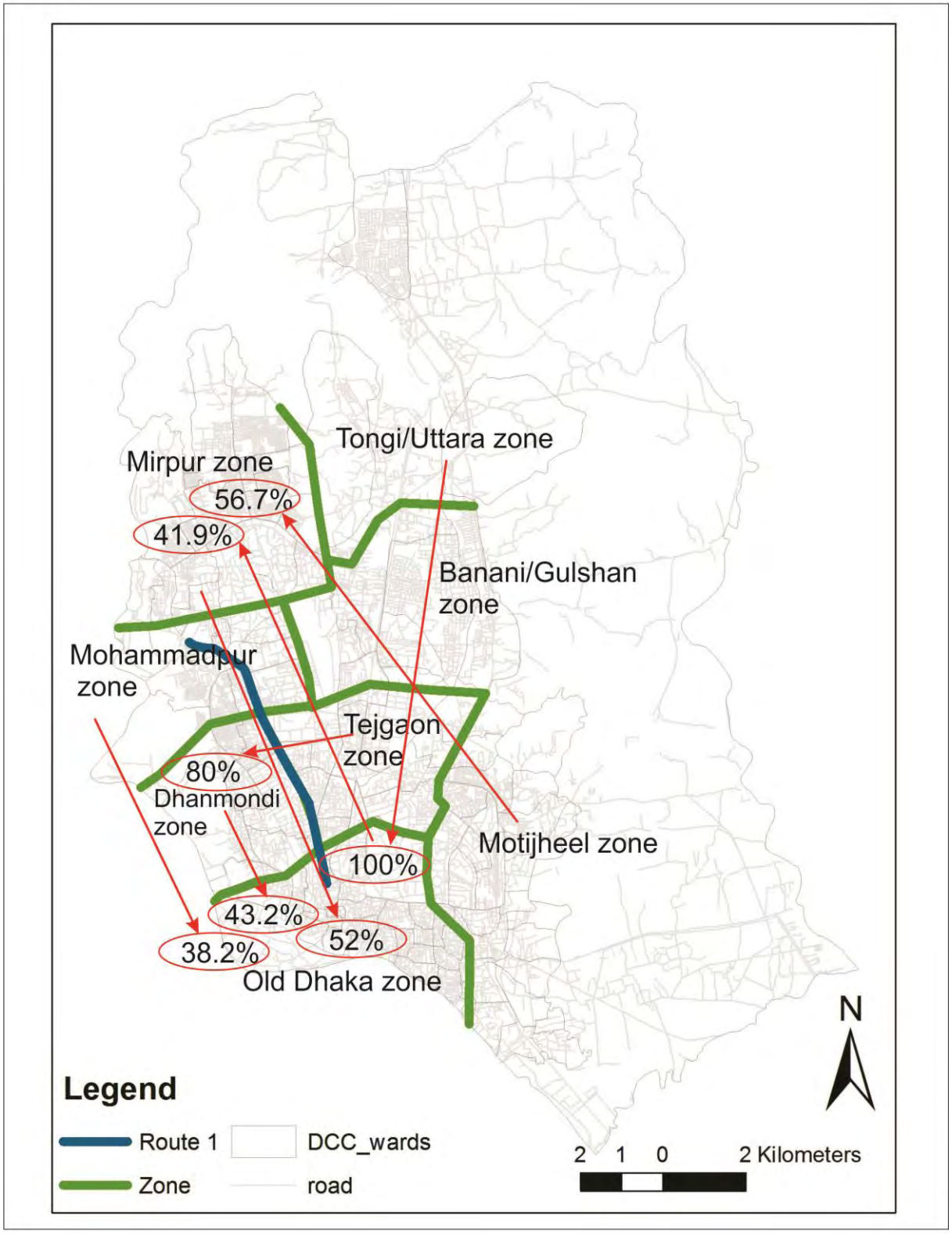


Figure 6.42: Route Identification of vehicle trips running along Route 02

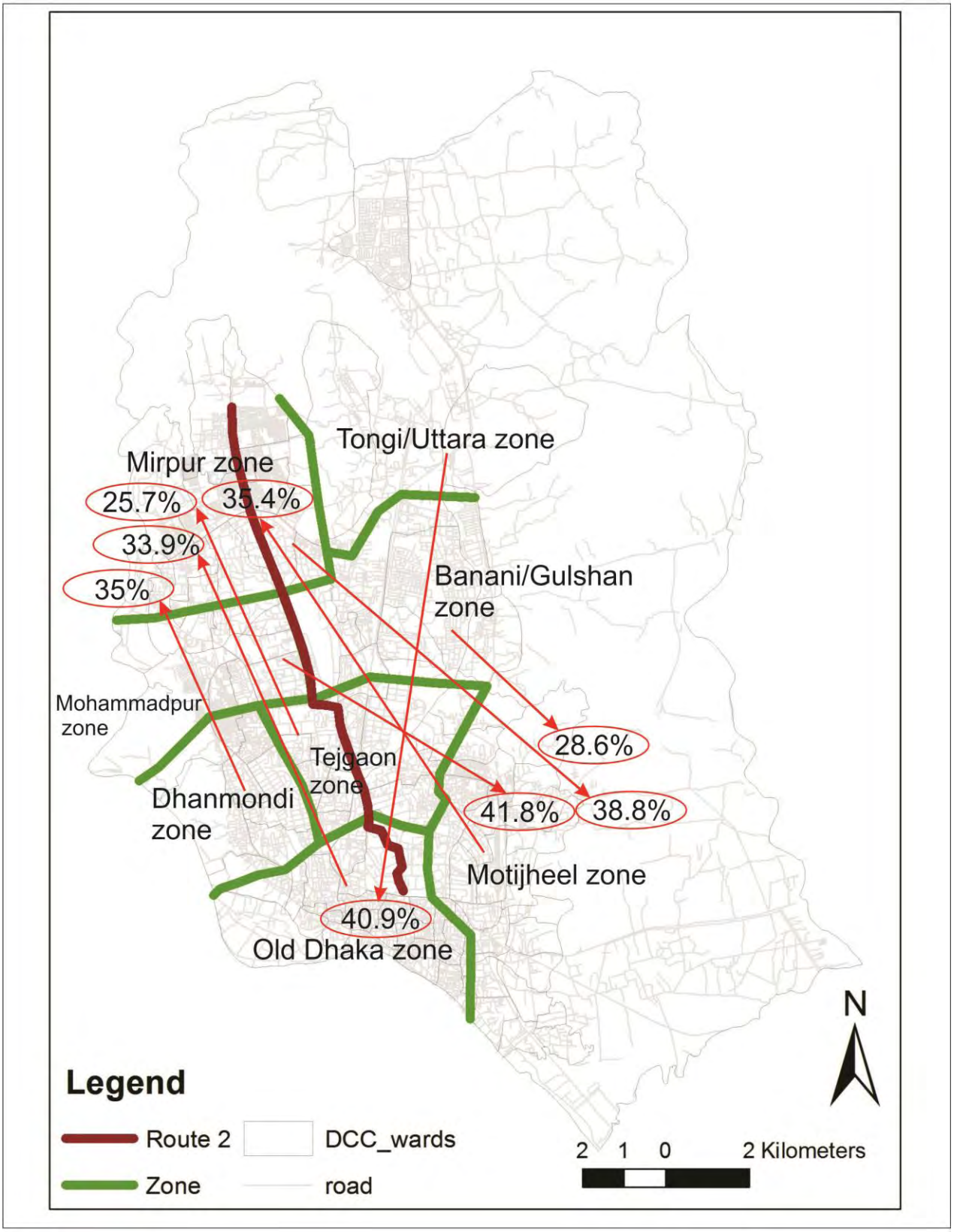


Figure 6.43: Route Identification of vehicle trips running along Route 03

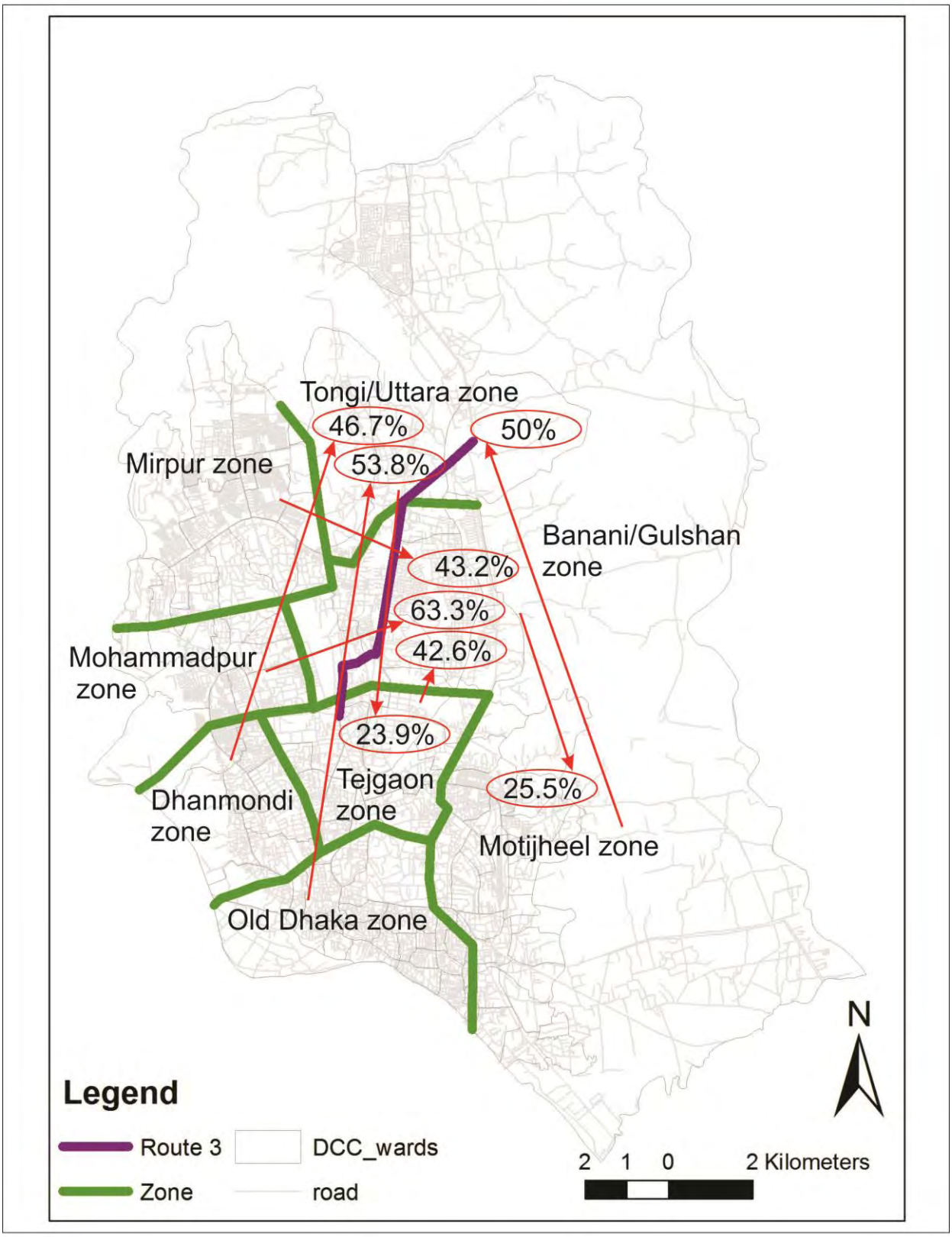
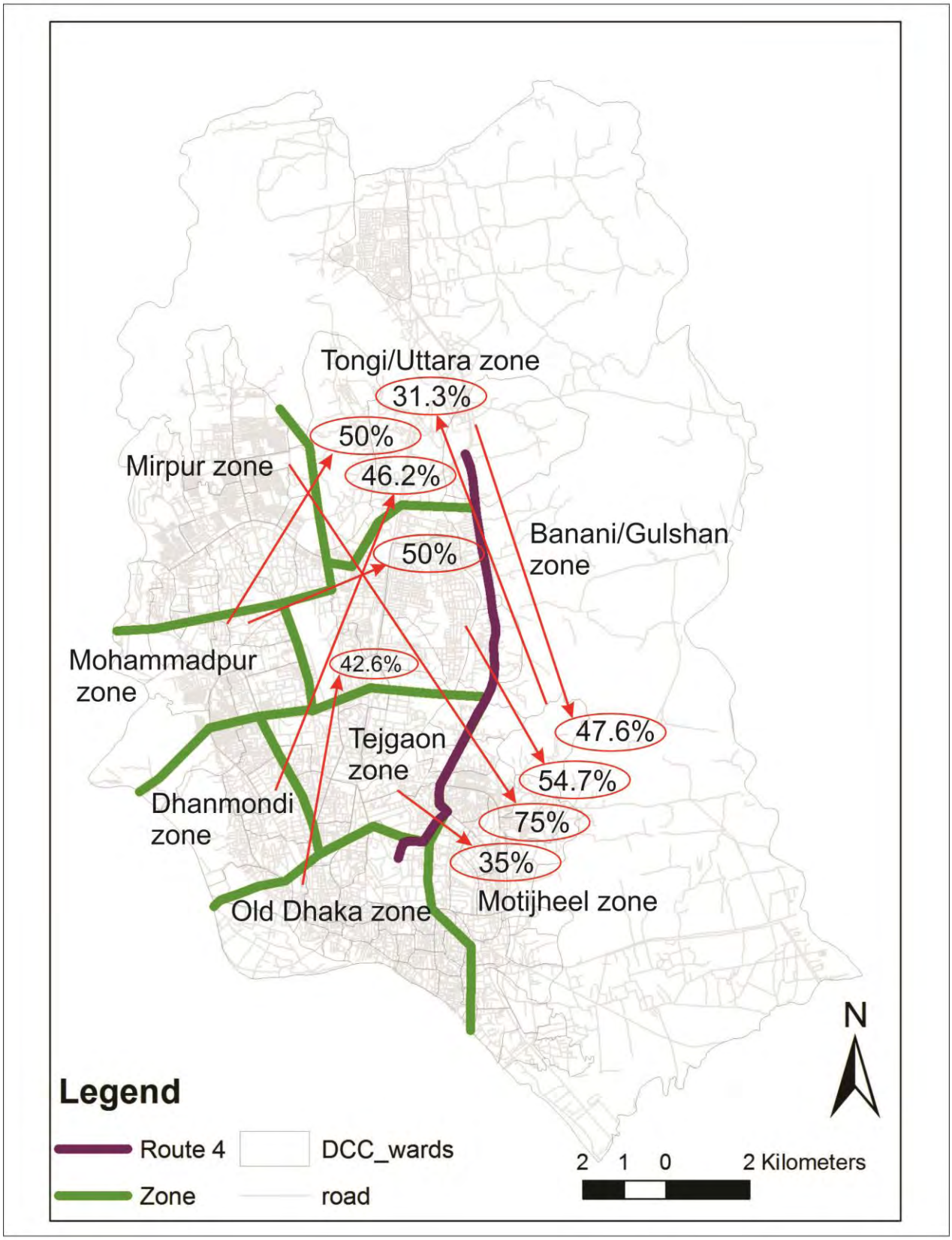


Figure 6.44: Route Identification of vehicle trips running along Route 04



CHAPTER 7

Determination of Optimum Traffic Volume

7.1 Introduction

Optimum traffic flow can be determined in consideration with numerous criteria. Computation of optimum traffic volume along all the study routes satisfying two criteria: vehicular emission standard and roadway capacity standard separately has been explored in this chapter. Also final optimum traffic volume for secondary alternative roads also has been determined in the later section of this chapter.

7.2 Optimum traffic volume satisfying vehicular emission standard

Vehicular emission of particular road link has been determined using traffic volume plying on that road link. Emission can be calculated in numerous ways. Based on distance and cold start emission can be calculated in the following way:

$$\text{Emission} = \Sigma_{i,j,k,l,m} (\text{Distance} * \text{Emission factor}_{i,j,k,l,m}) + \Sigma C_{i,j,k,l,m}$$

Here,
C = cold start emission
i = fuel type
j = vehicle type
k = pollutant type
l = operating condition
m = emission control technology

- Distance can be expressed also as Vehicle Kilometers Travelled (VKT/day)
- Emission factor in kg/unit of distance
- Number of vehicles along a selected link/road network can be multiplied with the total Emission value.

Here cold start emission (c) considered to be zero in context of avg. temperature and average speed range of our country (André, J. M. and Joumard, R., 2005). Equation can be modified as follows:

Standard wise emission for specific pollutant type and vehicle type (fuel wise) along a particular link of a given route = Length of that link*Emission Factor (EF)* Optimum Traffic volume (y)

Equation can be rewrite as follows:

Length of the specific link*Standard for Emission from motor vehicle*Traffic volume = Length of that link*Emission Factor* Traffic volume

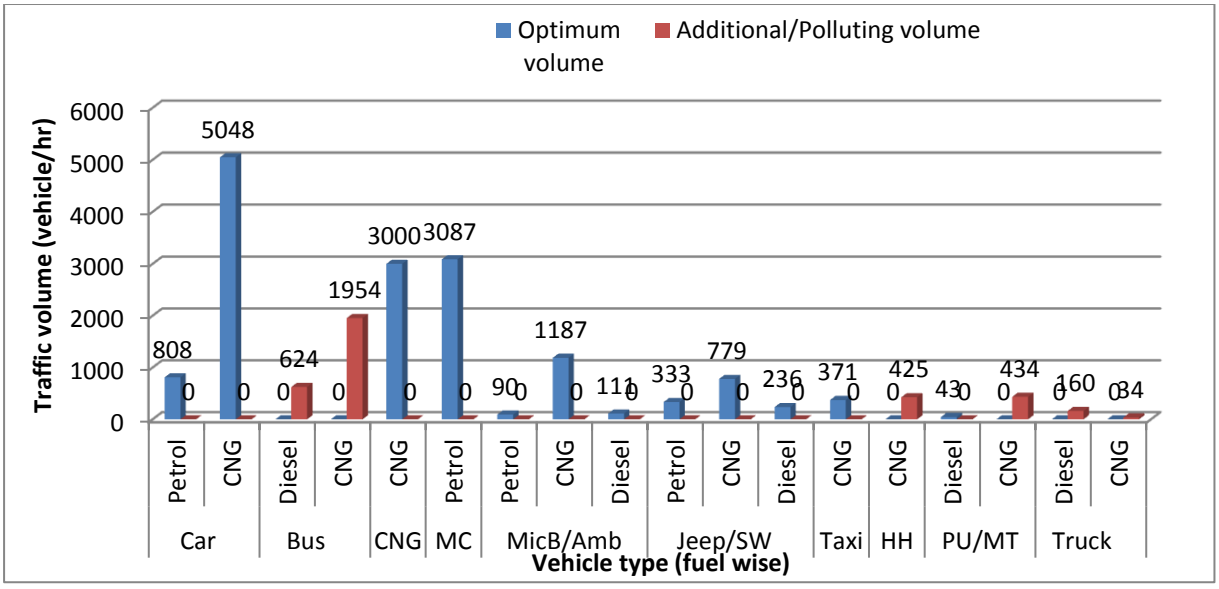
So, it can be said that if emission factor (gm/km) of vehicle mode (fuel wise) for each parameter/pollutant (CO, HC and NO_x) is similar or less than the amount stated in ECR, 1997 as emission standard for each pollutant then all the traffic flow from that specific vehicle category (fuel wise) are non-polluting volume and computed/considered as an optimum amount of traffic flow for that link. In such case there is no need to shift traffic along alternative route. But if emission factor for any of the pollutant exceeds the standard wise value (gm/km) then the whole traffic flow for that specific vehicle class (fuel wise) fall within pollution volume and will be in need of shifting along alternative route from the original route.

For example: while calculating optimum traffic volume for the first link of route 01 (Mirpur Road), we have to consider fuel wise vehicular flow data. Private car is the first vehicle category for our analysis. Both petrol and CNG driven private car volume data is collected for the analysis. Three pollutants are being considered for emission such as: CO, NO_x and HC. From ECR, 1997 emission standard for these three pollutants are 26, 4 and 4 gm/km respectively. Emission factor data for car (fuel type: petrol) has been found as 25, 1.5 and 4 gm/km respectively against the three emission parameter (pollutants). It is seen that for all the three parameters emission factor data for petrol driven private car has not exceeded the standard. Existing petrol driven private car volume has been collected as 96/hour along this link. So, it can be said that this traffic flow falls within non-polluting volume category and will not be needed to shift along any other route. For CNG driven private car similar result has been found (emission factor data for CNG driven car has not exceeded/far below from the standard against any of the three pollutants: 5, 1.5 and 2 gm/km respectively against CO, NOx and HC). Existing traffic flow data for car (fuel type: CNG) has been found as 601 and this volume is considered as optimum volume for link 01 of Route 01: Mirpur Road. This calculation procedure is repeated for each vehicle category (fuel wise) and total non-polluting traffic flow are summed up as optimum volume for specific link and pollution volume are summed up as shifting volume from that link along alternative route. Thus we can explore total number of traffic flow (both

optimum and shifting) along study links and also for each type of vehicle class (fuel wise) separately. Detail calculations of optimum traffic volume according to vehicular emission standard are shown in appendix D. Excel datasheet (printed copy) of existing, optimum and shifting traffic flow for all the study links along all four routes are also given in appendix.

7.2.1 Route wise comparison of total pollution traffic flow and non-polluting traffic flow

From the following four figures (from Fig. 7.1 to Fig. 7.4) it is being clearly understood that for each study route mainly bus (with both diesel and CNG fuel type), Leguna/Tempo/Human Hauler (fuel type: CNG), Pick up/Minitruck (fuel type: CNG) and Truck (with both diesel and CNG fuel type) contribute to emission as emission factors (gm/km) for these vehicle type (fuel wise) exceeds the emission standard (gm/km) given in ECR, 1997. As mentioned in appendix that for justified result emission standard has been upgraded by a slim margin for each parameter/pollutant. If that is not done then Private car (fuel type: petrol), Microbus/Ambulance/Jeep/Station wagon (fuel type: petrol and diesel) also contribute to vehicular emission. It is seen that only CNG driven vehicles contribute less amount of pollutant into air.



** CNG represents CNG Auto Rickshaw; MC= Motorcycle; MicB/Amb= Microbus/Ambulance; Taxi= Taxicab, HH=Human Hauler/ Leguna/Tempo; PU/MT= Pick up/Minitruck*

Figure 7.1: Total optimum and shifting volume for vehicle modes (fuel wise) along Mirpur Road (Route 01)

Table 7.1: Route wise polluting and non-polluting traffic volume status/scenario

Study Routes	Optimum/Non-polluting traffic volume	Shifting/Polluting volume
Route 01	15093	3631
Route 02	11797	3355
Route 03	3906	1232
Route 04	8362	2207

From the above table it is being depicted that Route 01 (Mirpur Road) is the most congested routes with maximum number of both non-polluting and pollution vehicles. On the other hand, Route 03 (Kuril to Bijoyshoroni) is the least congested routes. But as route length is not same for all four routes vehicle number does not play any significant role. In this study, Route 01 consists maximum number of links (11) and Route 03 consists minimum number of links (05).

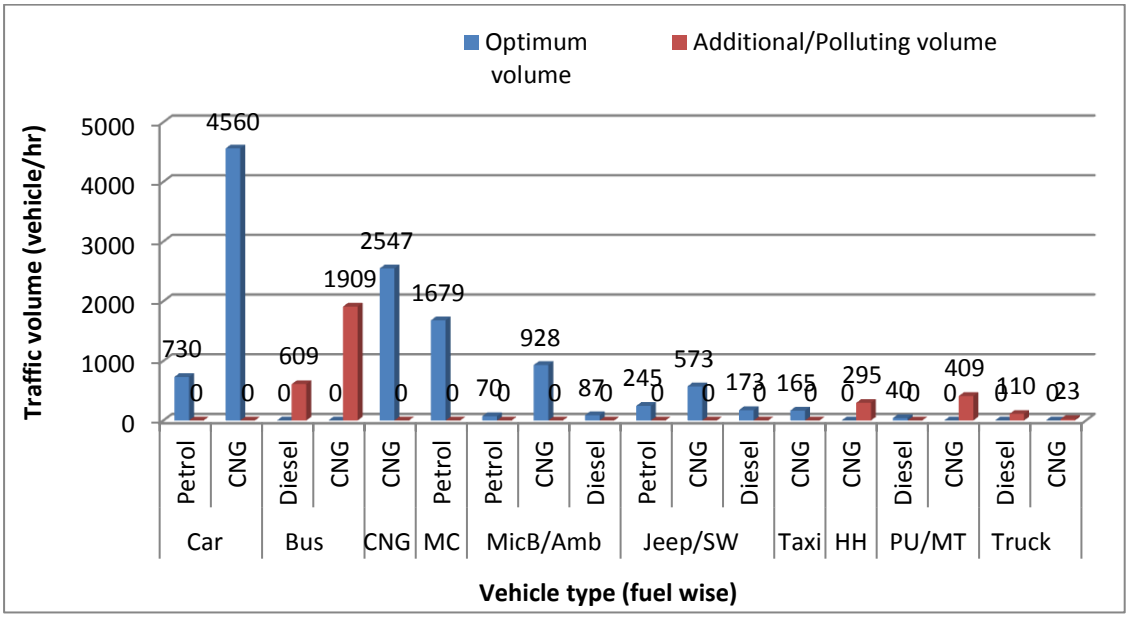


Figure 7.2: Total optimum and shifting volume for vehicle modes (fuel wise) along Pallabi to Anandabazar Route (Route 02)

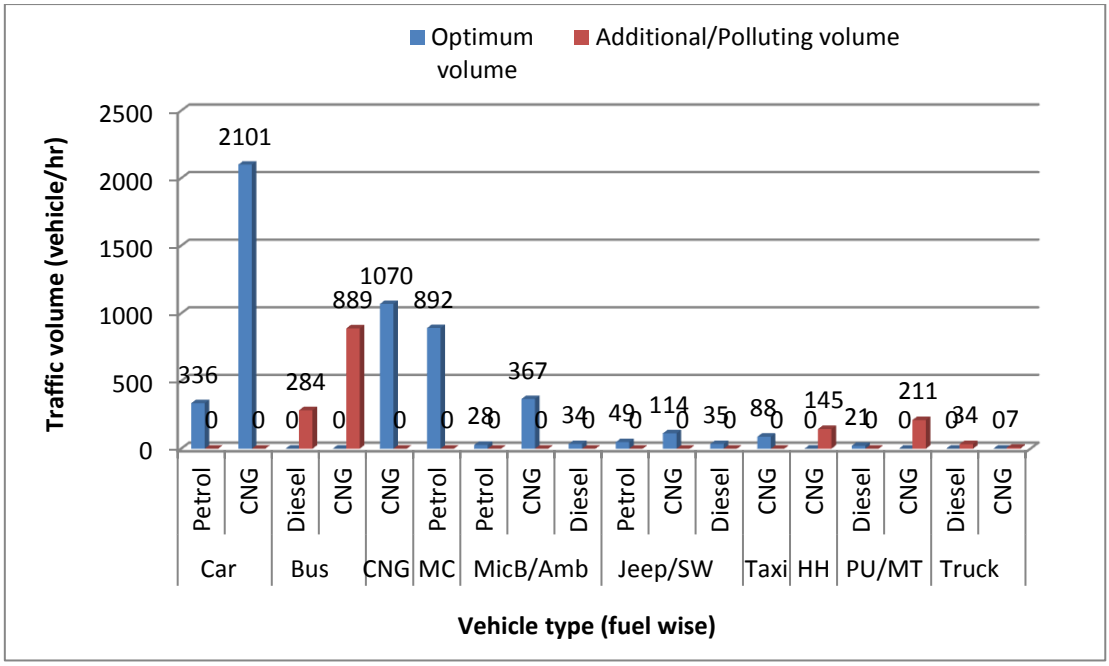


Figure 7.3: Total optimum and shifting volume for vehicle modes (fuel wise) along Kuril to Bijoyshoroni (Route 03)

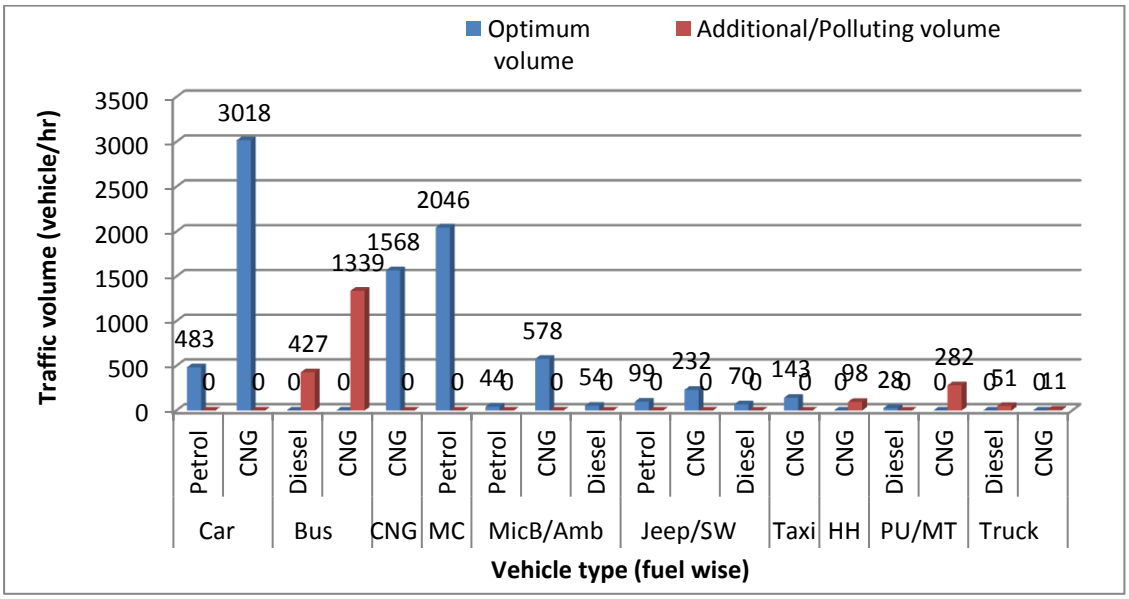


Figure 7.4: Total optimum and shifting volume for vehicle modes (fuel wise) along Kuril to Shegunbagicha (Route 04)

From the above four figures specific number of vehicle category (with fuel type) needed to shift along alternative routes and standard traffic volume (both vehicle class and fuel type wise) along four study routes has been found. This analysis is only according to vehicular emission standard.

7.2.2 Link wise inter comparison between traffic flow along specific route considering emission standard

In this portion of analysis from the optimum traffic volume and additional traffic volume, most and least polluted link along each study route has been identified.

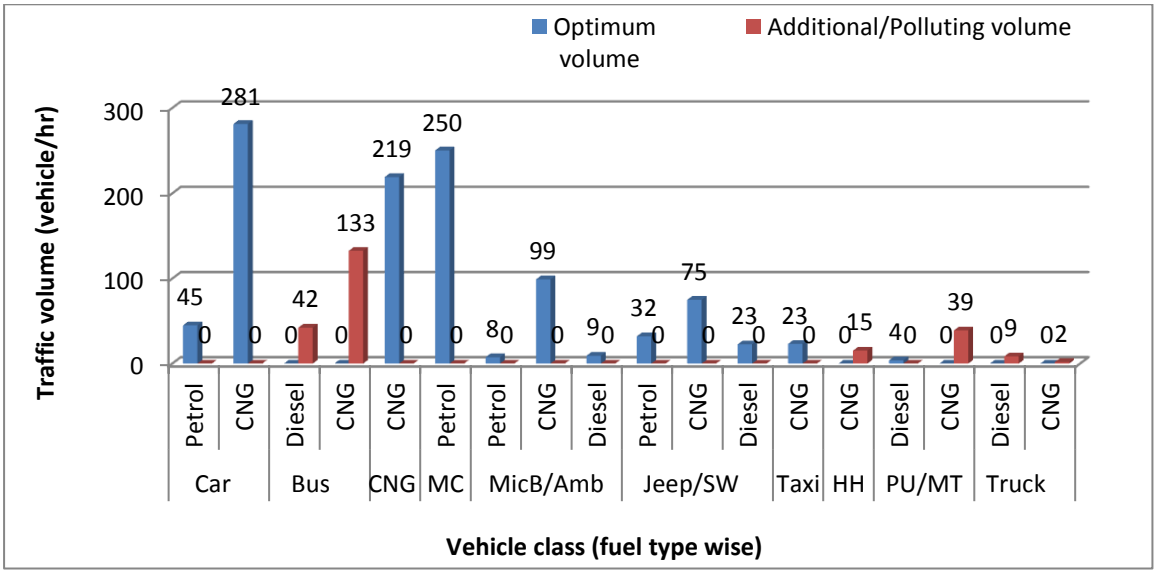


Figure 7.5: Fuel wise optimum and additional traffic flow along the least polluted link (Link 3: R3) of Mirpur Road (Route 01)

Besides that specific number of vehicle class (with fuel type) needed to shift along alternative routes and standard traffic volume has been shown for both types of links (most and least polluted) along four study routes. For Route 01 (Mirpur Road), link started from Agargaon Shishumela signal to Residential model college corner (north) is considered as the least polluted link among all the eleven links of Mirpur road as this link shows minimum shifting/additional traffic flow/volume after calculation of optimum volume according to vehicular emission standard. In total this link possess 1069 vehicles as optimum volume along the link and rest 239 vehicles are considered as additional traffic volume and are needed to be shifted along alternative route.

Photo 7.1 and 7.2: Excessive vehicular emission contributes in environmental pollution and degrades city environment in Dhaka
Source: URL 2

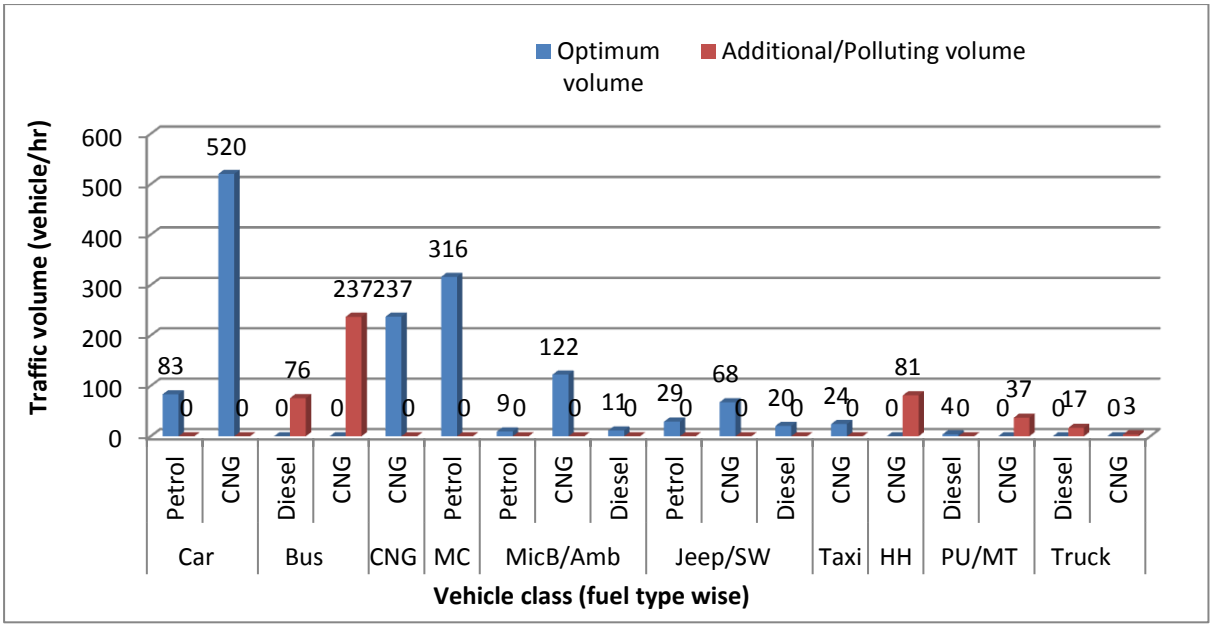


Figure 7.6: Fuel wise optimum and additional traffic flow along the most polluted link (Link 10: R10) of Route 01

From the above figure it is been observed that link no. R10 (Science lab signal to New market signal) is considered to be the most emission contributed links among all the 11 study links of Mirpur road consisting almost 451 polluting/additional vehicles plying on that specific link. Optimum number of vehicles computed is also high here in this link (1445). Some other links also possess high optimum traffic flow but this link contributes highest to environmental pollution through vehicular emission.

In the following two figures least and most polluted links along study route no. 2 (Pallabi to Anandabazar at Guslistan) has been identified. Link started from Pallabi Shoronee 11 to Mirpur 10 (R1) is found to be least polluted link with 136 additional/polluting vehicles after calculation. Optimum number of vehicles is also small here in this link. Link no. 9: R9 (Motsho bhaban to Kodom foara) is found as most amount of vehicular emission contributed link with 631 additional vehicles.

Photo 7.3: Huge volume of traffic cause pollution to the air of Dhaka
Source: Jahan. 2013

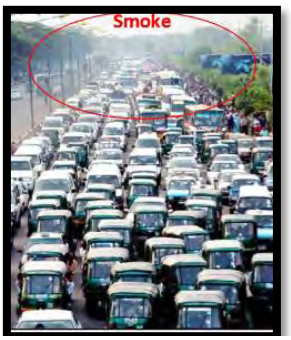


Photo 7.4: Vigorous growth of vehicles increase the level of air pollution
Source: URL 3

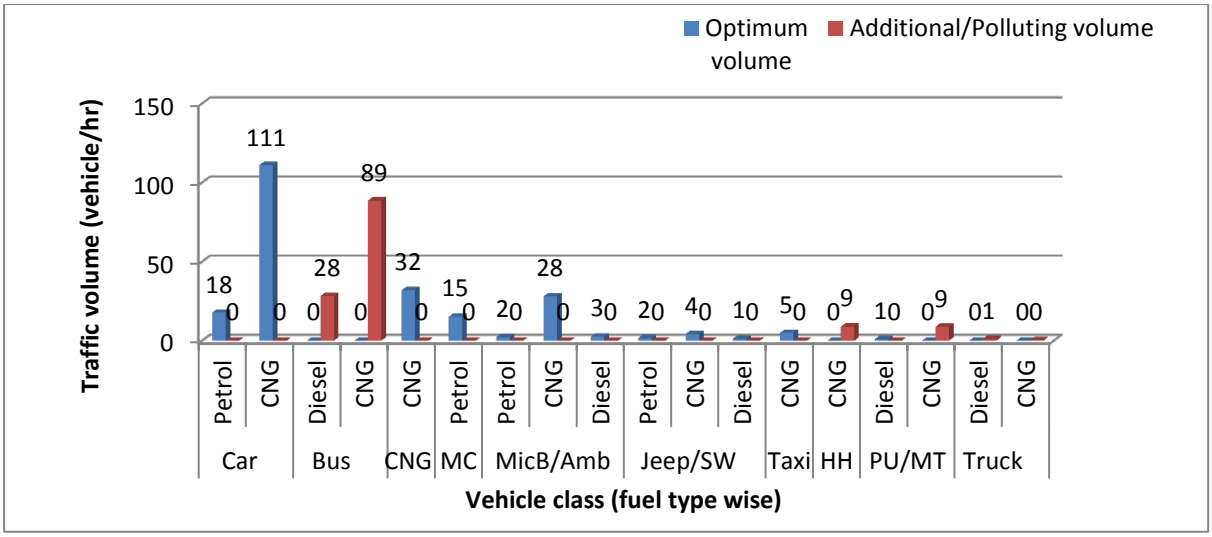


Figure 7.7: Fuel wise optimum and additional traffic flow along the least polluted link (Link 1: R1) of Route 02

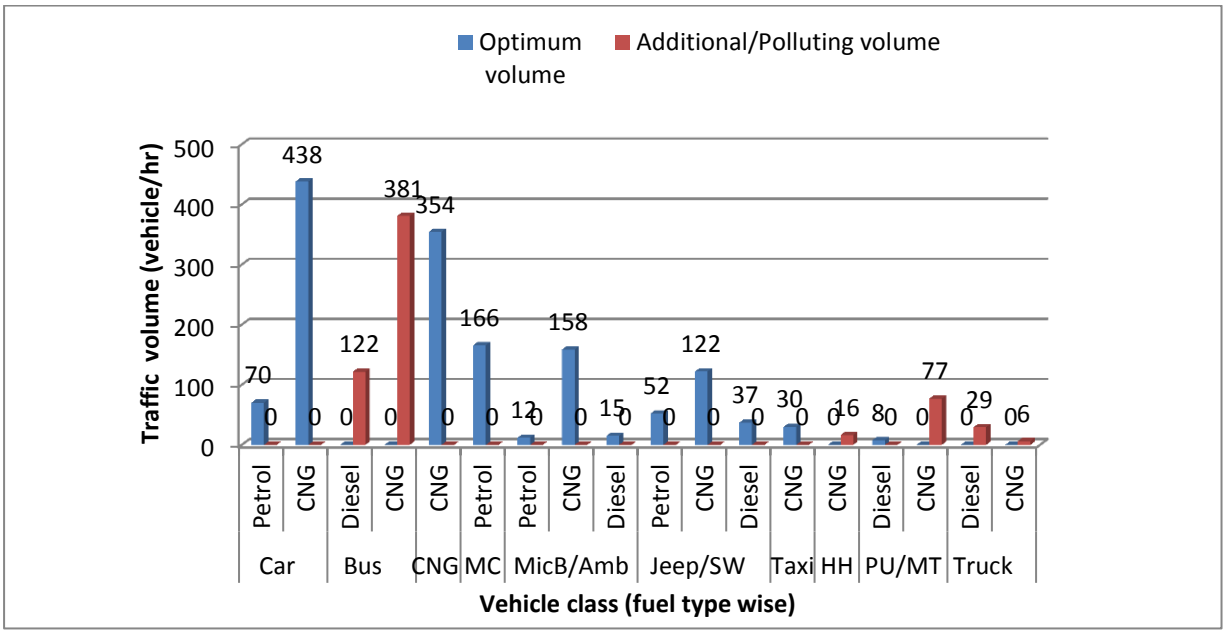


Figure 7.8: Fuel wise optimum and additional traffic flow along the most polluted link (Link 9: R9) of Route 02

In a similar way both least and most vehicular emission contributed links have been identified for the rest of the two study routes (Route 3: Kuril to Bijoy Shoroni) and (Route 4: Kuril to Shegunbagicha) which have been showed in the following four figures.

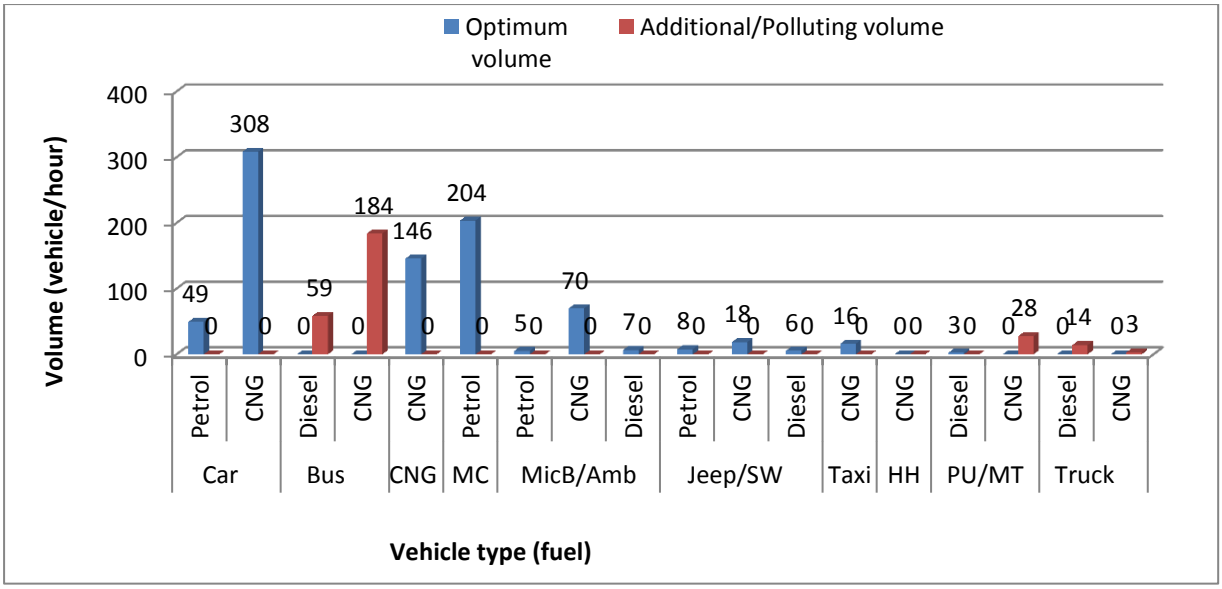


Figure 7.9: Fuel wise optimum and additional traffic flow along the least polluted link (Link 1: R1) of Route 03

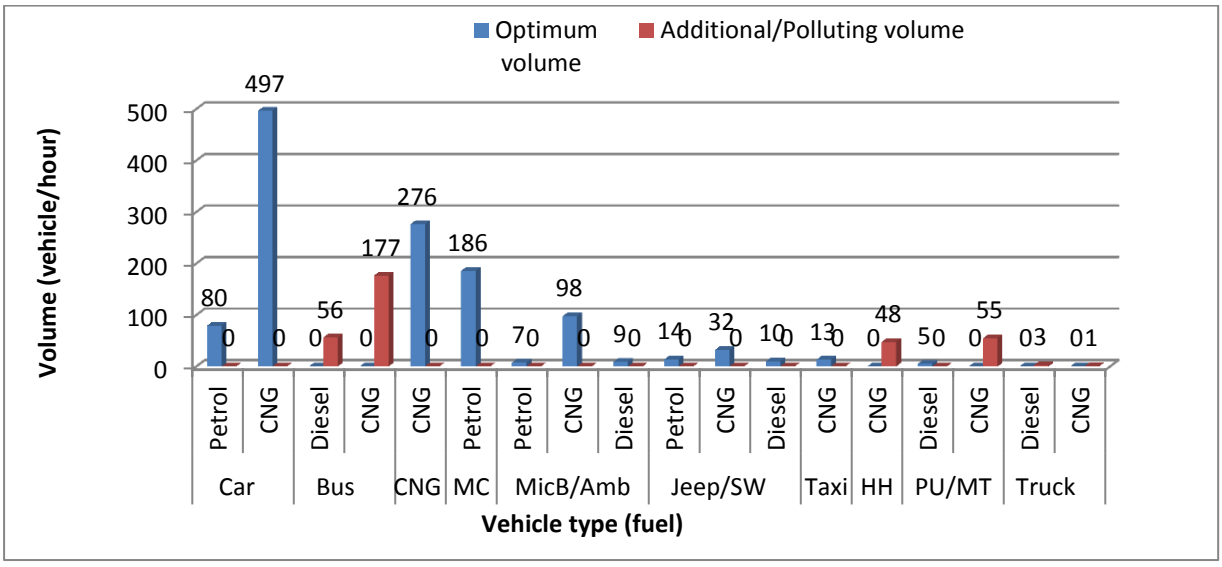


Figure 7.10: Fuel wise optimum and additional traffic flow along the most polluted link (Link 5: R5) of Route 03

Kuril to Banani rail crossing link is found as the least polluted link and Jahangir gate to Bijoy shoronee_Novo theatre signal is found to be the most emission contributing link along Kuril to Bijoy Shoroni route (Route no. 3). For route no. 4 (Kuril to Shegunbagicha), Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha and Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner) are found to be with the least and most number of polluting

vehicles after standard/optimum volume calculation considering vehicular emission as the sole criteria.

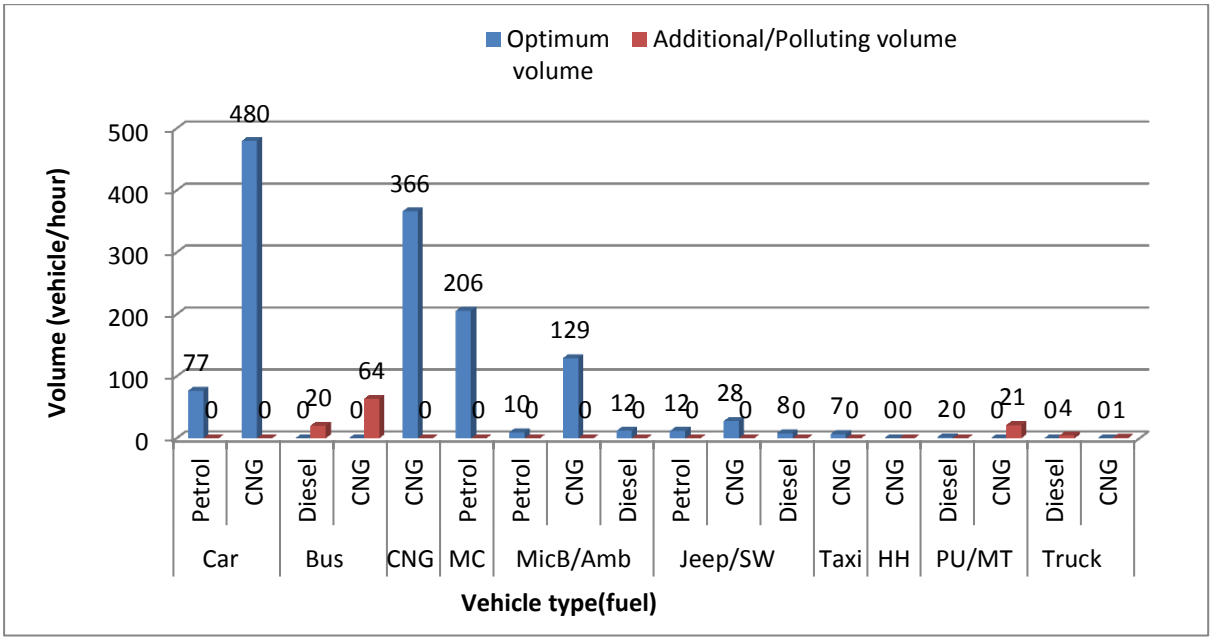


Figure 7.11: Fuel wise optimum and additional traffic flow along the least polluted link (Link 9: R9) of Route 04

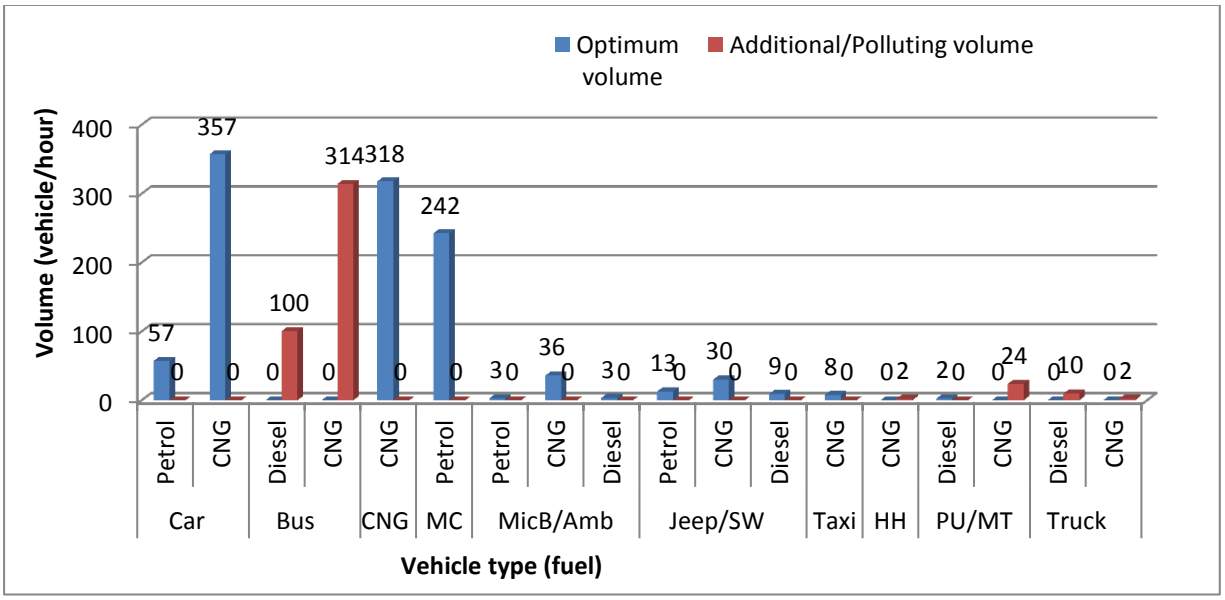


Figure 7.12: Fuel wise optimum and additional traffic flow along the most polluted link (Link 2: R2) of Route 04

7.3 Optimum traffic volume satisfying roadway capacity standard

While computing optimum traffic flow according to roadway capacity standard first carriageway width data along roads (link wise) has been collected from field survey. This collected data has been termed as original carriageway width data. Two feet of width has been excluded from the original width as kerb / slope width from both sides of the carriageway. After exclusion total carriageway width for each road has been summed up from both sides width.

According to Rahman, M. M. (2006), Original carriageway width has been calculated by excluding 18 feet width from total carriageway width of major arterial road assuming 45 degree (parking provided) single row parking space width of 18 feet. Effective carriageway width has been calculated excluding 40 feet width from total carriageway width assuming parking practice (90 degree and parallel in our country context). Present parking practice is 16 feet*2 rows as 90 degree plus 8 feet as parallel parking comes up into total 40 feet width (40 feet encroached for on street parking) exclusion from total carriageway width along a major arterial road.

Photo 7.5 and 7.6: Present on street parking practice (two rows 90 degree parking and one row parallel parking) along Route 01
Source: Field survey, 2014

Assuming 12 feet as per lane width, total number of lanes (both original and effective) has been found. The capacity of 12 feet lane is 1200 PCU/hour as recommended in Highway Capacity Manual (Douglas county HCM, 2009). Then after multiplication, both total original capacity (PCU/hour) and total effective capacity (PCU/hour) has been found for each study route (link wise). Detail calculation for each link along each study route has been given within appendix E. Total effective capacity computed for each link on four study routes has been considered as optimum traffic volume (in

PCU) satisfying roadway capacity standard. Similarly for other secondary and connector alternative routes effective roadway capacity has been calculated through excluding only 18 feet assuming that only provided parking space (18 ft) has been encroached as these are not primary arterial roads. But in practical context of our country it is been observed that both 90 degree and parallel parking practiced along secondary roads also.

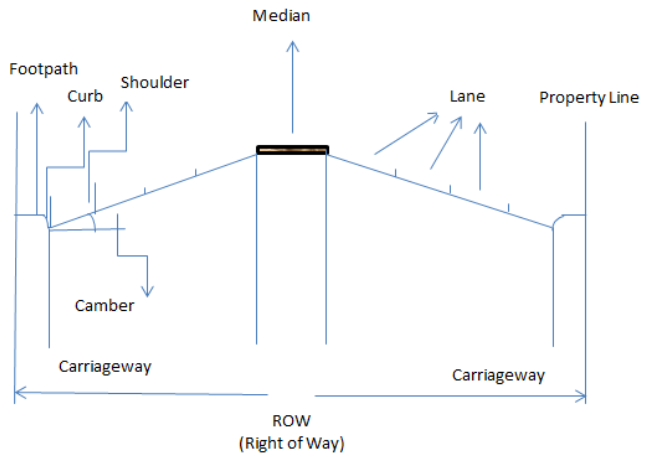


Figure 7.13 (a): Cross section of a major arterial road

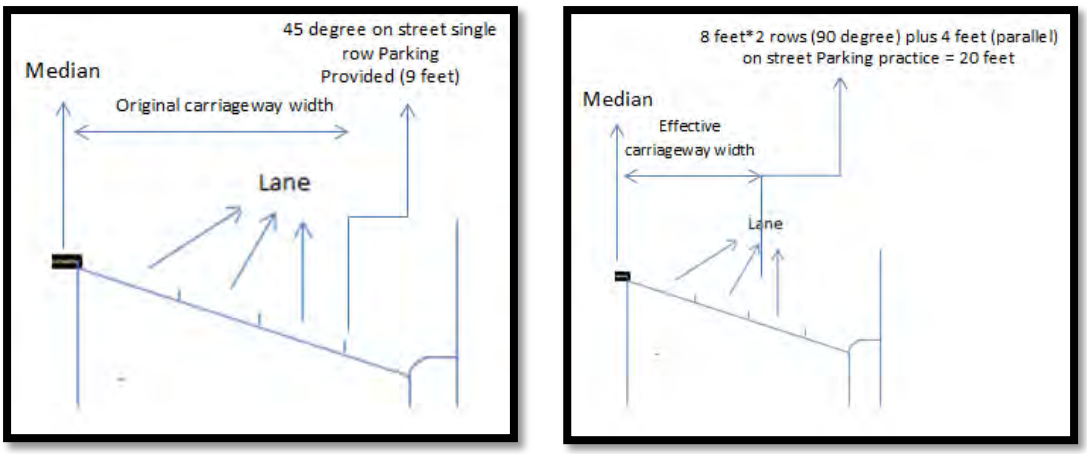


Figure 7.13: (b) Original carriageway width with parking space provided (ideal scenario) and (c) Effective carriageway width with illegal parking practice in Dhaka (real scenario)

7.3.1 Route wise deviation of total effective capacity from original capacity provided

As discussed earlier, effective carriageway width has been calculated for major arterial road through excluding a notable portion of road width from original carriageway width. Route wise deviation has been observed after the calculation (see detail in appendix E). There is a huge amount of deviation of total effective roadway

capacity from original roadway capacity provided. This is one of the major reasons of traffic congestion in Dhaka city as original roadway width is more than enough for major arterial roads of the city and road width provided is larger than many other world's largest city's road widths.

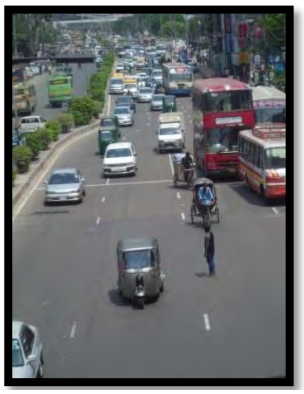


Photo 7.7 and 7.8: Enough carriageway width along Link 10 (Science lab to New market) and Link 1 (Technical Morh to Shyamoli cinema hall signal) of Route 01
Source: Field survey, 2014

Photo 7.9: Huge original roadway capacity provided along Route 02
Source: Field survey, 2014

Photo 7.10: Enough carriageway width provided at Banani along Route 03 (Kuril to Bijoyshoroni)
Source: Field survey, 2014

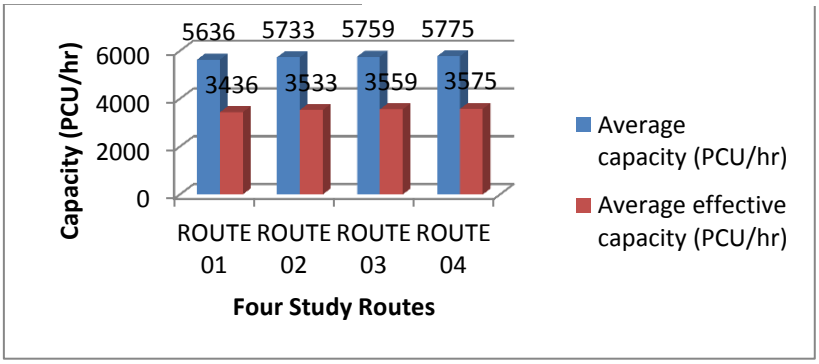


Figure 7.14: Deviation between effective capacity from original capacity provided along four study routes

From the above figure it can be clearly seen that almost similar kind of deviation occurred for the four major arterial routes. Average original capacity among four routes calculated as 5726 PCU/hour (approx.) and average effective capacity for these

routes found as 3526 PCU/hour. Overall average deviation for all four major arterial routes is 2200 PCU/hour. This deviation surely contributes to traffic congestion in the city. If full original capacity can be achieved then it could be expected to have a better traffic management scenario in our country.

7.3.2 Link wise total effective capacity along each study route

Now we have to discuss about total effective capacity of our roadway sections as we could not achieved total original roadway capacity provided in Dhaka's major arterial routes. It is important to analyse link wise variation in effective capacity along specific route as travel behaviour analysis indicates that most of the running vehicles prefer to stay along one specific route to reach their destination rather than shifting to parallel alternative routes. In this context it is important for any major arterial route to maintain a similar kind of effective roadway capacity along all the links/sections of a particular route. In the figure 7.14 (following figure) we can see that almost similar capacity is maintained throughout all the links along Mirpur Road. But in case of link no. 08 (Dhanmondi 27 signal to Panthapath Russel square signal) with length of 0.65 km, possess effective capacity of only 1650 PCU/hr. Original carriageway width from field survey was found to be only 31 ft (left carriageway) and 29.5 ft (right carriageway) for this specific link/road section whereas for other links along Mirpur Road carriageway width has been found from survey as 40 feet per side (on an average).

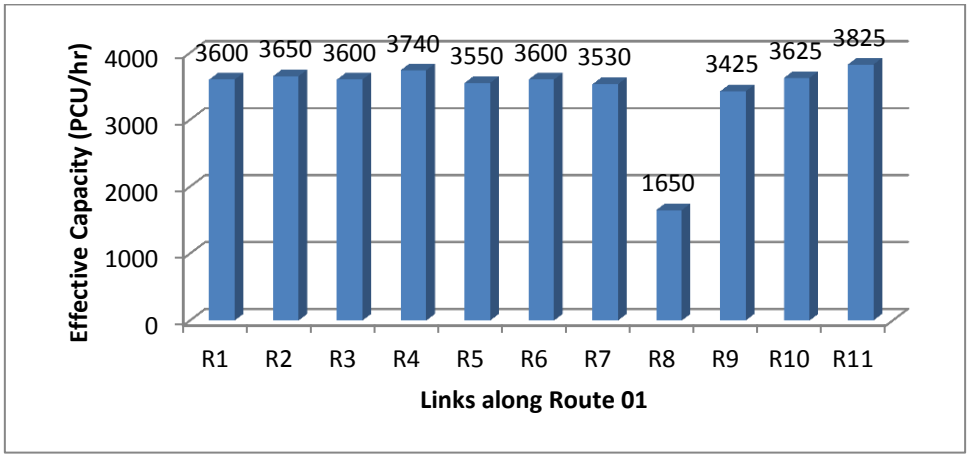


Figure 7.15: Link wise effective capacity variation along Mirpur Road (Route 01)

CASE STUDY 01

As previously said and from the above figure we can see that link no. 08 (Dhanmondi 27 signal to Panthapath Russel square signal) with length of 0.65 km, possess effective capacity of only 1650 PCU/hr. Original carriageway width from field survey was found to be only 31 ft (left carriageway) and 29.5 ft (right carriageway) for this specific link/road section whereas for other links along Mirpur Road carriageway width has been found from survey as 40 feet per side (on an average). This less amount of carriageway is because of a specific land use (Sobhanbagh Mosque) which is located beside that link through occupying a significant portion of the road. Whereas for all other study routes it has been found that existing traffic flow is less than capacity wise optimum traffic flow (see figure 7.22 and figure 8.2 in chapter 08) we can see that along Link 08: Route 01 (R8) capacity wise optimum traffic flow (1650 PCU/hr) is less than existing traffic volume (1969 PCU/hr).

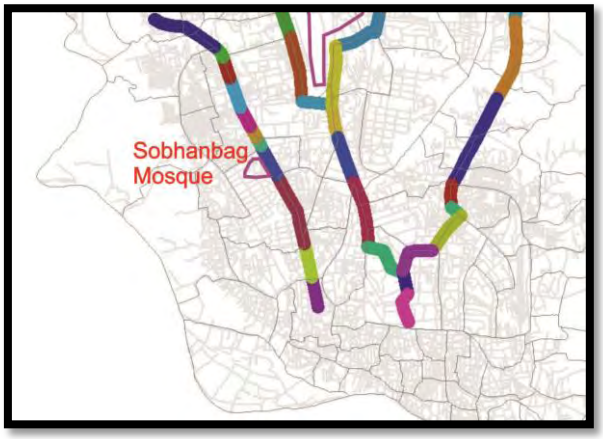


Figure 7.16: Location of Sobhanbagh Mosque along Link 08 of Mirpur road

Photo 7.11: Road side illegal encroachment reduces effective capacity of Link 10 (Science lab signal to New market signal) along Mirpur Road
Source: Field survey, 2014

Photo 7.12: Road side obstruction reduces effective roadway space of Link 02 (Mirpur 10 to Agargaon) along Pallabi to Anandabazar route
Source: Field survey, 2014

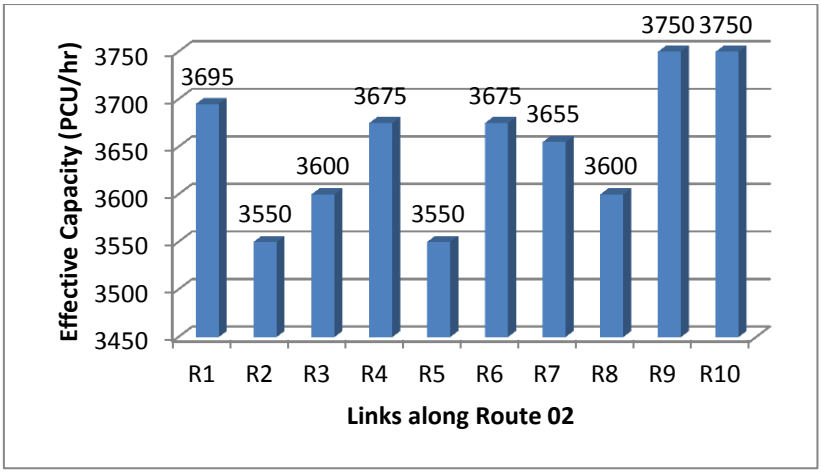


Figure 7.17: Link wise effective capacity variation along Pallabi to Anandabazar Route (Route 02)

In case of the 2nd major study route, Pallabi to Anandabazar at Gulistan effective capacity of road sections vary within a comparatively narrow margin (from 3550 PCU/hr to 3750 PCU/hr). For all the nine study sections/links less variation of carriageway width has been observed for this route. In this case, Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school road section and Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal road section show minimum capacity. On the other hand, Motsho bhaban to Kodom foara and Kodom foara to Anadabazar at Gulisthan, these two study links possess maximum effective roadway capacity for Route 02.

Photo: 7.13: Road side encroachment upon roadway space along route 02
Source: Field survey, 2014

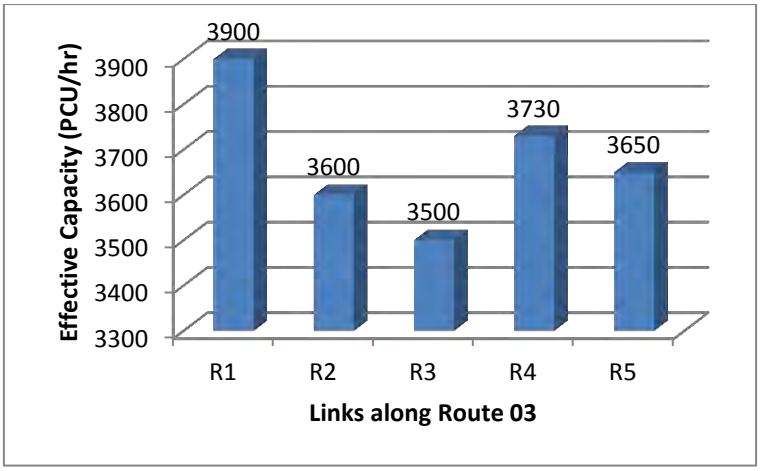


Figure 7.18: Link wise effective capacity variation along Kuril to Bijoyshoroni Road (Route 03)

From the above figure it can be said that almost similar capacity variation occurs along different links of Route no. 3 in compare to Route 02 study section. But here in Route 03 difference between links with maximum and minimum roadway effective capacity is a little bit higher (400 PCU/hour). Link no. 01 (Kuril to Banani rail crossing) shows maximum effective capacity on the other hand, link no. 3 (Banani DOHS to Mohakhali-Gulshan road) shows minimum capacity after calculation.

Similar kind of effective roadway capacity can be depicted from the following link wise capacity variation figure along Route 04. Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban) link found to be with minimum capacity (3450 PCU/hr) and link started from Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha found to be with maximum roadway capacity (3755 PCU/hr) along Route no. 4.

Photo 7.14: Damaged road condition along Link 03 (Banani DOHS to Mohakhali-Gulshan road intersection; near Mohakhali flyover starting point) of Route 03 (Kuril to Bijoyshoroni)
Source: Field survey, 2014

Photo 7.15: Roadside construction debris reduces space for vehicles along Route 04 (Kuril to Shegunbagicha)
Source: Field survey, 2014

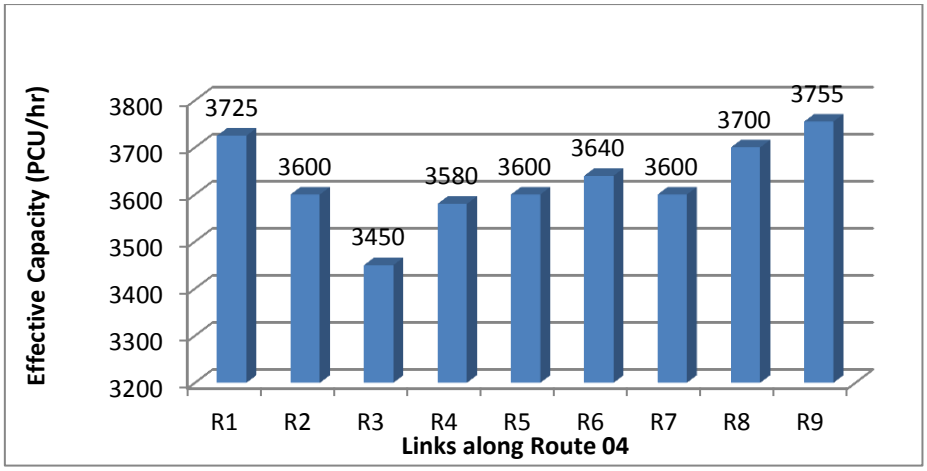


Figure 7.19: Link wise effective capacity variation along Kuril to Shegunbagicha Road (Route 04)

7.3.3 Analysis of existing traffic flow and effective roadway capacity

Optimum traffic flow determination in consideration with road capacity entirely depends on effective roadway capacity of the associated study road sections/links along four major arterial study routes. But it is also important to analyse the existing traffic flow along those routes (link wise) to make a comparison whether there are any additional traffic running along the study routes which will be needed to shift along alternative routes.

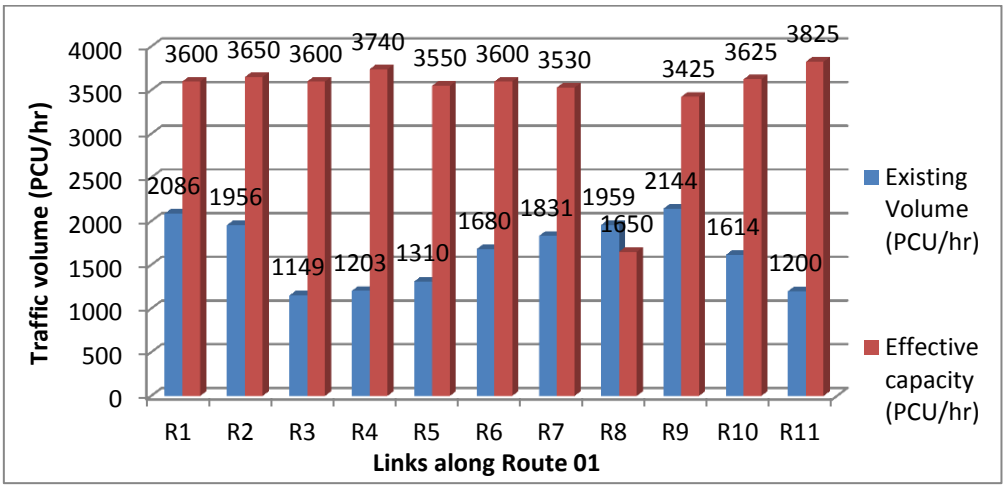


Figure 7.20: Comparative scenario of existing traffic flow and effective capacity along Mirpur Road (Route 01)

As previously said that major arterial roads of the city provides/possess a huge capacity with wide carriageway, it is very evident and obvious that for almost 100% of the study links along four major arterial routes existing traffic flow does not exceed the road capacity standard or effective roadway capacity. That's exactly shown from

figure no. 7.18 to figure no. 7.21.So it can be said that optimum traffic flow in consideration with road capacity for each route (link wise) is exactly the same to effective roadway capacity found for each study routes (link wise). As in all the cases existing traffic flow is less than road capacity, there is no additional traffic flow in consideration with road capacity criteria or in determining optimum/standard traffic volume satisfying road capacity criteria.

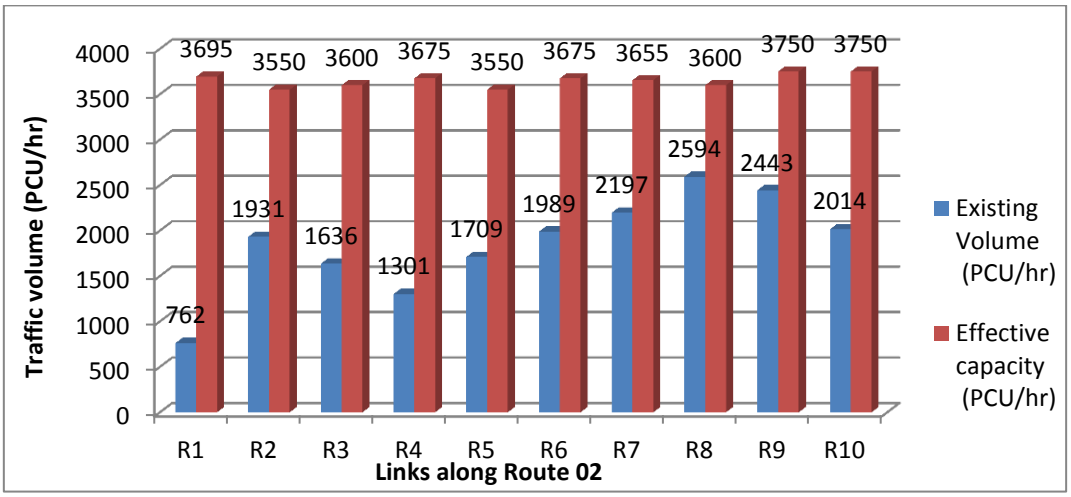


Figure 7.21: Comparative scenario of existing traffic flow and effective capacity along Pallabi to Anandabazar Road (Route 02)

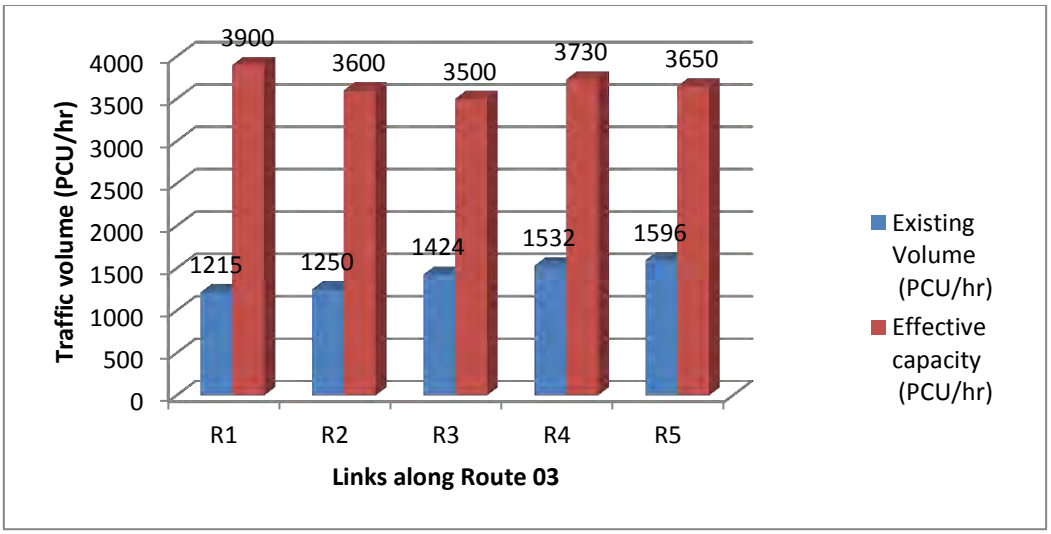


Figure 7.22: Comparative scenario of existing traffic flow and effective capacity along Kuril to Bijoyshoroni Road (Route 03)

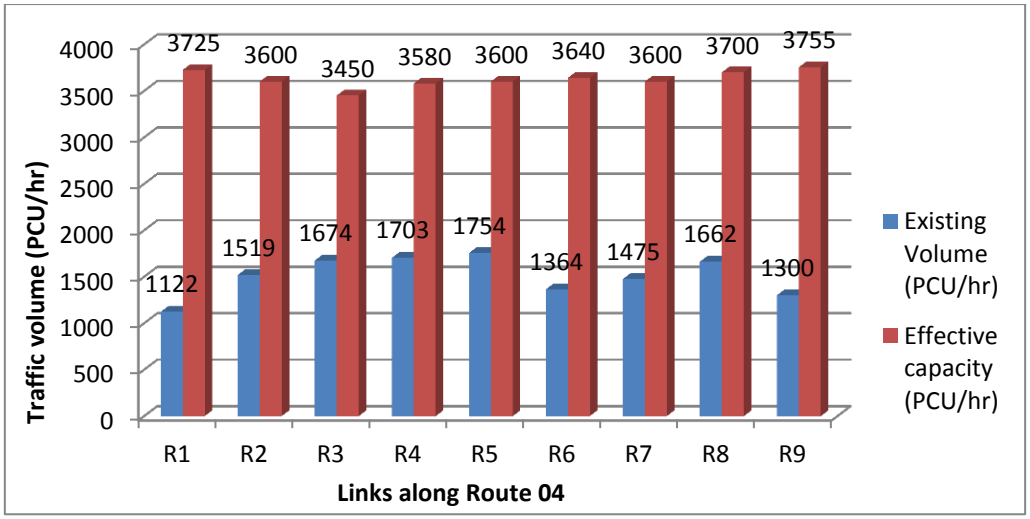


Figure 7.23: Comparative scenario of existing traffic flow and effective capacity along Kuril to Shegunbagicha Road (Route 04)

7.4 Comparative scenario building for existing traffic flow in consideration with both criteria (link and route wise)

For all the four cases, a general observation found from the following figures is that existing traffic flow is greater than emission wise optimum traffic volume but less than capacity wise optimum traffic flow. There is only one exception for link no. 08 (Dhanmondi 27 signal to Panthapath Russel square signal) along Mirpur Road having a capacity of only 1650 PCU/hr.

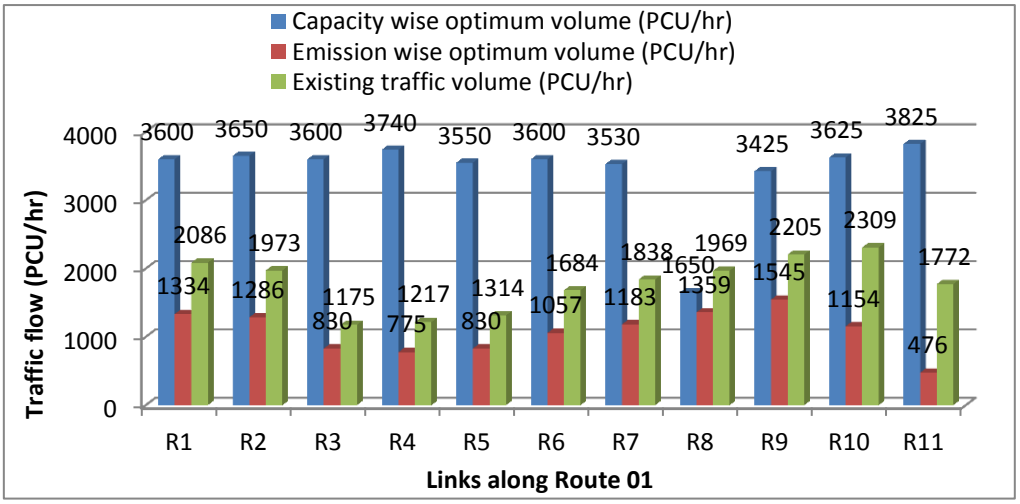


Figure 7.24: Link wise existing traffic flow scenario compare to both criteria along Mirpur Road (Route 01)

For this particular link (Link R8: Route 01), existing traffic flow is greater than both emission wise and road capacity wise standard traffic flow. For link no. 3 situation is somewhat better with minimum deviation of emission wise optimum traffic volume from existing traffic flow (only 295 PCU/hr). But link no. 11 (New market signal to Azimpur signal) shows most devastating situation with almost largest deviation of emission wise optimum traffic volume from existing traffic flow (1296 PCU/hr) and this link is in need of shifting largest PCU/hour to alternative route in compare to other links of Mirpur Road.

Photo 7.16 and 7.17: Congested existing traffic situation along Route 02 (Pallabi to Anandabazar)
Source: Field survey, 2014

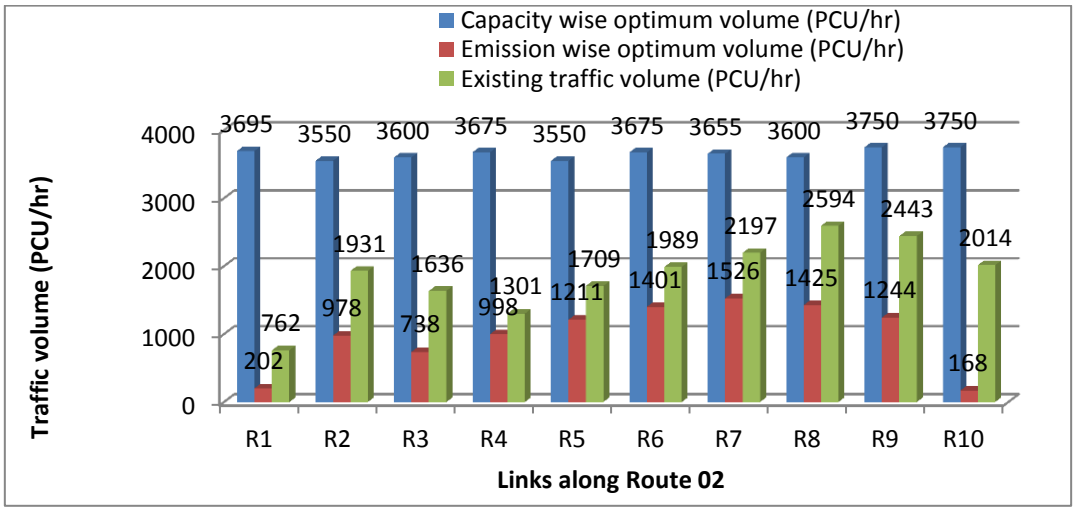


Figure 7.25: Link wise existing traffic flow scenario compare to both criteria along Pallabi to Anandabazar Road (Route 02)

In the above figure for Pallabi to Anandabazar route, existing traffic flow is greater than emission wise standard but less than road capacity standard traffic flow. Maximum number of traffic flow (1846 PCU/hr) needed to be shifted along

alternative route from link no. 10 (Kodom foara to Anadabazar) of this route. Only 303 PCU/hr traffic flow is needed to be shifted from link no. 04 (Bijoy shoroni) along Route 02.

Almost similar situation along all the links of Route 03 (Kuril to Bijoyshoroni) has been observed from the figure below. On an average 566 PCU/hr traffic flow is in need to be shifted from all the links of this route.

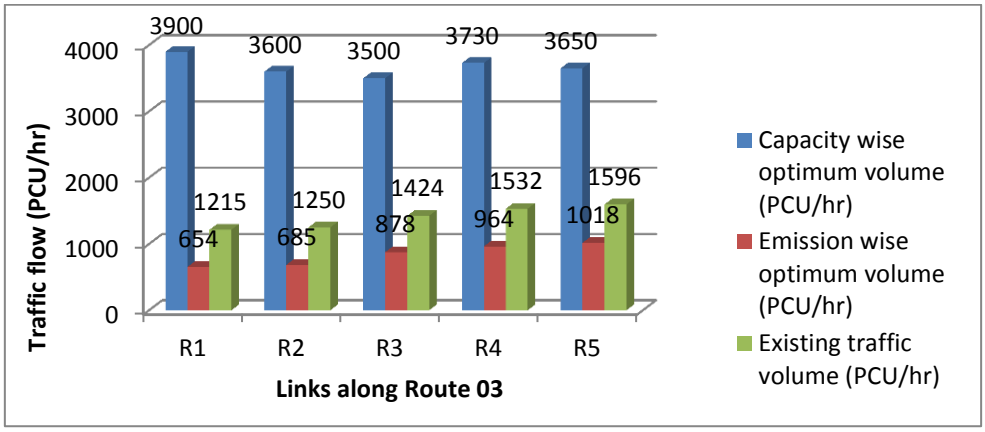


Figure 7.26: Link wise existing traffic flow scenario compare to both criteria along Kuril to Bijoyshoroni Road (Route 03)

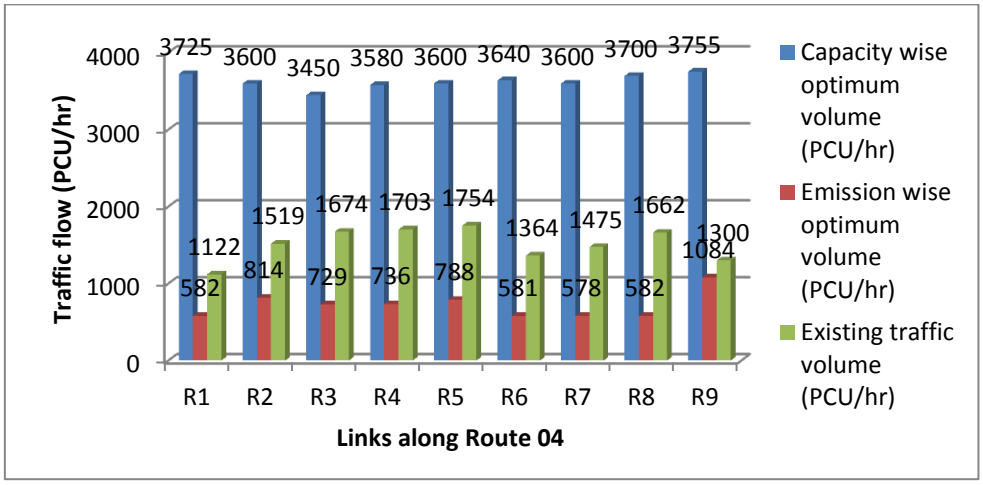


Figure 7.27: Link wise existing traffic flow scenario compare to both criteria along Kuril to Shegunbagicha Road (Route 04)

In the above figure for Route no. 04 (Kuril to Shegunbagicha) maximum traffic volume (1080) has been found in need to be shifted from link no. 08 (R8: Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road). Minimum traffic flow (216 PCU/hr) needed to be shifted from the immediate adjacent link, Link R9 (Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha).

Now if we want to see the overall route wise condition of existing traffic volume and optimum volume (both emission wise and road capacity wise), the following figure gives indication about this. Here average value of all the links has been taken for route wise analysis against all the three variables. From the figure, we can see that for all four routes existing traffic volume is greater than emission wise optimum volume but less than capacity wise optimum volume. According to this calculation, maximum number of vehicles is in need to be shifted along alternative route from Route no. 02 (Pallabi to Anandabazar route) and minimum vehicle PCU/hour needed to shift from Route no. 03 (Kuril to Bijoyshoroni).

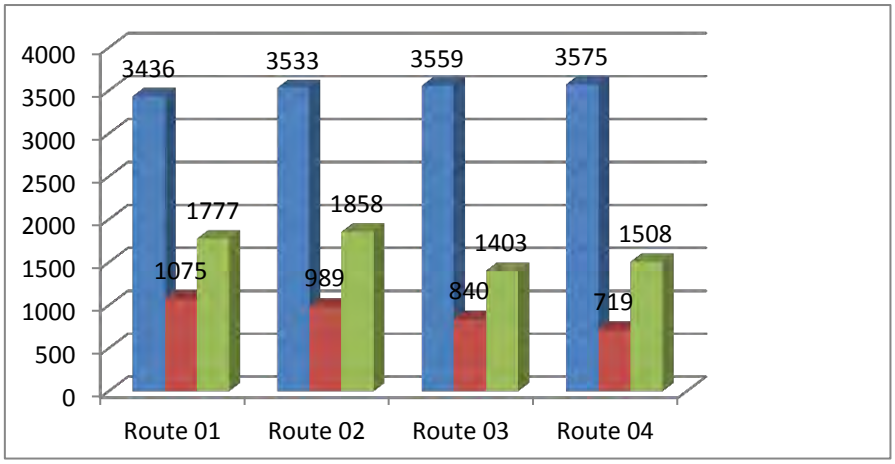


Figure 7.28: Route wise overall existing traffic flow scenario compare to both criteria

7.5 Determination of optimum traffic volume for secondary alternative roads

Determination of optimum traffic volume for secondary alternative routes is also important in this study context as additional vehicles from all the major arterial study routes (04 in number) has to be shifted along these alternative roads to reach their original destination. For this reason optimum traffic volume (PCU/hr) is also being calculated for the secondary roads through satisfying the same two criteria: vehicular emission standard and roadway capacity standard). In the following table emission wise standard/optimum traffic flow has been showed for all the alternative routes identified for the study.

Table 7.2: Emission wise optimum/standard traffic volume along some secondary alternative roads

Secondary Alternative Road	Optimum/Non-polluting volume (PCU/hr)	Shifting/additional/ polluting volume (PCU/hr)
Sat Masjid Road	2842	472
Panthapath	2440	357
Farmgate - Manikmia Avenue	1564	1380
Agargaon-PMO link Road	1831	638
New Eskaton Road	1051	232
Tongi Diversion Road	3562	1322
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	162	269
Green Road	736	20
Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco)	203	145
Hatirjheel Link road	320	210
Matikata road (infront of Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]	276	143
Total	**14989**	**5187**

**Detail calculations showing both no. of optimum and additional vehicles (vehicle class and fuel type wise) have been shown in appendix D.*

From the above table it can be seen that for each road there are some additional vehicles found according to vehicular emission standard. But for this study these secondary roads are used as alternative options and we have to assign additional vehicles to these roads from major arterial routes to relieve congestion from major routes of Dhaka, so in this context we ignore this emission wise optimum volume determination for secondary roads and will go for roadway capacity analysis to determine the optimum traffic volume for these secondary alternative routes. Following table shows total effective capacity assuming 12 feet per lane width for all the secondary roads considered for the study. In this case no exclusion has been done from original carriageway width found from field survey and original carriageway width has been considered as effective carriageway width for these alternative roads. We strongly discourage any kind of on street parking and other illegal encroachment along these secondary roads. One of the basic reasons for this is definitely that we have to assign additional vehicles from major arterial roads to these secondary roads. Also one of the major aims of this optimum traffic flow distribution (determination of optimum traffic volume) along arterial roads is to relieve excessive vehicular pressure from the major roads of Dhaka city.

Table 7.3: Roadway capacity (traffic volume in PCU/hour) of secondary alternative roads

Name of Road	Total Carriageway width (both sides)	No. of lanes (assuming 12' per lane width)	Standard capacity/lane (PCU/hr/lane)	Total capacity (PCU/hr)
Sat Masjid Road	60	5	1200	6000
Panthapath	58	4.833333333	1200	5800
Farmgate – Manikmia Avenue	150	12.5	1200	15000
Agargaon-Prime Minister Office Link Road	40	3.333333333	1200	4000
New Eskaton Road	70	5.833333333	1200	7000
Tongi diversion road	70	5.833333333	1200	7000
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	50	4.166666667	1200	5000
Green Road	40	3.333333333	1200	4000
Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco)	40	3.333333333	1200	4000
Hatirjheel Link road	60	5	1200	6000
Matikata road (Pallabi Mirpur – Banani, Raddison er shamne) [Mirpur flyover]	50	4.166666667	1200	5000

Carriageway width data source: Field survey, 2014

In the above table these effective capacity (PCU/hour) has been considered as optimum traffic volume standard for the above mentioned secondary roads.

7.6 Summary

In this chapter optimum traffic volume in consideration with both roadway capacity and vehicular emission has been determined for the major arterial routes (link wise) and also for some other secondary roads of Dhaka city. Separately emission wise optimum volume and capacity wise optimum traffic volume data has been calculated for all the study links along four major routes. These dataset will be given as input in GIS along with existing traffic volume dataset and optimum traffic flow distribution model (satisfying both the criteria) will be developed. In the following chapter GIS based traffic flow distribution model development using this data and calibration will be done.

Figure 7.29: Link wise Existing Traffic Volume (PCU/hour) along Four Major Study Routes

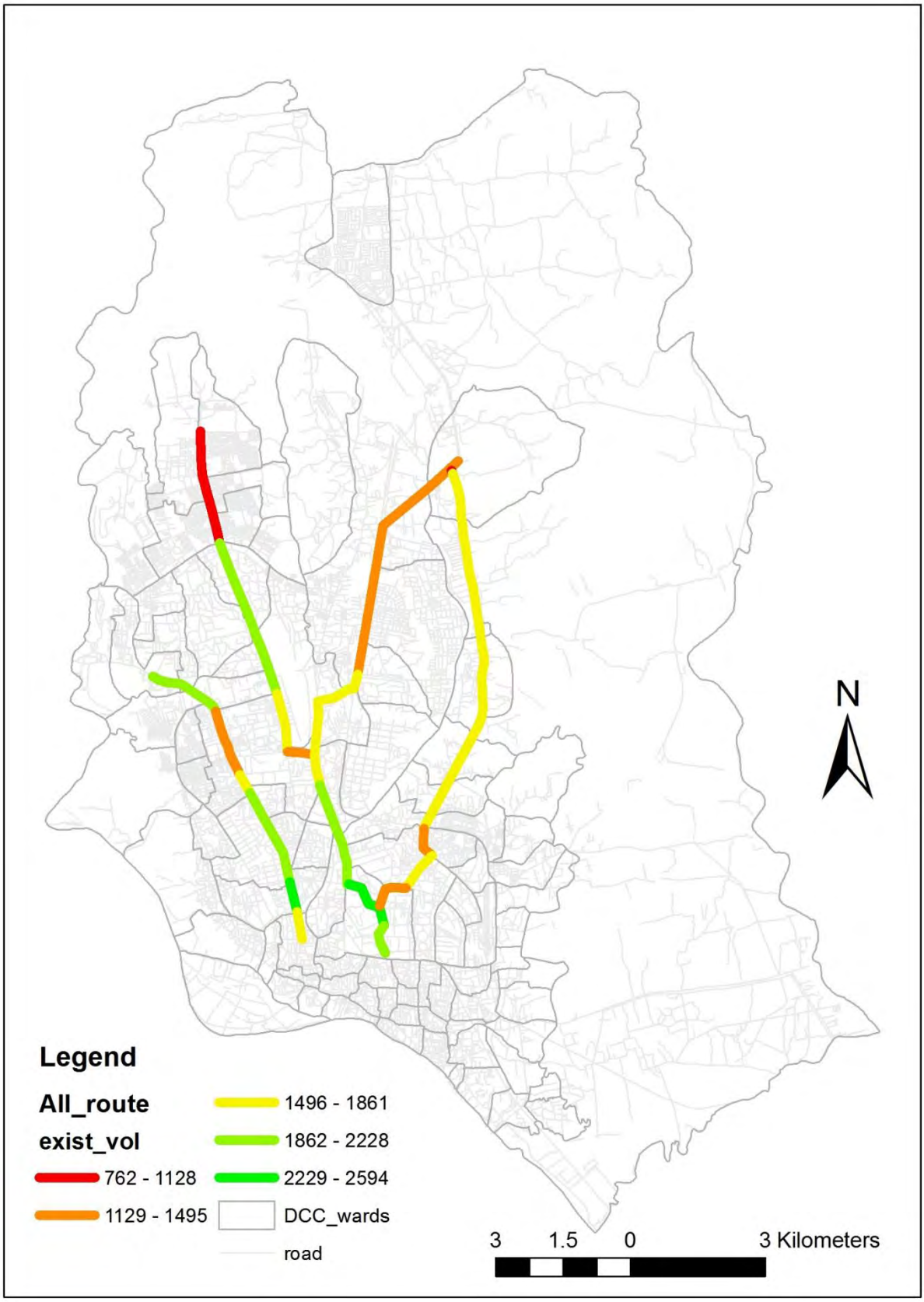


Figure 7.30: Existing Traffic Volume (PCU/hour) along both Primary Arterial and Secondary Alternative Roads

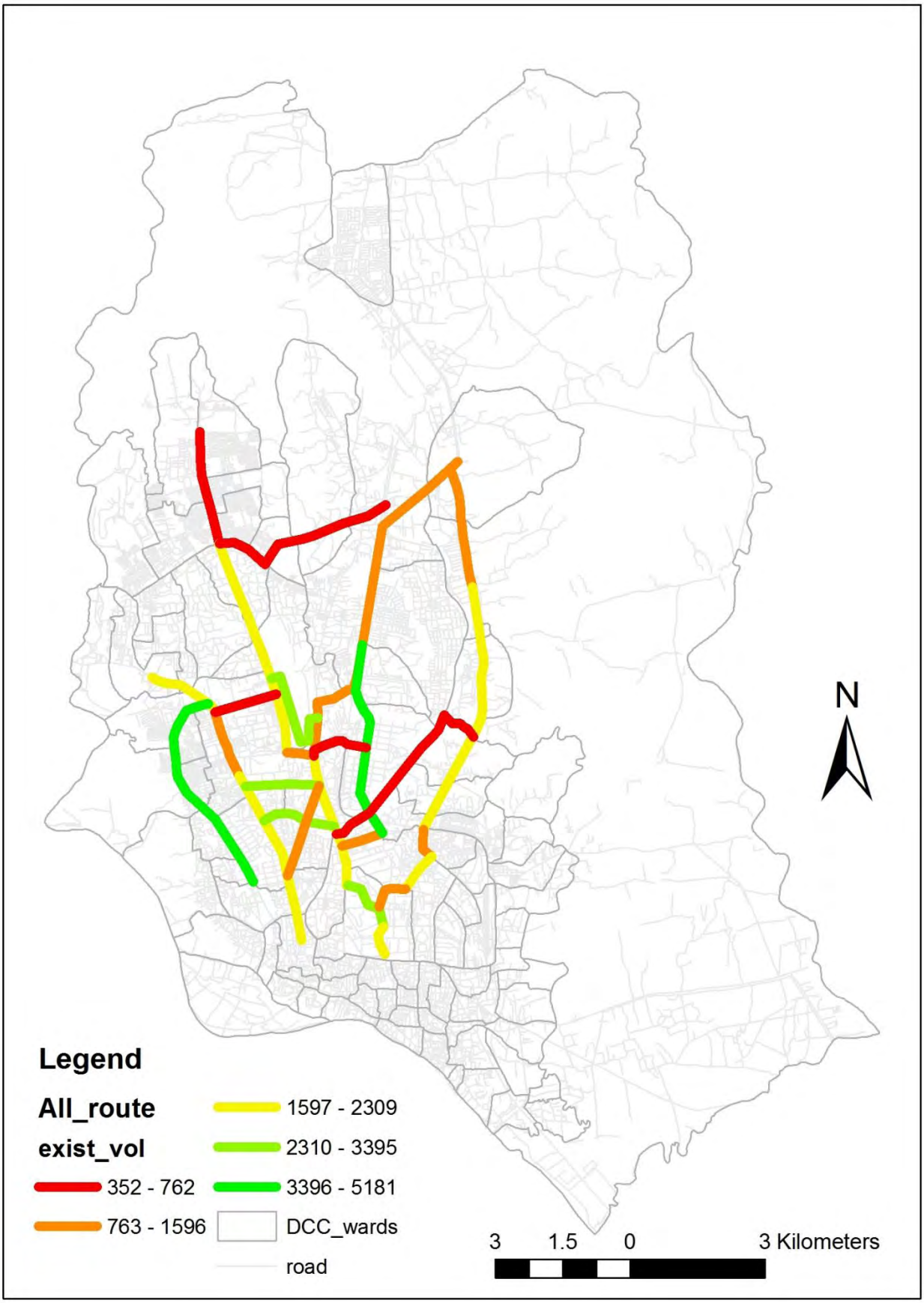


Figure 7.31: Emission wise Optimum Traffic Volume (PCU/hour) along both Primary Arterial and Secondary Alternative Roads

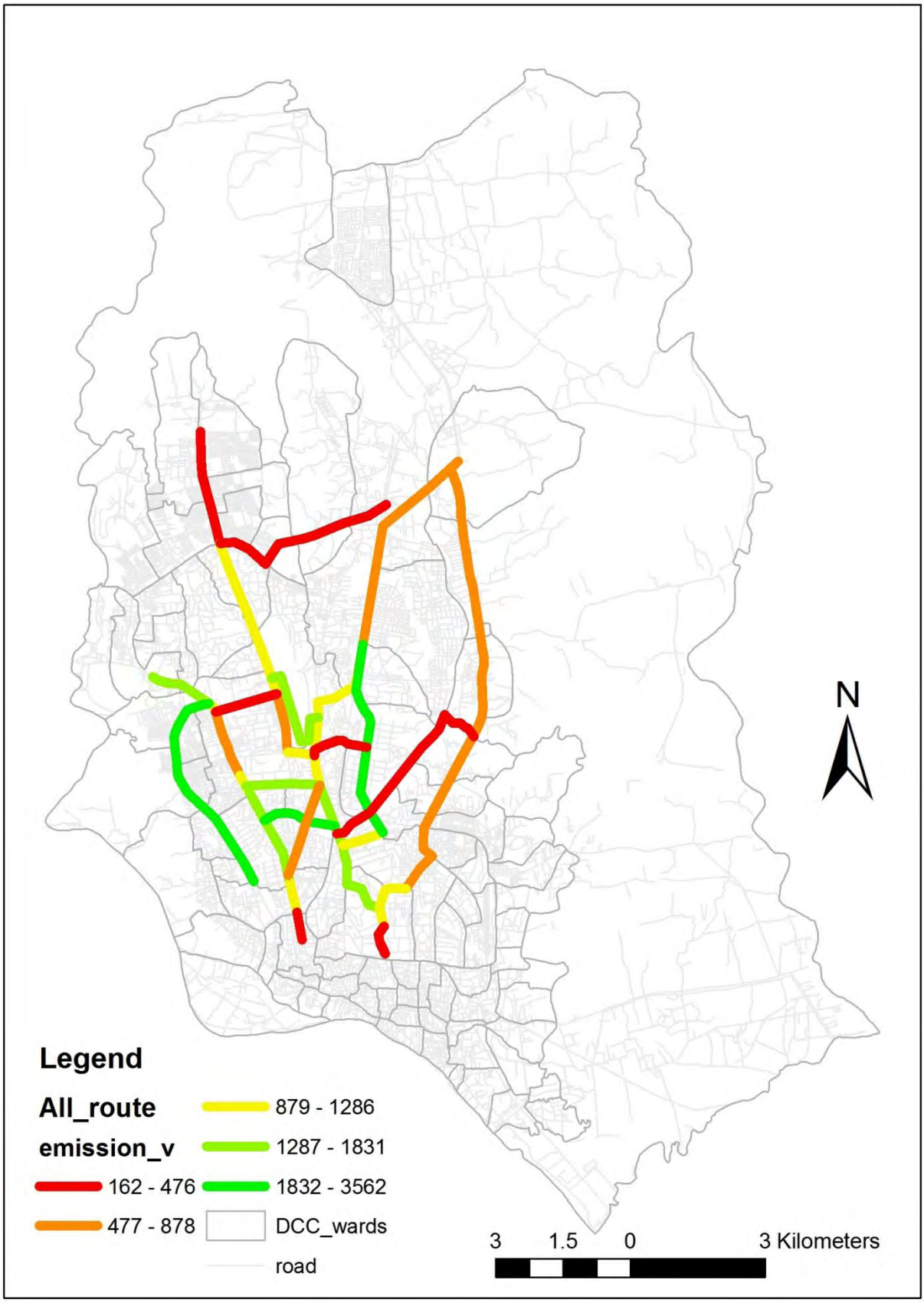
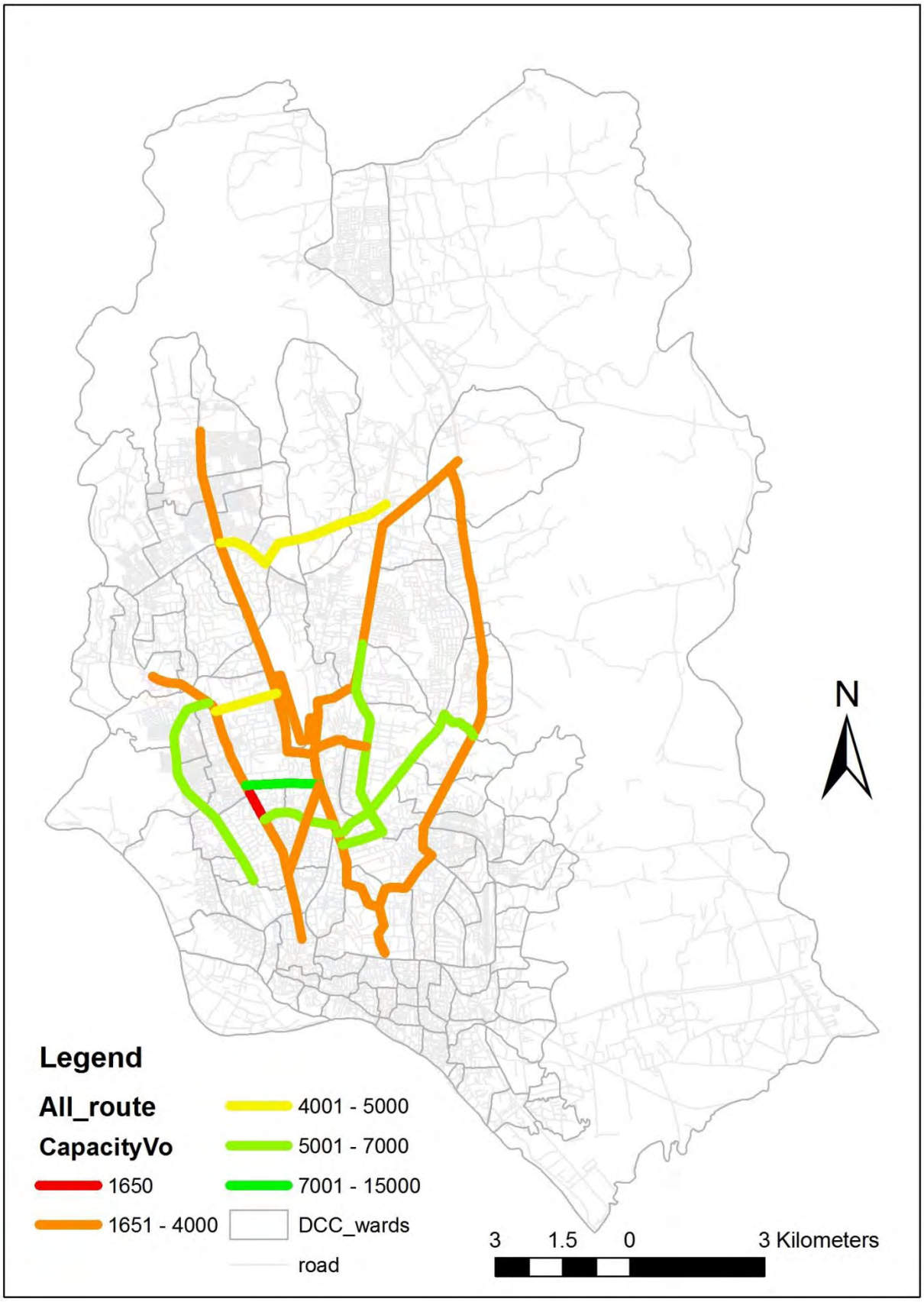


Figure 7.32: Roadway Capacity wise Optimum Traffic Volume (PCU/hour) along both Primary Arterial and Secondary Alternative Roads



CHAPTER 8

Model Development and Calibration using GIS

8.1 Introduction

In this chapter model developments and calibration using GIS has been executed for different traffic flow distribution along the major study routes to distribute traffic flow in an optimum way. After data processing, a GIS-based model of traffic flow distribution has been developed. Using GIS, traffic flow have been distributed in such a way that would not exceed the acceptable limit of pollution level and the capacity of a particular road type. The following variables have been used for GIS-based traffic flow modeling: 1) Traffic volume, 2) Vehicular emission and 3) Capacity of a particular type of road

The model has been executed for different traffic flow distribution. After each traffic flow distribution, the model has checked whether it will exceed both the acceptable limit of vehicular emission and the road capacity. The modeling result which has fulfilled the two criteria is the optimum traffic flow distribution. The obtained data on optimum traffic flow distribution has been analyzed using GIS. After that difference between actual (existing) and optimized traffic flow for each study route has been calculated and additional traffic flow has been distributed along existing alternative route in accordance with travel demand not exceeding the optimum traffic volume for that alternative route. Shifting of additional traffic volume to alternative secondary routes is not included within the GIS based model and has been shown within the next chapter titled Traffic Assignment.

8.2 Computation of Optimum traffic volume satisfying both criteria using GIS

Ultimate way to achieve the second objective of the research is to determine an optimum traffic volume satisfying both criteria (vehicular emission standard and road capacity standard) for all the major arterial routes (link wise). Emission wise and road capacity optimum volume has been determined separately in the earlier sections of this chapter. Now it is time to compute or determine the optimum traffic flow which

satisfy both of the above criteria and this optimum traffic volume will be used for developing GIS based traffic flow distribution model. In the model this optimum traffic flow (different for separate links) will be computed first and then will be assigned for each specific road section along four major study routes. Additional traffic volume for each link which is in need of shifting into alternative secondary roads will also be computed through GIS based model.

8.2.1 Background dataset for model development

In the previous chapter optimum traffic volume (both roadway capacity and vehicular emission wise) for all the study links have been determined. The following datasets have been used as three variables for developing the traffic flow distribution model.

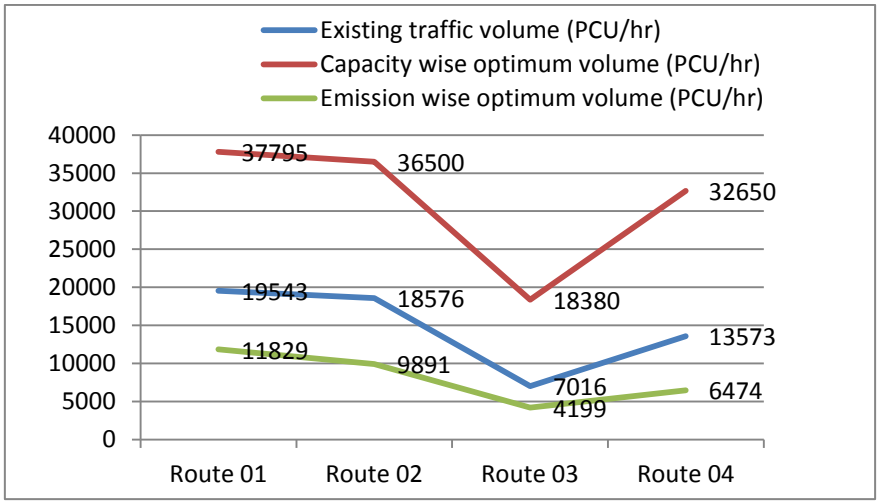


Figure 8.1: Total traffic volume dataset (existing, capacity wise optimum and emission wise optimum) among four major study routes

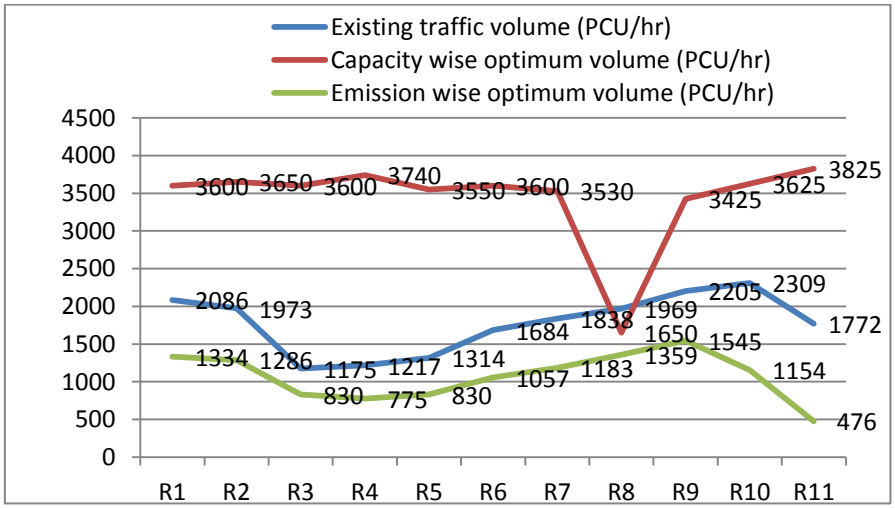


Figure 8.2: Link wise traffic volume dataset (existing, capacity wise optimum and emission wise optimum) along Route 01 (Mirpur road)

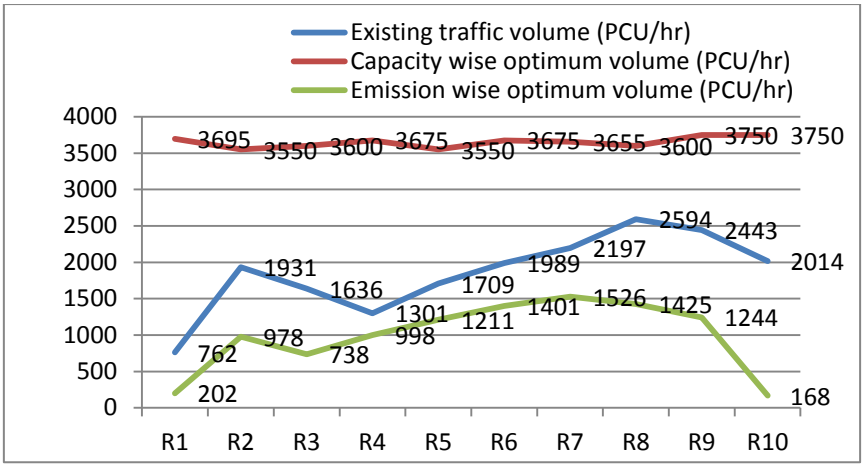


Figure 8.3: Link wise traffic volume dataset (existing, capacity wise optimum and emission wise optimum) along Route 02 (Pallabi to Anandabazar)

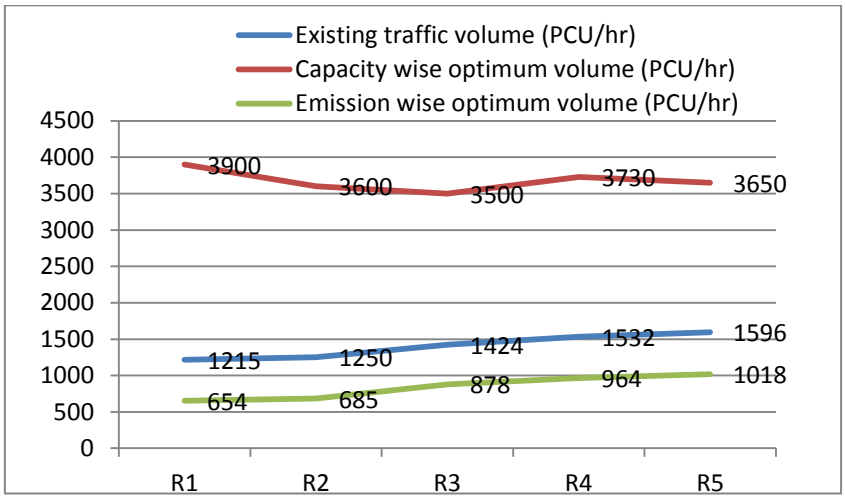


Figure 8.4: Link wise traffic volume dataset (existing, capacity wise optimum and emission wise optimum) along Route 03 (Kuril to Bijoyshoroni)

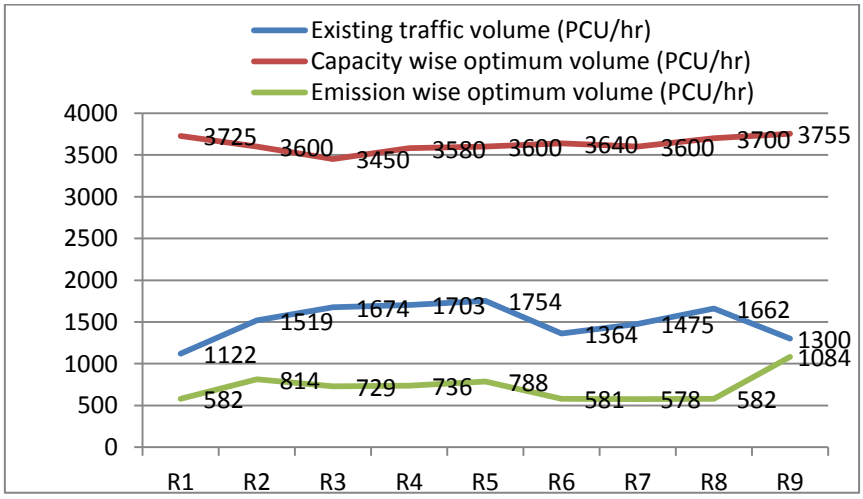


Figure 8.5: Link wise traffic volume dataset (existing, capacity wise optimum and emission wise optimum) along Route 04 (Kuril to Shegunbagicha)

8.2.2 GIS based traffic flow distribution model development

After calculating optimum traffic volume according to both vehicular emission standard and roadway capacity standard, standard or optimum volume has been found for four major routes (link wise) and other associated secondary roads. Lower traffic volume between the two volumes (one found after applying standardized emission value for particulates and other found from effective road capacity PCU/hour value calculation) along each road has been selected as the optimum volume for that particular road. Using Python based coding under Geo processing option of ArcGIS interface, traffic flow has been distributed in such a way that could not exceed the acceptable limit of pollution level and the capacity of a particular road type. Three types of variables have been used for GIS-based traffic flow modeling: existing traffic volume, traffic volume with acceptable limit of vehicular emission (acceptable amount of particulates emitted) and capacity of a particular type of road. The model would be executed for different traffic flow distribution. After each traffic flow distribution, the model has checked whether it will exceed both the acceptable limit of vehicular emission and the road capacity. The modeling result which would fulfill the two criteria and the traffic volume which is less or equal to both the traffic volume calculated according to emission and road capacity is the optimum traffic flow distribution and the optimum number of traffic for each road. The obtained data on optimum traffic flow distribution has been analyzed using GIS.

8.2.3 Detail procedure of coding using GIS

ArcGIS screenshot of the whole procedure has been given here step by step. First For each link we have set 3 types of data (variable).

1. Existing traffic volume (PCU/hour)

2. Emission wise optimum volume (PCU/ hour)

3. Road capacity wise optimum volume (PCU/ hour)

Using Geo processing option (python based coding) of ArcGIS, we have set up the above three types of traffic volume data in a way so that for each link optimum volume will be the lower one among variable no. 2 and 3. Then subtraction of the

optimum volume from existing volume (variable no. 1) to get the additional volume (PCU/hour) for each link has been done.

Algorithm/steps:

Step 01: Set three types of variable against each study link.

1. Existing traffic volume (PCU/ hour)

2. Emission wise optimum volume (PCU/ hour)

3. Road capacity wise optimum volume (PCU/ hour)

Step 02: Select the lower one among variable no. 2 and 3 as optimum traffic volume (PCU/ hour) for each link.

Step 03: Subtract the optimum volume from existing volume (variable no. 1) to get the additional volume (PCU/ hour) for each link.

First link wise shape files of four major study routes have been added as layer in ArcGIS interface. Attribute table dataset containing three variables have been prepared for each layer in ArcGIS. Screenshot of dataset containing three variables as input in attribute table linked with GIS based layer has been showed within appendix G. Using Geo processing option for coding through python Syntax / coding language has been written. There are in built vacant space for writing code in python. Shape file path has to be changed for each separate specific dataset from which GIS based model have to be developed.

Detail work procedure of GIS based model development is shown through ArcGIS screenshots within appendix G. In the attribute table variables have been included as existing vol, emission_v and Capacity Vo. Attribute table dataset has been attached with GIS based map. After using Geo processing-coding option and writing the syntax in python, run option has to be clicked. Then both final optimum volume and additional traffic volume (PCU/hour) for each link has been automatically shown.

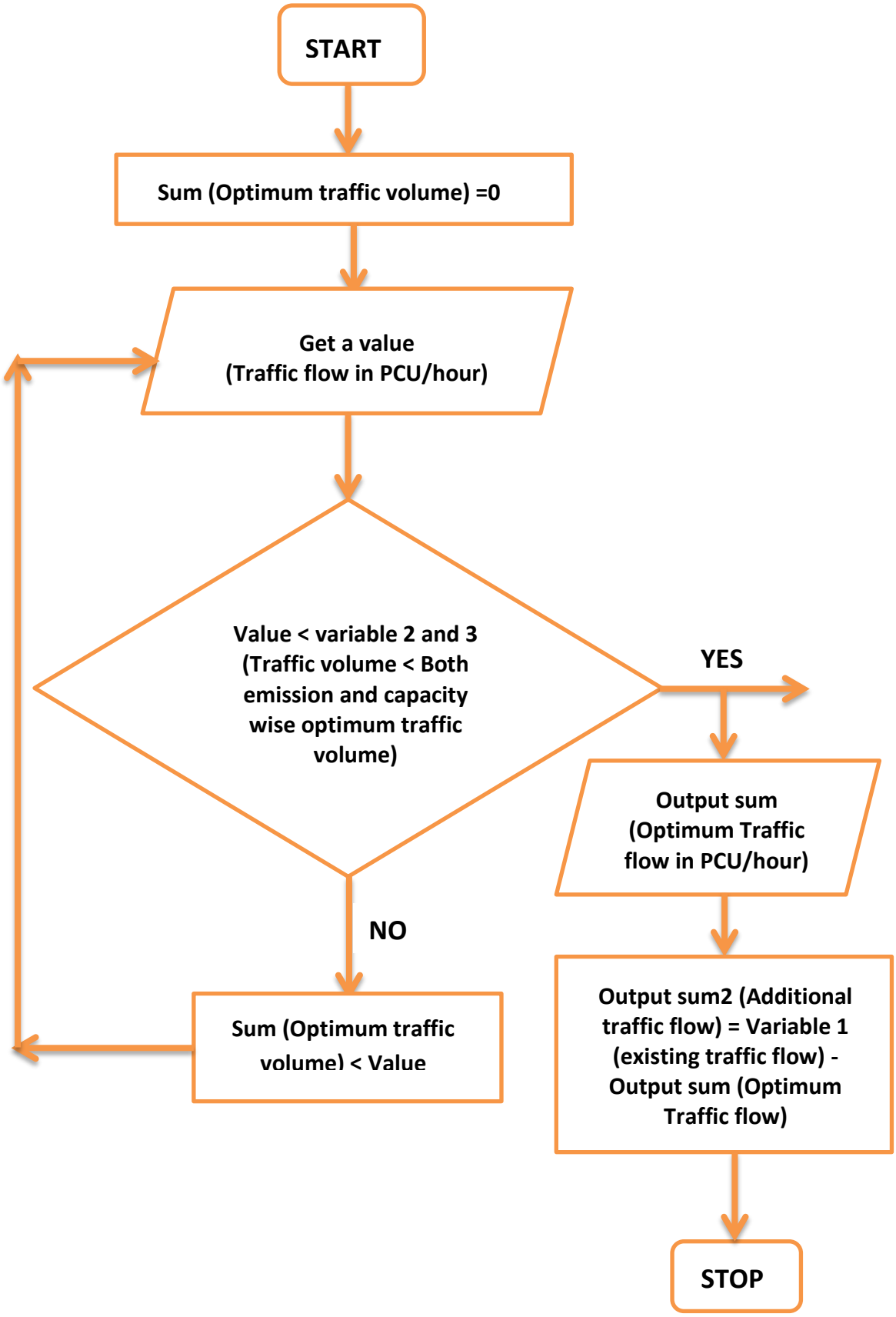


Figure 8.6: Algorithm developed for GIS based coding in python

8.2.4 Final optimum traffic flow and additional (shifting) traffic flow satisfying both criteria

As it has been said earlier that to determine final optimum volume (both link and route wise) is the ultimate focus of the second objective of this study, we have to determine the standard following two criteria. For each link three types of value has been computed: 1) existing traffic flow, 2) emission wise optimum volume and 3) capacity wise optimum volume. In order to satisfy both the criteria, optimum traffic flow can be determined in a way that does not exceed any of the standard traffic volumes (both emission wise and road capacity wise). In this way for each study link lower value between these two optimum volumes has been taken into consideration as optimum traffic flow for that particular link along specific route. Finally subtraction of optimum flow from existing traffic flow, additional traffic needed to be shifted from major arterial routes (link wise) has been found. Though we have selected emission wise volume as optimum for each particular study links but in case of computing additional traffic we have not considered only the polluting traffic but all other traffic flow except the optimum number of vehicle trips. For this to calculate additional vehicle trip subtraction of optimum volume from existing traffic flow has been done. Major reason of this decision for choosing extra additional traffic is to make major arterial road congestion free and reduce excessive vehicle pressure from the four major study roads so that vehicle can ensure highest mobility along these routes. Among the extra additional traffic there are non-pollution traffic specially NMT (Rickshaw, Bicycle etc.) for which special policy recommendation has been included within the Recommendation chapter. Only the through trips (short distance) for NMT will be allowed along the major roads but NMT is free to run all along the secondary alternative roads and all other connector and access roads to achieve full accessibility through NMT.

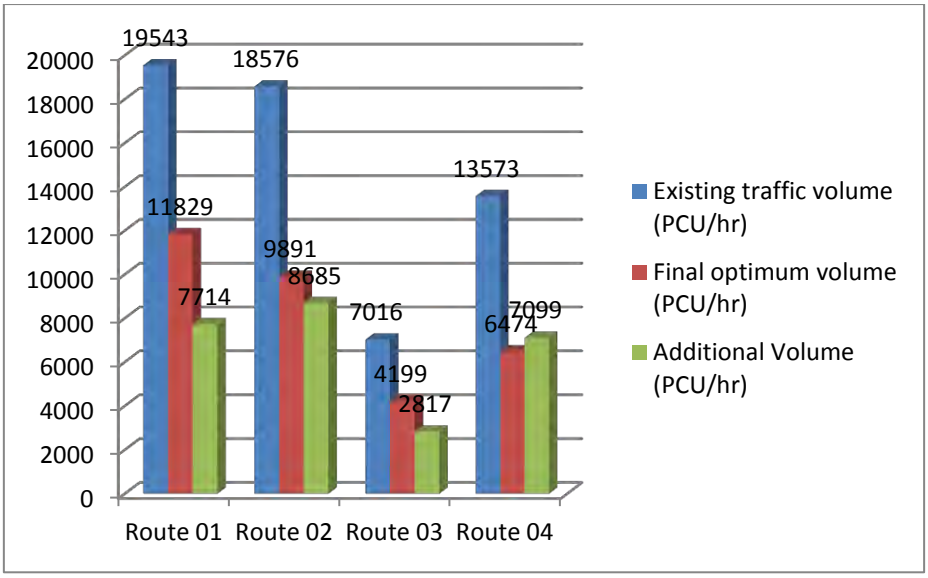


Figure 8.7: Route wise total optimum traffic flow with shifting (additional) traffic flow

In the above figure, optimum/standard traffic flow for all four major study routes has been showed in compare to existing traffic flow and total number of additional traffic volume (PCU/hour) from each study route also given here. From the figure it can be understood that maximum PCU/hour traffic flow in need of shifting to alternative route if from Route no. 02 (8685 PCU/hr). On the other hand, minimum traffic flow (2817 PCU/hr) shifting from Route no. 03 is necessary. From the previous route wise analysis of the three types of variables (see figure 7.26) we already predicted this outcome/picture depicted from the above figure. Route no. 01 and 04 are also not in a satisfactory condition from existing traffic volume, final optimum volume and additional/polluting volume analysis point of view. A large number of vehicles (6802 and 7099 PCU/hr) needed to be shifted along alternative routes from Route no. 01 and 04 respectively. Accommodating/assigning this huge amount of traffic along alternative routes is really a great problem/limitation for this research as we don't have enough options in hand in context of Dhaka.

The following table shows the overall scenario at a glance for all four major arterial study routes.

Table 8.1: Total optimum traffic flow with additional volume found from GIS based traffic flow distribution model

Existing Traffic volume		**Final optimum traffic volume**		**Additional Traffic volume**	
PCU/hour	Vehicle/hour	PCU/hour	Vehicle/hour	PCU/hour	Vehicle/hour
58708	51150	32393	40386	26315	10764

As for my research study area (four major study routes) has been divided into 35 links, so link wise analysis is very important to depict the true picture. Here link wise analysis has been done showing both final optimum traffic flow and additional/shifting traffic for each link along four routes. Here from the following figure, it is been observed that link no. 03 (Agargaon shishumela signal to Residential model college corner) possess minimum additional traffic for this route (Mirpur Road) and link no. 11 (New market signal to Azimpur signal) shows highest additional traffic shifting (1296 PCU/hr) in need. Higest number of optimum traffic flow (1545 PCU/hr) has been observed for link no. 09 (Russel square signal to Science lab signal) along Mirpur Road.

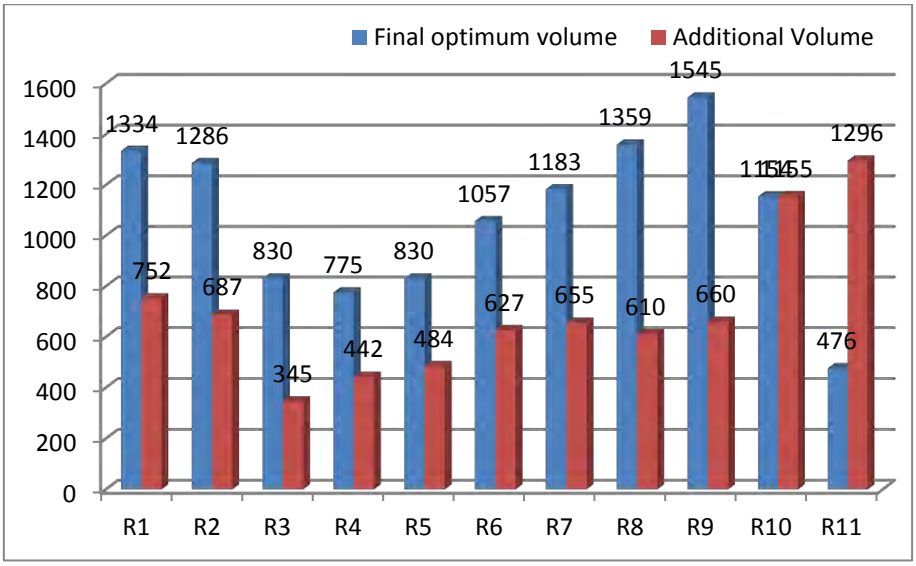


Figure 8.8: Link wise final optimum volume with additional traffic volume (PCU/hr) along Route 01

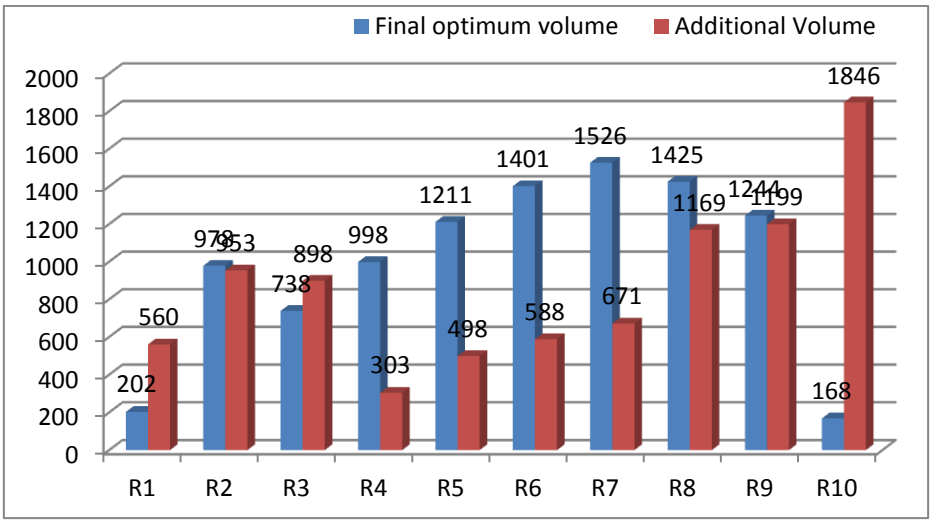


Figure 8.9: Link wise final optimum volume with additional traffic volume (PCU/hr) along Route 02

From the above figure for Route no. 02 (Pallabi to Anandabazar), link wise final optimum volume and additional volume both has been shown. For link no. 10 (Kodom foara to Anadabazar at Gulisthan) 1846 PCU/hr traffic flow has to be shifted along alternative route which is the highest shifting of additional vehicles for this route. It can be said that such a huge number of traffic shifting is nearly impossible in Dhaka as we have very fewer alternative routes as options and according to this research's first objective travel demand is also important, shifting vehicles must be assigned/accommodated in such a way so that they can reach their original destination.

In the figure below for Route no. 03 (Kuril to Bijoyshoroni) almost on an average number of traffic flow (566 PCU/hr) needed to be shifted as additional traffic for all five study links. Maximum number of optimum traffic volume (1018 PCU/hr) has been found for the link no. 05 started from Jahangir gate to Bijoy shoronee_Novo theatre signal.

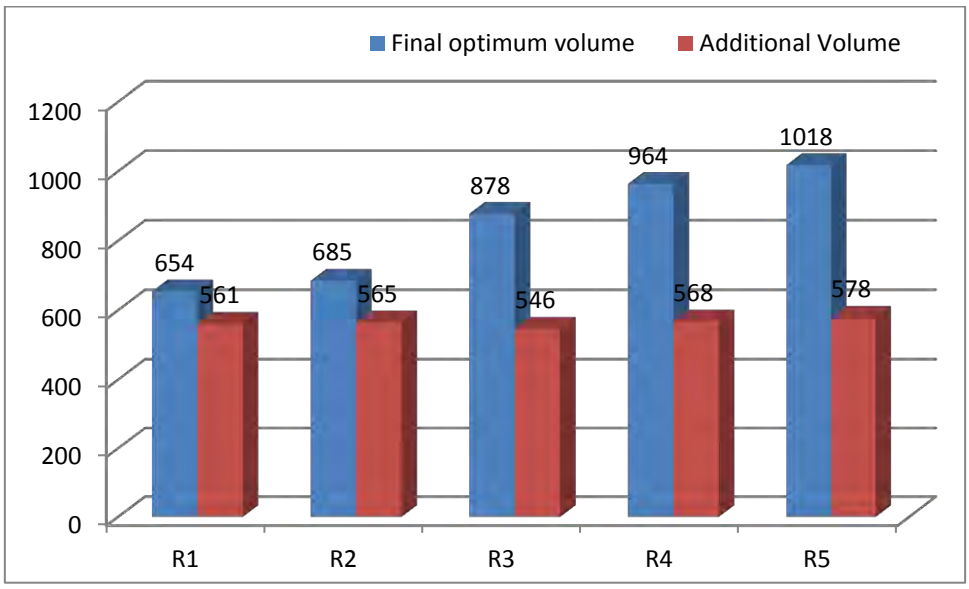


Figure 8.10: Link wise final optimum volume with additional traffic volume (PCU/hr) along Route 03

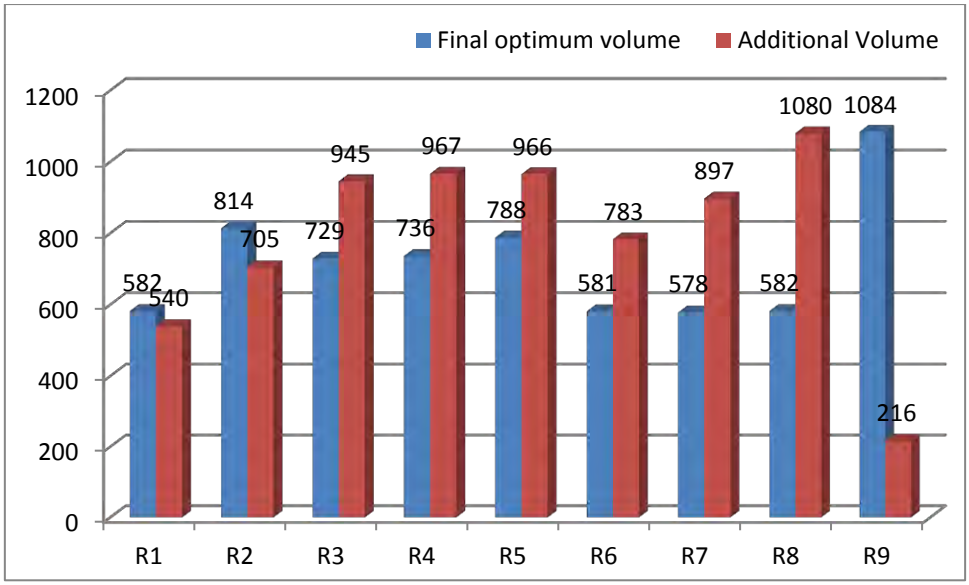


Figure 8.11: Link wise final optimum volume with additional traffic volume (PCU/hr) along Route 04

In the above figure (fig. 7.31) for almost six links among nine links along Kuril to Shegunbagicha route, additional traffic flow is greater than final optimum traffic flow. Maximum number of vehicles (PCU/hr) to be shifted from link no. 08 starting from infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road. Higest optimum traffic volume and lowest additional traffic flow has been observed for link no. 09 (Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha) along Route 04.

8.3 Summary

GIS based model has been developed through using only three variables here. This model can be used using many other variables also and for different kind of road network based datasets. In the next chapter additional traffic flow calculated in each link would be shifted to available secondary alternative roads through all or nothing assignment technique ignoring the travel time variability but fully based on secondary road capacity (PCU/hour).

Figure 8.12: Link wise Traffic Volume (existing, final optimum and additional) comparison among four major Study Routes

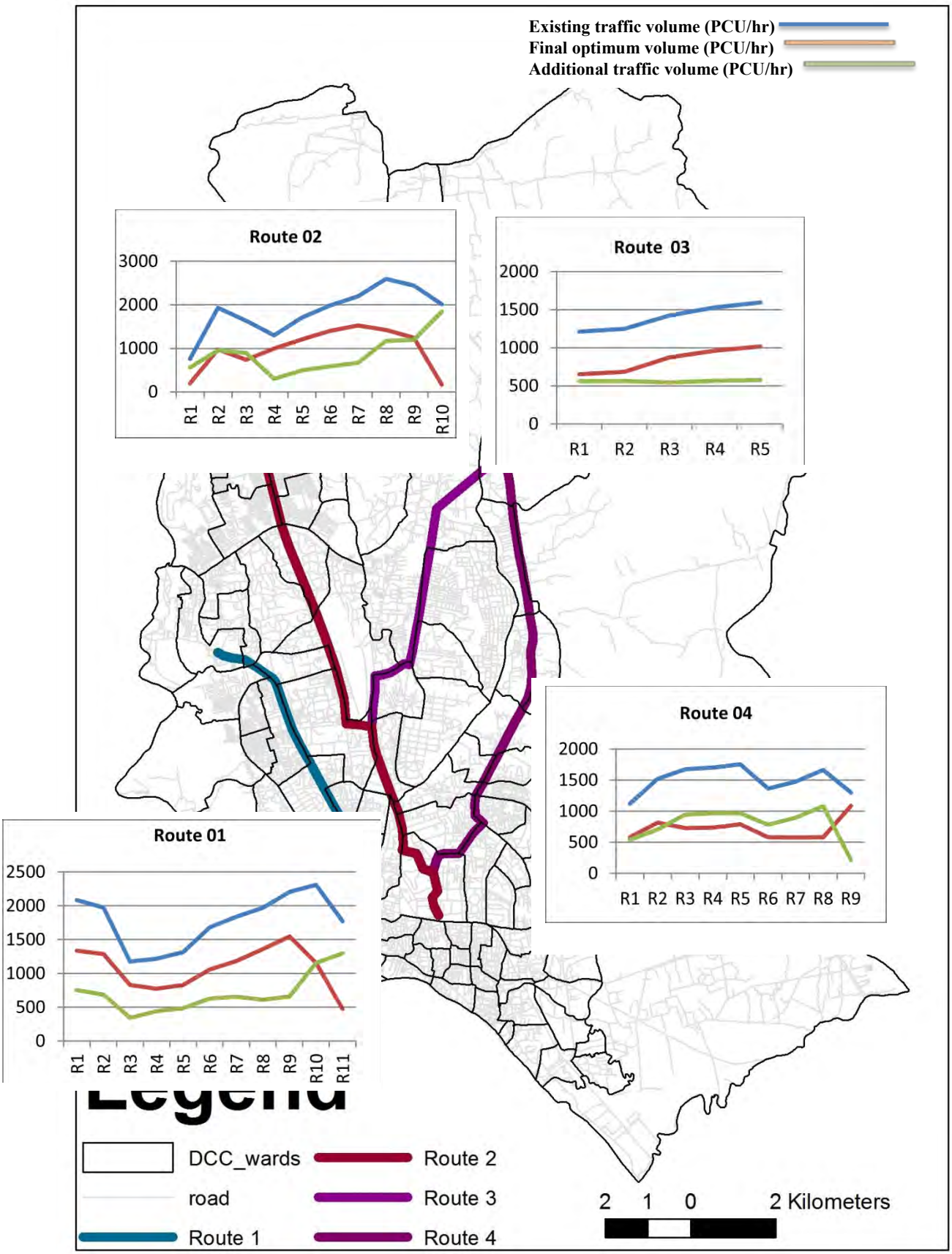


Figure 8.13: Final Optimum Traffic Volume (PCU/hour) satisfying two criteria (Emission wise and Road capacity wise) along both Primary Arterial and Secondary Alternative Roads

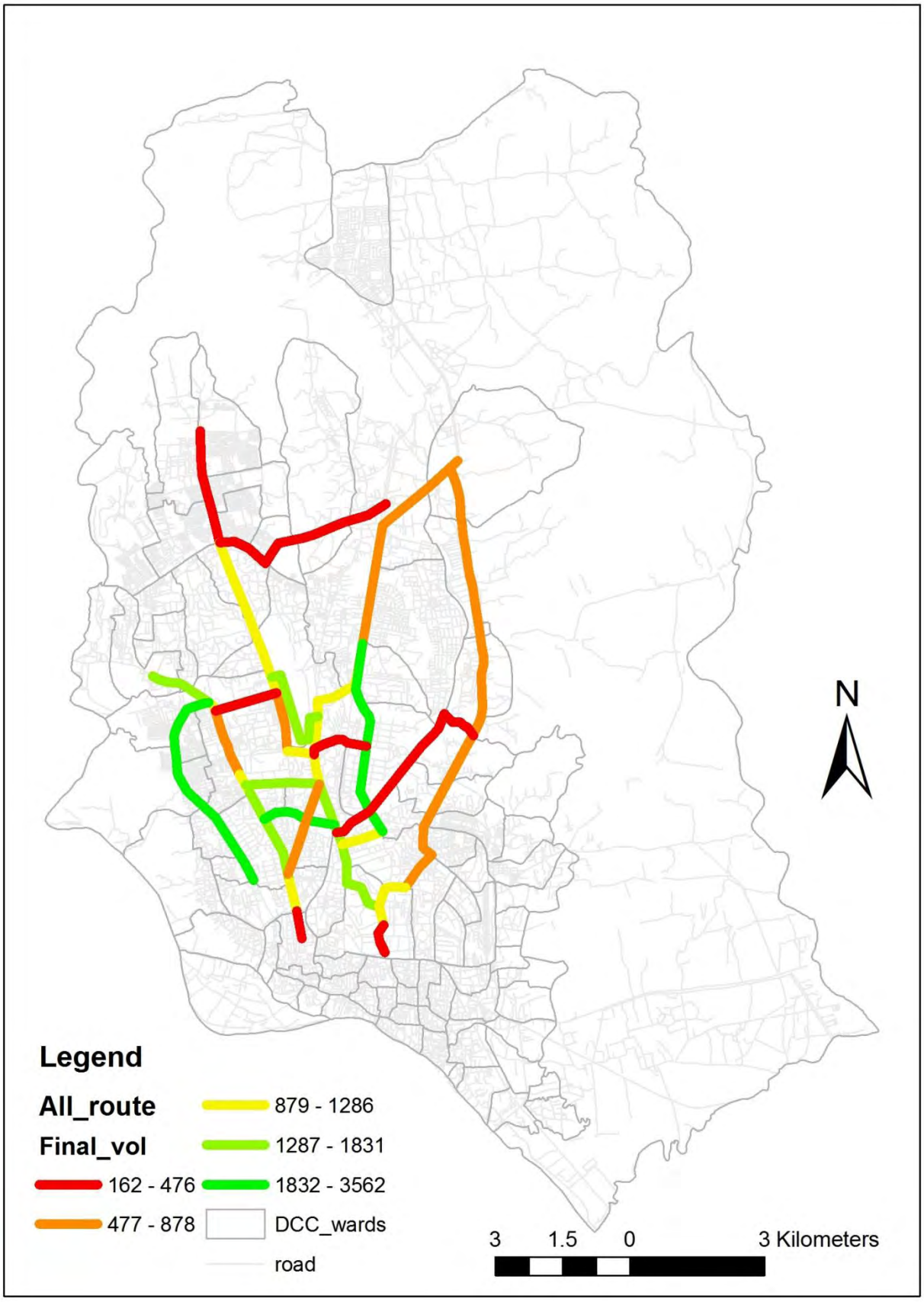
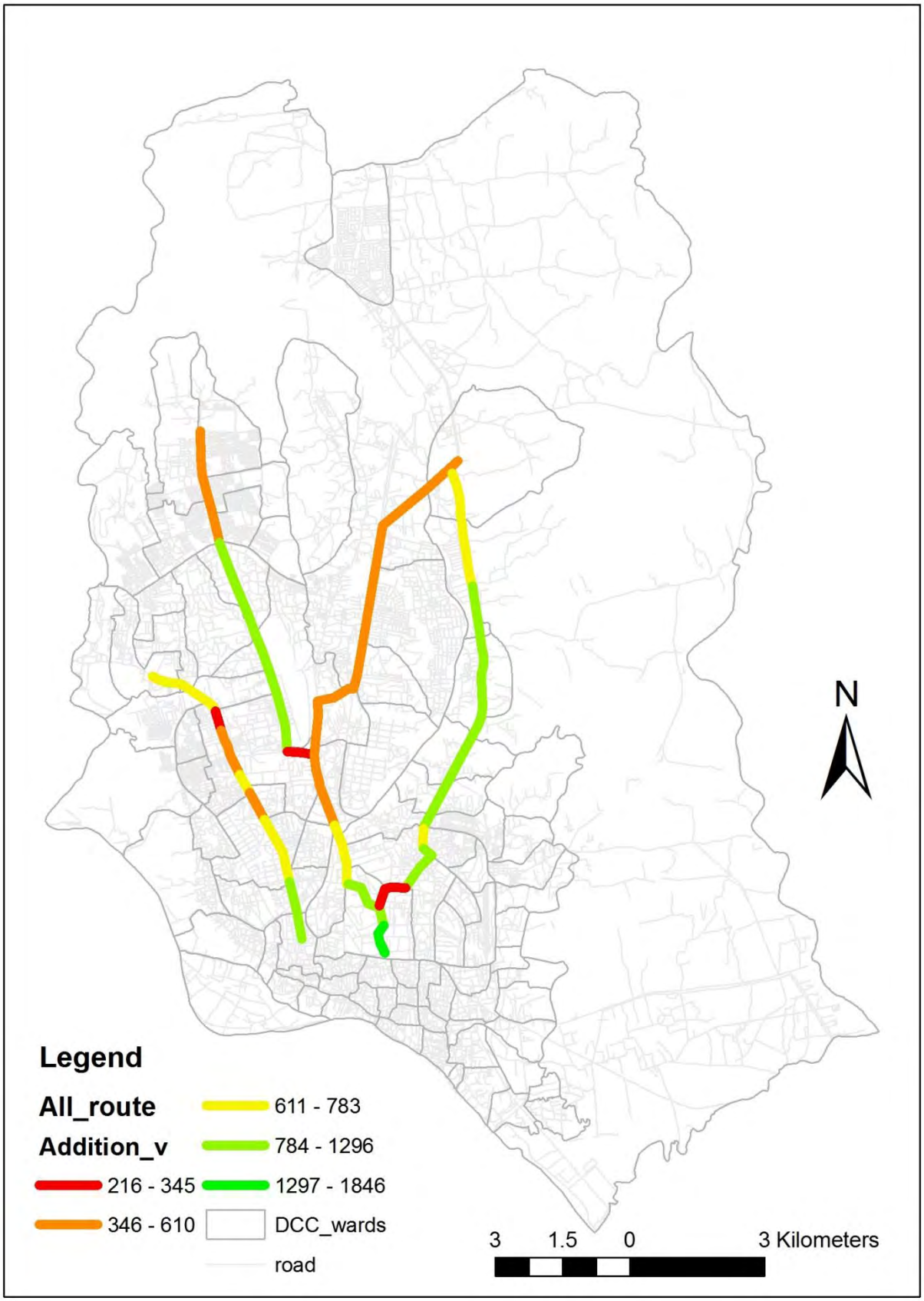


Figure 8.14: Link wise Additional Traffic Volume (PCU/hour) along Four Major Study Routes



CHAPTER 9

Traffic Assignment

9.1 Introduction

The third objective of the research is to shift additional traffic flow to existing alternative route in order to reach the same destination. From this context assignment of traffic volume is a foremost important part of the study. In chapter 07, difference between actual (existing) and optimized traffic flow for each study route has been calculated. From that finding, in this chapter additional traffic flow has been distributed along existing alternative route in accordance with travel demand not exceeding the optimum traffic volume for that alternative route. Travel demand has been calculated and route identification has been done in chapter 06. From Origin-Destination matrixes developed under travel demand estimation section of the study percentage of vehicles going into which destination zone has been identified. After combining the both dataset found from achievement of first two objectives of the study, assignment of traffic flow has been accomplished in this chapter. As there are lack of sufficient alternative routes and in most of the cases there is only one choice for shifting the additional traffic flow to alternative route, all or nothing assignment technique has been followed to assign the trips along alternative roads. In methodology chapter, it has been said that capacity restrained assignment technique will be followed to assign trips but in real scenario it is not possible for our context. All or nothing assignment technique takes no account of increasing congestion associated with increased volumes and assigns too many vehicles to the routes with shortest travel time. In Capacity Restraint assignment, practical capacity of each link of the network is fed into the computer as well as journey time. Though we use all or nothing assignment technique but consideration of effective roadway capacity has been included while assigning traffic but no account of shortest travel time has been achieved as there is lack of options/alternative routes to make the traffic flow reach their original destination.

9.2 Assignment of additional traffic flow along alternative route

9.2.1 Calculation of additional space to accommodate traffic along secondary roads

Calculation of space (PCU/hour) to accommodate additional traffic flow along secondary alternative roads has been done through comparing between existing traffic flow and optimum traffic flow along those routes. Existing traffic flow data has been found from traffic volume survey for five of the below listed roads and for other six roads volume data has been collected from DHUTS study of volume survey conducted by DTCB and JICA (2009). 2009 data has been converted to present year (2014) through applying the annual growth rate of traffic provided by STP. Optimum traffic flow has been determined from effective roadway capacity data for the roads (see chapter 07). Emission wise optimum volume for secondary roads has not been for considered as after applying emission wise optimum volume there is no space remains for additional traffic flow along those roads.

Table 9.1: Calculation of vacant space for additional traffic flow (PCU/hour)

Secondary Alternative Road	Existing volume (PCU/hr)	Optimum volume (PCU/hr)	Vacant space for additional volume (PCU/hr)
Sat Masjid Road	4470	6000	1530
Panthapath	2949	5800	2851
Farmgate - Manikmia Avenue	3395	15000	11605
Agargaon-PMO link Road	2708	4000	1292
New Eskaton Road	1474	7000	5526
Tongi Diversion Road	5181	7000	1819
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	432	5000	4568
Green Road	956	4000	3044
Bijoy sharani- Tajgaon link road	352	4000	3648
Hatirjheel Link road	535	6000	5465
Mirpur flyover	422	5000	4578
Total	**22874**	**68800**	**45926**

9.2.2 Shifting of additional traffic flow

Two important phases have been involved here for shifting additional traffic volume along alternative secondary routes. 1) Link wise shifting of traffic with specific destination zone from major routes and 2) Placement of shifting traffic along alternative routes in order to reach original destination.

Table 9.2: Percentage of shifted additional traffic flow along alternative roads with destination

Links along four major route	Additional traffic volume (%)	Additional vehicle shifted (%)	Alternative route	Original Destination zone
Route 01: Mirpur Road				
R1	36.03817	0	-	-
R2	34.8325	32.4	Saat masjid road	Dhanmondi
R3	29.37209	18.1	(IDB shamoly-Bijoyshoroni tejgaon link road), (IDB shamoly-Bijoyshoroni tejgaon link road-Tongi diversion road)	Tejgaon/Farmgate, Motijheel
R4	36.33078	38	Saat masjid road, (IDB shamoly-Bijoyshoroni tejgaon link road), (IDB shamoly-Bijoyshoroni tejgaon link road-Tongi diversion road)	Dhanmondi, Tejgaon/Farmgate, Motijheel
R5	36.84581	38.1	Farmgate manikmia avenue, (Farmgate manikmia avenue-Tongi diversion road), (Farmgate manikmia avenue-Hatirjheel link road)	Tejgaon/Farmgate, Motijheel, Banani/Gulshan
R6	37.21713	35.7	Farmgate manikmia avenue, (Farmgate manikmia avenue-Tongi diversion road), (Farmgate manikmia avenue-Hatirjheel link road)	Tejgaon/Farmgate, Motijheel, Banani/Gulshan, Uttara/Tongi
R7	35.65007	31.3	(Farmgate manikmia avenue-Green road)	Old Dhaka
R8	30.98358	14.6	Farmgate manikmia avenue, (Farmgate manikmia avenue-Tongi diversion road), (Farmgate manikmia avenue-Hatirjheel link road)	Tejgaon/Farmgate, Motijheel, Uttara/Tongi
R9	29.93084	10.4	(Panthopath-Green road)	Tejgaon/Farmgate
R10	50.02371	15.2	(Farmgate manikmia avenue-Tongi diversion road)	Motijheel
R11	73.13434	47.8	Saat masjid road	Mohammadpur, Dhanmondi

Route 02: Pallabi to Anandabazar at Gulistan				
R1	73.48999	18.2	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
R2	49.3476	5.8	(Banani-Mirpur flyover)	Banani/Gulshan
R3	54.89521	40	IDB shamoly	Mirpur
R4	23.30794	20.6	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
R5	29.14401	36.6	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
R6	29.54876	27.1	Farmgate manikmia avenue, Green road	Tejgaon/Farmgate, Old Dhaka
R7	30.54205	27.5	New eskaton road	Motijheel
R8	45.05705	32.1	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
R9	49.07666	28.3	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
R10	91.66013	16.7	(Bijoyshoroni tejgaon link road-Tongi diversion road)	Motijheel
Route 03: Kuril to Bijoyshoroni				
R1	46.15104	0	-	-
R2	45.18419	0	-	-
R3	38.36272	16	Banani-Mirpur flyover	Mirpur
R4	37.06429	12.4	Tongi diversion road	Motijheel
R5	36.21605	22.4	Tongi diversion road	Motijheel
Route 04: Kuril to Shegunbagicha				
R1	48.11336	0	-	-
R2	46.40872	0	-	-
R3	56.46322	0	-	-
R4	56.77364	40	Hatirjheel link road, (Hatirjheel link road-Panthopath-Green road), (Hatirjheel link road-Panthopath-Green road)	Motijheel, Old Dhaka, Tejgaon/Farmgate
R5	55.06167	33.3	Hatirjheel link road	Motijheel,Tejgaon/Farmgate
R6	57.40314	48.8	Hatirjheel link road	Motijheel
R7	60.81846	31.3	Hatirjheel link road	Motijheel
R8	64.98376	47.2	Hatirjheel link road	Motijheel,Tejgaon/Farmgate
R9	16.63687	15.5	Hatirjheel link road	Tejgaon/Farmgate

Percentage of additional traffic volume for each link has been calculated from link wise existing and additional traffic flow along major study routes. Link wise O-D matrixes have been developed under the first objective of the study. From each O-D matrix percentage of vehicles going into which destination zones has been found. Using the O-D matrix information on availability of alternative routes to particular destination zones, percentage of additional traffic has been assigned / shifted from major study links to available alternative roads which lead to those destination zones.

Photo 9.1: Green road act as parallel to Mirpur Road
Source: Field survey, 2014

Photo 9.2: Vehicles using connector road to reach Saat Masjid Road from Mirpur road
Source: Field survey, 2014

Photo 9.3: Rickshaws using connector road to reach Mirpur road from Saat Masjid Road
Source: Field survey, 2014

CASE STUDY 02

While shifting additional traffic along alternative secondary roads shifting from all the study links have not been possible because of lack in connector or parallel road to six of the study links. Besides that it is also observed that from the other study links it was not always possible to shift all additional vehicles. In case of Route no. 03 (Kuril to Bijoyshoroni), it is being found that from the first two links (Link 1 (R1): Kuril to Banani rail crossing and Link 2 (R2): Banani rail crossing to Banani DOHS); no additional vehicle was shifted because of lack in alternative road connected or parallel to these two links. But for the other three links (started from Banani DOHS to Bijoy shoronee_Novo theatre signal) very few percentage of additional vehicle have been able to be shifted along alternative roads (see table 9.2). Here in these three study links percentage of additional vehicle needed to be shifted was found as 111.63% but in real scenario after trip assignment only 50.8% additional vehicle trips have been found to be shifted along alternative road to reach their original destination. One of the major reasons of this situation is the location of Dhaka cantonment area occupying a huge amount of space by Bangladesh Army. Because of this restricted area no connector / alternative road has been made especially along Link 3 (R3): Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point), Link 4 (R4): Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate and Link 5 (R5): Jahangir gate to Bijoy shoronee_Novo theatre signal. These links are the most congested links found from the volume survey respectively possessing 1532 and 1596 PCU/hr which are the highest traffic flow in compare to other links of this route. Also there is a gradual increase of traffic volume observed from link 01 to link 05 along this particular route (see figure 7.20 in chapter 07).

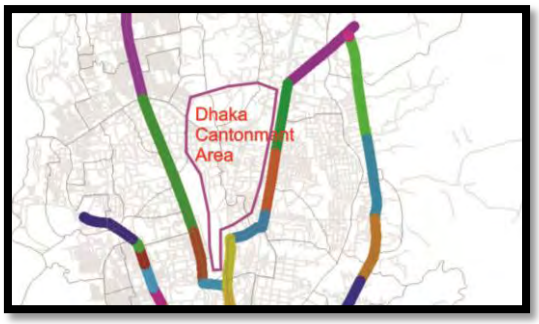


Figure 9.1: Location of Dhaka Cantonment area along Route 03 (Kuril to Bijotshoroni)

9.2.3 Cases of capacity exceed after accommodating additional traffic volume along alternative routes

After assigning traffic along alternative roads it has been seen that most of the roads can accommodate additional traffic within their capacity and possess sufficient vacant space to occupy additional traffic flow shifted from major routes. But only in case of two secondary roads: Sat Masjid Road and Tongi Diversion Road, roadway capacity has been exceeded. For sat Masjid road, capacity has been exceeded by only a limited margin (188 PCU/hour). But for Tongi diversion road because of excessive travel demand to some zone like Motijheel etc. capacity has been exceeded almost 2683 PCU/hour in case of accommodating additional vehicle.

Table 9.3: Capacity exceeded for only two alternative roads after traffic flow addition

Secondary Alternative Road	Existing volume (PCU/hour)	Optimum volume (PCU/hour)	Vacant space (PCU/hour)	Vehicle added from major links (PCU/hour)	Capacity exceeded (PCU/hour)
Sat Masjid Road	4470	6000	1530	1718	188
Tongi Diversion Road	5181	7000	1819	4502	2683

Detail calculation for all other routes has been given in appendix G.

9.2.4 Additional traffic flow remain in their original route

Additional traffic flow has been tried to shift along available alternative roads from major study routes. But because of excessive travel demand to some specific zones and lack in alternative secondary roads to reach those specific destination zones considerable amount of traffic (PCU/hour) has to remain along their original route. Six of the thirty five study links (highlighted in table 9.2) are not be able to shift any additional traffic because of having no connector roads to alternative secondary roads.

In this section of the chapter, additional traffic flow, traffic volume shifted from original roads and additional vehicle remain in original roads (both route wise and link wise) have been analysed through graphical representation.

In the following figure route wise additional traffic flow (both shifted and not shifted) has been portrayed. Among the four major study routes, Route 02 (Pallabi to Anandabazar) possesses highest additional traffic and highest number of traffic flow shifted from the route. For both Route 01 (Mirpur road) and 02, shifted traffic flow is greater in PCU/hour than remaining traffic flow in the original routes. But in case of Route no. 03 and 04, remaining traffic volume is greater than shifted traffic flow from original routes.

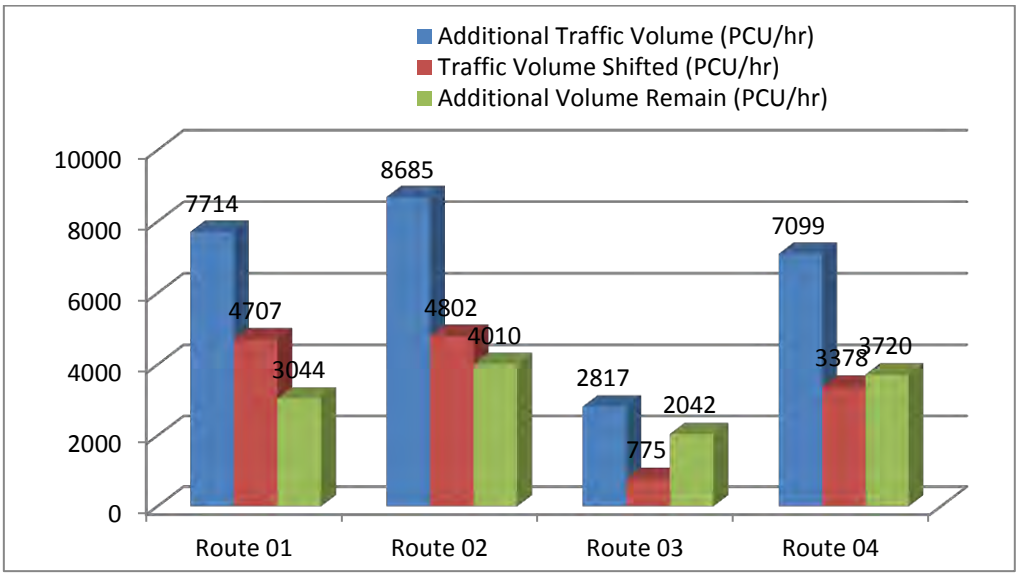


Figure 9.2: Route wise shifted and remaining additional traffic flow

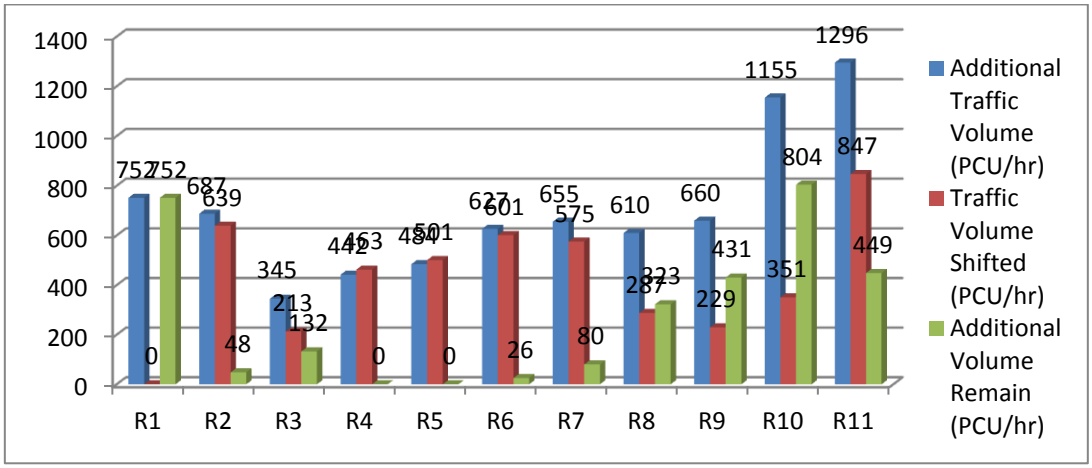


Figure 9.3: Link wise shifted and remaining additional traffic flow along Route 01

Link wise analysis also has been conducted. In the above figure for 11 links along Mirpur road total additional traffic flow with both shifted and not shifted flow has been shown. For the first link along Route 01 (Technical Morh to Shyamoli cinema hall signal) because of lack in connector/alternative road connected to it, no traffic flow has been shifted from this particular link. For the other links considerable amount of additional traffic are being able to be shifted along suitable and available alternative routes to reach their original destination zones. For most of the links except three study links along this route (see R8, R9, R10), shifted traffic flow is greater than remaining additional traffic. Link 8 (R8): Dhanmondi 27 signal to Panthapath Russel square signal, Link 9 (R9): Russel square signal to Science lab signal and Link 10 (R10): Science lab signal to New market signal; these three links share huge amount of traffic in compare to other links along Mirpur road. For this reason additional traffic volume is also high in cases of these three links.

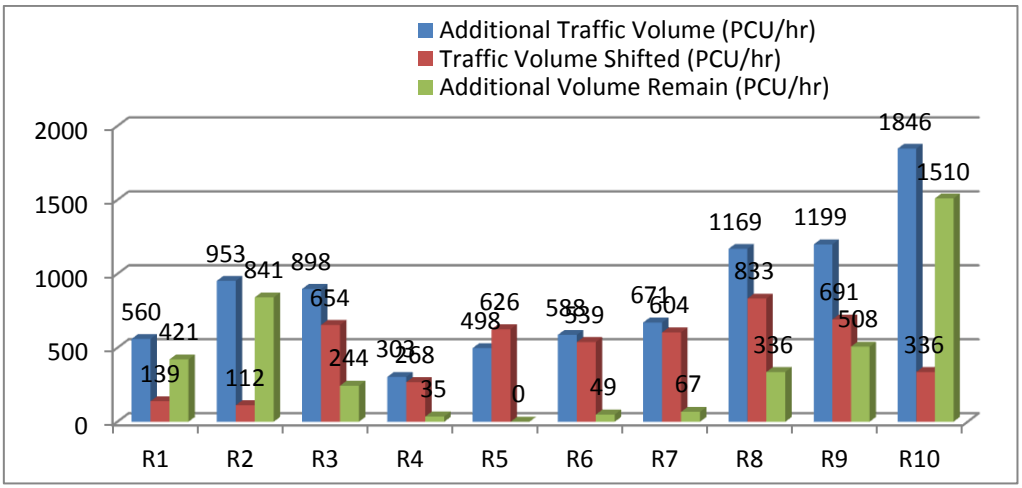


Figure 9.4: Link wise shifted and remaining additional traffic flow along Route 02

From the above figure, it can be seen that for the last link along route 02 (Kodom foara to Anadabazar at Gulisthan), total additional traffic volume is highest and for this additional traffic volume remaining in the original link after shifting is also being the highest in compare to other links of this route. Normally this particular link is very much congested all the time especially in peak hours. Link no. 2, 8 and 9 also show high additional traffic before shifting and after shifting of vehicles to alternative available secondary roads, only link no. 2 (Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school) show high traffic volume remaining in the original link.

For route no. 03 (Kuril to Bijoyshoroni) (see figure 9.4 below) limited number of vehicles shifted from the original route because of less availability of connector/alternative secondary roads to this route. For first two links (from Kuril to Banani rail crossing and from Banani rail crossing to Banani DOHS) no traffic volume could be shift to any other alternative roads. For link 3 and 4 significant amount of traffic can be shifted to alternative routes like Banani-Mirpur flyover and Tongi diversion road to make reach the additional vehicle trips to destination zones like Mirpur and Motijheel respectively. But still for this two links maximum number of additional trips remains in original route. Only for the last link (Jahangir gate to Bijoy shoronee_Novo theatre signal) which is the most congested link found from the practical observation during survey, considerable amount of additional trips (358 PCU/hr) have been shifted to alternative road but still some trips could not be shifted (221 PCU/hr) and remain in the original route.

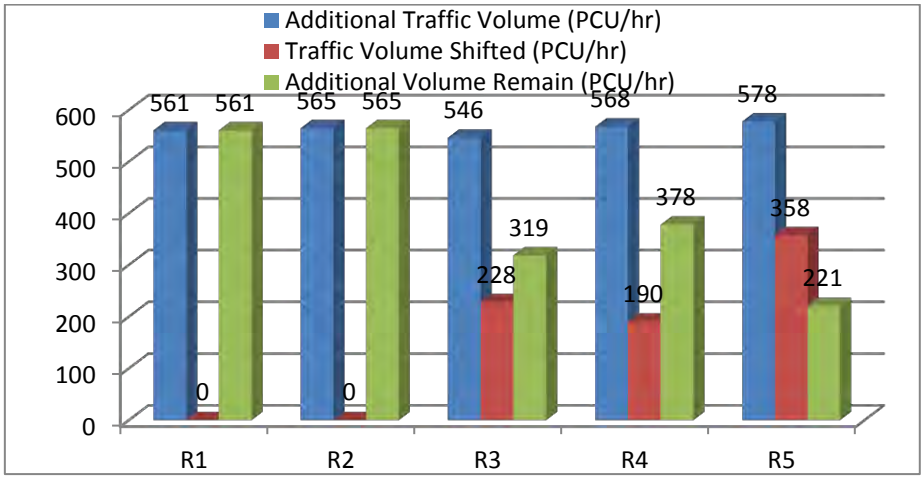


Figure 9.5: Link wise shifted and remaining additional traffic flow along Route 03

From the following figure it has been observed that along route no. 04, first 3 links (starting from Kuril to Bashundhara residential area entrance to Progoti Shoroni) no additional trips could be able to shift along alternative roads because of excessive vehicle pressure and lack of alternative roads connected to these links. But for rest of the links (starting from link 4: Rampura TV Bhaban to Hatirjheel connecting road point) significant amount of traffic shifted to alternative routes specially Hatirjheel link road to reach their original destinations like Motijheel and Tejgaon/Farmgate zones.

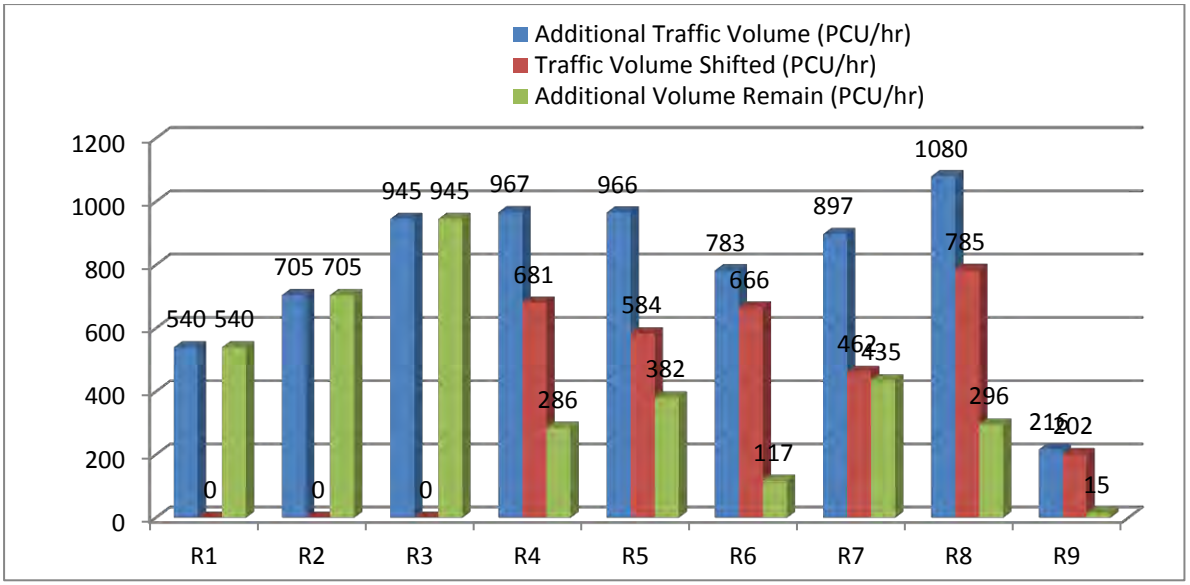


Figure 9.6: Link wise shifted and remaining additional traffic flow along Route 04

Detail database on Traffic volume along roads (both major study routes and alternative secondary roads) after trip assignment has been included within appendix G.

9.3 Summary

Vehicle trips have been assigned along alternative secondary roads if available through satisfying their original travel demand. But for some of the links it has not been possible because of lack of connector/alternative roads. Also dominance of some specific destination zones in travel demand of vehicle users have played significant role behind not shifting all the additional traffic from major arterial roads. For TAZ like Motijheel and Old Dhaka excessive travel demand has been observed. For this reason not all the additional vehicles going into these destination zones are shifted as there are lack of options for alternative secondary roads in Dhaka city. Parallel there are vehicular pressures along the available secondary roads also and travel demand existed for some other zones like Banani/Gulshan, Uttara/Tongi, Tejgaon/farmgate, Dhanmondi etc. In this chapter, firstly additional space to accommodate traffic along secondary roads has been calculated. Then assignment of additional traffic flow along available alternative roads according to destination has been done. Cases of capacity exceed after accommodating additional traffic volume along alternative routes have

been discussed. For all the secondary roads, existing and optimum volume, vacant space for additional vehicle, Vehicle added after trip assignment and capacity exceeded or not have been calculated. Lastly link wise additional traffic flow remain in their original route has been depicted through analysis. The next two chapters present some generic and specific recommendations including major findings with the expectation that these may partially or to a greater extent contribute the transport planners in future research in relevant field and policy makers in taking effective measures regarding standard traffic volume along major roads.

Figure 9.7: Additional Traffic Volume (PCU/hour) shifted from Major Routes to Secondary Alternative Roads

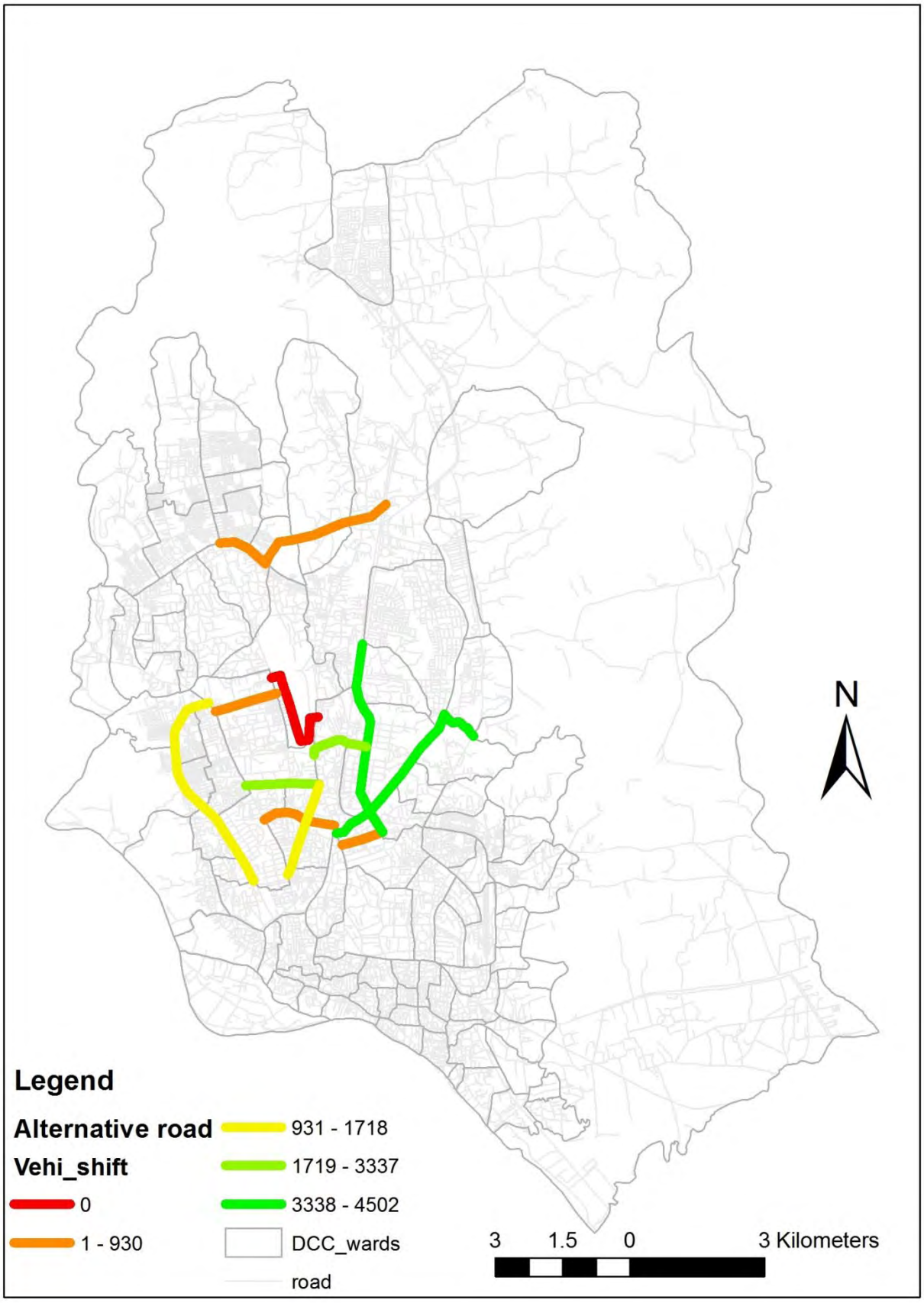
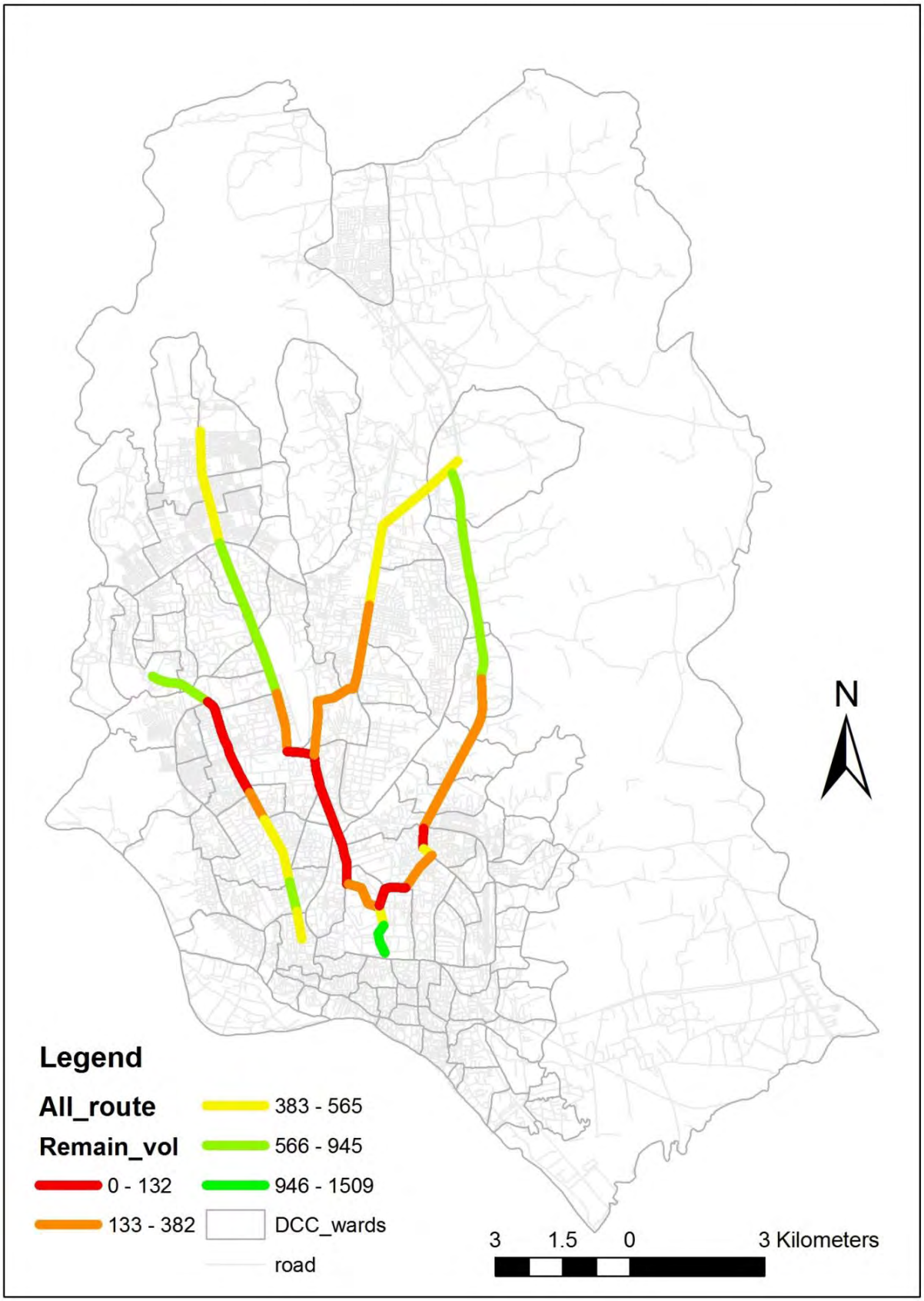


Figure 9.8: Additional Traffic Volume (PCU/hour) remaining in their Original Route



CHAPTER 10

Major Findings

Various findings have been obtained from the analysis of the study. This chapter discusses about the major findings that have been attained from thorough analysis of the study. Based on the findings some aspects have been tried to recommend through reducing congested traffic situation in Dhaka in the following chapter with concluding remarks.

10.1 Study findings

10.1.1 Major findings

Major findings regarding estimation of travel demand, determination of optimum traffic volume and assignment of additional traffic have been discussed in this section.

- As place of origin Mirpur zone (with 17.1% vehicle trip) plays most dominant role and on the other hand, Motijheel zone (with 19.2% vehicle trip) is found as the most prominent zone as place of destination within the overall study area.
- Work (56.5%) has been found as the most dominant purpose/function behind most of the vehicle trips made along the four major study routes.
- For private car, Old Dhaka zone is most prominent as a place of origin and Dhanmondi and Motijheel zone hold the second highest share as origin for trips made by car. On the other hand, Motijheel zone receives highest amount of trips made by car.
- Highest number of Public bus trips originates from Mirpur zone. Old Dhaka and Motijheel zone is found to receive highest bus trips as destination.
- For Non-motorized traffic (NMT), vehicle share is very low in compare to some other vehicle modes as some of the study links and routes are totally banned for NMT. For NMT, Mirpur zone contribute highest number of trips as both origin and destination. Dhanmondi and Uttora zone as destination zone contributes nil to NMT trips.

- Almost all TAZ got most of the vehicles for work purpose as this trip purpose shows dominant share for all the zones.
- Most of the areas are dominated by commercial land uses. Some areas are dominated by educational land uses. Residential land uses holds third position in determining trip pattern of vehicles. Some other land uses like recreational land use, hospital, embassy etc. are seen to dominate the travel pattern of vehicles to a specific zone in a very limited manner. Commercial land uses are found as major influencing land use category to direct vehicle trips into specific destination areas. Commercial land uses includes office, industry, shopping mall etc. which are liable for the majority vehicle trips in Dhaka city.
- Most of the private cars possess very low occupancy. Only one passenger (excluding driver) was found in the survey for the dominant share (42.1%) of cars. Almost 37.7% cars are seen to occupy only two passengers. Full occupancy with four passengers has been seen in case of only 2.8% private cars.
- Private car and other modes want to shift to alternative mode if proper service facility will be given and availability can be ensured. In case of car, people want to shift to other alternative public transport modes like bus, CNG, Taxi, NMT etc. A huge number of CNG users want to shift to bus as alternative travel mode. They choose bus at the top position. Car and taxi are also on their preference list of alternative mode. Motor cycle, Microbus, Taxi and NMT users also want to use public bus as alternative mode. NMT users are only willing to shift to bus and HH (Leguna etc.). Private car is seen as one of the preferred alternative modes for Micro bus, Jeep and Taxicab. One interesting finding is that some Motorcycle users want to shift to Leguna (HH etc.). Most important finding from the survey in alternative mode aspect is that no bus users are willing to shift any other alternative mode.
- Most of the vehicle users are not willing to shift to alternative routes. None of the private car users mentioned about any alternative route. Some bus drivers (for only 18 bus trips) mentioned some alternative route.
- For all the four major routes public vehicles possess the dominant share in compare to other vehicles.

- For each study route mainly bus (with both diesel and CNG fuel type), Leguna/Tempo/Human Hauler (fuel type: CNG), Pick up/Minitruck (fuel type: CNG) and Truck (with both diesel and CNG fuel type) contribute to emission as emission factors (gm/km) for these vehicle type (fuel wise) exceeds the emission standard (gm/km) given in ECR, 1997.
- Average original capacity among four routes calculated as 5726 PCU/hour (approx.) and average effective capacity for these routes found as 3526 PCU/hour. Overall average deviation for all four major arterial routes is 2200 PCU/hour.
- For almost 100% of the study links along four major arterial routes existing traffic flow does not exceed the road capacity standard or effective roadway capacity. As in all the cases existing traffic flow is less than road capacity, there is no additional traffic flow in consideration with road capacity criteria or in determining optimum/standard traffic volume satisfying road capacity criteria.
- For all the four major routes, existing traffic flow is greater than emission wise optimum traffic volume but less than capacity wise optimum traffic flow. There is only one exception for link no. 08 (Dhanmondi 27 signal to Panthapath Russel square signal) along Mirpur Road having a capacity of only 1650 PCU/hr.
- Maximum number of vehicles (8685 PCU/hour) is in need to be shifted along alternative route from Route no. 02 (Pallabi to Anandabazar route) and minimum vehicle (2817 PCU/hour) needed to shift from Route no. 03 (Kuril to Bijoyshoroni). A large number of vehicles (6802 and 7099 PCU/hr) needed to be shifted along alternative routes from Route no. 01 and 04 respectively.
- After assigning traffic along alternative roads it has been seen that most of the secondary roads can accommodate additional traffic within their capacity and possess sufficient vacant space to occupy additional traffic flow shifted from major routes. But only in case of two secondary roads: Sat Masjid Road and Tongi Diversion Road, roadway capacity has been exceeded.
- Six of the thirty five study links (highlighted in table 9.2) are not be able to shift any additional traffic because of having no connector roads to alternative secondary roads. List of the links is as follows:

- ✓ Route 1: Link 1 (R1): Technical Morh to Shyamoli cinema hall signal
- ✓ Route 3: Link 1 (R1): Kuril to Banani rail crossing
- ✓ Route 3: Link 2 (R2): Banani rail crossing to Banani DOHS
- ✓ Route 4: Link 1 (R1): Kuril to Bashundhara residential area entrance
- ✓ Route 4: Link 2 (R2): Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)
- ✓ Route 4: Link 3 (R3): Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)

10.1.2 Other findings

- Among all the vehicle trips coming to Mirpur zone, this TAZ receives lowest trip share (0.6%) for both medical and travel purposes. Mohammadpur zone receives lowest vehicle trips (2.3%) for shopping purpose. Dhanmondi zone (27.2%) and Old Dhaka zone (22.3%) receives a significant portion of education based trip. Motijheel zone receives a very limited number of vehicle trips with return purpose.
- Among all the vehicle trips going into all destinations for work purpose, Motijheel zone receives highest amount of vehicle trips (21.3%). Old Dhaka zone receives the highest portion of vehicle trip (20.6%) for education purpose. Dhanmondi and Motijheel zone receives the second highest percentage (16.4%) of education based vehicle trip each. For medical purpose highest number of vehicles (52.6%) goes to Old Dhaka zone. For travel purpose most of the vehicle trips go to Mohammadpur and Motijheel zone. From the analysis it has been revealed that among all the return trips made to different destination zones, Mirpur zone receives highest percentage (26%) of return trip. Uttara/Tongi and Banani/Gulshan zone hold the second position jointly to receive return trip (22%). Dhanmondi zone receives highest number of shopping trips (31.3%) among all the shopping trips made by vehicles to all zones. Uttara/Tongi zone and Mirpur zone receive highest number of vehicle trips (42.9%) for recreation purpose among all recreation trips has been made to all TAZs.
- From overall Origin-Destination (O-D) matrix along four major study routes it has been found that from Mirpur zone maximum number of vehicle trips goes

for Old Dhaka zone. From Mohammadpur zone majority vehicle trips go to Old Dhaka, Motijheel and Banani/Gulshan zone etc. Majority vehicle trips originate from Dhanmondi to reach Uttara/Tongi and Mirpur zone. Vehicles originating from Old Dhaka go mainly for Mirpur zone and from Motijheel zone majority vehicles go to reach Uttara/Tongi, Banani/Gulshan and Mirpur zone. From Tejgaon/Farmgate zone majority trips go to Banani/Gulshan zone. Significant portion of vehicle trips (40.4%) originates from Banani/Gulshan zone choose Motijheel zone as their destination. From Uttara/Tongi zone most of the vehicles go to Motijheel and Old Dhaka zone.

- Except Private car, bus, CNG Auto rickshaw and Motorcycle, other vehicle classes are not found in a significant amount from volume survey along the study routes so that sample size for O-D survey was also small for those vehicle classes.
- Maximum private car (23.8%) along Route 01 goes into Old Dhaka zone. Minimum vehicle trip by car (3%) end their trip in Uttara/Tongi zone. Maximum bus trips (34%) also go into Old Dhaka zone and second position as favourite destination of bus held by Mirpur zone (28.3%) along Mirpur Road. NMT running along Mirpur Road end their trip mainly Old Dhaka zone (60%) and Mohammadpur zone (40%).
- Along Pallabi to Anandabazar route most of the car trips go into Motijheel zone (22%) as destination and second highest number of car (18.2%) end their trip in Mirpur zone. In case of bus trips along this route, most of the trips go for Motijheel (31.9%), Old Dhaka (23.2%) and Mirpur zone (21.7%). NMT use this route to reach Mirpur (64.7%) and Tejgaon/Farmgate zone (35.3%). Leguna/HH etc. use this route to go Mirpur, Mohammadpur, Dhanmondi and Motijheel zone.
- Using route 03 (Kuril to Bijoyshoroni), private cars go mostly to Uttara/Tongi (30.4%) and Banani/Gulshan zone (21%). Most of the Bus trips also use this route to go to these two destination zones (31% and 21.1%). 100 % trips made by Tempo/Leguna/HH use this route to go only Banani/Gulshan zone.
- Private car trips which go into destination zones like Motijheel zone (29.8%) and Banani/Gulshan zone (25.8%) use route no. 04 (Kuril to Shegunbagicha). Bus trips use this route to reach mainly Old Dhaka, Uttara/Tongi, Motijheel

and Banana/Gulshan zone. Least number of bus trips (1.6%) among all the bus trips along route 04 go Mirpur zone.

- From link wise O-D matrix, route has been identified for vehicle trips.
- Almost 92% private car users are not willing to shift any other alternative mode. A limited portion of car users want to shift Bus, CNG, Taxi and Rickshaw.
- Route 01 (Mirpur Road) is the most congested routes with maximum number of both non-polluting and pollution vehicles. On the other hand, Route 03 (Kuril to Bijoyshoroni) is the least congested routes. But as route length is not same for all four routes vehicle number does not play any significant role. In this study, Route 01 consist maximum number of links (11) and Route 03 consists minimum number of links (05).
- Almost similar capacity is maintained throughout all the links along Mirpur Road. But in case of link no. 08 (Dhanmondi 27 signal to Panthapath Russel square signal) with length of 0.65 km, possess effective capacity of only 1650 PCU/hr.
- In case of the 2nd major study route, Pallabi to Anandabazar at Gulistan effective capacity of road sections vary within a comparatively narrow margin (from 3550 PCU/hr to 3750 PCU/hr). Almost similar capacity variation occurs along different links of Route no. 3 in compare to Route 02 study section. But here in Route 03 difference between links with maximum and minimum roadway effective capacity is a little bit higher (400 PCU/hour).
- For both Route 01 and 02, shifted traffic flow is greater in PCU/hour than remaining traffic flow in the original routes after assigning trip. But in case of Route no. 03 and 04, remaining traffic volume is greater than shifted traffic flow from original routes.

CHAPTER 11

Recommendation and Conclusion

Based on the study findings discussed in the previous chapter some specific policy recommendations have been formulated to reduce traffic congestion and to improve public health through ensuring a smooth travel to the vehicle (both motorized and non-motorized) and road users of Dhaka city.

11.1 Policy recommendation

11.1.1 Policies regarding Travel Demand Management (TDM) and Transportation System Management (TSM)

It has been found that for almost 100% of the study links along four major arterial routes existing traffic flow does not exceed the road capacity standard or effective roadway capacity. Though carriageway width of road is satisfactory or more than enough in Dhaka but traffic congestion existed. Congested streets and roadways result when too many people want to drive on the same routes at the same time, particularly during peak commute hours or special events. Transport Demand Management (TDM) programmes focus on changing or reducing travel demand, particularly at peak commute hours, instead of increasing roadway supply. So it can be said that TDM can make more efficient use of the current roadway system in Dhaka.

Photo 11.1: Examples of efficient use of road space following TSM actions (supply side)
Source: URL 4

- As work has been found as the most dominant purpose behind most of the vehicle trips, adaptation of integrated demand and supply management approach through the following measures is necessary:

✓ Reduction of the need for haphazard travel (as found from survey that from all the zones vehicle trips are made to all other zones for work purpose) planned mixed use development (work places near residence) is needed instead of haphazard development.

✓ Rescheduling the time of journey through modifying/shifting the starting and ending time of work and alternative work schedules can also reduce peak period commute travel, and thus can reduce traffic congestion. Promotion of shifting peak-hour work based travel to staggered work hours, flexible working hours, and flexible working week can be other TDM options.

- Some other TDM strategies like Road pricing (charging motorists directly for driving on a particular road or in a particular area), Parking pricing, Fuel pricing etc. can be adopted in present traffic situation of Dhaka. There are a number of possible road pricing schemes involving various time periods, areas and means of charging (Ison 2004). Two most successful road pricing schemes are London's congestion pricing and Singapore's electronic road pricing. London's congestion charging scheme was implemented in February 2003, and traffic impact assessed a year after showed significant improvements in terms reduction of auto uses, increase in bus ridership, reduction in delays, and increase in vehicle speeds (TfL 2004). In Singapore, the first road pricing scheme, known as the Area Licensing Scheme, was introduced in the restricted zone in 1975. In September 1998, the electronic road pricing system replaced the manual system for the restricted zone and expressways. The benefits of the introduction of the electronic road pricing scheme were an immediate increase of traffic speed by 22%, and total reduction of traffic in the restricted zone during the charging period by 13% (Keong 2002).
- Parking Management and Parking Pricing are effective ways to reduce automobile travel, and tend to be particularly effective in urban areas where congestion problems are greatest. Efficient pricing of on-street parking would

make urban driving more expensive but more efficient, due to lower levels of traffic congestion and the relative ease in finding a parking space near destinations, as well as providing new revenues. Fuel price increases can help reduce traffic congestion by reducing travel demand. INRIX (2008) results indicated that a 28% increase in average fuel prices during the first half of 2008 contributed to a 3% reduction in average national Travel Time Index values. Distance-Based Fees (also called Pay-As- You-Drive, Mileage-Based and Per-Mile pricing) tend to be economically more efficient and fairer than existing pricing practices. Converting fixed costs into distance-based charges gives motorists a new opportunity to save money when they reduce their mileage. Telework involves the use of telecommunications to substitute for physical travel, and gives people a way to avoid travelling under congested conditions. Employer based transport demand management strategies (commute trip reduction programme, also known as travel plan) include public and private sector programmes and services that encourage employees to change their commuting practices, incentives that make publicly provided travel modes more attractive, disincentives to solo commuting, and employer management policies that offer employees flexibility in travel mode choices (Hasan and Rahman, nd).

- Six of the thirty five study links were not be able to shift any additional traffic because of having no connector roads to alternative secondary roads and in some cases because of unavailability of alternative roads. Alternative roads connected to those links can be constructed (if possible) under supply side policies of TSM to reduce excessive vehicle pressure from the specified links.
- Some TSM actions (supply side) like physically improving local intersections, coordinating signal timing for arterial roadways, computerizing area-wide signal coordination in downtown grid networks, television monitoring of traffic etc. can be taken for Traffic Signalization Improvements.

11.1.2 Policies regarding Bus Priority Measures to Reduce Congestion

Public transport should be designed around the customer and not around a technology. For this, facilitation of public transport system with diverse scopes in order to use road space in a more effective way is an urgent need for Dhaka. One of the most

important findings from this study was that no bus users are willing to shift to any other alternative mode. Also another important finding was that for all the four major routes public vehicles (especially bus) possess the dominant share in compare to other vehicles. For these reasons, some bus priority measures are recommended here to serve the majority people's travel need.

- Introduction of consolidated and well integrated bus network. From this study it has been depicted that highest number of Public bus trips originates from Mirpur zone and Old Dhaka and Motijheel zone is found to receive highest bus trips as destination. BRT (Bus Rapid Transit) system can be developed along some specific routes starting from Mirpur and ended at both Old Dhaka and Motijheel area and vice versa. Restructuring of bus operator companies can be done. Only companies of about 100 buses could participate in the bidding process for issuance of new route permits.

- Creation of exclusive separate bus lane along the most demandable bus links especially for Route 01 (Mirpur Road) and Link no. 09 (Motsho bhaban to Kodom foara) along Route 02 (Pallabi to Gulistan) which occupies the highest number of bus. Also for link no. 08 (Shahbagh to Motsho bhaban), 03 (Agargaon to Bijoy shoroni) and 07 (Karwan bazaar_SAARC foara to Shahbagh) having a significant number of bus/km length of those links need separate bus lane along Route 02.

Photo 11.2: Practical examples of separate bus lanes in foreign countries
Source: URL 5

- Under TSM, some supply side actions like reservation of the curb lane of major arterial streets (for both Route 01 and 02) for buses only and reservation of an entire street, in the CBD (Motijheel zone), for the exclusive use of buses can be taken for efficient use of road space.

- Integration of bus network with pedestrian and FFT facilities.

Photo 11.3: Intermodal coordination between bus and pedestrian at public spaces
Source: URL 6

- While calculating number of bus per km length of each route, Mirpur Road (Route 01) shows prominent position. From study findings it has been proved that Mirpur Road is a busy route for buses. The loading and unloading of buses near intersections causes traffic congestion. This kind of activity near intersections should be restricted by enforcing law. Bus stoppage near intersection should be prohibited as well.

11.1.3 Policies regarding restriction on private car

Though a huge portion of private car users also are not willing to shift to alternative other modes found from this study, but it is all because of unavailability of proper public transport options in Dhaka. It is of utmost importance to restrict car with creating public transport alternatives for the car users.

- Enforcement of strong regulations to control the existing growth of private vehicles especially private car as most of the private cars have been found possessing very low occupancy from this study .

Photo: 11.4: Comparative scenario in case of occupancy and road space occupied between car and bus
Source: Bari, M. (nd)

- On street car parking can be restricted along all four major study routes. At present there is provision for on street parking in Mirpur Road and all other routes except Route 03 (Kuril to Bijoyshoroni). A large number of vehicles use the space of the road for on street parking. From this study overall average deviation between original and effective capacity for all four major arterial routes was found as 2200 PCU/hour. Because of poor law restriction, a lot more cars than allowed use the road space for on street parking. For this reason, the effective width of carriageway is significantly decreased. By restricting on street parking in those roads, the width of effective carriageway/effective roadway capacity can be increased, which will ensure better flow of vehicles. Along some highly congested links on street car parking can be fully prohibited except in case of emergency situation.
- Private cars are major portion of total vehicles in major study routes. By facilitating public transport in this area, the uses of private vehicles can be decreased and discouraged. By decreasing the number of private vehicles in the above roads, traffic flow will become better.

Photo 11.5: Better traffic flow can be achieved through decreasing number of private cars

- It has been found from the study that Route 04 (Kuril to Shegunbagicha) shares lowest number of per km cars among all the routes. So along at least some of the most congested links (Link 3: Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban), Link 4: Rampura TV Bhaban to Hatirjheel connecting road point, Link 5: DIT (Hatirjheel connecting road point to Malibagh rail crossing) and Link 8: Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road) of this route, restriction on private car can be imposed. This vehicle restriction technique also can be termed as one of the demand side TSM actions: car free planning.
- Off-street parking restrictions, such as pricing differentials to discourage all-day parking, the elimination of free parking, and parking subsidies, and to

limit vehicular traffic: these supply side TSM actions can be taken for better parking management of vehicles especially private car.

11.1.4 Policies regarding NMT and pedestrian

Promotion of NMT (Rickshaw, Rickshaw van, Bicycle etc.) is needed as a pollution free mode.

- For Non-motorized traffic (NMT), vehicle share is very low in compare to some other vehicle modes as some of the study links and routes are totally banned for NMT. For NMT, Mirpur zone contribute highest number of trips as both origin and destination. Dhanmondi and Uttora zone as destination zone contributes nil to NMT trips. In case of Mirpur zone 61.1% of NMT trips originates and ends both within the zone. Also in case of Banani/Gulshan zone 33.3% trips ends within the same zone. So it can be said that most of the NMT trips are intra zone trips. For these findings of the study it has been recommended that only the through trips (short distance) for NMT will be allowed along the major roads through creating separate NMT lane (practical example: Link 10 (R10): Science lab signal to New market signal along Route 01) but NMT will be free to run all along the secondary alternative roads and all other connector and access roads to achieve full accessibility through NMT. By banning on street car parking, enough space to create additional lane for rickshaw is possible.

- Pedestrian movement is heavily disturbed by the roadside hawker activity in footpaths. The footpath along the Mirpur Road is fully occupied by hawkers. This leaves little space for pedestrians. The condition of the footpath is also very poor in several locations. From the Level of Service for pedestrian movement along this particular route, it has been seen that though the LOS value between base year and forecasting year ranges between B and C. But in practical situation this LOS cannot be achieved because of the market hindrance and poor footpath condition (Sharmeen, 2011). Real scenario for pedestrians is more deteriorating. For these reasons, pedestrians have a tendency to use the carriageway which conflicts with the traffic flow. Market from the footpath should be eradicated to ensure free pedestrian flow in the footpaths. Condition of the footpath should be improved by providing

pedestrian facilities. This policy of banning illegal encroachment by hawkers can be implemented for other major routes of this study (if applicable) also.

Photo 11.6: Separate pedestrian lane and pedestrian friendly crosswalks
Source: URL 7

- Some TSM actions (supply side) like widening sidewalks, providing lighting, benches, and pedestrian malls, building grade separations (underpasses or overpasses), building bikeways, and installing pedestrian controls at intersections can be taken for pedestrians and bicyclists.

Photo 11.7: Separate lane for bicycle
Source: URL 8

11.1.5 Other policies

- Another important finding from this study was that most of the vehicle users are not willing to shift to alternative routes. One of the basic reasons is lack of knowledge of vehicle drivers on alternative route network available to reach their original destination. Proper knowledge building training about the existing transportation route network can be provided to the drivers while providing license so that over dependence on some major routes can be

minimized and vehicle users are encouraged to use other available routes/options to reach specific TAZs.

- From this study it has been found that for each study route mainly bus (with both diesel and CNG fuel type), Leguna/Tempo/Human Hauler (fuel type: CNG), Pick up/Minitruck (fuel type: CNG) and Truck (with both diesel and CNG fuel type) contribute to emission as emission factors (gm/km) for these vehicle type (fuel wise) exceeds the emission standard (gm/km) given in ECR, 1997. Use of HH, Leguna, Tempo, Truck etc. can be restricted to consider its negative environmental impact. With the developed technology, vehicle engines should be modified so that pollution could get reduced. As CNG driven buses cause extensive pollution because of their higher emission factor, engine design for buses could be modified so that their emission factor could get reduced.
- Provision of more roadside greeneries to minimize vehicular emission.

  Jahan, 2013 developed an overall scenario of emission mitigation by roadside greeneries in Dhaka obtained from CO2 absorption pattern along these four major routes. From the field survey of her study, total 23574 trees of different sizes have been found along both sides of road and on the median of selected major routes. Total area covered by grass, shrubs and creepers along pedestrian walk way, median and roadside boundary wall and fences found is 8.1 hectares. All these greeneries contribute to mitigate total 18.39 Tons of CO2 on the streets of Dhaka, which is only 9.49% of emitted pollution. Still, 90.51% of vehicle emitted CO2 remain exuded in the traffic area of Dhaka. In her study she recommended that plantation of more trees with the increase of emission cannot be the only solution for better traffic environment. Vehicular air pollution at the same time should be controlled at its source. Some issues from transportation aspect should also be considered for mitigating air pollution like provision of public transport as a measure to reduce traffic volume, encourage environment friendly vehicles etc.

Photo 11.8: Densely planted row of large sized trees can reduce higher amount of vehicular emission
Source: URL 9

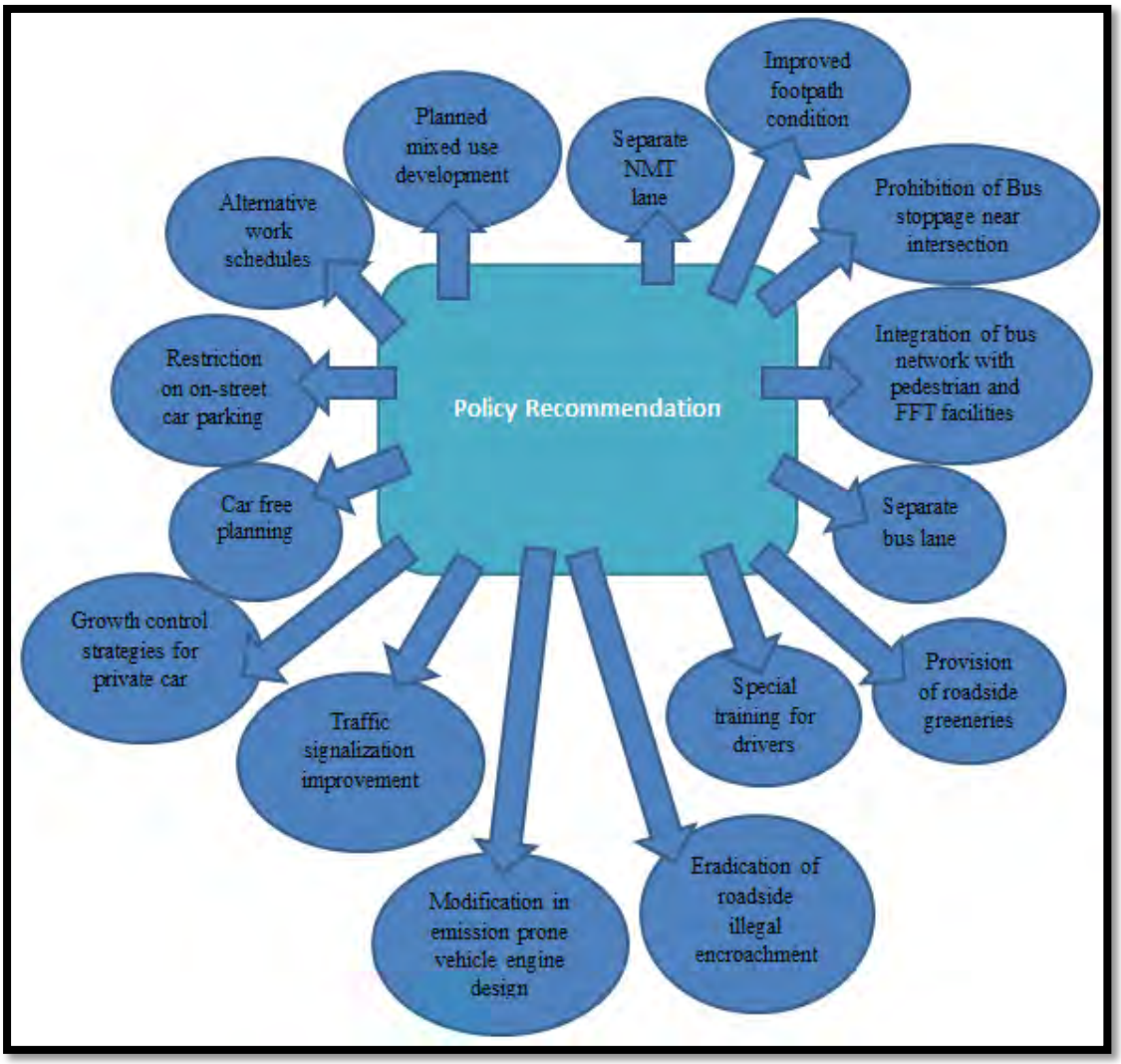


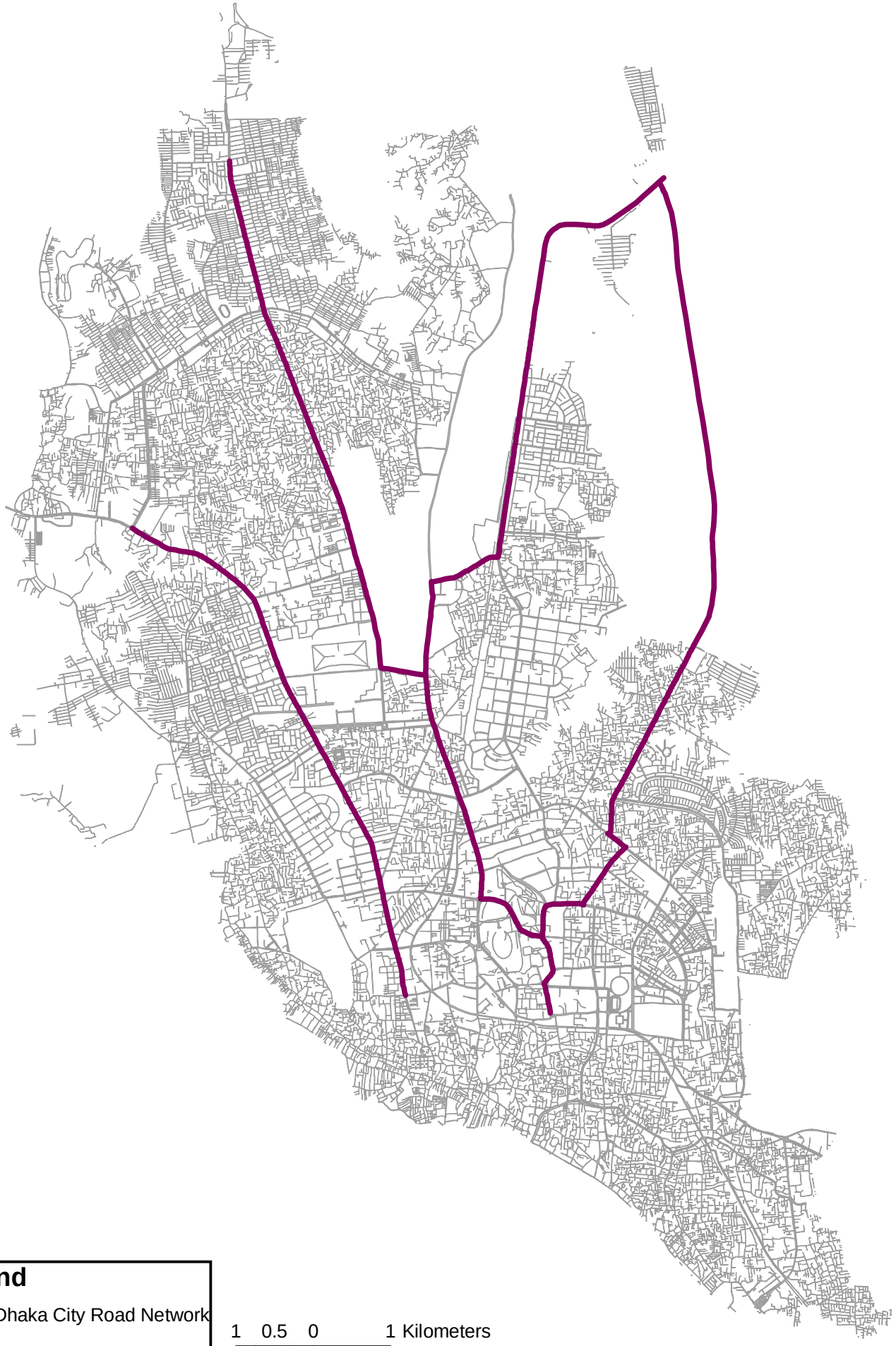
Figure 11.1: Flow diagram of policy recommendation based on the study findings

11.2 Concluding remarks

The purpose of the whole study was to determine standard traffic volume for major routes of megacity Dhaka based on some justified criteria so that congested traffic situation can be reduced. Major focus of the research was to find measures to reduce traffic congestion along the major routes. As vehicle number is increasing day by day in Dhaka so reducing travel demand is the most effective option to reduce congestion. To reduce travel demand, traditional zoning concept can be followed. Some specific TDM and TSM strategies (both demand and supply side policies) can be adopted to reduce the existing traffic congestion of Dhaka. Also policy makers have to be aware and conscious about the alarming situation of transportation scenario in Dhaka. Suggested effective measures regarding optimization of traffic volume must be taken as early as possible otherwise worse situation can be happened in near future.

The findings thus obtained in this study would guide research based practical work that can be done in future. After assigning additional vehicles along secondary roads though it was found that only for two roads roadway capacity have been exceeded but in real scenario we know that traffic congestion exist in secondary roads also. Traffic Impact Assessment and overall impact on surrounding areas of the abovementioned secondary roads after assigning additional vehicle trips also can be conducted through future study. From this study travel demand of vehicle trips has successfully been estimated. Congested traffic routes have also been identified. All these findings can serve as guidelines for the betterment of the present transportation condition of the city.

Figure 4.1: Selected Major Roads of Dhaka City



Data Source: RAJUK

Figure 4.2: Selected Routes of the Study

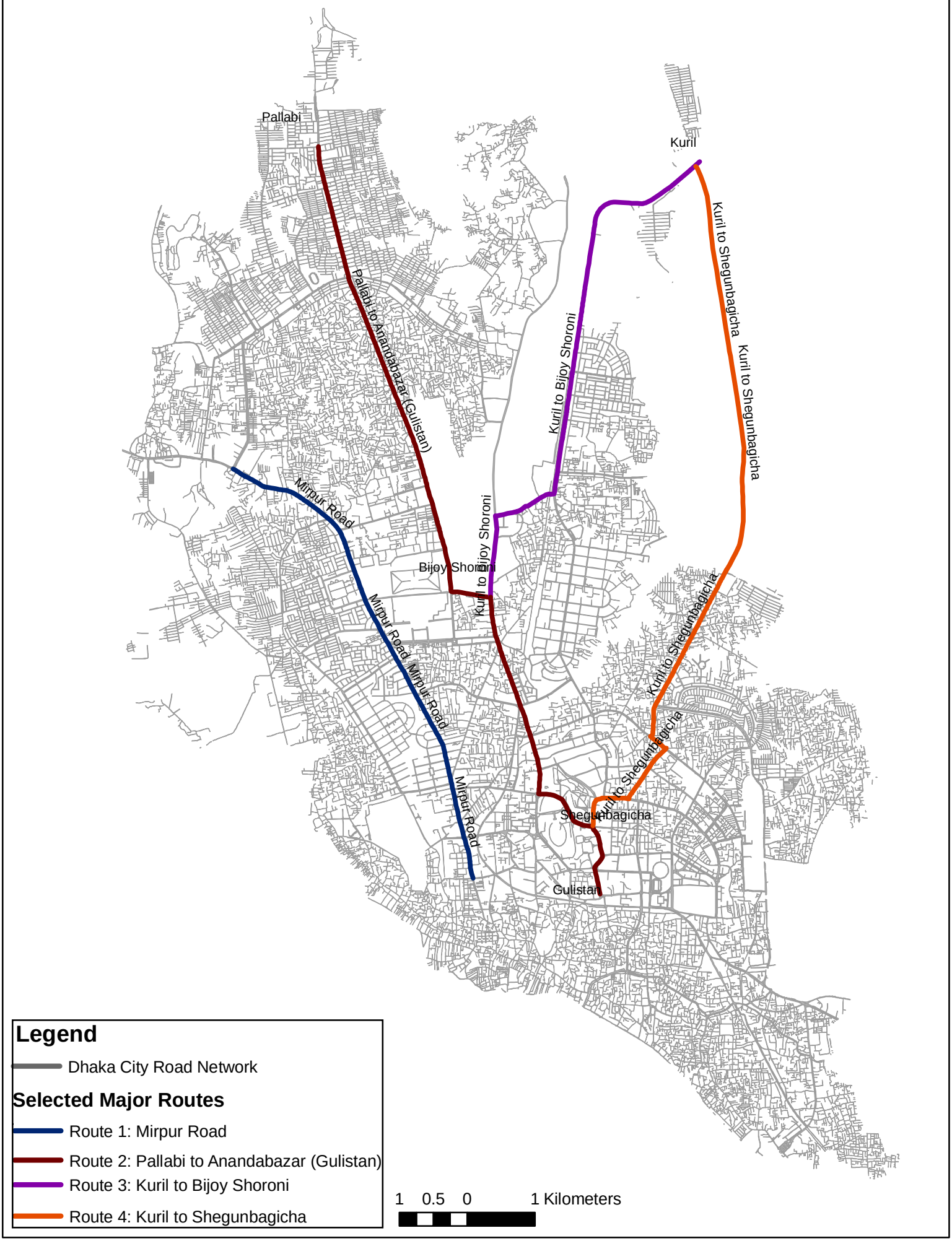
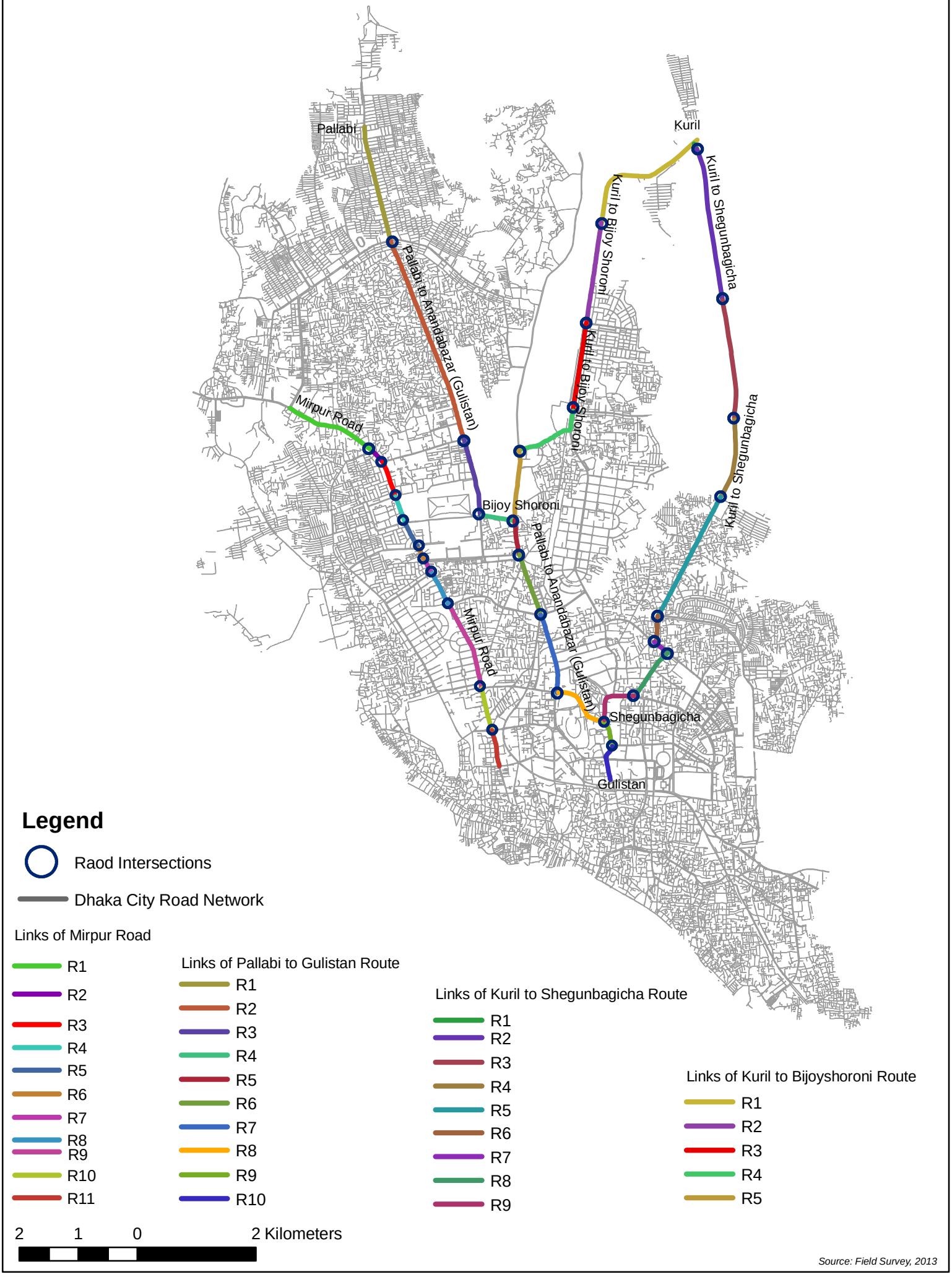


Figure 4.3: Divided Links of Selected Major Routes



Source: Field Survey, 2013

DATA ON CARRIAGEWAY WIDTH

ROUTE 01: MIRPUR ROAD

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Technical Morh to Shyamoli cinema hall signal					
Shyamoli cinema hall signal to Agargaon shishumela signal					
Agargaon shishumela signal to Residential model college corner (north)					
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road					
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal					
Asad gate signal to Lalmatia signal infront of Aarong					
Lalmatia Aarong signal to Dhanmondi 27 signal					
Dhanmondi 27 signal to Panthapath Russel square signal					
Russel square signal to Science lab signal					
Science lab signal to New market signal					
New market signal to Azimpur signal					

ROUTE 02: PALLABI-ANANDABAZAR AT GULISTAN

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Pallabi Shoronee 11 to Mirpur 10					
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school					
Agargaon to Bijoy shoroni					
Bijoy shoroni					
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal					
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara					
Karwan bazaar_SAARC foara to Shahbagh					
Shahbagh to Motsho bhaban					
Motsho bhaban to Kodom foara					
Kodom foara to Anadabazar_Gulisthan					

ROUTE 03: KURIL TO BIJOYSHORONEE

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Kuril to Banani rail crossing					
Banani rail crossing to Banani DOHS					
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)					
Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate					
Jahangir gate to Bijoy shoronee_Novo theatre signal					

ROUTE 04: KURIL TO SHEGUNBAGICHA

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Kuril to Bashundhara residential area entrance					
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)					
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)					
Rampura TV Bhaban to Hatirjheel connecting road point					
DIT (Hatirjheel connecting road point to Malibagh rail crossing)					
Malibagh rail crossing to Mouchak Morh					
Mouchak Morh to infront of Polwel gas station at Outer circular road					
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road					
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagichas					

CARRIAGEWAY DATA OF SOME ALTERNATIVE ROADS

Name of Road	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Sat Masjid Road					
Panthapath					
Farmgate – Manikmia Avenue					
Agargaon-Prime Minister Office Link Road					
New Eskaton Road					
Tongi diversion road					
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)					
Green Road					
Bijoy sharani- Tejgaon link road (Rangs Bhaban-Nabisco)					
Hatirjheel Link road					
Matikata road (infront of Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]					

Measurement unit feet

CO-ORDINATION SCHEMA

Objective	Complex variable	Simple variable	Data type	Data source	Data collection method
To study the existing travel demand along some major routes of Dhaka city	Travel demand	Origin and Destination land use Trip purpose Number of occupants Intermediate stop Preferred alternative route Preferred alternative mode	Both Qualitative and Quantitative	Primary	Cordon survey (direct interview method)
To develop a GIS-based traffic flow distribution model by keeping pollution level within acceptable limit and not exceeding road type capacity	Selected roads	Major arterial roads and some associated alternative secondary roads	Quantitative	Secondary	GIS data of Dhaka Detail Area Plan (DAP) maps
	Motorized Traffic volume	Number of MT passing a link/road section per unit of time along major arterial roads	Quantitative	Secondary	MURP thesis (2013)
	Non-motorized Traffic volume	Number of NMT passing a link/road section per unit of time along major arterial roads	Quantitative	Primary	NMT Volume survey
	Traffic volume (both MT and NMT)	Number of MT and NMT passing a link/road section per unit of time along some alternative secondary roads	Quantitative	Secondary	DHUTS data collected by DTCB and JICA study team (2009)
	Vehicular emission	Vehicle emission factors Vehicle kilometers travelled (VKT) Standards for emission from motor vehicles	Quantitative	Secondary	Various Literatures, MURP thesis (2013) and ECR (1997)
	Roadway capacity	Carriageway width Capacity per lane (PCU/hour)	Quantitative	Primary and Secondary	Field survey and DITS (1994)
	Optimum traffic volume	Comparison between emission standard wise traffic volume (nonpolluting volume) and road capacity wise traffic volume	Quantitative	Processed data	Processed data through GIS using non pollution volume and capacity wise volume
To shift additional traffic flow to existing alternative route in order to reach the same destination	Trip assignment	Difference between actual and optimized traffic flow for each study route	Quantitative	Processed data	Processed data through GIS using existing and optimum traffic volume along each study road
		Destination land use of vehicle classes	Quantitative	Processed data	Processed data through GIS using O-D survey findings and difference between actual and optimized traffic flow for each study route
		Assignment of traffic volume	Quantitative	Processed data	Processed data through GIS using optimized traffic flow for each study route

Checklist for
Cordon Interview Survey
INCOMING VEHICLES
(Direction: from N1-N2)

Route name:	**Interviewer:**
Link name:	**Date:**
Cordon station:	**Time:**

Vehicle class (Sample size)	No. of occupants	Origin	Destination	Purpose of trip	Intermediate stop		Preferred route (alternative)	Preferred mode
					Precise address	Stop purpose		
Car		1. Mirpur zone 2. Mohammad pur zone 3. Dhanmondi zone 4. Old Dhaka zone 5. Mothijheel zone 6. Tejgaon zone 7. Bonani & Gulshan zone 8. Tongi & Uttora zone 9. Others	1. Mirpur zone 2. Mohammad pur zone 3. Dhanmondi zone 4. Old Dhaka zone 5. Mothijheel zone 6. Tejgaon zone 7. Bonani & Gulshan zone 8. Tongi & Uttora zone 9. Others	1. Work trip 2. Educational purpose 3. Visit 4. Medical 5. Travel 6. Return trip 7. Shopping 8. Recreation 9. Others				1. Bus 2. CNG 3. Taxi 4. Car 5. Motor cycle 6. Rickshaw 7. Leguna
Bus								
CNG Auto Richshaw/ Mishuk								

Motor cycle								
Micro Bus/ Ambulance								
Jeep/Station wagon								
Taxi cab								
Leguna/ Tempo/ Human Haular								
Pick up/Mini Truck								
Truck								
NMT (Rickshaw/ Rickshaw van/ Bi-cycle)								

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(All data and information will be used for research purpose only)

Checklist for
TRAFFIC VOLUME SURVEY

Road name:	**Interviewer:**
Road section:	**Date:**
Traffic count station:	**Time:**

Type of vehicle (NMT)	**PEAK HOUR Traffic volume**	**Remarks**
	Number of vehicles	
Rickshaw		
Rickshaw van		
Bi-cycle		

Checklist for
Cordon Interview Survey
OUTGOING VEHICLES
(Direction: from N2-N1)

Route name:	**Interviewer:**
Link name:	**Date:**
Cordon station:	**Time:**

Vehicle class (Sample size)	No. of occupants	Origin	Destination	Purpose of trip	Intermediate stop		Preferred route (alternative)	Preferred mode
					Precise address	Stop purpose		
Car		1. Mirpur zone 2. Mohammad pur zone 3. Dhanmondi zone 4. Old Dhaka zone 5. Mothijheel zone 6. Tejgaon zone 7. Bonani & Gulshan zone 8. Tongi & Uttora zone 9. Others	1. Mirpur zone 2. Mohammad pur zone 3. Dhanmondi zone 4. Old Dhaka zone 5. Mothijheel zone 6. Tejgaon zone 7. Bonani & Gulshan zone 8. Tongi & Uttora zone 9. Others	1. Work trip 2. Educational purpose 3. Visit 4. Medical 5. Travel 6. Return trip 7. Shopping 8. Recreation 9. Others				1. Bus 2. CNG 3. Taxi 4. Car 5. Motor cycle 6. Rickshaw 7. Leguna
Bus								
CNG Auto Richshaw/ Mishuk								

Motor cycle								
Micro Bus/ Ambulance								
Jeep/Station wagon								
Taxi cab								
Leguna/ Tempo/ Human Haular								
Pick up/Mini Truck								
Truck								
NMT (Rickshaw/ Rickshaw van/ Bi-cycle)								

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(All data and information will be used for research purpose only)

Checklist for
TRAFFIC VOLUME SURVEY

Road name:	**Interviewer:**
Road section:	**Date:**
Traffic count station:	**Time:**

Type of vehicle (both MT & NMT)	**PEAK HOUR Traffic volume**	**Remarks**
	Number of vehicles	
Car		
Bus		
CNG Auto Richshaw/Mishuk		
Motor cycle		
Micro Bus/ Ambulance		
Jeep/Station wagon		
Taxi cab		
Leguna/ Tempo/ Human Haular		
Pick up/Mini Truck		
Truck		
NMT (Rickshaw/ Rickshaw van/Bi-cycle)		

DATA ON CARRIAGEWAY WIDTH

ROUTE 01: MIRPUR ROAD

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Technical Morh to Shyamoli cinema hall signal	4	40	4	40	3.5
Shyamoli cinema hall signal to Agargaon shishumela signal	4.5	40.5	4	40	4
Agargaon shishumela signal to Residential model college corner (north)	5	39.5	4	40.5	4.5
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road	4	41.9	3.75	39.5	4.5
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal	4	39.5	4	40	4
Asad gate signal to Lalmatia signal infront of Aarong	4	40	4	40	4
Lalmatia Aarong signal to Dhanmondi 27 signal	4.5	39.3	3.75	40	4.25
Dhanmondi 27 signal to Panthapath Russel square signal	5	29.5	3	31	5
Russel square signal to Science lab signal	4.5	38.75	5.25	39.5	4.5
Science lab signal to New market signal	5	40.75	5	39.5	5
New market signal to Azimpur signal	5	41.5	4.5	40.75	4.5

ROUTE 02: PALLABI-ANANDABAZAR AT GULISTAN

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Pallabi Shoronee 11 to Mirpur 10	5	40.25	5.25	40.7	4.5
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school	5.5	39.5	5	40	5
Agargaon to Bijoy shoroni	5	40	5	40	5
Bijoy shoroni	6	40.25	15	40.5	6.5
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal	5	40	2.5	39.5	5
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara	6.5	40.25	2.5	40.5	5.5
Karwan bazaar_SAARC foara to Shahbagh	5	40.55	3	40	6.5
Shahbagh to Motsho bhaban	4.5	39.5	2	40.5	4.5
Motsho bhaban to Kodom foara	5.5	40.5	2.5	41	5
Kodom foara to Anadabazar_Gulisthan	6	41.5	3.5	40	5.5

ROUTE 03: KURIL TO BIJOYSHORONEE

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Kuril to Banani rail crossing	5.5	40.5	5	42.5	5.5
Banani rail crossing to Banani DOHS	5	39.5	5	40.5	6
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)	5.5	40	3.5	39	5
Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate	6	40.3	4.5	41	6
Jahangir gate to Bijoy shoronee_Novo theatre signal	5.5	40.5	3.5	40	5

ROUTE 04: KURIL TO SHEGUNBAGICHA

Name of Link	Footpath width (Right)	Carriageway width (Right)	Median width	Carriageway width (Left)	Footpath width (Left)
Kuril to Bashundhara residential area entrance	4.5	40	5	41.25	5
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)	3.5	40.5	4	39.5	5
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)	5	38.5	3.5	40	4.4
Rampura TV Bhaban to Hatirjheel connecting road point	4.5	39.3	3.5	40.5	5
DIT (Hatirjheel connecting road point to Malibagh rail crossing)	5	40.5	4	39.5	4.5
Malibagh rail crossing to Mouchak Morh	4.5	39.9	3	40.5	5
Mouchak Morh to infront of Polwel gas station at Outer circular road	4.5	40.5	4.5	39.5	4
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road	4.3	40.5	3.5	40.5	4.5
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagichas	4.5	41.3	4	40.25	4

Measurement unit feet
Source: Field survey, 2014

Raosoft®

Sample size calculator

What margin of error can you accept? 5% is a common choice	5 %	The margin of error is the amount of error that you can tolerate. If 90% of respondents answer *yes*, while 10% answer *no*, you may be able to tolerate a larger amount of error than if the respondents are split 50-50 or 45-55. Lower margin of error requires a larger sample size.
What confidence level do you need? Typical choices are 90%, 95%, or 99%	95 %	The confidence level is the amount of uncertainty you can tolerate. Suppose that you have 20 yes-no questions in your survey. With a confidence level of 95%, you would expect that for one of the questions (1 in 20), the percentage of people who answer *yes* would be more than the margin of error away from the true answer. The true answer is the percentage you would get if you exhaustively interviewed everyone. Higher confidence level requires a larger sample size.
What is the population size? If you don't know, use 20000	20000	How many people are there to choose your random sample from? The sample size doesn't change much for populations larger than 20,000.
What is the response distribution? Leave this as 50%	50 %	For each question, what do you expect the results will be? If the sample is skewed highly one way or the other,the population probably is, too. If you don't know, use 50%, which gives the largest sample size. See below under **More information** if this is confusing.
Your recommended sample size is	**377**	This is the minimum recommended size of your survey. If you create a sample of this many people and get responses from everyone, you're more likely to get a correct answer than you would from a large sample where only a small percentage of the sample responds to your survey.

Online surveys with Vovici have completion rates of 66%!

Alternate scenarios

With a sample size of	100	200	300	With a confidence level of	90	95	99
Your margin of error would be	**9.78%**	**6.89%**	**5.62%**	Your sample size would need to be	**267**	**377**	**643**

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More information

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SAMPLE SIZE FOR CORDON (O-D) SURVEY

ROUTE 01: MIRPUR ROAD

Name of Link	Sample size of vehicles									
	Car	Bus	CNG	MC	MicB/ Amb	Jeep /SW	Taxi	HH	PU/ MT	Truck
Technical Morh to Shyamoli cinema hall signal	12	5	7	5	2	2	1	5	2	1
Shyamoli cinema hall signal to Agargaon shishumela signal	10	5	7	6	3	3	1	1	1	1
Agargaon shishumela signal to Residential model college corner (north)	6	3	4	4	2	1	1	1	1	1
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road	6	3	3	4	2	2	1	1	1	1
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal	7	4	3	4	2	2	1	1	1	1
Asad gate signal to Lalmatia signal infront of Aarong	9	4	4	5	2	3	1	1	1	1
Lalmatia Aarong signal to Dhanmondi 27 signal	11	5	5	4	2	2	1	1	1	1
Dhanmondi 27 signal to Panthapath Russel square signal	11	5	6	5	3	3	1	0	1	1
Russel square signal to Science lab signal	12	4	7	6	3	3	2	0	1	1
Science lab signal to New market signal	5	5	4	6	3	2	1	2	1	1
New market signal to Azimpur signal	5	4	3	4	2	2	1	2	1	1

ROUTE 02: PALLABI-ANANDABAZAR AT GULISTAN

Name of Link	Sample size of vehicles									
	Car	Bus	CNG	MC	MicB/ Amb	Jeep /SW	Taxi	HH	PU/ MT	Truck
Pallabi Shoronee 11 to Mirpur 10	4	3	1	1	1	1	1	1	1	1
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school	14	7	6	6	4	2	1	2	1	1
Agargaon to Bijoy shoroni	12	6	4	4	2	2	1	2	1	1
Bijoy shoroni	15	3	7	4	3	3	1	1	1	1
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal	18	6	8	6	3	3	1	1	2	1
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara	21	6	10	7	4	4	1	1	2	1
Karwan bazaar_SAARC foara to Shahbagh	22	7	11	7	4	4	1	1	2	1
Shahbagh to Motsho bhaban	18	13	11	7	5	5	1	1	2	1
Motsho bhaban to Kodom foara	13	13	9	5	5	6	1	1	3	1
Kodom foara to Anadabazar_Gulisthan	3	4	2	2	1	1	1	2	1	1

ROUTE 03: KURIL TO BIJOYSHORONEE

Name of Link	Sample size of vehicles									
	Car	Bus	CNG	MC	MicB/ Amb	Jeep /SW	Taxi	HH	PU/ MT	Truck
Kuril to Banani rail crossing	21	14	9	12	5	2	1	0	2	1
Banani rail crossing to Banani DOHS	23	14	9	11	5	2	2	0	2	1
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)	33	13	14	9	3	2	2	3	3	1
Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate	31	14	16	11	7	4	1	3	4	1
Jahangir gate to Bijoy shoronee_Novo theatre signal	33	14	16	11	7	4	1	3	4	1

ROUTE 04: KURIL TO SHEGUNBAGICHA

Name of Link	Sample size of vehicles									
	Car	Bus	CNG	MC	MicB/ Amb	Jeep /SW	Taxi	HH	PU/ MT	Truck
Kuril to Bashundhara residential area entrance	13	7	5	8	2	2	1	0	1	1
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)	16	8	12	9	2	2	1	1	1	1
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)	15	8	6	9	3	3	2	1	3	1
Rampura TV Bhaban to Hatirjheel connecting road point	14	9	6	9	4	3	2	1	3	1
DIT (Hatirjheel connecting road point to Malibagh rail crossing)	14	9	6	14	4	3	2	1	3	1
Malibagh rail crossing to Mouchak Morh	14	6	4	9	3	1	1	1	1	1
Mouchak Morh to infront of Polwel gas station at Outer circular road	14	6	5	7	2	2	1	1	1	1
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road	13	6	5	7	2	2	1	1	1	1
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagichas	21	4	14	8	6	2	1	0	1	1

TRAFFIC VOLUME DATA ALONG SECONDARY ROADS (DTCA DATA, 2009)

		Large Bus			Minibus			Micro Bus			Truck				Light Vehicle					Moto		NMT		Grand Total
Road Name	24 hr/ 16 hr	Large Bus	Large Staff Bus	Large School Bus	Mini bus	Mini bus Staff Bus	Mini bus School Bus	Micro Bus	Micro Staff Bus	Micro School Bus	Truck 3-Axle /Truck Trailer	Tanker/ Tank Lorry	Medium Truck/ Truck 2-Axle	Pickup /Small Van	Car/ SW	Taxi	Jeep	Auto-tempo	Laguna/ Maxi	Motor -cycle	Auto-rickshw / CNG/ Mishuk	Bi-Cycle	Rickshaw/ Rickshaw Van	
Tongi Diversion Road	24	1,668	88	6	3,985	133	5	6,648	551	71	181	139	2,382	4,197	23,095	3,545	2,382	658	557	7,427	28,373	2,199	10,146	98,436
Sat Masjid Road	16	1,304	49	42	359	47	33	2,619	118	102	3	0	57	588	18,898	1,201	1,183	0	1,358	3,245	5,361	1,788	36,759	75,114
New Eskaton Road	24	814	6	4	88	19	7	1,763	83	30	47	3	353	969	8,557	886	866	76	88	3,884	5,667	1,291	6,632	32,133
Panthapath	16	407	24	1	54	49	3	3,016	383	15	32	13	176	1,860	12,711	1,241	1,929	0	27	3,098	9,385	812	3,391	38,627
Farmgate-Manikmia Avenue	16	1,260	123	23	4,838	110	10	2,240	345	81	5	46	133	1,206	9,635	886	1,503	3	925	3,005	5,439	501	6,888	39,205
Agargaon-PMO link Road	16	1,196	57	4	57	132	18	2,910	400	52	29	13	193	1,702	10,949	1,607	1,337	338	1,920	2,759	6,889	235	154	32,951

Source: Dhaka Urban Transport Network Development Study (DHUTS) data, 2009

TRAFFIC VOLUME DATA ALONG SECONDARY ROADS (Field survey, 2014)

Name of secondary alternative roads	Peak hour traffic volume (vehicle / 3 hour)										
	Car	Bus	CNG Auto Rickshaw/ Mishuk	Motor cycle	Microbus/ Ambulance	Jeep/ Station wagon	Taxi cab	Leguna /Tempo/HH	Pick up/ Mini truck	Truck	NMT
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	600	225	150	36	32	18	0	65	36	12	18
Green Road	1350	450	99	36	48	18	12	0	18	0	1500
Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco)	366	165	330	72	76	21	10	45	27	0	70
Hatirjheel Link road	768	270	279	27	70	31	12	28	27	8	70
Matikata road (Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]	660	150	129	34	117	25	35	40	20	0	35

Source: Traffic volume survey, 2014

LINK WISE MOTORIZED TRAFFIC VOLUME DATA (YEAR 2013) ALONG FOUR MAJOR ROUTES

Name of Link	Traffic volume (ADT in day light hour/12hr)									
	Car	Bus	CNG	Motor cycle	MicB/ Amb	Jeep /Station wagon	Taxi cab	Leguna/ Tempo/ HH	PU/ MT	Truck
Technical Morh to Shyamoli cinema hall signal	7774	2836	4692	2996	1311	1247	315	330	785	214
Shyamoli cinema hall signal to Agargaon shishumela signal	6522	2985	4577	4155	1485	1463	333	530	678	152
Agargaon shishumela signal to Residential model college corner (north)	3640	1952	2444	2792	1292	144	259	170	478	115
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road	4218	1907	1663	2315	1052	1222	252	381	304	174
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal	4400	2192	2048	2703	1252	1022	289	296	356	170
Asad gate signal to Lalmatia signal infront of Aarong	5770	2778	2592	3163	1400	1437	359	578	456	241
Lalmatia Aarong signal to Dhanmondi 27 signal	7329	2818	2815	2766	1241	1252	496	589	548	274
Dhanmondi 27 signal to Panthapath Russel square signal	7718	2818	3711	3440	1815	1515	422	0	463	207
Russel square signal to Science lab signal	8366	2755	4292	3992	2052	1759	785	0	489	252
Science lab signal to New market signal	3366	3485	2644	3526	1596	1304	270	904	452	226
New market signal to Azimpur signal	2844	2218	1974	2578	985	1359	363	963	315	141
Pallabi Shoronee 11 to Mirpur 10	1437	1304	356	170	367	81	56	100	107	15
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school	5925	2822	2600	2233	1581	737	126	693	241	26
Agargaon to Bijoy shoroni	5111	2466	1755	1478	700	607	111	563	237	107
Bijoy shoroni	6254 .93	1204	2689	1485	1185	1030	285	344	344	167
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal	7814	2218	3492	2274	1174	1170	141	167	581	122
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara	8821	2544	4177	2648	1404	1374	204	237	744	167
Karwan bazaar_SAARC foara to Shahbagh	9355	2915	4492	3037	1611	1611	274	296	841	178
Shahbagh to Motsho bhaban	7688	5618	4444	2977	1800	2011	281	193	815	293

Motsho bhaban to Kodom foara	5670	5603	3951	1848	2066	2355	333	181	941	396
Kodom foara to Anadabazar_Gulisthan	918	1389	452	574	218	74	30	518	59	15
Kuril to Banani rail crossing	3988	2703	1626	2270	911	356	181	0	337	189
Banani rail crossing to Banani DOHS	4422	2696	1604	1974	952	263	237	0	385	189
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)	6329	2515	2615	1629	456	326	285	533	563	15
Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate	6011	2566	3003	1996	1192	626	133	556	633	30
Jahangir gate to Bijoy shoronee_Novo theatre signal	6425	2600	3081	2074	1278	626	148	533	674	33
Kuril to Bashundhara residential area entrance	3751	1807	1296	2215	537	478	115	0	300	122
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)	4622	2311	3544	2703	467	578	85	22	293	133
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)	4333	2300	1507	2448	878	615	422	274	711	78
Rampura TV Bhaban to Hatirjheel connecting road point	4166	2489	1615	2492	1063	648	359	274	696	85
DIT (Hatirjheel connecting road point to Malibagh rail crossing)	4155	2500	1581	4026	1196	670	356	248	693	96
Malibagh rail crossing to Mouchak Morh	4170	1618	1074	2618	611	115	26	185	141	7
Mouchak Morh to infront of Polwel gas station at Outer circular road	3966	1707	1307	1915	544	367	52	44	185	44
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road	3670	1715	1481	2103	556	463	107	41	178	59
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagichas	6207	941	4081	2296	1689	537	78	0	259	59

Source: Jahan, 2013

LINK WISE NON-MOTORIZED TRAFFIC VOLUME DATA (YEAR 2014) ALONG FOUR MAJOR ROUTES

Name of Link	Traffic volume (ADT in day light hour/12hr)		NMT ban status	
	Rickshaw	Rickshaw van	Bi cycle	
Route 01				
Technical Morh to Shyamoli cinema hall signal (R1)	1602	708	690	Ban
Shyamoli cinema hall signal to Agargaon shishumela signal (R2)	0	210	648	Complete Ban
Agargaon shishumela signal to Residential model college corner (north) (R3)	96	336	678	Complete Ban
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road (R4)	108	72	522	Complete Ban
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal (R5)	0	12	210	Complete Ban
Asad gate signal to Lalmatia signal infront of Aarong (R6)	12	12	144	Complete Ban
Lalmatia Aarong signal to Dhanmondi 27 signal (R7)	12	24	378	Complete Ban
Dhanmondi 27 signal to Panthapath Russel square signal (R8)	132	36	288	Complete Ban
Russel square signal to Science lab signal (R9)	1698	36	186	Ban
Science lab signal to New market signal (R10)	19644	936	564	Ban but have rickshaw lane
New market signal to Azimpur signal (R11)	14196	582	4776	No Ban
Route 02				
Pallabi Shoronee 11 to Mirpur 10 (R1)	7416	1188	1128	No Ban
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school (R2)	9690	984	1626	No Ban
Agargaon to Bijoy shoroni (R3)	9162	1368	1878	No Ban
Bijoy shoroni (R4)	0	0	0	Complete Ban and no survey done
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal (R5)	0	0	0	Complete Ban and no survey done
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara (R6)	0	0	0	Complete Ban and no survey done
Karwan bazaar_SAARC foara to Shahbagh (R7)	0	0	0	Complete Ban and no survey done

Shahbagh to Motsho bhaban (R8)	0	0	0	Complete Ban and no survey done
Motsho bhaban to Kodom foara (R9)	0	0	0	Complete Ban and no survey done
Kodom foara to Anadabazar_Gulisthan (R10)	44280	2256	1884	No ban
Route 03				
Kuril to Banani rail crossing (R1)	0	0	0	Complete Ban and no survey done
Banani rail crossing to Banani DOHS (R2)	0	0	0	Complete Ban and no survey done
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) (R3)	0	0	0	Complete Ban and no survey done
Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate (R4)	0	0	0	Complete Ban and no survey done
Jahangir gate to Bijoy shoronee_Novo theatre signal (R5)	0	0	0	Complete Ban and no survey done
Route 04				
Kuril to Bashundhara residential area entrance (R1)	3672	630	804	No ban
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner) (R2)	5832	402	1290	No ban
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban) (R3)	10926	852	1608	No ban
Rampura TV Bhaban to Hatirjheel connecting road point (R4)	10734	570	1848	No ban
DIT (Hatirjheel connecting road point to Malibagh rail crossing) (R5)	10140	1032	1914	No ban
Malibagh rail crossing to Mouchak Morh (R6)	12570	672	1482	No ban
Mouchak Morh to infront of Polwel gas station at Outer circular road (R7)	15786	522	912	No ban
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road (R8)	21444	372	684	No ban
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagicha (R9)	0	0	306	Complete Ban
Source: Primary (field) survey, 2014				

LINK WISE TRAFFIC VOLUME DATA (YEAR 2014) ALONG FOUR MAJOR ROUTES (PCU/HOUR)

Name of Link	Traffic volume (PCU/hour)										
	Car	Bus	CNG	Motor cycle	MicB/ Amb	Jeep /SW	Taxi cab	Leguna/ Tempo/ HH	PU/ MT	Truck	NMT
Technical Morh to Shyamoli cinema hall signal	697	509	295	81	118	112	28	15	106	38	89
Shyamoli cinema hall signal to Agargaon shishumela signal	585	535	287	112	133	131	30	24	91	27	18
Agargaon shishumela signal to Residential model college corner (north)	326	350	153	75	116	13	23	8	64	21	26
College gate Residential model college corner to signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road	378	342	104	62	94	110	23	17	41	31	15
Signal point at Aurongazeb road and Zia uddyan road crossing on Mirpur road to Asad gate signal	395	393	129	73	112	92	26	13	48	30	4
Asad gate signal to Lalmatia signal infront of Aarong	517	498	163	85	126	129	32	26	61	43	3
Lalmatia Aarong signal to Dhanmondi 27 signal	657	505	177	74	111	112	44	26	74	49	8
Dhanmondi 27 signal to Panthapath Russel square signal	692	505	233	93	163	136	38	0	62	37	10
Russel square signal to Science lab signal	750	494	269	107	184	158	70	0	66	45	61
Science lab signal to New market signal	302	625	166	95	143	117	24	41	61	41	695
New market signal to Azimpur signal	255	398	124	69	88	122	33	43	42	25	572
Pallabi Shoronee 11 to Mirpur 10	129	234	22	5	33	7	5	4	14	3	306
Rokeya Shoronee Mirpur 10 to Agargaon Sher-E-Bangla Govt Boy's High school	531	506	163	60	142	66	11	31	32	5	383
Agargaon to Bijoy shoroni	458	442	110	40	63	54	10	25	32	19	382
Bijoy shoroni	561	216	169	40	106	92	26	15	46	30	0
Airport road Bijoy shoroni Novo theatre signal to Farmgate-Khamarbari signal	701	398	219	61	105	105	13	7	78	22	0
Farmgate-Khamarbari signal to Karwan bazaar_SAARC foara	791	456	262	71	126	123	18	11	100	30	0
Karwan bazaar_SAARC foara to Shahbagh	839	523	282	82	144	144	25	13	113	32	0
Shahbagh to Motsho bhaban	689	1007	279	80	161	180	25	9	110	53	0
Motsho bhaban to Kodom foara	508	1005	248	50	185	211	30	8	127	71	0
Kodom foara to Anadabazar_Gulisthan	82	249	28	15	20	1	3	23	8	3	1583
Kuril to Banani rail crossing	358	485	102	61	82	32	16	0	45	34	0
Banani rail crossing to Banani DOHS	397	483	101	53	85	24	21	0	52	34	0
Banani DOHS to Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point)	568	451	164	44	41	29	26	24	76	3	0

Mohakhali-Gulshan road intersection (near Mohakhali flyover starting point) to Jahangir gate	539	460	188	54	107	56	12	25	85	5	0
Jahangir gate to Bijoy shoronee_Novo theatre signal	576	466	193	56	115	56	13	24	91	6	0
Kuril to Bashundhara residential area entrance	336	324	81	60	48	43	10	0	40	22	157
Progoti Shoroni (Bashundhara residential area entrance to Royal Thai embassy corner)	414	414	222	73	42	52	8	1	39	24	229
Progoti Shoroni (Royal Thai embassy corner to Rampura TV Bhaban)	389	412	95	66	79	55	38	12	96	14	419
Rampura TV Bhaban to Hatirjheel connecting road point	374	446	101	67	95	58	32	12	94	15	408
DIT (Hatirjheel connecting road point to Malibagh rail crossing)	373	448	99	108	107	60	32	11	93	17	404
Malibagh rail crossing to Mouchak Morh	374	290	67	70	55	10	2	8	19	1	466
Mouchak Morh to infront of Polwel gas station at Outer circular road	356	306	82	52	49	33	5	2	25	8	559
Infront of Polwel gas station at Outer circular road to Rajmoni cinema hall at Kakrail VIP road	329	308	93	57	50	42	10	2	24	11	739
Rajmoni cinema hall at Kakrail VIP road to Motsho bhaban at Shegunbagichas	557	169	256	62	151	48	7	0	35	11	5
Name of Secondary/alternative Roads											
Tongi diversion road	1388	707	1194	134	437	143	213	37	593	38	297
Sat Masjid Road	1704	331	338	88	256	107	108	61	87	1	1390
New Eskaton Road	514	113	238	70	113	52	53	5	119	6	190
Panthapath	1146	97	592	84	308	174	112	1	275	8	152
Farmgate – Manikmia Avenue	869	1147	343	81	240	135	80	42	181	9	266
Agargaon-Prime Minister Office Link Road	987	264	435	75	303	121	145	102	256	8	14
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	200	150	35	4	11	6	0	11	18	8	1
Green Road	450	300	23	4	16	6	4	0	9	0	200
Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco)	122	110	77	7	25	7	3	8	14	0	5
Hatirjheel Link road	256	180	65	3	23	10	4	5	14	5	5
Mirpur flyover (Pallabi Mirpur – Banani, Raddison er shamne)	220	100	30	3	39	8	12	7	10	0	2

Database containing distribution of specific trip purpose at exact destination address

Destination	trip purpose	Destination	trip purpose	Destination	trip purpose	Destination	trip purpose	Destination	trip purpose	Destination	trip purpose
Malibag	Education	Gulistan		Motijheel		Jatrabari	Work	Moghbazar	Visit	Bonosree	Visit
Science lab	Work	Azimpur		Gulistan		Shegunbagicha	Work	Motijheel	Work	Malibag	Work
Dhanmondi	Education	Kathalbagan	Visit	Sadarghat		Polton		Motijheel		Komolapur	
Kolabagan	Work	Farmgate	Work	Banglamotor	Work	Komolapur		Nabisco	Work	Bonosree	Work
Panthopath	Work	Science lab	Work	Malibag	Work	Motijheel		Shahbagh	Work	Doinik bangla	Work
New market	Work	Poribagh	Work	Panthopath	Work	Motijheel		Jatrabari		Gulistan	
Lalmatia	Work	Shahbagh	Work	Farmgate	Work	Jatrabari		Doinik bangla	Education	Badda	Visit
Mohammadpur	Work	Azimpur	Visit	Aftabnogor	Work	Postogola	Work	Farmgate	Work	Badda	Work
Motijheel		Lalmatia	Work	Khamarbari		Panthopath	Work	Panthopath	Work	Badda	Work
Azimpur		New market	Work	Doinik bangla	Work	Shahbagh	Work	Banani	Work	Motijheel	Work
Sadarghat		Gulistan	Work	Kallyanpur	Travel	Banglamotor	Work	Gulshan 02	Work	New market	Education
Taltola	Work	Motijheel	Work	Mirpur 13	Visit	Shegunbagicha	Work	Agargaon	Work	Shantinogor	Education
Dhanmondi	Education	Azimpur		Mirpur 11	Work	Shantinogor	Education	Mirpur 10	Work	Jatrabari	Visit
Kolabagan	Work	Motijheel		Mirpur 10	Return trip	Banglamotor	Work	Mohakhali	Work	Malibag	Return trip
Shahbagh	Work	Kallyanpur	Travel	Mirpur 2	Work	Nilkhet	Work	Uttora	Work	Shantibag	Visit
New market	Work	Agargaon	Work	Kazipara	Return trip	Dhaka medical	Visit	Mirpur 02		khilgaon	
Mohammadpur	Visit	Banani	Work	Mirpur 12		Motshobhaban	Work	Kazipara	Work	Jatrabari	
Elephant road	Work	Agargaon	Work	Mirpur 10		Pressclub	Work	Mohammadpur	Visit	Sadarghat	
Shegunbagicha	Work	Shaorapara	Work	Mirpur 12		Karwanbazar	Work	Kallyanpur	Travel	Jatrabari	
Agargaon	Work	Shaorapara	Education	Mirpur 02	Work	Moghbazar	Work	Tejgaon	Work	Postogola	
Mohakhali		Mirpur 10	Education	Shaorapara	Visit	Polton	Work	Asadgate	Work	Motijheel	Work
New market		Farmgate	Work	Kazipara	Work	Motijheel	Work	Mirpur 02	Visit	Arambagh	Work
Mohammadpur	Education	Polton	Work	Mirpur 10	Work	Shegunbagicha	Work	Banani	Work	Rampura	Work
Shamoly	Medical	Panthopath	Work	Mirpur 11	Return trip	Sadarghat	Work	Agargaon		Malibag	Business
Farmgate	Work	Dhanmondi	Education	Mirpur 10		Manikdi	Visit	Shegunbagicha	Work	Aftabnogor	Visit
Asadgate	Work	Banani	Education	Farmgate	Work	Mohammadpur	Education	Arambagh	Work	Mouchak	Work
Dhanmondi	Education	Tejgaon	Work	Farmgate	Education	Mirpur 11	Work	Highcourt	Work	Gulistan	
Tejgaon	Work	Komolapur		Shahbagh	Work	Kallyanpur	Travel	Shahbagh	Education	Motijheel	
Motijheel	Work	Uttora		DU	Education	Mirpur 10	Return trip	Kakrail	Work	Nobabgonj	Work
Dhanmondi 27	Work	Azimpur		Motijheel	Work	Mohakhali	Return trip	Gulistan	Travel	Shantinogor	Education
Khilgaon/Badda		Azimpur		Tejgaon	Work	Banani	Work	Nazimuddin road	Visit	Motijheel	Work
Jatrabari		Khilgaon		Polton	Work	Gulshan 02		Polton	Work	Razarbag	Work
Azimpur		Gulistan		Gulshan 01	Work	Banani	Work	Shantinogor	Visit	Bijoynogor	Return trip
Mohakhali	Work	Dhanmondi 27	Work	Motijheel		Gulshan 01	Work	Bijoynogor	Work	Maoa	
Kakrail	Work	Fokirapul	Work	Jatrabari		Panthopath	Shopping	Pressclub	Work	Azimpur	
New market	Work	Guistan	Work	Postogola		Shegunbagicha	Work	Motijheel		Jatrabari	
Dhanmondi	Education	Banani	Work	Motijheel	Work	Shantinogor	Education	Motijheel		Gulistan	
Khamarbari	Work	Mohakhali	Work	Panthopath	Work	Shahbagh	Work	Motijheel		khilgaon	
Dhanmondi	Education	Farmgate	Work	Shahbagh	Work	Sadarghat	Work	Sadarghat		Postogola	
Dhanmondi	Education	Badda	Work	Banani	Work	Hatirpool	Shopping	Eskaton	Work	Komolapur	Travel
Kathalbagan	Work	Karwanbazar	Work	Banglamotor	Work	Polton	Work	Doinik bangla	Work	Komolapur	
New market	Work	Motijheel	Work	Shegunbagicha	Work	Motijheel	Education	Sadarghat	Travel	Shantinogor	Education
Motijheel	Work	Mohammadpur		Tejgaon	Work	Sadarghat	Travel	Kakrail	Education	Shegunbagicha	Work
Banglamotor	Work	Farmgate	Work	Shantinogor	Work	Malibag	Work	Gulistan	Work	Arambagh	Work
Shegunbagicha	Work	Mirpur 11	Return trip	Jatrabari	Work	Shegunbagicha	Work	Shahbagh	Work	Gulshan 01	Shopping
Mohakhali		Mirpur 10	Work	Shahbagh	Work	Motijheel		Moghbazar	Work	Badda	
Farmgate	Work	Kazipara	Work	Farmgate	Work	Komolapur		Elephant road	Work	Abdullahpur	
Farmgate	Work	Mirpur 12	Work	Mirpur 10	Return trip	Motijheel		Pressclub	Work	Tangail	
Jhigatola	Visit	Mirpur 13	Education	Mohammadpur	Visit	Sadarghat		Gulistan	Work	Banani	
Azimpur	Education	Mirpur 12		Mirpur 02	Work	Hatirpool	Work	Polton	Work	Badda	
Dhanmondi 27	Shopping	Mirpur 12		Mirpur 10	Work	Motijheel	Work	Motijheel	Work	Abdullahpur	
Motijheel		Shaorapara	Work	Mirpur 11	Work	Eskaton	Visit	Polton	Work	Mymensingh	
Sadarghat		Pallabi	Visit	Mirpur 01	Work	Shantinogor	Education	Jatrabari	Work	Gulshan 01	Ambassy
Poribagh	Work	Mirpur 10	Work	Mirpur 10	Work	Shahbagh	Work	Kallyanpur	Travel	Badda	Business
Azimpur	Education	Kazipara	Visit	Mirpur 12		DU	Education	Lalmatia	Work	Gulshan 01	Office
Panthopath	Work	Taltola	Visit	Agargaon	Work	Shegunbagicha	Work	Banani	Return trip	Gulshan 01	Office
Banglamotor	Work	Agargaon	Work	IDB	Visit	Elephant road	Work	Mohakhali	Work	Gulshan 01	Visit
Science lab	Work	Mirpur 02	Work	Mirpur 10	Work	Banglamotor	Work	Shamoly	Work	Mohakhali	Office
Jhigatola	Visit	Mirpur 10		Mirpur 11	Work	Moghbazar	Work	Mirpur 10	Return trip	Amtoli	Business

Science lab	Work	Shaorapara	Work	Asadgate	Work	Motijheel	Work	Farmgate	Work	Amtoli	Business
Shegunbagicha	Work	Polton	Work	Shahbagh	Work	Polton	Work	Dhanmondi 32	Return trip	Gulshan 01	Work
Kawranbazar	Work	Farmgate	Work	Farmgate	Education	Komolapur	Work	Banani	Work	Bonosree	Home based trip
New market	Shopping	Dhanmondi 02	Education	DU	Work	Gulistan	Work	Lalmatia	Work	Mohakhali	Work
Dhanmondi 6	Education	Panthopath	Work	Polton	Work	Dhanmondi 27	Visit	Savar		Gulshan 01	Work
Taltola	Work	Rajarbagh	Work			Mirpur 10	Work	Mirpur 12		Gulshan 01	Business
Mirpur 11	Work	Azimpur		Polton	Work	Gulistan		Dhanmondi	Education	Gulshan 01	
Mohakhali	Work	Mohakhali		Mohammadpur	Work	Azimpur		Mirpur 12		Gulshan 02	
Mirpur 10	Visit	Mohakhali		Banani	Work	Mirpur 14		Tejgaon	Work	Uttora	Work
Panthopath	Work	Motijheel		Tejgaon	Work	Mohakhali		Mohakhali	Work	Mohakhali	Work
Dhanmondi 27	Work	Gulistan		Mohammadpur	Work	Mohakhali		Mohakhali	Work	Mohakhali	Work
Hatirjheel	Work	Mirpur zoo		Kochukhet	Visit	Mohakhali		Tejgaon	Work	Polton	Office
Shahbagh	Work	Tejgaon	Work	Niketon	Return trip	Mirpur zoo		Mohakhali	Work	Shantinogor	Education
Niketon	Return trip	Farmgate	Business	Dhanmondi	Education	Dhanmondi	Visit	Amtoli	Office	Shegunbagicha	Return trip
Jhigatola	Visit	Dhanmondi	Visit	Farmgate	Work	Mohakhali		Brac	Office	Gulshan 01	Work
Tejgaon	Work	Mohakhali	Home based trip	Mohammadpur	Visit	Polton	Work	Gulshan 01	Work	Malibag	Visit
Taltola	Return trip	Mohakhali	Work	Dhanmondi	Return trip	Mohakhali	Work	Polton	Work	Jatrabari	Visit
Mirpur 14	Work	Banglamotor	Business	Mohakhali	Return trip	Panthopath	Visit	Uttora	Return trip	Aftabnogor	Work
Mirpur 10	Education	Panthopath	Work	Tejgaon	Work	Motijheel	Work	Kakoli	Return trip	Jatrabari	
Mohammadpur	Visit	Mohammadpur	Visit	Sadarghat		Tejgaon	Work	Motijheel	Work	Postogola	
										Azimpur	
										Gulistan	
										Gulshan 01	Office
										Motshobhaban	Work
										Shegunbagicha	Work
										Badda	Work
										Mohakhali	Work
										Malibag	Work
										Motijheel	Work
										Shantinogor	Work
										Razarbag	Work
										Jatrabari	Business
										Gulistan	
										Mouchak	Work
										Shiddeshwari	Education

** Missing values in the database are for public vehicle like bus, HH etc. where specific one trip purpose could not be found. Each row in the database consist data on one vehicle trip. Total 1536 vehicle trips have been surveyed through road side interview method along four major arterial routes. A representative sample of 496 vehicle trips have been taken for this particular analysis which finally shows distribution of land use category/Land use dominance at different destination places (see chapter 06). Land use demand within a particular area has been explored from the analysis based on the above dataset found from O-D survey.*

ORIGIN-DESTINATION MATRIX
Route 1: Mirpur Road

Matrix 2: Origin-Destination Matrix for Link R2 (Shyamoli Cinema Hall Signal to Agargaon Shishu Mela Singal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Total
Mirpur Zone			31.3%	25.0%	18.8%	18.8%	6.3%	100.0%
Mohammadpur Zone			57.1%		14.3%	28.6%		100.0%
Dhanmondi Zone		25.0%	50.0%	25.0%				100.0%
Old Dhaka Zone	85.7%		14.3%					100.0%
Motijheel Zone	100.0%							100.0%
	24.3%	2.7%	32.4%	13.5%	10.8%	13.5%	2.7%	100.0%

Matrix 3: Origin-Destination Matrix for Link R3 (Agargaon Shishu Mela Signal to Residential Model College Corner (North)) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination						
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Total
Mirpur Zone			22.2%	44.4%	11.1%	22.2%	100.0%
Mohammadpur Zone				83.3%		16.7%	100.0%
Old Dhaka Zone	80.0%	20.0%					100.0%
Motijheel Zone	100.0%						100.0%
	27.3%	4.5%	9.1%	40.9%	4.5%	13.6%	100.0%

Matrix 4: Origin-Destination Matrix for Link R4 (From College gate Residential Model College Corner to the Signal Point at Aurongajeb Road and Zia Uddyan Road Crossing on Mirpur Road) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination					
	Mirpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Total
Mirpur Zone		12.5%	75.0%	12.5%		100.0%
Mohammadpur Zone		42.9%	14.3%	14.3%	28.6%	100.0%
Dhanmondi Zone	100.0%					100.0%
Old Dhaka Zone	100.0%					100.0%
Motijheel Zone	100.0%					100.0%
	28.6%	19.0%	33.3%	9.5%	9.5%	100.0%

Matrix 5: Origin-Destination Matrix for Link R5 (From the Signal Point at Aurongajeb Road and Zia Uddyan Road Crossing on Mirpur Road to Asadgate Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Total
Mirpur Zone			25.0%	25.0%	37.5%	12.5%		100.0%
Mohammadpur Zone			16.7%	16.7%	16.7%	33.3%	16.7%	100.0%

Dhanmondi Zone	100.0%							100.0%
Old Dhaka Zone	100.0%							100.0%
Motijheel Zone		100.0%						100.0%
	19.0%	14.3%	14.3%	14.3%	19.0%	14.3%	4.8%	100.0%

Matrix 6: Origin-Destination Matrix for Link R6 (Asadgate Signal to Lalmatia Signal infront of Aarong) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone			28.6%	71.4%					100.0%
Mohammadpur Zone					20.0%	10.0%	50.0%	20.0%	100.0%
Dhanmondi Zone	100.0%								100.0%
Old Dhaka Zone	75.0%	25.0%							100.0%
Motijheel Zone	50.0%	50.0%							100.0%
	25.0%	14.3%	7.1%	17.9%	7.1%	3.6%	17.9%	7.1%	100.0%

Matrix 7: Origin-Destination Matrix for Link R7 (Lalmatia Aarong Signal to Dhanmondi 27 Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination						
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Uttara/Tongi zone	Total
Mirpur Zone			50.0%	50.0%			100.0%
Mohammadpur Zone			12.5%	62.5%	25.0%		100.0%
Old Dhaka Zone	60.0%	40.0%					100.0%
Motijheel Zone	50.0%	33.3%				16.7%	100.0%
Tejgaon/Farmgate zone			75.0%	25.0%			100.0%
	21.9%	12.5%	25.0%	31.3%	6.3%	3.1%	100.0%

Matrix 8: Origin-Destination Matrix for Link R8 (Dhanmondi 27 Signal to Panthapath/Russel Square Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Uttara/ Tongi zone	Total
Mirpur Zone				100.0%				100.0%
Mohammadpur Zone			25.0%	62.5%	12.5%			100.0%
Dhanmondi Zone				57.1%	28.6%	14.3%		100.0%
Old Dhaka Zone	28.6%	28.6%	28.6%				14.3%	100.0%
Motijheel Zone	40.0%	40.0%	20.0%					100.0%
	11.8%	11.8%	14.7%	47.1%	8.8%	2.9%	2.9%	100.0%

Matrix 9: Origin-Destination Matrix for Link R9 (Russel Square Signal to Science Lab Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone			20.0%	80.0%					100.0%
Mohammadpur Zone			14.3%	57.1%	28.6%				100.0%
Dhanmondi Zone				26.7%	33.3%	13.3%	13.3%	13.3%	100.0%
Old Dhaka Zone	21.4%	28.6%				21.4%	21.4%	7.1%	100.0%
Motijheel Zone		100.0%							100.0%
Uttara/Tongi zone				100.0%					100.0%
	6.3%	10.4%	6.3%	35.4%	14.6%	10.4%	10.4%	6.3%	100.0%

Matrix 10: Origin-Destination Matrix for Link R10 (Science Lab Signal to New Market Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination					
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Total
Mirpur Zone				100.0%		100.0%
Mohammadpur Zone				100.0%		100.0%
Dhanmondi Zone			16.7%	83.3%		100.0%
Old Dhaka Zone	21.1%	26.3%	26.3%		26.3%	100.0%
Tejgaon/Farmgate zone			100.0%			100.0%
Uttara/Tongi zone				100.0%		100.0%
	12.1%	15.2%	21.2%	36.4%	15.2%	100.0%

Matrix 11: Origin-Destination Matrix for Link R11 (New Market Signal to Azimpur Signal) of Route 1 (Mirpur Road)

Zone of origin	Zone of destination						
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Total
Mirpur Zone				100.0%			100.0%
Mohammadpur Zone				100.0%			100.0%
Dhanmondi Zone				100.0%			100.0%
Old Dhaka Zone	6.7%	53.3%	20.0%		13.3%	6.7%	100.0%
	4.3%	34.8%	13.0%	34.8%	8.7%	4.3%	100.0%

Route 2: Pallabi to Anandabazar at Gulistan

Matrix 12: Origin-Destination Matrix for Link R1 (Pallabi Shaarhe 11 to Mirpur 10) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination					Total
	Mirpur Zone	Mohammadpur Zone	Old Dhaka Zone	Motijheel Zone	Banani/ Gulshan zone	
Mirpur Zone	20.0%	30.0%	20.0%	20.0%	10.0%	100.0%
Uttara/Tongi zone	100.0%					100.0%
	27.3%	27.3%	18.2%	18.2%	9.1%	100.0%

Matrix 13: Origin-Destination Matrix for Link R2 (Rokeya Shoronee(Mirpur 10 to Agargaon_Sher-E- Bangla Govt. Boys' High School)) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone	25.7%	2.9%	8.6%	8.6%	25.7%	14.3%	8.6%	5.7%	100.0%
Mohammad pur Zone	75.0%			25.0%					100.0%
Dhanmondi Zone	100.0%								100.0%
Old Dhaka Zone	100.0%								100.0%
Motijheel Zone	100.0%								100.0%
Tejgaon/ Farmgate zone	100.0%								100.0%
Banani/Guls han zone	50.0%	50.0%							100.0%
	46.2%	3.8%	5.8%	7.7%	17.3%	9.6%	5.8%	3.8%	100.0%

Matrix 14: Origin-Destination Matrix for Link R3 (Agargaon to Bijoy Shoroni) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination							Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	
Mirpur Zone			17.6%	23.5%	23.5%	29.4%	5.9%	100.0%
Mohammadpur Zone			33.3%			66.7%		100.0%
Dhanmondi Zone	100.0%							100.0%
Old Dhaka Zone	100.0%							100.0%
Motijheel Zone	100.0%							100.0%
Tejgaon/ Farmgate zone	75.0%	25.0%						100.0%
	40.0%	2.9%	11.4%	11.4%	11.4%	20.0%	2.9%	100.0%

Matrix 15: Origin-Destination Matrix for Link R4 (Bijoy Shoroni) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Total
Mirpur Zone			6.7%	33.3%	46.7%	13.3%		100.0%
Mohammadpur Zone				20.0%		60.0%	20.0%	100.0%
Dhanmondi Zone	33.3%					33.3%	33.3%	100.0%
Old Dhaka Zone	100.0%							100.0%
Motijheel Zone	66.7%	33.3%						100.0%
Tejgaon/ Farmgate zone	66.7%	33.3%						100.0%
Banani/Gulshan zone	100.0%							100.0%
	26.5%	8.8%	2.9%	17.6%	20.6%	17.6%	5.9%	100.0%

Matrix 16: Origin-Destination Matrix for Link R5 (Airport Road (Bijoy Shoroni Novo theatre Signal to Farmgate-Khamarbari signal)) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Total
Mirpur Zone				15.4%	61.5%	23.1%		100.0%
Mohammadpur Zone					100.0%			100.0%
Dhanmondi Zone	100.0%							100.0%
Old Dhaka Zone		25.0%					75.0%	100.0%
Motijheel Zone		50.0%				50.0%		100.0%
Tejgaon/ Farmgate zone	16.7%		33.3%	33.3%			16.7%	100.0%
Banani/Gulshan zone			33.3%		66.7%			100.0%
Uttara/Tongi zone				66.7%	16.7%	16.7%		100.0%
	7.3%	4.9%	9.8%	19.5%	36.6%	12.2%	9.8%	100.0%

Matrix 17: Origin-Destination Matrix for Link R6 (Farmgate-Khamarbari Signal to Karwan Bazar_SAARC Foara) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone				20.0%	80.0%				100.0%
Mohammadpur Zone			14.3%	28.6%	42.9%	14.3%			100.0%
Dhanmondi Zone	25.0%						50.0%	25.0%	100.0%
Old Dhaka Zone	33.3%	33.3%				33.3%			100.0%

Motijheel Zone	57.1%	28.6%					14.3%		100.0%
Tejgaon/ Farmgate zone			60.0%		20.0%	20.0%			100.0%
Banani/Gulshan zone			33.3%	33.3%	33.3%				100.0%
Uttara/Tongi zone				33.3%	33.3%	33.3%			100.0%
	14.6%	8.3%	10.4%	14.6%	31.3%	12.5%	6.3%	2.1%	100.0%

Matrix 18: Origin-Destination Matrix for Link R7 (Karwan Bazar_SAARC Foara to Shahbag) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Others	Total
Mirpur Zone				75.0%	25.0%				100.0%
Mohammadpur Zone				20.0%	40.0%	40.0%			100.0%
Dhanmondi Zone					100.0%				100.0%
Old Dhaka Zone	30.8%	15.4%	15.4%			23.1%	15.4%		100.0%
Motijheel Zone		37.5%	12.5%			25.0%	12.5%	12.5%	100.0%
Tejgaon/ Farmgate zone		25.0%		50.0%	25.0%				100.0%
Banani/Gulshan zone				66.7%	33.3%				100.0%
Uttara/Tongi zone				33.3%	66.7%				100.0%
Others					100.0%				100.0%
	7.8%	13.7%	5.9%	23.5%	27.5%	13.7%	5.9%	2.0%	100.0%

Matrix 19: Origin-Destination Matrix for Link R8 (Shahbag to Motsho Bhobon) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone					100.0%				100.0%
Mohammadpur Zone				5.9%	64.7%	5.9%	11.8%	11.8%	100.0%
Dhanmondi Zone					33.3%	55.6%		11.1%	100.0%
Old Dhaka Zone			27.3%		27.3%	27.3%	18.2%		100.0%
Motijheel Zone	16.7%	16.7%	33.3%	16.7%		16.7%			100.0%
Tejgaon/ Farmgate zone			60.0%	40.0%					100.0%
Banani/Gulshan zone			25.0%	50.0%		25.0%			100.0%
Uttara/Tongi zone		100.0%							100.0%
Others						100.0%			100.0%
	1.8%	5.4%	16.1%	10.7%	32.1%	21.4%	7.1%	5.4%	100.0%

Matrix 20: Origin-Destination Matrix for Link R9 (Motsho Bhobon to Kodom Foara) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Total
Mirpur Zone		7.1%		35.7%	42.9%	7.1%	7.1%	100.0%
Mohammadpur Zone				14.3%	57.1%	14.3%	14.3%	100.0%
Dhanmondi Zone				12.5%	75.0%	12.5%		100.0%
Old Dhaka Zone	30.0%	20.0%	30.0%		10.0%	10.0%		100.0%
Motijheel Zone	33.3%	27.8%	16.7%			22.2%		100.0%
Banani/Gulshan zone		100.0%						100.0%
Uttara/Tongi zone				100.0%				100.0%
	15.0%	16.7%	10.0%	13.3%	28.3%	13.3%	3.3%	100.0%

Matrix 21: Origin-Destination Matrix for Link R10 (Kodom Foara to Anondo Bazar_Gulistan) of Route 2 (Pallabi to Anandabazar at Gulistan)

Zone of origin	Zone of destination							
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/G ulshan zone	Total
Mirpur Zone				50.0%	50.0%			100.0%
Mohammadpur Zone				40.0%	20.0%	20.0%	20.0%	100.0%
Dhanmondi Zone				100.0%				100.0%
Old Dhaka Zone	50.0%	25.0%	25.0%					100.0%
	16.7%	8.3%	8.3%	33.3%	16.7%	8.3%	8.3%	100.0%

<u>Route 3: Kuril to Bijoyshoroni</u>

Matrix 22: Origin-Destination Matrix for Link R1 (Kuril to Banani Rail Crossing) of Route 3 (Kuril to Bijoyshoroni)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone								100.0%	100.0%
Mohammadpur Zone								100.0%	100.0%
Dhanmondi Zone	12.5%							87.5%	100.0%
Old Dhaka Zone							12.5%	87.5%	100.0%
Motijheel Zone	20.0%							80.0%	100.0%

Tejgaon/ Farmgate zone	25.0%							75.0%	100.0%
Banani/Gulshan zone								100.0%	100.0%
Uttara/Tongi zone	19.2%	15.4%	11.5%	19.2%	3.8%	26.9%	3.8%		100.0%
Others						100.0%			100.0%
	13.8%	6.9%	5.2%	8.6%	1.7%	15.5%	3.4%	44.8%	100.0%

Matrix 23: Origin-Destination Matrix for Link R2 (Banani Rail Crossing to Banani DOHS) of Route 3 (Kuril to Bijoyshoroni)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone								100.0%	100.0%
Mohammadpur Zone								100.0%	100.0%
Dhanmondi Zone	37.5%						25.0%	37.5%	100.0%
Old Dhaka Zone	16.7%						16.7%	66.7%	100.0%
Motijheel Zone	22.2%							77.8%	100.0%
Tejgaon/ Farmgate zone	60.0%							40.0%	100.0%
Banani/Gulshan zone	16.7%					50.0%		33.3%	100.0%
Uttara/Tongi zone	16.0%	8.0%	16.0%	16.0%	12.0%	28.0%	4.0%		100.0%
Others						100.0%			100.0%
	21.2%	3.0%	6.1%	6.1%	4.5%	21.2%	6.1%	31.8%	100.0%

Matrix 24: Origin-Destination Matrix for Link R3 (Banani DOHS to Mohakhali - Gulshan Road Intersection (Near Mohakhali Flyover starting Point)) of Route 3 (Kuril to Bijoyshoroni)

Zone of origin	Zone of destination						
	Mirpur Zone	Motijheel Zone	Tejgaon/ Framgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Others	Total
Mirpur Zone	11.1%	33.3%		33.3%	22.2%		100.0%
Mohammadpur Zone	10.0%		10.0%	60.0%	20.0%		100.0%
Dhanmondi Zone	33.3%			33.3%	33.3%		100.0%
Old Dhaka Zone	28.6%		7.1%	21.4%	42.9%		100.0%
Motijheel Zone			10.0%	50.0%	40.0%		100.0%
Tejgaon/ Farmgate zone	10.0%	5.0%	5.0%	50.0%	20.0%	10.0%	100.0%
Banani/Gulshan zone	33.3%				66.7%		100.0%
	16.0%	5.3%	5.3%	40.0%	30.7%	2.7%	100.0%

Matrix 25: Origin-Destination Matrix for Link R4 (Mohakhali Gulshan Road Intersection (Near Mohakhali Flyover starting Point) to Jahangir Gate) of Route 3 (Kuril to Bijoyshoroni)

Zone of origin	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone					11.1%		50.0%	38.9%	100.0%
Mohammadpur Zone							84.6%	15.4%	100.0%
Dhanmondi Zone							66.7%	33.3%	100.0%
Old Dhaka Zone							60.0%	40.0%	100.0%
Motijheel Zone							33.3%	66.7%	100.0%
Tejgaon/ Farmgate zone					9.1%		63.6%	27.3%	100.0%
Banani/Gulshan zone	8.0%	20.0%	16.0%	24.0%	20.0%	12.0%			100.0%
Uttara/Tongi zone			11.1%	44.4%	22.2%	22.2%			100.0%
Others				50.0%	50.0%				100.0%
	2.2%	5.6%	5.6%	12.4%	12.4%	5.6%	37.1%	19.1%	100.0%

Matrix 26: Origin-Destination Matrix for Link R5 (Jahangir Gate to Bijoy Shoroni_Novo theatre signal) of Route 3 (Kuril to Bijoyshoroni)

Zone of origin	Zone of destination								Total
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone				37.5%			50.0%	12.5%	100.0%
Mohammadpur Zone							100.0%		100.0%
Dhanmondi Zone							100.0%		100.0%
Old Dhaka Zone							66.7%	33.3%	100.0%
Motijheel Zone	11.1%						77.8%	11.1%	100.0%
Tejgaon/ Farmgate zone	9.5%		4.8%			4.8%	42.9%	38.1%	100.0%
Banani/Gulshan zone		5.0%	10.0%	20.0%	45.0%	10.0%	10.0%		100.0%
Uttara/Tongi zone			27.3%		54.5%	9.1%	9.1%		100.0%
Others			16.7%		66.7%	16.7%			100.0%
	3.5%	1.2%	8.2%	8.2%	22.4%	5.9%	36.5%	14.1%	100.0%

Route 4: Kuril to Shegunbagicha

Matrix 27: Origin-Destination Matrix for Link R1 (Kuril to Bashundhara Residential Area Entrance) of Route 34 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination					
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Banani/Gulshan zone	Uttara/Tongi zone	Total
Mohammadpur Zone					100.0%	100.0%
Old Dhaka Zone	50.0%			25.0%	25.0%	100.0%
Motijheel Zone	33.3%				66.7%	100.0%
Tejgaon/ Farmgate zone					100.0%	100.0%
Banani/Gulshan zone	25.0%	8.3%	41.7%		25.0%	100.0%
Uttara/Tongi zone		23.5%	52.9%	23.5%		100.0%
	15.4%	12.8%	35.9%	12.8%	23.1%	100.0%

Matrix 28: Origin-Destination Matrix for Link R2 (Progoti Shoroni(Bashundhara Residential Area Entrance to Royal Thai Embassy Corner)) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination						
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mohammadpur Zone					100.0%		100.0%
Dhanmondi Zone						100.0%	100.0%
Old Dhaka Zone	11.1%			11.1%	22.2%	55.6%	100.0%
Motijheel Zone					28.6%	71.4%	100.0%
Tejgaon/Farmgate zone	50.0%				50.0%		100.0%
Banani/Gulshan zone		66.7%				33.3%	100.0%
Uttara/Tongi zone		32.1%	42.9%	14.3%	10.7%		100.0%
	3.9%	21.6%	23.5%	9.8%	17.6%	23.5%	100.0%

Matrix 29: Origin-Destination Matrix for Link R3 (Progoti Shoroni (Royal Thai Embassy Corner to Rampura TV Bhobon)) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination						
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Mirpur Zone			50.0%		50.0%		100.0%
Dhanmondi Zone						100.0%	100.0%
Old Dhaka Zone					16.7%	83.3%	100.0%
Motijheel Zone	20.0%				20.0%	60.0%	100.0%
Tejgaon/ Farmgate zone	50.0%				50.0%		100.0%
Banani/ Gulshan zone	6.7%	26.7%	53.3%			13.3%	100.0%
Uttara/Tongi zone		30.0%	60.0%	10.0%			100.0%
	7.3%	17.1%	36.6%	2.4%	9.8%	26.8%	100.0%

Matrix 30: Origin-Destination Matrix for Link R4 (DIT (Rampura TV Bhobon to Hatirjheel Connecting Road Point)) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination						Total
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Dhanmondi Zone					100.0%		100.0%
Old Dhaka Zone	8.3%			8.3%	41.7%	41.7%	100.0%
Motijheel Zone	12.5%			12.5%	25.0%	50.0%	100.0%
Tejgaon/ Farmgate zone	100.0%						100.0%
Banani/Gulshan zone		40.0%			60.0%		100.0%
Uttara/Tongi zone		21.7%	39.1%	8.7%	30.4%		100.0%
	6.0%	14.0%	18.0%	8.0%	36.0%	18.0%	100.0%

Matrix 31: Origin-Destination Matrix for Link R5 (DIT (Hatirjheel Connecting Road Point to Malibag Rail Crossing) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination							Total
	Mirpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone				100.0%				100.0%
Dhanmondi Zone						25.0%	75.0%	100.0%
Old Dhaka Zone	18.2%				9.1%	63.6%	9.1%	100.0%
Motijheel Zone	9.1%					45.5%	45.5%	100.0%
Banani/Gulshan zone				85.7%		14.3%		100.0%
Uttara/Tongi zone		9.1%	27.3%	63.6%				100.0%
	6.7%	2.2%	6.7%	31.1%	2.2%	31.1%	20.0%	100.0%

Matrix 32: Origin-Destination Matrix for Link R6 (Malibagh RailCrossing to Mouchak Morh) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination						Total
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	
Mirpur Zone			100.0%				100.0%
Dhanmondi Zone					100.0%		100.0%
Old Dhaka Zone	12.5%			12.5%	37.5%	37.5%	100.0%
Motijheel Zone	20.0%				60.0%	20.0%	100.0%
Banani/Gulshan zone		7.1%	92.9%				100.0%
Uttara/Tongi zone		40.0%	60.0%				100.0%
	4.9%	12.2%	48.8%	2.4%	22.0%	9.8%	100.0%

Matrix 33: Origin-Destination Matrix for Link R7 (Mouchak Morh to In front of Polwel Gas Station at Outer Circular Road) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination								
	Mirpur Zone	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Dhanmondi Zone							66.7%	33.3%	100.0%
Old Dhaka Zone	12.5%					12.5%	50.0%	25.0%	100.0%
Motijheel Zone					26.1%	13.0%	30.4%	30.4%	100.0%
Tejgaon/ Farmgate zone				12.5%	87.5%				100.0%
Banani/Gulshan zone		25.0%	25.0%		50.0%				100.0%
Uttara/Tongi zone				100.0%					100.0%
	2.1%	2.1%	2.1%	6.3%	31.3%	8.3%	27.1%	20.8%	100.0%

Matrix 34: Origin-Destination Matrix for Link R8 (In front of Polwel Gas Station at Outer Circular Road to Rajmoni Cinema Hall at Kakrail VIP Road) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination						
	Mirpur Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/Gulshan zone	Uttara/Tongi zone	Total
Dhanmondi Zone	33.3%				33.3%	33.3%	100.0%
Motijheel Zone		8.3%	29.2%	12.5%	25.0%	25.0%	100.0%
Tejgaon/ Farmgate zone					100.0%		100.0%
Banani/Gulshan zone			100.0%				100.0%
Uttara/Tongi zone		100.0%					100.0%
Others			100.0%				100.0%
	2.8%	8.3%	38.9%	8.3%	22.2%	19.4%	100.0%

Matrix 35: Origin-Destination Matrix for Link R9 (From Rajmoni Cinema Hall at Kakrail VIP Road to Motsho bhobon at Shegunbagicha) of Route 4 (Kuril to Shegunbagicha)

Zone of origin	Zone of destination							
	Mohammadpur Zone	Dhanmondi Zone	Old Dhaka Zone	Motijheel Zone	Tejgaon/ Farmgate zone	Banani/ Gulshan zone	Uttara/ Tongi zone	Total
Dhanmondi Zone		20.0%				30.0%	50.0%	100.0%
Old Dhaka Zone						100.0%		100.0%
Motijheel Zone	10.3%	10.3%		10.3%	31.0%	27.6%	10.3%	100.0%

Tejgaon/ Farmgate zone	25.0%	25.0%	50.0%					100.0%
Banani/Gulshan zone	44.4%	11.1%	33.3%	11.1%				100.0%
Uttara/Tongi zone			66.7%	33.3%				100.0%
	13.8%	12.1%	12.1%	8.6%	15.5%	24.1%	13.8%	100.0%

Cold excess unit emission according to average speed and ambient temperature for Euro 0 gasoline cars with catalyst according to the season

Cold excess unit emission in g/km, average speed in km/h, ambient temperature in °C

pollutant:		CO							
speed range:		0 - 10	10 - 20	20 - 30	30 - 40	40- 50	50- 60	60- 70	70-200
average speed:		5	15	25	35	45	55	65	75
-30 - -20°C:	-25	8.736	9.676	9.248	8.740	8.604	7.952	7.673	6.871
-20 - -10°C:	-15	6.945	7.683	7.338	6.929	6.820	6.302	6.084	5.449
-10 - 0°C:	-5	5.135	5.672	5.413	5.108	5.027	4.645	4.486	4.018
0 - 10°C:	5	3.305	3.646	3.477	3.278	3.226	2.980	2.879	2.579
10 - 20°C:	15	1.455	1.602	1.527	1.439	1.416	1.307	1.264	1.132
20 - 30°C:	25	0	0	0	0	0	0	0	0
30 - 40°C:	35	0	0	0	0	0	0	0	0

pollutant:		CO_2							
speed range:		0 - 10	10 - 20	20 - 30	30 - 40	40- 50	50- 60	60- 70	70-200
average speed:		5	15	25	35	45	55	65	75
-30 - -20°C:	-25	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
-20 - -10°C:	-15	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
-10 - 0°C:	-5	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
0 - 10°C:	5	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
10 - 20°C:	15	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
20 - 30°C:	25	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804
30 - 40°C:	35	2.176	2.460	2.384	2.295	2.272	2.106	2.023	1.804

pollutant:		HC							
speed range:		0 - 10	10 - 20	20 - 30	30 - 40	40- 50	50- 60	60- 70	70-200
average speed:		5	15	25	35	45	55	65	75
-30 - -20°C:	-25	5.810E-1	6.412E-1	6.116E-1	5.770E-1	5.678E-1	5.245E-1	5.068E-1	4.539E-1
-20 - -10°C:	-15	4.711E-1	5.189E-1	4.946E-1	4.661E-1	4.586E-1	4.236E-1	4.095E-1	3.669E-1
-10 - 0°C:	-5	3.597E-1	3.955E-1	3.766E-1	3.547E-1	3.489E-1	3.221E-1	3.116E-1	2.792E-1
0 - 10°C:	5	2.469E-1	2.709E-1	2.577E-1	2.425E-1	2.385E-1	2.202E-1	2.132E-1	1.910E-1
10 - 20°C:	15	1.327E-1	1.453E-1	1.380E-1	1.298E-1	1.276E-1	1.178E-1	1.141E-1	1.023E-1
20 - 30°C:	25	1.690E-2	1.850E-2	1.760E-2	1.650E-2	1.620E-2	1.500E-2	1.450E-2	1.300E-2
30 - 40°C:	35	0	0	0	0	0	0	0	0

pollutant:		NOx							
speed range:		0 - 10	10 - 20	20 - 30	30 - 40	40- 50	50- 60	60- 70	70-200
average speed:		5	15	25	35	45	55	65	75
-30 - -20°C:	-25	1.729E-1	1.958E-1	1.901E-1	1.834E-1	1.816E-1	1.684E-1	1.617E-1	1.441E-1
-20 - -10°C:	-15	1.419E-1	1.606E-1	1.557E-1	1.500E-1	1.485E-1	1.377E-1	1.322E-1	1.179E-1
-10 - 0°C:	-5	1.102E-1	1.246E-1	1.207E-1	1.160E-1	1.148E-1	1.064E-1	1.022E-1	9.110E-2
0 - 10°C:	5	7.770E-2	8.770E-2	8.490E-2	8.150E-2	8.060E-2	7.470E-2	7.170E-2	6.400E-2
10 - 20°C:	15	4.430E-2	5.000E-2	4.830E-2	4.630E-2	4.580E-2	4.240E-2	4.070E-2	3.640E-2
20 - 30°C:	25	1.010E-2	1.130E-2	1.100E-2	1.050E-2	1.030E-2	9.600E-3	9.200E-3	8.200E-3
30 - 40°C:	35	0	0	0	0	0	0	0	0

Source: André, J. M. and Joumard, R., 2005

EMISSION STANDARDS

Table 01: Standards for emission from motor vehicles

Parameter	Unit	Standard Limit
Black smoke	HSU	65
CO	gm/km (% area)	24 (04)
HC	gm/km (ppm)	02 (180)
NO_x	gm/km (ppm)	02 (600)

Source: Environmental Conservation Rule (ECR), 1997

**for better result emission standard limit has been estimated to upgrade by a narrow margin (2 gm/km for each parameter)*

Table 02: Standards for air (density in microgram/cusec meter)

Area category	SPM	SO_2	CO	NO_x
Commercial and Mixed	400	100	5000	100

Source: Environmental Conservation Rule (ECR), 1997

Table 03: Updated (2005) Bangladesh national air quality standard & WHO guideline values

Pollutants	Averaging Time	Who Guidelines	Bangladesh Standards
CO	1 hour	30 mg/m^3	40 mg/m^3 (35 ppm)
	8 hour	10 mg/m^3	10 mg/m^3 (9 ppm)
SO_2	24 hour	125 mg/m^3	365 mg/m^3 (140 ppb)
	Annual	50 mg/m^3	80 mg/m^3 (30 ppb)
NO_2	24 hour	---	---
	Annual	40 mg/m^3	100 mg/m^3 (53 ppb)
Ozone	1 hour	---	235 mg/m^3 (120 ppb)
	8 hour	120 mg/m^3	157 mg/m^3 (80 ppb)
PM_{10}	24 hour	---	150 mg/m^3
	Annual	---	50 mg/m^3
$PM_{2.5}$	24 hour	---	65 mg/m^3
	Annual	---	15 mg/m^3

Source: ADB, 2006

EMISSION FACTOR STANDARDS

Table 04: Emission factors in grams/km and vehicle usage in Dhaka (contingent estimates from available data from different sources)

Emission Categories	CO	NOX	SO2	HC	PM-10
1. LD Gasoline Vehicles	25.00	1.50	0.08	4.00	0.10
2. Taxicab	5.00	1.50	0.00	2.00	0.03
3. CNG Auto rickshaw	5.00	1.50	0.00	2.00	0.03
4. LD Diesel Vehicles	5.00	8.50	0.40	2.00	0.80
5. Bus	10.00	17.00	0.80	4.00	1.60
6. Truck	10.00	17.00	0.80	4.00	1.60
7. Motorcycle	5.00	0.30	0.02	4.00	0.10

Source: Rabbani and Sharif, 2005

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME ALONG MAJOR STUDY LINKS

Link	Vehicle type	Fuel type	Emission factor			Standard Emission			Volume	(Standard emission - Emission factor)			Non-polluting volume	Pollution volume
			CO	NO_X	HC	CO	NO_X	HC						
L1	Car	Petrol	25	1.5	4	26	4	4	96	1	2.5	0	96	0
		CNG	5	1.5	2	26	4	4	601	21	2.5	2	601	0
	Bus	Diesel	10	17	4	26	4	4	62	16	-13	0	FALSE	62
		CNG	10	17	4	26	4	4	193	16	-13	0	FALSE	193
	CNG	CNG	5	1.5	2	26	4	4	421	21	2.5	2	421	0
	MC	Petrol	5	0.3	4	26	4	4	269	21	3.7	0	269	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	101	21	2.5	2	101	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	28	1	2.5	0	28	0
		CNG	5	1.5	2	26	4	4	65	21	2.5	2	65	0
		Diesel	25	1.5	4	26	4	4	20	1	2.5	0	20	0
	Taxi	CNG	5	1.5	2	26	4	4	28	21	2.5	2	28	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	30	16	-13	0	FALSE	30
	PU/MT	Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	10	17	4	26	4	4	64	16	-13	0	FALSE	64
	Truck	Diesel	10	17	4	26	4	4	16	16	-13	0	FALSE	16
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**2018**					**367**
L2	Car	Petrol	25	1.5	4	26	4	4	81	1	2.5	0	81	0
		CNG	5	1.5	2	26	4	4	504	21	2.5	2	504	0
	Bus	Diesel	10	17	4	26	4	4	65	16	-13	0	FALSE	65
		CNG	10	17	4	26	4	4	203	16	-13	0	FALSE	203
	CNG	CNG	5	1.5	2	26	4	4	410	21	2.5	2	410	0
	MC	Petrol	5	0.3	4	26	4	4	373	21	3.7	0	373	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	9	1	2.5	0	9	0
		CNG	5	1.5	2	26	4	4	114	21	2.5	2	114	0
		Diesel	25	1.5	4	26	4	4	11	1	2.5	0	11	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	32	1	2.5	0	32	0
		CNG	5	1.5	2	26	4	4	76	21	2.5	2	76	0
		Diesel	25	1.5	4	26	4	4	23	1	2.5	0	23	0
	Taxi	CNG	5	1.5	2	26	4	4	30	21	2.5	2	30	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	48	16	-13	0	FALSE	48
	PU/MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	55	16	-13	0	FALSE	55
	Truck	Diesel	10	17	4	26	4	4	11	16	-13	0	FALSE	11
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**2052**					**384**

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME ALONG MAJOR STUDY LINKS

L3	Car	Petrol	25	1.5	4	26	4	4	45	1	2.5	0	45	0
		CNG	5	1.5	2	26	4	4	281	21	2.5	2	281	0
	Bus	Diesel	10	17	4	26	4	4	42	16	-13	0	FALSE	42
		CNG	10	17	4	26	4	4	133	16	-13	0	FALSE	133
	CNG	CNG	5	1.5	2	26	4	4	219	21	2.5	2	219	0
	MC	Petrol	5	0.3	4	26	4	4	250	21	3.7	0	250	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	99	21	2.5	2	99	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	32	1	2.5	0	32	0
		CNG	5	1.5	2	26	4	4	75	21	2.5	2	75	0
		Diesel	25	1.5	4	26	4	4	23	1	2.5	0	23	0
	Taxi	CNG	5	1.5	2	26	4	4	23	21	2.5	2	23	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	15	16	-13	0	FALSE	15
	PU/MT	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	39	16	-13	0	FALSE	39
	Truck	Diesel	10	17	4	26	4	4	9	16	-13	0	FALSE	9
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1308**					**239**
L4	Car	Petrol	25	1.5	4	26	4	4	52	1	2.5	0	52	0
		CNG	5	1.5	2	26	4	4	326	21	2.5	2	326	0
	Bus	Diesel	10	17	4	26	4	4	41	16	-13	0	FALSE	41
		CNG	10	17	4	26	4	4	130	16	-13	0	FALSE	130
	CNG	CNG	5	1.5	2	26	4	4	149	21	2.5	2	149	0
	MC	Petrol	5	0.3	4	26	4	4	208	21	3.7	0	208	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	5	1.5	2	26	4	4	81	21	2.5	2	81	0
		Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	27	1	2.5	0	27	0
		CNG	5	1.5	2	26	4	4	63	21	2.5	2	63	0
		Diesel	25	1.5	4	26	4	4	19	1	2.5	0	19	0
	Taxi	CNG	5	1.5	2	26	4	4	23	21	2.5	2	23	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	34	16	-13	0	FALSE	34
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	25	16	-13	0	FALSE	25
	Truck	Diesel	10	17	4	26	4	4	13	16	-13	0	FALSE	13
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1209**					**246**
L5	Car	Petrol	25	1.5	4	26	4	4	54	1	2.5	0	54	0
		CNG	5	1.5	2	26	4	4	340	21	2.5	2	340	0
	Bus	Diesel	10	17	4	26	4	4	48	16	-13	0	FALSE	48
		CNG	10	17	4	26	4	4	149	16	-13	0	FALSE	149
	CNG	CNG	5	1.5	2	26	4	4	184	21	2.5	2	184	0

	MC	Petrol	5	0.3	4	26	4	4	242	21	3.7	0	242	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	96	21	2.5	2	96	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	23	1	2.5	0	23	0
		CNG	5	1.5	2	26	4	4	53	21	2.5	2	53	0
		Diesel	25	1.5	4	26	4	4	16	1	2.5	0	16	0
	Taxi	CNG	5	1.5	2	26	4	4	26	21	2.5	2	26	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	27	16	-13	0	FALSE	27
	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	10	17	4	26	4	4	29	16	-13	0	FALSE	29
	Truck	Diesel	10	17	4	26	4	4	13	16	-13	0	FALSE	13
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1321**					**268**
L6	Car	Petrol	25	1.5	4	26	4	4	71	1	2.5	0	71	0
		CNG	5	1.5	2	26	4	4	446	21	2.5	2	446	0
	Bus	Diesel	10	17	4	26	4	4	60	16	-13	0	FALSE	60
		CNG	10	17	4	26	4	4	189	16	-13	0	FALSE	189
	CNG	CNG	5	1.5	2	26	4	4	232	21	2.5	2	232	0
	MC	Petrol	5	0.3	4	26	4	4	284	21	3.7	0	284	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	107	21	2.5	2	107	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	32	1	2.5	0	32	0
		CNG	5	1.5	2	26	4	4	75	21	2.5	2	75	0
		Diesel	25	1.5	4	26	4	4	23	1	2.5	0	23	0
	Taxi	CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	52	16	-13	0	FALSE	52
	PU/MT	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	37	16	-13	0	FALSE	37
	Truck	Diesel	10	17	4	26	4	4	18	16	-13	0	FALSE	18
		CNG	10	17	4	26	4	4	4	16	-13	0	FALSE	4
	Car					26	4	4	**1683**					**360**
L7		Petrol	25	1.5	4	26	4	4	91	1	2.5	0	91	0
	Bus	CNG	5	1.5	2	26	4	4	567	21	2.5	2	567	0
		Diesel	10	17	4	26	4	4	61	16	-13	0	FALSE	61
	CNG	CNG	10	17	4	26	4	4	192	16	-13	0	FALSE	192
	MC	CNG	5	1.5	2	26	4	4	252	21	2.5	2	252	0
	MicB/ Amb	Petrol	5	0.3	4	26	4	4	248	21	3.7	0	248	0
		Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
	Jeep/	CNG	5	1.5	2	26	4	4	95	21	2.5	2	95	0

	SW	Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Taxi	Petrol	25	1.5	4	26	4	4	28	1	2.5	0	28	0
		CNG	5	1.5	2	26	4	4	65	21	2.5	2	65	0
		Diesel	25	1.5	4	26	4	4	20	1	2.5	0	20	0
	Leguna/ Tempo/ HH	CNG	5	1.5	2	26	4	4	44	21	2.5	2	44	0
	PU/MT	CNG	10	17	4	26	4	4	53	16	-13	0	FALSE	53
	Truck	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	45	16	-13	0	FALSE	45
		Diesel	10	17	4	26	4	4	20	16	-13	0	FALSE	20
		CNG	10	17	4	26	4	4	4	16	-13	0	FALSE	4
						26	4	4	**1805**					**375**
L8	Car	Petrol	25	1.5	4	26	4	4	95	1	2.5	0	95	0
		CNG	5	1.5	2	26	4	4	597	21	2.5	2	597	0
	Bus	Diesel	10	17	4	26	4	4	61	16	-13	0	FALSE	61
		CNG	10	17	4	26	4	4	192	16	-13	0	FALSE	192
	CNG	CNG	5	1.5	2	26	4	4	333	21	2.5	2	333	0
	MC	Petrol	5	0.3	4	26	4	4	308	21	3.7	0	308	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	11	1	2.5	0	11	0
		CNG	5	1.5	2	26	4	4	139	21	2.5	2	139	0
		Diesel	25	1.5	4	26	4	4	13	1	2.5	0	13	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	34	1	2.5	0	34	0
		CNG	5	1.5	2	26	4	4	78	21	2.5	2	78	0
		Diesel	25	1.5	4	26	4	4	24	1	2.5	0	24	0
	Taxi	CNG	5	1.5	2	26	4	4	38	21	2.5	2	38	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	38	16	-13	0	FALSE	38
	Truck	Diesel	10	17	4	26	4	4	15	16	-13	0	FALSE	15
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1982**					**309**
L9	Car	Petrol	25	1.5	4	26	4	4	103	1	2.5	0	103	0
		CNG	5	1.5	2	26	4	4	647	21	2.5	2	647	0
	Bus	Diesel	10	17	4	26	4	4	60	16	-13	0	FALSE	60
		CNG	10	17	4	26	4	4	187	16	-13	0	FALSE	187
	CNG	CNG	5	1.5	2	26	4	4	385	21	2.5	2	385	0
	MC	Petrol	5	0.3	4	26	4	4	358	21	3.7	0	358	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	12	1	2.5	0	12	0
		CNG	5	1.5	2	26	4	4	157	21	2.5	2	157	0
		Diesel	25	1.5	4	26	4	4	15	1	2.5	0	15	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	39	1	2.5	0	39	0
		CNG	5	1.5	2	26	4	4	91	21	2.5	2	91	0

		Diesel	25	1.5	4	26	4	4	28	1	2.5	0	28	0
	Taxi	CNG	5	1.5	2	26	4	4	70	21	2.5	2	70	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	40	16	-13	0	FALSE	40
	Truck	Diesel	10	17	4	26	4	4	19	16	-13	0	FALSE	19
		CNG	10	17	4	26	4	4	4	16	-13	0	FALSE	4
						26	4	4	**2218**					**310**
L10	Car	Petrol	25	1.5	4	26	4	4	83	1	2.5	0	83	0
		CNG	5	1.5	2	26	4	4	520	21	2.5	2	520	0
	Bus	Diesel	10	17	4	26	4	4	76	16	-13	0	FALSE	76
		CNG	10	17	4	26	4	4	237	16	-13	0	FALSE	237
	CNG	CNG	5	1.5	2	26	4	4	237	21	2.5	2	237	0
	MC	Petrol	5	0.3	4	26	4	4	316	21	3.7	0	316	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	9	1	2.5	0	9	0
		CNG	5	1.5	2	26	4	4	122	21	2.5	2	122	0
		Diesel	25	1.5	4	26	4	4	11	1	2.5	0	11	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	29	1	2.5	0	29	0
		CNG	5	1.5	2	26	4	4	68	21	2.5	2	68	0
		Diesel	25	1.5	4	26	4	4	20	1	2.5	0	20	0
	Taxi	CNG	5	1.5	2	26	4	4	24	21	2.5	2	24	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	81	16	-13	0	FALSE	81
	PU/MT	Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	10	17	4	26	4	4	37	16	-13	0	FALSE	37
	Truck	Diesel	10	17	4	26	4	4	17	16	-13	0	FALSE	17
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1896**					**451**
L11	Car	Petrol	25	1.5	4	26	4	4	35	1	2.5	0	35	0
		CNG	5	1.5	2	26	4	4	220	21	2.5	2	220	0
	Bus	Diesel	10	17	4	26	4	4	48	16	-13	0	FALSE	48
		CNG	10	17	4	26	4	4	151	16	-13	0	FALSE	151
	CNG	CNG	5	1.5	2	26	4	4	177	21	2.5	2	177	0
	MC	Petrol	5	0.3	4	26	4	4	231	21	3.7	0	231	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	5	1.5	2	26	4	4	75	21	2.5	2	75	0
		Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	30	1	2.5	0	30	0
		CNG	5	1.5	2	26	4	4	70	21	2.5	2	70	0
		Diesel	25	1.5	4	26	4	4	21	1	2.5	0	21	0
	Taxi	CNG	5	1.5	2	26	4	4	33	21	2.5	2	33	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	86	16	-13	0	FALSE	86

	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	10	17	4	26	4	4	26	16	-13	0	FALSE	26
	Truck	Diesel	10	17	4	26	4	4	10	16	-13	0	FALSE	10
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1232**					**323**
L12	Car	Petrol	25	1.5	4	26	4	4	18	1	2.5	0	18	0
		CNG	5	1.5	2	26	4	4	111	21	2.5	2	111	0
	Bus	Diesel	10	17	4	26	4	4	28	16	-13	0	FALSE	28
		CNG	10	17	4	26	4	4	89	16	-13	0	FALSE	89
	CNG	CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
	MC	Petrol	5	0.3	4	26	4	4	15	21	3.7	0	15	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	28	21	2.5	2	28	0
		Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	4	21	2.5	2	4	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Taxi	CNG	5	1.5	2	26	4	4	5	21	2.5	2	5	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	9	16	-13	0	FALSE	9
	PU/MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	9	16	-13	0	FALSE	9
	Truck	Diesel	10	17	4	26	4	4	1	16	-13	0	FALSE	1
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**358**					**136**
L13	Car	Petrol	25	1.5	4	26	4	4	73	1	2.5	0	73	0
		CNG	5	1.5	2	26	4	4	458	21	2.5	2	458	0
	Bus	Diesel	10	17	4	26	4	4	61	16	-13	0	FALSE	61
		CNG	10	17	4	26	4	4	192	16	-13	0	FALSE	192
	CNG	CNG	5	1.5	2	26	4	4	233	21	2.5	2	233	0
	MC	Petrol	5	0.3	4	26	4	4	200	21	3.7	0	200	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	9	1	2.5	0	9	0
		CNG	5	1.5	2	26	4	4	121	21	2.5	2	121	0
		Diesel	25	1.5	4	26	4	4	11	1	2.5	0	11	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	16	1	2.5	0	16	0
		CNG	5	1.5	2	26	4	4	38	21	2.5	2	38	0
		Diesel	25	1.5	4	26	4	4	12	1	2.5	0	12	0
	Taxi	CNG	5	1.5	2	26	4	4	11	21	2.5	2	11	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	62	16	-13	0	FALSE	62
	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	10	17	4	26	4	4	28	16	-13	0	FALSE	28
	Truck	Diesel	10	17	4	26	4	4	2	16	-13	0	FALSE	2
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0

						26	4	4	**1532**					**345**
L14	Car	Petrol	25	1.5	4	26	4	4	63	1	2.5	0	63	0
		CNG	5	1.5	2	26	4	4	395	21	2.5	2	395	0
	Bus	Diesel	10	17	4	26	4	4	54	16	-13	0	FALSE	54
		CNG	10	17	4	26	4	4	168	16	-13	0	FALSE	168
	CNG	CNG	5	1.5	2	26	4	4	157	21	2.5	2	157	0
	MC	Petrol	5	0.3	4	26	4	4	133	21	3.7	0	133	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	5	1.5	2	26	4	4	54	21	2.5	2	54	0
		Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	13	1	2.5	0	13	0
		CNG	5	1.5	2	26	4	4	31	21	2.5	2	31	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	10	21	2.5	2	10	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	50	16	-13	0	FALSE	50
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	19	16	-13	0	FALSE	19
	Truck	Diesel	10	17	4	26	4	4	8	16	-13	0	FALSE	8
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1178**					**301**
L15	Car	Petrol	25	1.5	4	26	4	4	77	1	2.5	0	77	0
		CNG	5	1.5	2	26	4	4	483	21	2.5	2	483	0
	Bus	Diesel	10	17	4	26	4	4	26	16	-13	0	FALSE	26
		CNG	10	17	4	26	4	4	82	16	-13	0	FALSE	82
	CNG	CNG	5	1.5	2	26	4	4	241	21	2.5	2	241	0
	MC	Petrol	5	0.3	4	26	4	4	133	21	3.7	0	133	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	91	21	2.5	2	91	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	23	1	2.5	0	23	0
		CNG	5	1.5	2	26	4	4	53	21	2.5	2	53	0
		Diesel	25	1.5	4	26	4	4	16	1	2.5	0	16	0
	Taxi	CNG	5	1.5	2	26	4	4	26	21	2.5	2	26	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	31	16	-13	0	FALSE	31
	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	10	17	4	26	4	4	28	16	-13	0	FALSE	28
	Truck	Diesel	10	17	4	26	4	4	12	16	-13	0	FALSE	12
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1344**					**182**
L16	Car	Petrol	25	1.5	4	26	4	4	97	1	2.5	0	97	0
		CNG	5	1.5	2	26	4	4	604	21	2.5	2	604	0
	Bus	Diesel	10	17	4	26	4	4	48	16	-13	0	FALSE	48

		CNG	10	17	4	26	4	4	151	16	-13	0	FALSE	151
	CNG	CNG	5	1.5	2	26	4	4	313	21	2.5	2	313	0
	MC	Petrol	5	0.3	4	26	4	4	204	21	3.7	0	204	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	90	21	2.5	2	90	0
		Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	26	1	2.5	0	26	0
		CNG	5	1.5	2	26	4	4	61	21	2.5	2	61	0
		Diesel	25	1.5	4	26	4	4	18	1	2.5	0	18	0
	Taxi	CNG	5	1.5	2	26	4	4	13	21	2.5	2	13	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	15	16	-13	0	FALSE	15
	PU/MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	47	16	-13	0	FALSE	47
	Truck	Diesel	10	17	4	26	4	4	9	16	-13	0	FALSE	9
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1717**					**272**
L17	Car	Petrol	25	1.5	4	26	4	4	109	1	2.5	0	109	0
		CNG	5	1.5	2	26	4	4	682	21	2.5	2	682	0
	Bus	Diesel	10	17	4	26	4	4	55	16	-13	0	FALSE	55
		CNG	10	17	4	26	4	4	173	16	-13	0	FALSE	173
	CNG	CNG	5	1.5	2	26	4	4	375	21	2.5	2	375	0
	MC	Petrol	5	0.3	4	26	4	4	237	21	3.7	0	237	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	108	21	2.5	2	108	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	30	1	2.5	0	30	0
		CNG	5	1.5	2	26	4	4	71	21	2.5	2	71	0
		Diesel	25	1.5	4	26	4	4	22	1	2.5	0	22	0
	Taxi	CNG	5	1.5	2	26	4	4	18	21	2.5	2	18	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	21	16	-13	0	FALSE	21
	PU/MT	Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	10	17	4	26	4	4	61	16	-13	0	FALSE	61
	Truck	Diesel	10	17	4	26	4	4	12	16	-13	0	FALSE	12
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**2001**					**325**
L18	Car	Petrol	25	1.5	4	26	4	4	116	1	2.5	0	116	0
		CNG	5	1.5	2	26	4	4	723	21	2.5	2	723	0
	Bus	Diesel	10	17	4	26	4	4	63	16	-13	0	FALSE	63
		CNG	10	17	4	26	4	4	198	16	-13	0	FALSE	198
	CNG	CNG	5	1.5	2	26	4	4	403	21	2.5	2	403	0
	MC	Petrol	5	0.3	4	26	4	4	272	21	3.7	0	272	0
	MicB/	Petrol	25	1.5	4	26	4	4	9	1	2.5	0	9	0

	Amb	CNG	5	1.5	2	26	4	4	123	21	2.5	2	123	0
		Diesel	25	1.5	4	26	4	4	12	1	2.5	0	12	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	36	1	2.5	0	36	0
		CNG	5	1.5	2	26	4	4	83	21	2.5	2	83	0
		Diesel	25	1.5	4	26	4	4	25	1	2.5	0	25	0
	Taxi	CNG	5	1.5	2	26	4	4	25	21	2.5	2	25	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	27	16	-13	0	FALSE	27
	PU/MT	Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	10	17	4	26	4	4	69	16	-13	0	FALSE	69
	Truck	Diesel	10	17	4	26	4	4	13	16	-13	0	FALSE	13
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**2207**					**372**
L19	Car	Petrol	25	1.5	4	26	4	4	95	1	2.5	0	95	0
		CNG	5	1.5	2	26	4	4	594	21	2.5	2	594	0
	Bus	Diesel	10	17	4	26	4	4	122	16	-13	0	FALSE	122
		CNG	10	17	4	26	4	4	382	16	-13	0	FALSE	382
	CNG	CNG	5	1.5	2	26	4	4	398	21	2.5	2	398	0
	MC	Petrol	5	0.3	4	26	4	4	267	21	3.7	0	267	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	10	1	2.5	0	10	0
		CNG	5	1.5	2	26	4	4	138	21	2.5	2	138	0
		Diesel	25	1.5	4	26	4	4	13	1	2.5	0	13	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	45	1	2.5	0	45	0
		CNG	5	1.5	2	26	4	4	104	21	2.5	2	104	0
		Diesel	25	1.5	4	26	4	4	32	1	2.5	0	32	0
	Taxi	CNG	5	1.5	2	26	4	4	25	21	2.5	2	25	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	17	16	-13	0	FALSE	17
	PU/MT	Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	10	17	4	26	4	4	66	16	-13	0	FALSE	66
	Truck	Diesel	10	17	4	26	4	4	22	16	-13	0	FALSE	22
		CNG	10	17	4	26	4	4	5	16	-13	0	FALSE	5
						26	4	4	**2342**					**614**
L20	Car	Petrol	25	1.5	4	26	4	4	70	1	2.5	0	70	0
		CNG	5	1.5	2	26	4	4	438	21	2.5	2	438	0
	Bus	Diesel	10	17	4	26	4	4	122	16	-13	0	FALSE	122
		CNG	10	17	4	26	4	4	381	16	-13	0	FALSE	381
	CNG	CNG	5	1.5	2	26	4	4	354	21	2.5	2	354	0
	MC	Petrol	5	0.3	4	26	4	4	166	21	3.7	0	166	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	12	1	2.5	0	12	0
		CNG	5	1.5	2	26	4	4	158	21	2.5	2	158	0
		Diesel	25	1.5	4	26	4	4	15	1	2.5	0	15	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	52	1	2.5	0	52	0
		CNG	5	1.5	2	26	4	4	122	21	2.5	2	122	0
		Diesel	25	1.5	4	26	4	4	37	1	2.5	0	37	0

	Taxi	CNG	5	1.5	2	26	4	4	30	21	2.5	2	30	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	16	16	-13	0	FALSE	16
	PU/MT	Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	10	17	4	26	4	4	77	16	-13	0	FALSE	77
	Truck	Diesel	10	17	4	26	4	4	29	16	-13	0	FALSE	29
		CNG	10	17	4	26	4	4	6	16	-13	0	FALSE	6
						26	4	4	**2093**					**631**
L21	Car	Petrol	25	1.5	4	26	4	4	11	1	2.5	0	11	0
		CNG	5	1.5	2	26	4	4	71	21	2.5	2	71	0
	Bus	Diesel	10	17	4	26	4	4	30	16	-13	0	FALSE	30
		CNG	10	17	4	26	4	4	94	16	-13	0	FALSE	94
	CNG	CNG	5	1.5	2	26	4	4	41	21	2.5	2	41	0
	MC	Petrol	5	0.3	4	26	4	4	51	21	3.7	0	51	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	5	1.5	2	26	4	4	17	21	2.5	2	17	0
		Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	4	21	2.5	2	4	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Taxi	CNG	5	1.5	2	26	4	4	3	21	2.5	2	3	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	46	16	-13	0	FALSE	46
	PU/MT	Diesel	25	1.5	4	26	4	4	0	1	2.5	0	0	0
		CNG	10	17	4	26	4	4	5	16	-13	0	FALSE	5
	Truck	Diesel	10	17	4	26	4	4	1	16	-13	0	FALSE	1
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**381**					**177**
L22	Car	Petrol	25	1.5	4	26	4	4	49	1	2.5	0	49	0
		CNG	5	1.5	2	26	4	4	308	21	2.5	2	308	0
	Bus	Diesel	10	17	4	26	4	4	59	16	-13	0	FALSE	59
		CNG	10	17	4	26	4	4	184	16	-13	0	FALSE	184
	CNG	CNG	5	1.5	2	26	4	4	146	21	2.5	2	146	0
	MC	Petrol	5	0.3	4	26	4	4	204	21	3.7	0	204	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	5	1.5	2	26	4	4	70	21	2.5	2	70	0
		Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	18	21	2.5	2	18	0
		Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
	Taxi	CNG	5	1.5	2	26	4	4	16	21	2.5	2	16	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0

		CNG	10	17	4	26	4	4	28	16	-13	0	FALSE	28
	Truck	Diesel	10	17	4	26	4	4	14	16	-13	0	FALSE	14
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1126**					**287**
L23	Car	Petrol	25	1.5	4	26	4	4	55	1	2.5	0	55	0
		CNG	5	1.5	2	26	4	4	342	21	2.5	2	342	0
	Bus	Diesel	10	17	4	26	4	4	58	16	-13	0	FALSE	58
		CNG	10	17	4	26	4	4	183	16	-13	0	FALSE	183
	CNG	CNG	5	1.5	2	26	4	4	144	21	2.5	2	144	0
	MC	Petrol	5	0.3	4	26	4	4	177	21	3.7	0	177	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	5	1.5	2	26	4	4	73	21	2.5	2	73	0
		Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	5	1.5	2	26	4	4	14	21	2.5	2	14	0
		Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
	Taxi	CNG	5	1.5	2	26	4	4	21	21	2.5	2	21	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	10	17	4	26	4	4	31	16	-13	0	FALSE	31
	Truck	Diesel	10	17	4	26	4	4	14	16	-13	0	FALSE	14
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**1141**					**290**
L24	Car	Petrol	25	1.5	4	26	4	4	78	1	2.5	0	78	0
		CNG	5	1.5	2	26	4	4	489	21	2.5	2	489	0
	Bus	Diesel	10	17	4	26	4	4	55	16	-13	0	FALSE	55
		CNG	10	17	4	26	4	4	171	16	-13	0	FALSE	171
	CNG	CNG	5	1.5	2	26	4	4	234	21	2.5	2	234	0
	MC	Petrol	5	0.3	4	26	4	4	146	21	3.7	0	146	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	35	21	2.5	2	35	0
		Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	17	21	2.5	2	17	0
		Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
	Taxi	CNG	5	1.5	2	26	4	4	26	21	2.5	2	26	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	48	16	-13	0	FALSE	48
	PU/MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	46	16	-13	0	FALSE	46
	Truck	Diesel	10	17	4	26	4	4	1	16	-13	0	FALSE	1
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**1369**					**321**
L25	Car	Petrol	25	1.5	4	26	4	4	74	1	2.5	0	74	0

		CNG	5	1.5	2	26	4	4	465	21	2.5	2	465	0
	Bus	Diesel	10	17	4	26	4	4	56	16	-13	0	FALSE	56
		CNG	10	17	4	26	4	4	174	16	-13	0	FALSE	174
	CNG	CNG	5	1.5	2	26	4	4	269	21	2.5	2	269	0
	MC	Petrol	5	0.3	4	26	4	4	179	21	3.7	0	179	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	91	21	2.5	2	91	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	14	1	2.5	0	14	0
		CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	12	21	2.5	2	12	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	50	16	-13	0	FALSE	50
	PU/MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	52	16	-13	0	FALSE	52
	Truck	Diesel	10	17	4	26	4	4	2	16	-13	0	FALSE	2
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**1502**					**334**
L26	Car	Petrol	25	1.5	4	26	4	4	80	1	2.5	0	80	0
		CNG	5	1.5	2	26	4	4	497	21	2.5	2	497	0
	Bus	Diesel	10	17	4	26	4	4	56	16	-13	0	FALSE	56
		CNG	10	17	4	26	4	4	177	16	-13	0	FALSE	177
	CNG	CNG	5	1.5	2	26	4	4	276	21	2.5	2	276	0
	MC	Petrol	5	0.3	4	26	4	4	186	21	3.7	0	186	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	98	21	2.5	2	98	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	14	1	2.5	0	14	0
		CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	13	21	2.5	2	13	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	48	16	-13	0	FALSE	48
	PU/MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	55	16	-13	0	FALSE	55
	Truck	Diesel	10	17	4	26	4	4	3	16	-13	0	FALSE	3
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**1567**					**339**
L27	Car	Petrol	25	1.5	4	26	4	4	46	1	2.5	0	46	0
		CNG	5	1.5	2	26	4	4	290	21	2.5	2	290	0
	Bus	Diesel	10	17	4	26	4	4	39	16	-13	0	FALSE	39
		CNG	10	17	4	26	4	4	123	16	-13	0	FALSE	123
	CNG	CNG	5	1.5	2	26	4	4	116	21	2.5	2	116	0
	MC	Petrol	5	0.3	4	26	4	4	199	21	3.7	0	199	0

	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	41	21	2.5	2	41	0
		Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	11	1	2.5	0	11	0
		CNG	5	1.5	2	26	4	4	25	21	2.5	2	25	0
		Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
	Taxi	CNG	5	1.5	2	26	4	4	10	21	2.5	2	10	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	24	16	-13	0	FALSE	24
	Truck	Diesel	10	17	4	26	4	4	9	16	-13	0	FALSE	9
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**952**					**197**
L28	Car	Petrol	25	1.5	4	26	4	4	57	1	2.5	0	57	0
		CNG	5	1.5	2	26	4	4	357	21	2.5	2	357	0
	Bus	Diesel	10	17	4	26	4	4	100	16	-13	0	FALSE	100
		CNG	10	17	4	26	4	4	314	16	-13	0	FALSE	314
	CNG	CNG	5	1.5	2	26	4	4	318	21	2.5	2	318	0
	MC	Petrol	5	0.3	4	26	4	4	242	21	3.7	0	242	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	36	21	2.5	2	36	0
		Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	13	1	2.5	0	13	0
		CNG	5	1.5	2	26	4	4	30	21	2.5	2	30	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Taxi	CNG	5	1.5	2	26	4	4	8	21	2.5	2	8	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	24	16	-13	0	FALSE	24
	Truck	Diesel	10	17	4	26	4	4	10	16	-13	0	FALSE	10
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1530**					**452**
L29	Car	Petrol	25	1.5	4	26	4	4	54	1	2.5	0	54	0
		CNG	5	1.5	2	26	4	4	335	21	2.5	2	335	0
	Bus	Diesel	10	17	4	26	4	4	50	16	-13	0	FALSE	50
		CNG	10	17	4	26	4	4	156	16	-13	0	FALSE	156
	CNG	CNG	5	1.5	2	26	4	4	135	21	2.5	2	135	0
	MC	Petrol	5	0.3	4	26	4	4	220	21	3.7	0	220	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	5	1.5	2	26	4	4	67	21	2.5	2	67	0
		Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	14	1	2.5	0	14	0
		CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0

		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	38	21	2.5	2	38	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	25	16	-13	0	FALSE	25
	PU/MT	Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	10	17	4	26	4	4	58	16	-13	0	FALSE	58
	Truck	Diesel	10	17	4	26	4	4	6	16	-13	0	FALSE	6
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**1216**					**296**
L30	Car	Petrol	25	1.5	4	26	4	4	52	1	2.5	0	52	0
		CNG	5	1.5	2	26	4	4	322	21	2.5	2	322	0
	Bus	Diesel	10	17	4	26	4	4	54	16	-13	0	FALSE	54
		CNG	10	17	4	26	4	4	169	16	-13	0	FALSE	169
	CNG	CNG	5	1.5	2	26	4	4	145	21	2.5	2	145	0
	MC	Petrol	5	0.3	4	26	4	4	223	21	3.7	0	223	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	5	1.5	2	26	4	4	82	21	2.5	2	82	0
		Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	14	1	2.5	0	14	0
		CNG	5	1.5	2	26	4	4	34	21	2.5	2	34	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	25	16	-13	0	FALSE	25
	PU/MT	Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	10	17	4	26	4	4	57	16	-13	0	FALSE	57
	Truck	Diesel	10	17	4	26	4	4	6	16	-13	0	FALSE	6
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**1245**					**312**
L31	Car	Petrol	25	1.5	4	26	4	4	51	1	2.5	0	51	0
		CNG	5	1.5	2	26	4	4	321	21	2.5	2	321	0
	Bus	Diesel	10	17	4	26	4	4	54	16	-13	0	FALSE	54
		CNG	10	17	4	26	4	4	170	16	-13	0	FALSE	170
	CNG	CNG	5	1.5	2	26	4	4	142	21	2.5	2	142	0
	MC	Petrol	5	0.3	4	26	4	4	361	21	3.7	0	361	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	92	21	2.5	2	92	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	15	1	2.5	0	15	0
		CNG	5	1.5	2	26	4	4	35	21	2.5	2	35	0
		Diesel	25	1.5	4	26	4	4	10	1	2.5	0	10	0
	Taxi	CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	22	16	-13	0	FALSE	22

	PU/MT	Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
		CNG	10	17	4	26	4	4	56	16	-13	0	FALSE	56
	Truck	Diesel	10	17	4	26	4	4	7	16	-13	0	FALSE	7
		CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
						26	4	4	**1392**					**312**
L32	Car	Petrol	25	1.5	4	26	4	4	52	1	2.5	0	52	0
		CNG	5	1.5	2	26	4	4	322	21	2.5	2	322	0
	Bus	Diesel	10	17	4	26	4	4	35	16	-13	0	FALSE	35
		CNG	10	17	4	26	4	4	110	16	-13	0	FALSE	110
	CNG	CNG	5	1.5	2	26	4	4	96	21	2.5	2	96	0
	MC	Petrol	5	0.3	4	26	4	4	235	21	3.7	0	235	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	5	1.5	2	26	4	4	47	21	2.5	2	47	0
		Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	6	21	2.5	2	6	0
		Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
	Taxi	CNG	5	1.5	2	26	4	4	2	21	2.5	2	2	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	17	16	-13	0	FALSE	17
	PU/MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	11	16	-13	0	FALSE	11
	Truck	Diesel	10	17	4	26	4	4	1	16	-13	0	FALSE	1
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**947**					**174**
L33	Car	Petrol	25	1.5	4	26	4	4	49	1	2.5	0	49	0
		CNG	5	1.5	2	26	4	4	307	21	2.5	2	307	0
	Bus	Diesel	10	17	4	26	4	4	37	16	-13	0	FALSE	37
		CNG	10	17	4	26	4	4	116	16	-13	0	FALSE	116
	CNG	CNG	5	1.5	2	26	4	4	117	21	2.5	2	117	0
	MC	Petrol	5	0.3	4	26	4	4	172	21	3.7	0	172	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	42	21	2.5	2	42	0
		Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	19	21	2.5	2	19	0
		Diesel	25	1.5	4	26	4	4	6	1	2.5	0	6	0
	Taxi	CNG	5	1.5	2	26	4	4	5	21	2.5	2	5	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	4	16	-13	0	FALSE	4
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	15	16	-13	0	FALSE	15
	Truck	Diesel	10	17	4	26	4	4	3	16	-13	0	FALSE	3
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**909**					**176**

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME ALONG MAJOR STUDY LINKS

L34	Car	Petrol	25	1.5	4	26	4	4	45	1	2.5	0	45	0
		CNG	5	1.5	2	26	4	4	284	21	2.5	2	284	0
	Bus	Diesel	10	17	4	26	4	4	37	16	-13	0	FALSE	37
		CNG	10	17	4	26	4	4	117	16	-13	0	FALSE	117
	CNG	CNG	5	1.5	2	26	4	4	133	21	2.5	2	133	0
	MC	Petrol	5	0.3	4	26	4	4	189	21	3.7	0	189	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	43	21	2.5	2	43	0
		Diesel	25	1.5	4	26	4	4	4	1	2.5	0	4	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	10	1	2.5	0	10	0
		CNG	5	1.5	2	26	4	4	24	21	2.5	2	24	0
		Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
	Taxi	CNG	5	1.5	2	26	4	4	10	21	2.5	2	10	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	4	16	-13	0	FALSE	4
	PU/MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	15	16	-13	0	FALSE	15
	Truck	Diesel	10	17	4	26	4	4	4	16	-13	0	FALSE	4
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**930**					**177**
L35	Car	Petrol	25	1.5	4	26	4	4	77	1	2.5	0	77	0
		CNG	5	1.5	2	26	4	4	480	21	2.5	2	480	0
	Bus	Diesel	10	17	4	26	4	4	20	16	-13	0	FALSE	20
		CNG	10	17	4	26	4	4	64	16	-13	0	FALSE	64
	CNG	CNG	5	1.5	2	26	4	4	366	21	2.5	2	366	0
	MC	Petrol	5	0.3	4	26	4	4	206	21	3.7	0	206	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	10	1	2.5	0	10	0
		CNG	5	1.5	2	26	4	4	129	21	2.5	2	129	0
		Diesel	25	1.5	4	26	4	4	12	1	2.5	0	12	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	12	1	2.5	0	12	0
		CNG	5	1.5	2	26	4	4	28	21	2.5	2	28	0
		Diesel	25	1.5	4	26	4	4	8	1	2.5	0	8	0
	Taxi	CNG	5	1.5	2	26	4	4	7	21	2.5	2	7	0
	Leguna/ Tempo/ HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/MT	Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	10	17	4	26	4	4	21	16	-13	0	FALSE	21
	Truck	Diesel	10	17	4	26	4	4	4	16	-13	0	FALSE	4
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
									1448					**111**

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME / HOUR ALONG SECONDARY ALTERNATIVE ROADS

Road name	Vehicle type	Fuel type	Emission factor			Standard Emission			Volume	Standard emission-Emission factor			Non-pollution volume/ Optimum volume	Pollution volume/ shifting volume
			CO	NOX	HC	CO	NOX	HC						
Tongi Diversion Road	Car	Petrol	25	1.5	4	26	4	4	192	1	2.5	0	192	0
		CNG	5	1.5	2	26	4	4	1196	21	2.5	2	1196	0
	Bus	Diesel	10	17	4	26	4	4	86	16	-13	0	FALSE	86
		CNG	10	17	4	26	4	4	268	16	-13	0	FALSE	268
	CNG	CNG	5	1.5	2	26	4	4	1705	21	2.5	2	1705	0
	MC	Petrol	5	0.3	4	26	4	4	446	21	3.7	0	446	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	28	1	2.5	0	28	0
		CNG	5	1.5	2	26	4	4	374	21	2.5	2	374	0
		Diesel	25	1.5	4	26	4	4	35	1	2.5	0	35	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	35	1	2.5	0	35	0
		CNG	5	1.5	2	26	4	4	83	21	2.5	2	83	0
		Diesel	25	1.5	4	26	4	4	25	1	2.5	0	25	0
	Taxi	CNG	5	1.5	2	26	4	4	213	21	2.5	2	213	0
	HH	CNG	10	17	4	26	4	4	73	16	-13	0	FALSE	73
	PU/ MT	Diesel	25	1.5	4	26	4	4	36	1	2.5	0	36	0
		CNG	10	17	4	26	4	4	360	16	-13	0	FALSE	360
	Truck	Diesel	10	17	4	26	4	4	16	16	-13	0	FALSE	16
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**5174**				**4368**	**806**
Sat Masjid Road	Car	Petrol	25	1.5	4	26	4	4	235	1	2.5	0	235	0
		CNG	5	1.5	2	26	4	4	1468	21	2.5	2	1468	0
	Bus	Diesel	10	17	4	26	4	4	40	16	-13	0	FALSE	40
		CNG	10	17	4	26	4	4	125	16	-13	0	FALSE	125
	CNG	CNG	5	1.5	2	26	4	4	483	21	2.5	2	483	0
	MC	Petrol	5	0.3	4	26	4	4	293	21	3.7	0	293	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	17	1	2.5	0	17	0
		CNG	5	1.5	2	26	4	4	219	21	2.5	2	219	0
		Diesel	25	1.5	4	26	4	4	255	1	2.5	0	255	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	26	1	2.5	0	26	0
		CNG	5	1.5	2	26	4	4	62	21	2.5	2	62	0
		Diesel	25	1.5	4	26	4	4	19	1	2.5	0	19	0
	Taxi	CNG	5	1.5	2	26	4	4	108	21	2.5	2	108	0
	HH	CNG	10	17	4	26	4	4	122	16	-13	0	FALSE	122
	PU/ MT	Diesel	25	1.5	4	26	4	4	5	1	2.5	0	5	0
		CNG	10	17	4	26	4	4	53	16	-13	0	FALSE	53
	Truck	Diesel	10	17	4	26	4	4	0	16	-13	0	FALSE	0
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**3530**				**3190**	**341**
New Eskaton Road	Car	Petrol	25	1.5	4	26	4	4	71	1	2.5	0	71	0
		CNG	5	1.5	2	26	4	4	443	21	2.5	2	443	0
	Bus	Diesel	10	17	4	26	4	4	14	16	-13	0	FALSE	14
		CNG	10	17	4	26	4	4	43	16	-13	0	FALSE	43
	CNG	CNG	5	1.5	2	26	4	4	341	21	2.5	2	341	0
	MC	Petrol	5	0.3	4	26	4	4	233	21	3.7	0	233	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	5	1.5	2	26	4	4	96	21	2.5	2	96	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	13	1	2.5	0	13	0
		CNG	5	1.5	2	26	4	4	30	21	2.5	2	30	0
		Diesel	25	1.5	4	26	4	4	9	1	2.5	0	9	0
	Taxi	CNG	5	1.5	2	26	4	4	53	21	2.5	2	53	0
	HH	CNG	10	17	4	26	4	4	10	16	-13	0	FALSE	10
	PU/ MT	Diesel	25	1.5	4	26	4	4	7	1	2.5	0	7	0
		CNG	10	17	4	26	4	4	72	16	-13	0	FALSE	72
	Truck	Diesel	10	17	4	26	4	4	2	16	-13	0	FALSE	2

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME / HOUR ALONG SECONDARY ALTERNATIVE ROADS

		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**1455**				**1313**	**141**
Pantha path	Car	Petrol	25	1.5	4	26	4	4	158	1	2.5	0	158	0
		CNG	5	1.5	2	26	4	4	988	21	2.5	2	988	0
	Bus	Diesel	10	17	4	26	4	4	12	16	-13	0	FALSE	12
		CNG	10	17	4	26	4	4	37	16	-13	0	FALSE	37
	CNG	CNG	5	1.5	2	26	4	4	846	21	2.5	2	846	0
	MC	Petrol	5	0.3	4	26	4	4	279	21	3.7	0	279	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	20	1	2.5	0	20	0
		CNG	5	1.5	2	26	4	4	263	21	2.5	2	263	0
		Diesel	25	1.5	4	26	4	4	25	1	2.5	0	25	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	43	1	2.5	0	43	0
		CNG	5	1.5	2	26	4	4	101	21	2.5	2	101	0
		Diesel	25	1.5	4	26	4	4	30	1	2.5	0	30	0
	Taxi	CNG	5	1.5	2	26	4	4	112	21	2.5	2	112	0
	HH	CNG	10	17	4	26	4	4	2	16	-13	0	FALSE	2
	PU/ MT	Diesel	25	1.5	4	26	4	4	17	1	2.5	0	17	0
		CNG	10	17	4	26	4	4	167	16	-13	0	FALSE	167
	Truck	Diesel	10	17	4	26	4	4	3	16	-13	0	FALSE	3
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**3103**				**2881**	**222**
Farmgate - Manikmia Avenue	Car	Petrol	25	1.5	4	26	4	4	89	1	2.5	0	89	0
		CNG	5	1.5	2	26	4	4	555	21	2.5	2	555	0
	Bus	Diesel	10	17	4	26	4	4	206	16	-13	0	FALSE	206
		CNG	10	17	4	26	4	4	645	16	-13	0	FALSE	645
	CNG	CNG	5	1.5	2	26	4	4	269	21	2.5	2	269	0
	MC	Petrol	5	0.3	4	26	4	4	141	21	3.7	0	141	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	18	1	2.5	0	18	0
		CNG	5	1.5	2	26	4	4	241	21	2.5	2	241	0
		Diesel	25	1.5	4	26	4	4	23	1	2.5	0	23	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	25	1	2.5	0	25	0
		CNG	5	1.5	2	26	4	4	59	21	2.5	2	59	0
		Diesel	25	1.5	4	26	4	4	18	1	2.5	0	18	0
	Taxi	CNG	5	1.5	2	26	4	4	73	21	2.5	2	73	0
	HH	CNG	10	17	4	26	4	4	118	16	-13	0	FALSE	118
	PU/ MT	Diesel	25	1.5	4	26	4	4	16	1	2.5	0	16	0
		CNG	10	17	4	26	4	4	158	16	-13	0	FALSE	158
	Truck	Diesel	10	17	4	26	4	4	15	16	-13	0	FALSE	15
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**2671**				**1527**	**1145**
Agargaon -PMO link Road	Car	Petrol	25	1.5	4	26	4	4	101	1	2.5	0	101	0
		CNG	5	1.5	2	26	4	4	630	21	2.5	2	630	0
	Bus	Diesel	10	17	4	26	4	4	49	16	-13	0	FALSE	49
		CNG	10	17	4	26	4	4	153	16	-13	0	FALSE	153
	CNG	CNG	5	1.5	2	26	4	4	332	21	2.5	2	332	0
	MC	Petrol	5	0.3	4	26	4	4	127	21	3.7	0	127	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	23	1	2.5	0	23	0
		CNG	5	1.5	2	26	4	4	303	21	2.5	2	303	0
		Diesel	25	1.5	4	26	4	4	28	1	2.5	0	28	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	22	1	2.5	0	22	0
		CNG	5	1.5	2	26	4	4	53	21	2.5	2	53	0
		Diesel	25	1.5	4	26	4	4	16	1	2.5	0	16	0
	Taxi	CNG	5	1.5	2	26	4	4	127	21	2.5	2	127	0
	HH	CNG	10	17	4	26	4	4	267	16	-13	0	FALSE	267
	PU/ MT	Diesel	25	1.5	4	26	4	4	25	1	2.5	0	25	0
		CNG	10	17	4	26	4	4	249	16	-13	0	FALSE	249
	Truck	Diesel	10	17	4	26	4	4	16	16	-13	0	FALSE	16
		CNG	10	17	4	26	4	4	3	16	-13	0	FALSE	3
						26	4	4	**2525**				**1786**	**738**

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME / HOUR ALONG SECONDARY ALTERNATIVE ROADS

Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	Car	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	17	21	2.5	2	17	0
	Bus	Diesel	10	17	4	26	4	4	7	16	-13	0	FALSE	7
		CNG	10	17	4	26	4	4	23	16	-13	0	FALSE	23
	CNG	CNG	5	1.5	2	26	4	4	21	21	2.5	2	21	0
	MC	Petrol	5	0.3	4	26	4	4	12	21	3.7	0	12	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	5	1.5	2	26	4	4	9	21	2.5	2	9	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	5	1.5	2	26	4	4	3	21	2.5	2	3	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Taxi	CNG	5	1.5	2	26	4	4	0	21	2.5	2	0	0
	HH	CNG	10	17	4	26	4	4	22	16	-13	0	FALSE	22
	PU/ MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	11	16	-13	0	FALSE	11
	Truck	Diesel	10	17	4	26	4	4	3	16	-13	0	FALSE	3
		CNG	10	17	4	26	4	4	1	16	-13	0	FALSE	1
						26	4	4	**137**				**71**	**67**
Green Road	Car	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	21	21	2.5	2	21	0
	Bus	Diesel	10	17	4	26	4	4	1	16	-13	0	FALSE	1
		CNG	10	17	4	26	4	4	5	16	-13	0	FALSE	5
	CNG	CNG	5	1.5	2	26	4	4	18	21	2.5	2	18	0
	MC	Petrol	5	0.3	4	26	4	4	12	21	3.7	0	12	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	5	1.5	2	26	4	4	14	21	2.5	2	14	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	5	1.5	2	26	4	4	3	21	2.5	2	3	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Taxi	CNG	5	1.5	2	26	4	4	4	21	2.5	2	4	0
	HH	CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
	PU/ MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	5	16	-13	0	FALSE	5
	Truck	Diesel	10	17	4	26	4	4	0	16	-13	0	FALSE	0
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**92**				**81**	**11**
Bijoy sharani-Tajgaon link road (Rangs Bhaban-Nabisco)	Car	Petrol	25	1.5	4	26	4	4	8	1	2.5	0	8	0
		CNG	5	1.5	2	26	4	4	52	21	2.5	2	52	0
	Bus	Diesel	10	17	4	26	4	4	9	16	-13	0	FALSE	9
		CNG	10	17	4	26	4	4	28	16	-13	0	FALSE	28
	CNG	CNG	5	1.5	2	26	4	4	32	21	2.5	2	32	0
	MC	Petrol	5	0.3	4	26	4	4	24	21	3.7	0	24	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	22	21	2.5	2	22	0
		Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	4	21	2.5	2	4	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0

CALCULATION OF EMISSION WISE OPTIMUM TRAFFIC VOLUME / HOUR ALONG SECONDARY ALTERNATIVE ROADS

	Taxi	CNG	5	1.5	2	26	4	4	3	21	2.5	2	3	0
	HH	CNG	10	17	4	26	4	4	15	16	-13	0	FALSE	15
	PU/ MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	8	16	-13	0	FALSE	8
	Truck	Diesel	10	17	4	26	4	4	0	16	-13	0	FALSE	0
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**212**				**152**	**60**
Hatirjheel Link road	Car	Petrol	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	5	1.5	2	26	4	4	23	21	2.5	2	23	0
	Bus	Diesel	10	17	4	26	4	4	4	16	-13	0	FALSE	4
		CNG	10	17	4	26	4	4	14	16	-13	0	FALSE	14
	CNG	CNG	5	1.5	2	26	4	4	29	21	2.5	2	29	0
	MC	Petrol	5	0.3	4	26	4	4	9	21	3.7	0	9	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	20	21	2.5	2	20	0
		Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	6	21	2.5	2	6	0
		Diesel	25	1.5	4	26	4	4	2	1	2.5	0	2	0
	Taxi	CNG	5	1.5	2	26	4	4	4	21	2.5	2	4	0
	HH	CNG	10	17	4	26	4	4	9	16	-13	0	FALSE	9
	PU/ MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	8	16	-13	0	FALSE	8
	Truck	Diesel	10	17	4	26	4	4	2	16	-13	0	FALSE	2
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**141**				**103**	**39**
Matikata road (infront of Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]	Car	Petrol	25	1.5	4	26	4	4	4	1	2.5	0	4	0
		CNG	5	1.5	2	26	4	4	24	21	2.5	2	24	0
	Bus	Diesel	10	17	4	26	4	4	5	16	-13	0	FALSE	5
		CNG	10	17	4	26	4	4	16	16	-13	0	FALSE	16
	CNG	CNG	5	1.5	2	26	4	4	23	21	2.5	2	23	0
	MC	Petrol	5	0.3	4	26	4	4	11	21	3.7	0	11	0
	MicB/ Amb	Petrol	25	1.5	4	26	4	4	3	1	2.5	0	3	0
		CNG	5	1.5	2	26	4	4	33	21	2.5	2	33	0
		Diesel	25	1.5	4	26	4	4	3	1	2.5	0	3	0
	Jeep/ SW	Petrol	25	1.5	4	26	4	4	2	1	2.5	0	2	0
		CNG	5	1.5	2	26	4	4	5	21	2.5	2	5	0
		Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
	Taxi	CNG	5	1.5	2	26	4	4	12	21	2.5	2	12	0
	HH	CNG	10	17	4	26	4	4	13	16	-13	0	FALSE	13
	PU/ MT	Diesel	25	1.5	4	26	4	4	1	1	2.5	0	1	0
		CNG	10	17	4	26	4	4	6	16	-13	0	FALSE	6
	Truck	Diesel	10	17	4	26	4	4	0	16	-13	0	FALSE	0
		CNG	10	17	4	26	4	4	0	16	-13	0	FALSE	0
						26	4	4	**162**				**122**	**40**

CALCULATION OF ROAD CAPACITY (LINK WISE) ALONG FOUR MAJOR STUDY ROUTES (Original carriageway width data source: Field survey, 2014)

Link no.	Original carriage way width from survey (left)	after exclude slope/ kerb width	Original carriage way width from survey (right)	after kerb width exclusion	Total carriage way width (both sides)	Original carriageway provided/ Provided carriageway width	Effective carriage way width	No. of lanes (assuming 12' per lane width)	Effective no. of lanes (assuming 12' per lane width)	Standard capacity/ lane (PCU/hr/ lane)	Total capacity (PCU)	Total Effective Capacity (PCU)	Standard capacity/ lane (PCU/hr/ lane)	Total capacity (PCU)	Total Effective Capacity (PCU)
L1	40	38	40	38	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L2	40	38	40.5	38.5	76.5	58.5	36.5	4.875	3.041666667	1400	6825	4258.33333	1200	5850	3650
L2	40.5	38.5	39.5	37.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L4	39.5	37.5	41.9	39.9	77.4	59.4	37.4	4.95	3.116666667	1400	6930	4363.33333	1200	5940	3740
L5	40	38	39.5	37.5	75.5	57.5	35.5	4.791666667	2.958333333	1400	6708.333333	4141.66667	1200	5750	3550
L6	40	38	40	38	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L7	40	38	39.3	37.3	75.3	57.3	35.3	4.775	2.941666667	1400	6685	4118.33333	1200	5730	3530
L8	31	29	29.5	27.5	56.5	38.5	16.5	3.208333333	1.375	1400	4491.666667	1925	1200	3850	1650
L9	39.5	37.5	38.75	36.75	74.25	56.25	34.25	4.6875	2.854166667	1400	6562.5	3995.83333	1200	5625	3425
L10	39.5	37.5	40.75	38.75	76.25	58.25	36.25	4.854166667	3.020833333	1400	6795.833333	4229.16667	1200	5825	3625
L11	40.75	38.75	41.5	39.5	78.25	60.25	38.25	5.020833333	3.1875	1400	7029.166667	4462.5	1200	6025	3825
L12	40.7	38.7	40.25	38.25	76.95	58.95	36.95	4.9125	3.079166667	1400	6877.5	4310.83333	1200	5895	3695
L13	40	38	39.5	37.5	75.5	57.5	35.5	4.791666667	2.958333333	1400	6708.333333	4141.66667	1200	5750	3550
L14	40	38	40	38	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L15	40.5	38.5	40.25	38.25	76.75	58.75	36.75	4.895833333	3.0625	1400	6854.166667	4287.5	1200	5875	3675
L16	39.5	37.5	40	38	75.5	57.5	35.5	4.791666667	2.958333333	1400	6708.333333	4141.66667	1200	5750	3550
L17	40.5	38.5	40.25	38.25	76.75	58.75	36.75	4.895833333	3.0625	1400	6854.166667	4287.5	1200	5875	3675
L18	40	38	40.55	38.55	76.55	58.55	36.55	4.879166667	3.045833333	1400	6830.833333	4264.16667	1200	5855	3655
L19	40.5	38.5	39.5	37.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L20	41	39	40.5	38.5	77.5	59.5	37.5	4.958333333	3.125	1400	6941.666667	4375	1200	5950	3750
L21	40	38	41.5	39.5	77.5	59.5	37.5	4.958333333	3.125	1400	6941.666667	4375	1200	5950	3750
L22	42.5	40.5	40.5	38.5	79	61	39	5.083333333	3.25	1400	7116.666667	4550	1200	6100	3900
L23	40.5	38.5	39.5	37.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L24	39	37	40	38	75	57	35	4.75	2.916666667	1400	6650	4083.33333	1200	5700	3500
L25	41	39	40.3	38.3	77.3	59.3	37.3	4.941666667	3.108333333	1400	6918.333333	4351.66667	1200	5930	3730
L26	40	38	40.5	38.5	76.5	58.5	36.5	4.875	3.041666667	1400	6825	4258.33333	1200	5850	3650
L27	41.25	39.25	40	38	77.25	59.25	37.25	4.9375	3.104166667	1400	6912.5	4345.83333	1200	5925	3725
L28	39.5	37.5	40.5	38.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L29	40	38	38.5	36.5	74.5	56.5	34.5	4.708333333	2.875	1400	6591.666667	4025	1200	5650	3450
L30	40.5	38.5	39.3	37.3	75.8	57.8	35.8	4.816666667	2.983333333	1400	6743.333333	4176.66667	1200	5780	3580
L31	39.5	37.5	40.5	38.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L32	40.5	38.5	39.9	37.9	76.4	58.4	36.4	4.866666667	3.033333333	1400	6813.333333	4246.66667	1200	5840	3640
L33	39.5	37.5	40.5	38.5	76	58	36	4.833333333	3	1400	6766.666667	4200	1200	5800	3600
L34	40.5	38.5	40.5	38.5	77	59	37	4.916666667	3.083333333	1400	6883.333333	4316.66667	1200	5900	3700
L35	40.25	38.25	41.3	39.3	77.55	59.55	37.55	4.9625	3.129166667	1400	6947.5	4380.83333	1200	5955	3755

Source: Field survey, 2014

Major Road Speed (km/hr)	Minor Road Sight Distance (m)	Main Road Sight Distance (m)
40	3	20
50	3	30
60	3	40
70	3	55
80	3	65

Table 2: STOP Sign Sight Distance Guidelines

Source: Ogden et al (1989)

	Primary	Secondary	Connector	Local
Traffic Volume	high	medium-high	low-medium	low
Traffic Composition				
Through Traffic	yes	yes	no	no
Heavy trucks	yes	yes	preferably no	no
Light trucks	yes	yes	yes	yes
Buses	yes	yes	maybe	no
Minibuses	no	yes	yes	no
Tempos	no	maybe	yes	no
Autorickshaws	yes	yes	yes	yes
Rickshaws	no	maybe	yes	yes
Non motorised goods vehicles	no	maybe	yes	yes
Passenger cars	yes	yes	yes	yes
Parking1				
Peak Periods	no	no	yes	yes
Day-Off-Peak	no	preferably no	yes	yes
Night	maybe	maybe	yes	yes
Road Geometry				
No. of Lanes in each direction	3	2	2	1
Median	yes	maybe	no	no
Pedestrian paths	no	maybe	yes	maybe
Mid-block Control of Access	yes	some	no	no
Pedestrian Crossing				
Grade Separated	yes	no	no	no
At-Grade Controlled	yes	yes	maybe	no

Table 7: Proposed Road Classification

Design Criteria	Primary	Secondary	Connector	Local
Number of lanes in each direction	3	2	2	1
Median width (metres)	2-.5	2-.5	None	None
Shoulder (metres)	3-1	2-0	None	None
Outer Separator (metres)	2-1.5	None	None	None
Footpahts (metres)	2	2	3	2
Pedestrian Crossing	Grade Sep/Signalized	Signalized	Preferably Sig.	Free

Table 8: Recommended Road Design Criteria

Lane Width	Through	Turning	Kerb
Maximum	3.7	3.5	5.5
Desirable	3.5	3.1	3.1-3.8
Minimum	3.1	2.4	3.1

Table 9: Lane Width Dimensions

Road Type	Design Speed (km/h)	Stopping sight distance (m)	Minimum safe overtaking distance (m)
Primary	90-70	130-90	350-240
Secondary	60-50	75-60	180-140
Connector	50-40	60-40	140
Local	40-20	40-20	N/A

Table 10: Speed and Sight Parameters

Source: Ogden & Bennett (1989)

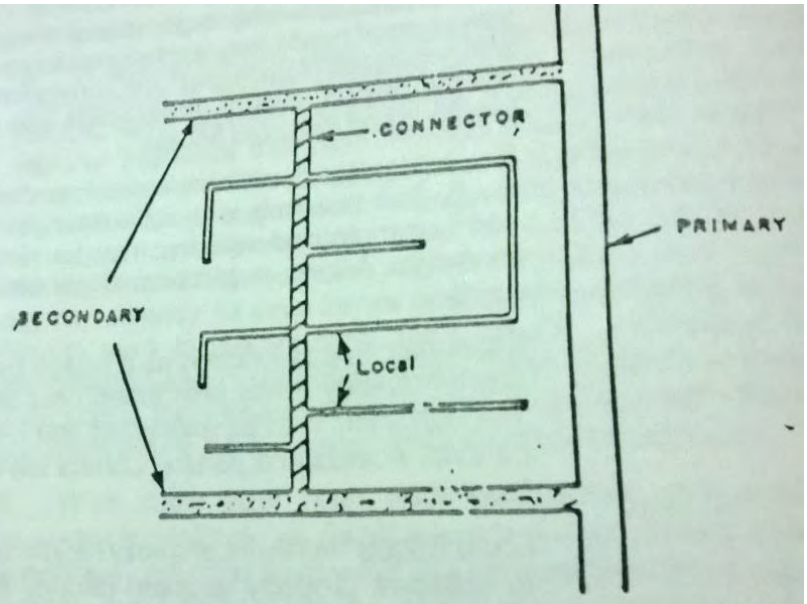


Figure 20: Road Classification Example

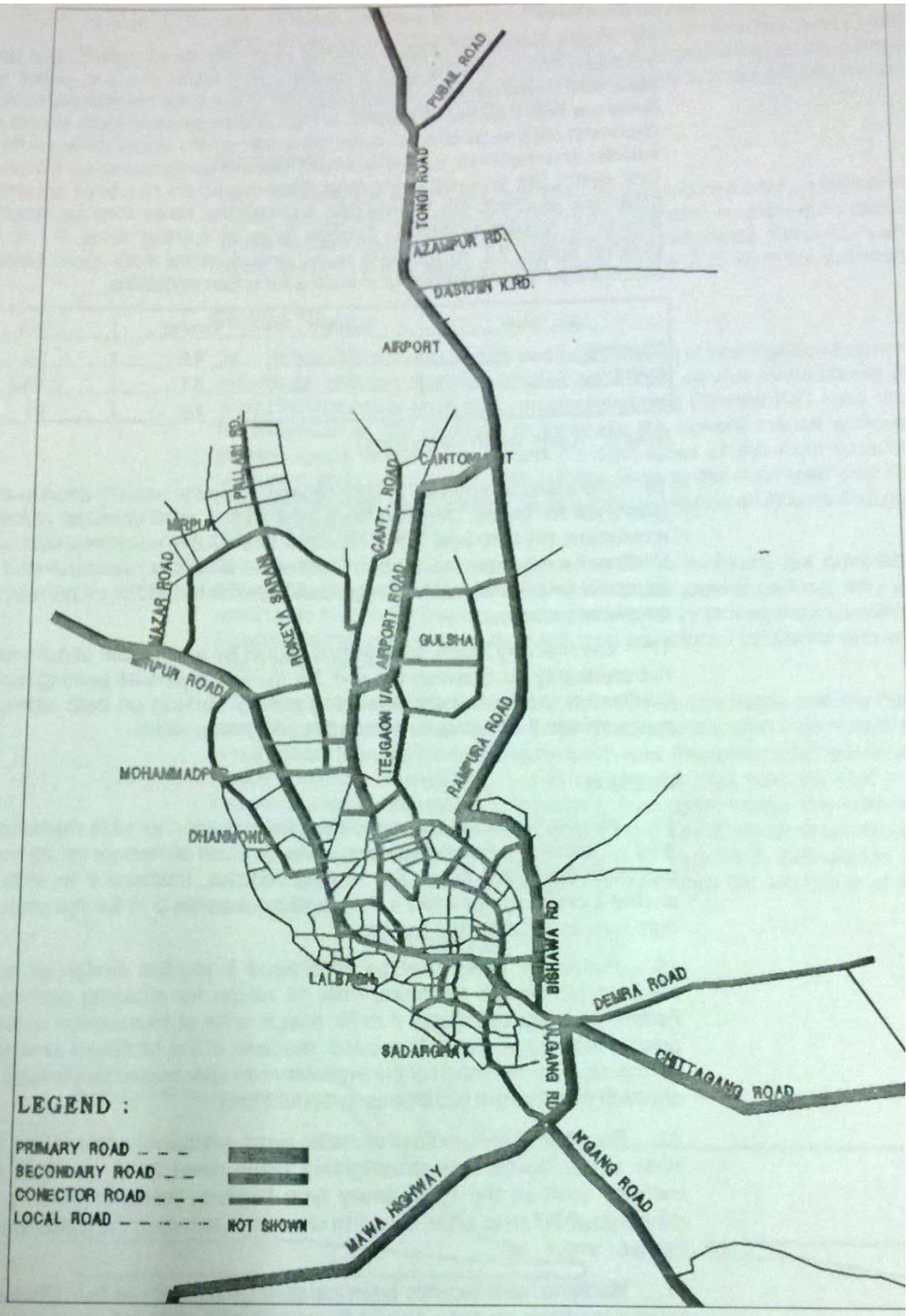


Figure 21: Suggested Dhaka Classified Road Network

Pollution under Control Certificate
[See Rule 7A]

It is hereby certified that vehicle No ..... of Mr. ..... of .... (address) emits the following gaseous substances as measured at two-thirds of the maximum rotating speed of the vehicle :-

Parameter	Unit	Limit of Standards	Measurement taken
Black Smoke	Hartridge Smoke Unit (HSU)	65	
Carbon Monoxide	gm/k.m. percent area	24 04	
Hydrocarbon	gm/k.m. ppm	02 180	
Oxides of Nitrogen	gm/k.m. ppm	02 600	

(2) The measurements so taken do not exceed the standards specified in Schedule-6.

(3) This Certificate shall remain valid till .....

Signature of Director
General/Authorized Officer
Seal
Department of Environment

[1] This form was inserted in the rules by gazette notification S.R.O.29-Law/2002 w.e.f. 28/2/2000.

SCHEDULE – 2

Standards for Air
[See Rule 12]

Density in microgram per cusec meter

Sl. No.	Categories of Area	Suspended Particulate Maters (SPM)	Sulphur-dioxide	Carbon Monoxide	Oxides Nitrogen
a.	Industrial and mixed	500	120	5000	100
b.	Commercial and mixed	400	100	5000	100
c.	Residential and rural	200	80	2000	80
d.	Sensitive	100	30	1000	30

Notes:

(1) At national level, sensitive area includes monuments, health center, hospital, archeological site, educational institution, and government designated areas (if any).

(2) Industrial units located in areas not designated as industrial areas shall not discharge pollutants which may contribute to exceeding the standard for air surrounding the areas specified at Sl. nos. c and d above.

(3) Suspended Particulate Matter means airborne particles of a diameter of 10 micron or less.

SCHEDULE – 6

Standards for Emission from Motor Vehicles
[See Rule 12]

Parameter	Unit	Standard Limit
Black Smoke	Hartridge Smoke Unit (HSU)	65
Carbon Monoxide	gm/k.m. percent area	24 04
Hydrocarbon	gm/k.m. ppm	02 180
Oxides of Nitrogen	gm/k.m. ppm	02 600

* As measured at two thirds of maximum rotating speed.

SCHEDULE – 7

Standards for Emission from Mechanized Vessels
[See Rule 12]

Parameter	Unit	Standard Limit
Black Smoke*	Hartridge Smoke Unit (HSU)	65

* As measured at two thirds of maximum rotating speed.

Only relevant forms and standards (schedule) from ECR, 97 are attached here.
Source: ECR, 1997

Detail work procedure (screenshots) at ArcGIS interface to build model

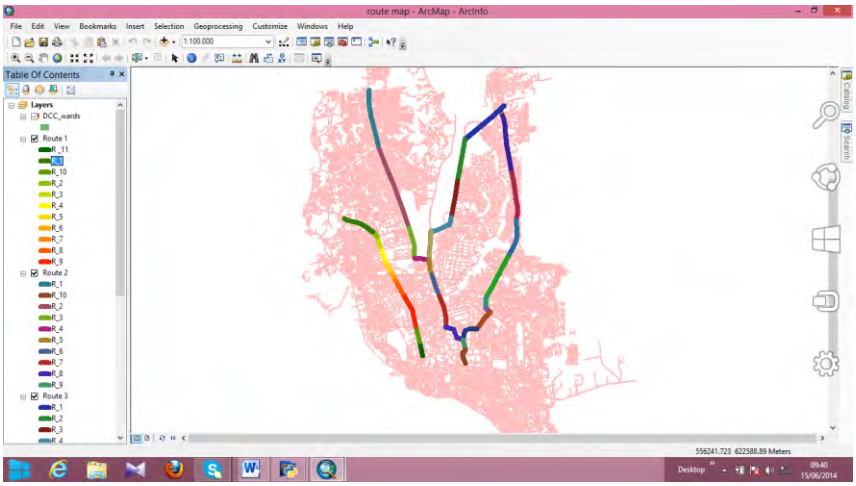


Figure 1: Link wise Shape files of four major study routes as layer in ArcGIS

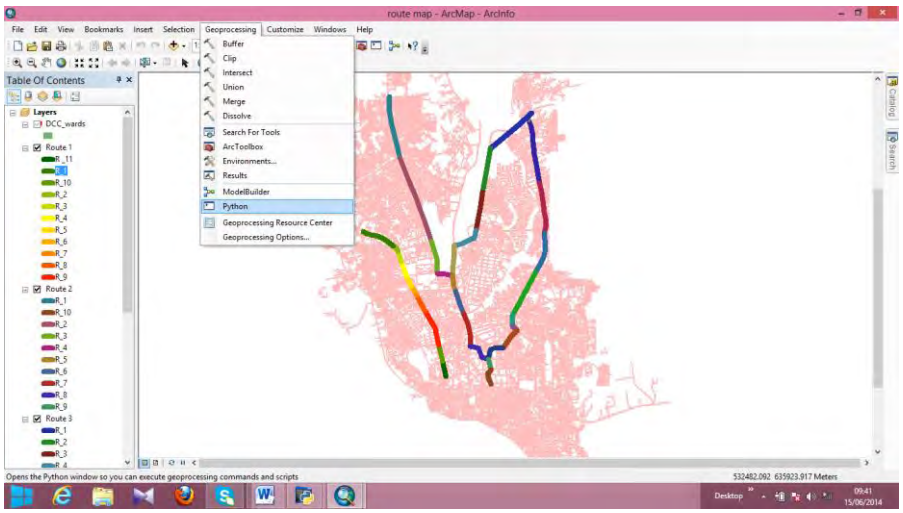


Figure 2: Using Geo processing option for coding through python

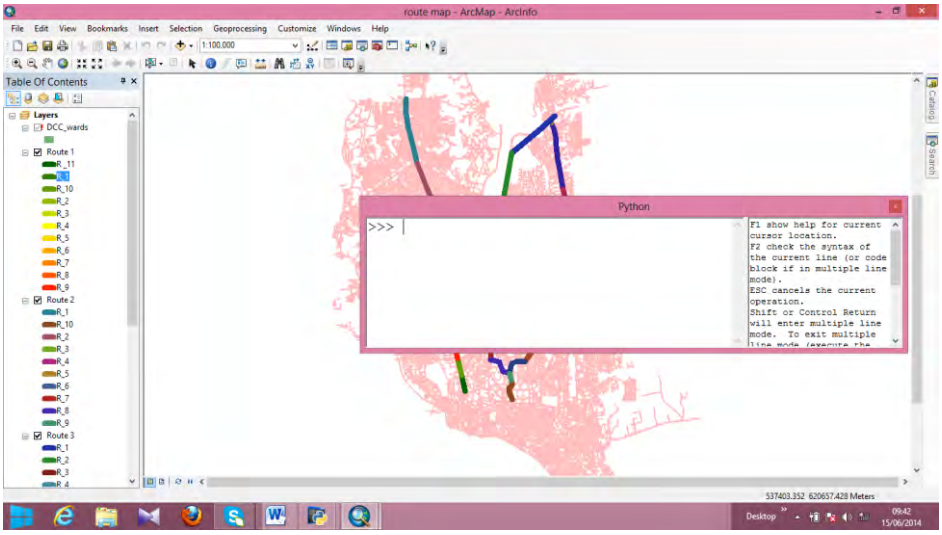


Figure 3: Space for writing code in python

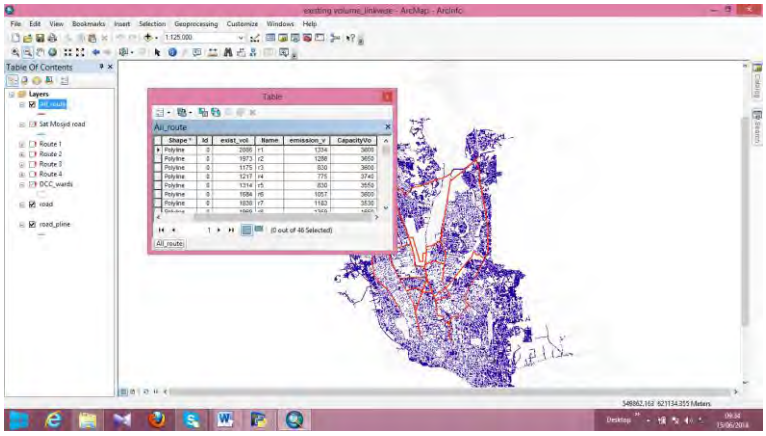
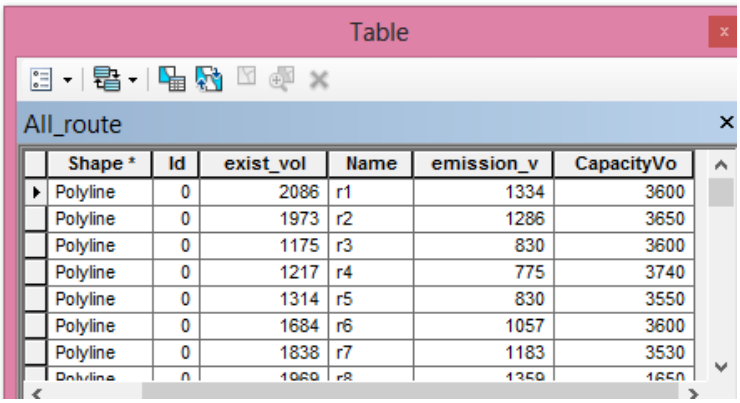


Figure 4: ArcGIS interface with attribute table dataset containing three variables

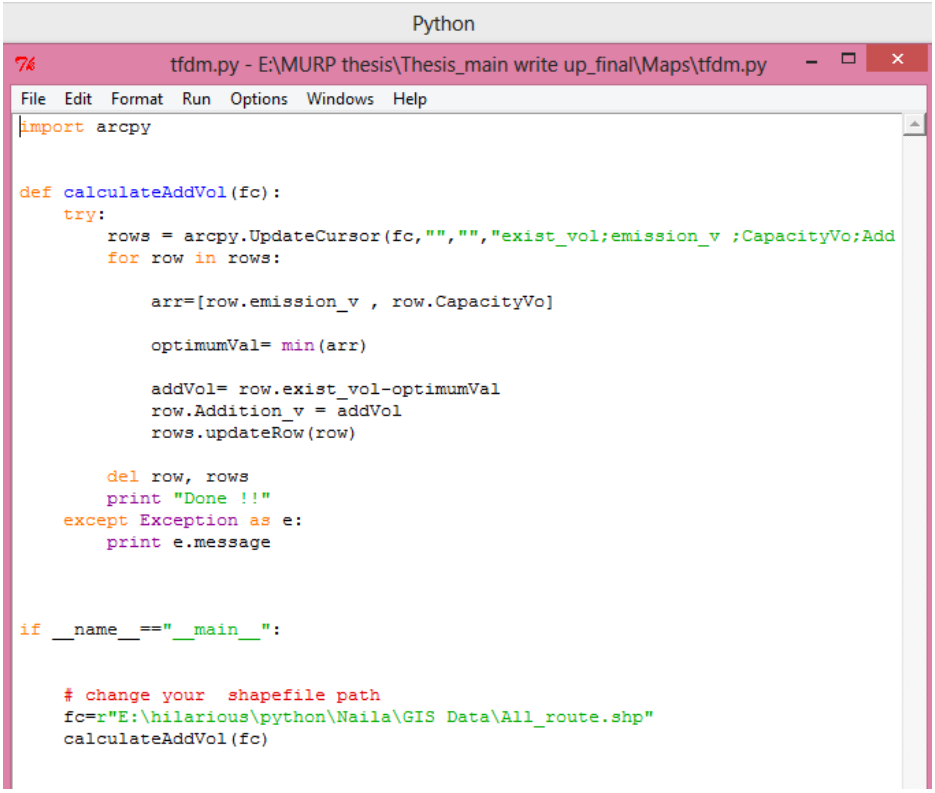


Table

All_route

Shape *	Id	exist_vol	Name	emission_v	CapacityVo
Polyline	0	2086	r1	1334	3600
Polyline	0	1973	r2	1286	3650
Polyline	0	1175	r3	830	3600
Polyline	0	1217	r4	775	3740
Polyline	0	1314	r5	830	3550
Polyline	0	1684	r6	1057	3600
Polyline	0	1838	r7	1183	3530
Polyline	0	1969	r8	1359	1650

Figure 5: Dataset of three variables as input in attribute table linked with GIS based layer



Python

tfdm.py - E:\MURP thesis\Thesis_main write up_final\Maps\tfdm.py

File Edit Format Run Options Windows Help

```
import arcpy


def calculateAddVol(fc):
    try:
        rows = arcpy.UpdateCursor(fc,"","","exist_vol;emission_v ;CapacityVo;Add
        for row in rows:

            arr=[row.emission_v , row.CapacityVo]

            optimumVal= min(arr)

            addVol= row.exist_vol-optimumVal
            row.Addition_v = addVol
            rows.updateRow(row)

        del row, rows
        print "Done !!"
    except Exception as e:
        print e.message


if __name__=="__main__":


    # change your  shapefile path
    fc=r"E:\hilarious\python\Naila\GIS Data\All_route.shp"
    calculateAddVol(fc)
```

Figure 6: Syntax / coding language used in python

Traffic volume along roads (both major study routes and alternative secondary roads) after trip assignment

Secondary Alternative Road	Existing volume (PCU/hr)	Optimum volume (PCU/hr)	Vacant space for additional vehicle (PCU/hr)	Vehicle added (PCU/hr)	Capacity exceeded (PCU/hr)
Sat Masjid Road	4470	6000	1530	1718	188
Panthapath	2949	5800	2851	468	0
Farmgate - Manikmia Avenue	3395	15000	11605	2855	0
Agargaon-PMO link Road	2708	4000	1292	0	0
New Eskaton Road	1474	7000	5526	604	0
Tongi Diversion Road	5181	7000	1819	4502	2683
Sayad Mahbub Moreshed Avenue (IDB-Shymoli)	432	5000	4568	930	0
Green Road	956	4000	3044	1333	0
Bijoy sharani- Tajgaon link road (Rangs Bhaban-Nabisco)	352	4000	3648	3337	0
Hatirjheel Link road	535	6000	5465	3919	0
Matikata road (infront of Pallabi Mirpur – Banani, Raddison) [Mirpur flyover]	422	5000	4578	340	0

Route 01			
Link number	**Additional/Polluting Volume (PCU/hr)**	**Traffic Volume Shifted (PCU/hr)**	**Additional Volume Remain (PCU/hr)**
R1	752	0	752
R2	687	639	48
R3	345	213	132
R4	442	463	0
R5	484	501	0
R6	627	601	26
R7	655	575	80
R8	610	287	323
R9	660	229	431
R10	1155	351	804
R11	1296	847	449
	7714	**4707**	**3044**

Route 02			
Link number	**Additional/Polluting Volume (PCU/hr)**	**Traffic Volume Shifted (PCU/hr)**	**Additional Volume Remain (PCU/hr)**
R1	560	139	421
R2	953	112	841
R3	898	654	244
R4	303	268	35
R5	498	626	0
R6	588	539	49
R7	671	604	67

R8	1169	833	336
R9	1199	691	508
R10	1846	336	1510
	8685	**4802**	**4010**
Route 03			
Link number	**Additional/Polluting Volume (PCU/hr)**	**Traffic Volume Shifted (PCU/hr)**	**Additional Volume Remain (PCU/hr)**
R1	561	0	561
R2	565	0	565
R3	546	228	319
R4	568	190	378
R5	578	358	221
	2817	**775**	**2042**
Route 04			
Link number	**Additional/Polluting Volume (PCU/hr)**	**Traffic Volume Shifted (PCU/hr)**	**Additional Volume Remain (PCU/hr)**
R1	540	0	540
R2	705	0	705
R3	945	0	945
R4	967	681	286
R5	966	584	382
R6	783	666	117
R7	897	462	435
R8	1080	785	296
R9	216	202	15
	7099	**3378**	**3720**

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