RATIONALIZING PUBLIC TRANSPORT: A EURO-ASIAN PERSPECTIVE

MAHER NIGER

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Specialization: Urban planning and management

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ABSTRACT

Public transport plays an important role in providing easy and affordable accessibility and mobility for dwellers in a city. Connecting people and goods from one point to the other, cities connectivity within and with other cities is directly relative to the economic, social and cultural success to its urban growth. The efficiency of the public transport infrastructure is higher in areas with a higher demand for such transportation, which in return is economically viable to its high investment. However when the demand exceeds the supply level (e.g. capacity) of this public transport infrastructure, they tend to reduce in their efficiency. This demand for transportation is brought about by the increased population of connecting nodes, cities, the rural-urban migration, and the scope for socio-economical facilities i.e. better opportunities for jobs, health facilities and educational scope etc. thus the economic viability of the people which leads to an increase in the usage of private vehicles. In an over densely populated city like Dhaka, rationalizing public transport is the only option to minimize the mismatch between demand and supply.

The main goal of this research is to study rationalization of public transport, particularly public transport system design (routes and their categorization) in Dhaka, Bangladesh, based on European public transport planning tradition and best practices. The study comprises of three consecutive phases. In the first phase the problem analysis is performed through literature review and study area inventory with respect to road network, existing bus routes, their hierarchy, bus stops, population data, terminal and organizations etc. The second phase studies public transportation planning theory and rationalization concept in public bus route network planning using the literature base and European best practices. A theoretical framework of rationalization is established, which is accordingly implemented in the context of the study area. Finally, a proposal regarding bus network improvement for Dhaka has been prepared based on EU experience in the rationalization of public transport and recommendations made on public transportation planning and policies.

As the study progresses, the findings suggests five main components are closely associated for rationalizing public transport; network, system planning, institutional framework, organization and finance. The framework is interdependent on components and sub-components: hierarchy, dedicated bus route, terminal location, service provision, special planning, demand analysis, infrastructure, public-private relationship, government role, fare structure, policies, service integration, subsidies and management of public transport; share the relative success and failure depending different level of performances of the components. For implementation of this framework in Dhaka, specific guiding objectives rules needs to be considered. Objectives includes; reduce congestion and delays on the transport network, develop an efficient public transport system, strengthen institutional policy and regulatory framework, prepare long-term urban transport plan with future growth forecast, service to future land-use planning for the capital area, and improve road safety and environment sustainability.

The findings of this research help planners and decision makers to optimize the investment in transport infrastructure. Furthermore it set an example on the investigation of theory and practice of rationalizing public transport.

Keywords: Rationalization, Public transport planning and policies, Transport network, Theoretical framework, Route hierarchy and mass rapid transit.

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ACRONYMS

BBS	:	Bangladesh Bureau of Statistics
BRT	:	Bus Rapid Transit
BRTA	:	Bangladesh Road Transportation Authority
BRTC	:	Bangladesh Road Transportation Corporation
CBD	:	Central Business District.
CNG	:	Compressed Natural Gas.
DCC	:	Dhaka City Corporation.
DITS	:	Dhaka Integrated Transport Study.
DMA	:	Dhaka Metropolitan Area.
DMDP	:	Dhaka Metropolitan Development Plan.
DUTP	:	Dhaka Urban Transport Project.
EBRD	:	European Bank of Reconstruction and Development.
GIS	:	Geographic Information System.
JBIC	:	Japan Bank for International Cooperation.
JICA	:	Japan International Cooperation Agency.
LRT	:	Light Rail Transit.
MRT	:	Mass Rapid Transit.
NMT	:	Non Motorized Transport.
PT	:	Public Transport.
RAJUK	:	Rajdhani Unnayan Kartipakha.
RHD	:	Roads and Highway Department.
SPZ	:	Specific Planning Zone.
STP	:	Strategic Transport Plan.
TAZ	:	Traffic Analysis Zone.
WB	:	World Bank.

1. INTRODUCTION

This chapter starts with a general introduction, background and justification of the research. It further continues with defining research problem, and research objective. Research questions are accordingly shown for each research objectives in the following sections. At the end of chapter, a conceptual framework structuring the ideas of the research will be explained.

1.1. General introduction

Mobility and accessibility provided by the transport system play a major role in influencing the location of social and economic activity and shaping the form and size of cities(Zuidgeest, 2005).Transportation is the backbone for the development of a city, both socially and economically (Murray & Davis, 1998; World Bank, 1996). Gwilliam (2002), argues that congestion slows down the economic growth. This is as a result of time lost in congestion which has an economic value (Banister, 2008). The efficiency of transportation network is fundamental to the connectivity of the social and physical functioning of the urban settlements, a precondition for economic prosperity and creation of a liveable city.

With the growth of the city footprint, travel distance to connect furthers destination point's increase causing a direct proportional expansion in the mobility network. As the city develops socially and economically, land prices in the city centre rises and higher density of land sharing results to congestion. The urban poor may become displaced and move to the city outskirts for settlement. The rich on the other hand, because of their quest for more space, also move much further away from the city centre. This introduces urban sprawl and makes the city size large introducing longer distances between activity places. With such long distances between activities, walking and cycling become unsuitable modes of transport. Without the provision of an efficient public transport, people tend to rely on the use of private automobile (Banister, 2008; Gwilliam, 2002). The use of private automobiles for individual mobility increases the carbon footprint apart from creating congestion on roads, has other environmental and economical detrimental effects. The provision of an efficient transportation system is thus needed to curb the continual increase in private automobile use and promote shared mobility fostering responsible citizenship.

1.2. Background of research

The evolution and growth of a city is much related to the transportation of its people between activity locations (Murray & Davis, 1998; Rodrigue, Comtois, & al, 2009). Transportation planning is therefore a critical element in the development of a city. A proficient transportation network forms the basis by which the economic development of a city evolves and the means of interaction in society flourishes. The inefficiency of such infrastructures therefore hinders the development and interaction of cities mobility.

Public Transport (PT) planning can be seen as an important component of transportation planning. Public transport is a collection of modes of transport which are available to the public irrespective of ownership (White, 2002), also called mass-transit in a city context. It can be provided by various types of modes; however, in most urban centres in developing cities, it is provided by a wide range of buses and minibuses. Public transport plays a crucial role in the overall success of a city's transportation system. It sustains

mobility of the working class unable to afford private vehicle, to those who can't have their own car, helps in creating and maintaining liveable communities with high density land use, relieves congestion, assures long term sustainability in terms of shared resource consumption and being responsive to the environment. It also provides large number of transport opportunities at once in order to meet the maximum demand during the peak hours. Studies have shown, in trying to control congestion on the roads, options like the integration of land use and transport, widening or construction of new roads have been effective. However, the provision of public transport has proven to be much efficient in controlling congestions and to have efficient public dispersion.

The efficiency of public transport infrastructure is much affected by the demand for major infrastructures. It is most efficient in areas with higher demand for such transportation, which in return is economically viable to its high investment. However when the demand exceeds the supply level (e.g. capacity) of those infrastructures, efficiency drops and safety on the road is compromised. This demand for transportation is brought about by the increased population of connecting nodes, cities, the rural-urban migration, and the scope for socio-economical facilities i.e. better opportunities for jobs, medical facility and educational scope etc. thus the economic viability of the people which leads to an increase in the usage of private vehicles.

Public transport system is a process evolving over time and is not always directly responsive to the changing demand vs. supply to achieve equilibrium overnight, like a private vehicle solution. Capital investment is simply too high for a mass transit network. Then the question arises as to how best to cope with increasing change in demand with the existing infrastructure public transport infrastructure. The public transport infrastructure investment is directly proportional to the possible economical turnover and the population serviced.

1.3. Justification

From the research background, it is quite clear that various factors such as population of a city; the rural-urban migration, the scope for socio-economic facilities etc. have come to realize the important role-play in finding sustainable solutions to solving this question with existing infrastructure for public transport. This increase in population and economy in a city leads to higher trip rates. Without proper spatial planning of the city in terms of land use distribution, this may lead to long travel times as well. With the increase in the economic status coupled with the lack of alternative transportation modes, private automobile ownership and trips may increase (M.G. Badami & Haider, 2007; Palmner, Astrop, & al., 1996; World Bank, 1996). The increase in private automobile use which typically has a lower occupancy rate may lead to an increase in congestion on the roads without the proper transportation infrastructures (Alterkawi, 2006; Beirão & SarsfieldCabral, 2007; Gwilliam, 2002; Martens, 2004).

Experiences in most countries show that construction of new roads or widening of roads only solves the problem of congestion for a while (Tiwari, 2002). It encourages the use of private vehicles which lead again to congestion and its associated side effects like air and noise pollution (Beirão & SarsfieldCabral, 2007). As a result of the financial constraints faced by many countries, especially the developing countries, an improved public transport system seems the most likely solution to controlling congestion on the roads as compared to investing in the construction of road infrastructures (Palmner, et al., 1996). This move to tell us that the provision of an efficient public transport is a more likely answer to curbing congestion in future plans of a city (Mackett, 2001; Newman & Kenworthy, 1999).

In a developing city like Dhaka, to invest more on infrastructure to meet the growing demand is often quite expensive rather an effort is needed to tackle the problem with innovative planning solutions and

rethinking the existing infrastructure. One way to solve this problem is rationalizing the existing public transport network structure. The concept of rationalization can be defined as a structured process to increase the effectiveness with a maximize use of existing resources. Rationalization in terms of road infrastructure or systems can be achieved in a various ways, by establishing hierarchy of routes, optimize bus-stop points with density distribution changes, proper integration of motorized and non motorized transport and providing policy framework etc. This study is concerned with the rationalization of public transport system (restructuring strategic route network) focusing on establishing hierarchy of routes, based on planning lessons from European best practice.

1.4. Research problem

With the growing urban population and the demand for mobility increasing, pressure is added to the limited infrastructural spine of cities in the developing world. It is reaching at the height of alarming condition of congestion and inadequate poor quality of resources these cities are depending on. Being major connection and mobility facilitator, the transport network is faced with growing challenges and problems than ever before. These problems are triggered by interrelated trends such as urban population growth and (rapid and unplanned) growth of cities (TranSafety, 1998). The inherent characteristics of developing countries like population density, low income and spatially separated land uses and lack of resources force these countries to depend on public transport, which can transport large numbers of people at low cost. Generally in less developed countries, more than three quarters of peak travel public transport are required for work trips (Ingram, 1998).

However, urban transportation systems are wilting under the pressure of ever growing demands on an inadequate road network (Santhakumar, 2003). This poses a problem for the future if infrastructure network planning is not done in a systematic way. With the increase in demand for reduced travel time on a growing number of vehicles the challenge posed is of planning well served road network and maximizing the existing route plans.

Government approaches to minimize traffic congestion include creation of a new link in a congested network, the provision of new infrastructure, augmenting the capacity of existing transport networks (Scott, Novak, & al, 2006), intelligent transport system, manipulating infrastructure demand and land use policies and regulations (Button & D. Hensher, 2001). This intervention are seen as one sided, giving inadequate attention transport network design (Vuchic, 2007).

With the growing population and economical limitations, the existing public transport capacities in most of the developing countries do not satisfy the demand. The quality of travel on public transport is poor, roads are badly maintained and managed and in most cases there is no hierarchy in the routes. Public transportation systems which face the particular challenge caused from the accumulation of rapid and uneven change with unfavourable inheritance from the past, potential for improving existing system by rationalizing systems. Dhaka, the capital city of Bangladesh is one of the most over-populated cities in the world. It houses about 14 million populations within 2,000 sq. km. land area (which means 7000 persons/sq. km). With a growth rate of about 8 percent per year, it is expected to be the seventh position in terms of population by 2015 (Nagari, 2001). Rapid population increase over the past decade has resulted in its transport services not being able to respond to the travel needs of its residents.

Demand has not been matched by sufficient investment in transport infrastructure, services and management. Traffic and public transport conditions in Dhaka have seriously deteriorated, characterized by traffic congestion and delays, inadequate traffic management, public transport crisis, unaffordable and inaccessible public transport for may people, high accident rates, and increasing air pollution problems

(DUTP, 1998). The crisis in public transport is largely the result of growing concentration of population and economic activities, and inadequate public transport systems. However, the projected population of the city is expected to be around 16 million by the year 2015 and around 24 million by 2021 (DDC, 1998; DDC., 1998); already alarming and will make the situation more critical if appropriate measures are not taken to tackle the increasing travel demand.

Further, the road hierarchy is poorly established and most new development is taking place without any coherent road system (DDC, 1998). This rapid population growth together with the limited space available for new transport infrastructure will further aggravate the heavy congestion in Dhaka. The existing road network in metropolitan Dhaka needs a planned restructuring to support an efficient public transport system. This restructuring should be based on standard and functional road classification system, which provides a hierarchy of roads, viz: Local streets, Collectors, Arterials, Access Controlled Freeways etc.

This research looks at rationalizing bus routes and upgrading bus transport services based on European public transport planning tradition and best practices. An efficient use of limited space is therefore critical for ensuring people's mobility, improving their quality of life, and boosting economic growth.

1.5. Research objectives and questions

1.5.1. Research objectives

The main objective of this research is to study rationalization of public transport, particularly public transport system design (routes and their categorization) in Dhaka, Bangladesh, based on European public transport planning tradition and best practices.

To aid in achieving this objective, several sub-objectives have been set:

1. To map and analyze public transport route structure and provision of public bus services with reference to travel demand in Dhaka
2. To derive the main spatial and non-spatial factors driving public transport problems in Dhaka.
3. To derive a public transport rationalization concept from European best practices and scientific knowledge that is applicable to cities such as Dhaka.
4. To apply the European rationalization concept of public transport system design (focusing on routes and their categorization) to Dhaka and draw planning and policy lessons.
5. To recommend on improving public transport system design.

1.5.2. Research questions

To help address these sub-objectives, the following questions have been asked. It is deemed that answering these questions is going to help in answering the main objective of this research.

Table 1-1: Research questions

Sub Objectives	Research Questions
1. To map and analyze public transport route structure and provision of public services with reference to travel demand in Dhaka.	1. What kind of route structures exists in the study area? 2. How did the system develop over time (planned development vs. organic development)? 3. What is the existing route hierarchy, if any? Can we identify major transport corridor? 4. How can we analyze and map current public transport travel demand?
2.To derive the main spatial and non-spatial factors driving public transport problems in Dhaka	1. What indicators are suitable to analyze and map the mismatch between demand and supply? 2. What are the main spatial factors and non spatial factors that influence public transport problem in Dhaka?
3. To derive a public transport rationalization concept from European best practices and scientific knowledge that is applicable to cities such as Dhaka.	1. What are the (formal and informal) European procedures for planning and designing PT systems, focusing on route design? 2. How is the concept of rationalization in PT design defined and executed? 3. What are the best practices of PT rationalization in European cities? 4. How would European transport planners rationalize PT systems in a developing city like Dhaka?
4. To apply the European rationalization concept of public transport system design (focusing on routes and their categorization) to Dhaka and draw planning and policy lessons.	1. What are the planning lessons to be drawn from European PT planners? 2. What are the policy lessons to be drawn from European PT planners? 3. Which lessons need to be operationalized/ adjusted for Dhaka? 4. How can the European rationalization concept be implemented for Dhaka?
5. To recommend on improving public transport system design.	1. What are the planning options to improve the PT system design? 2. What policy options can improve the quality of bus service in terms of routes, bus stops and capacity?

1.6. Conceptual framework

This conceptual framework is designed in three phases which are as follows:

1. To provide a general description of the city transport system, problem identification and demand analysis of the study area.
2. To develop and apply a public transportation theory and rationalization concept in public bus route network with the help of Literature and European best practice.
3. To draw planning lessons and recommendation on bus route hierarchy of study area.

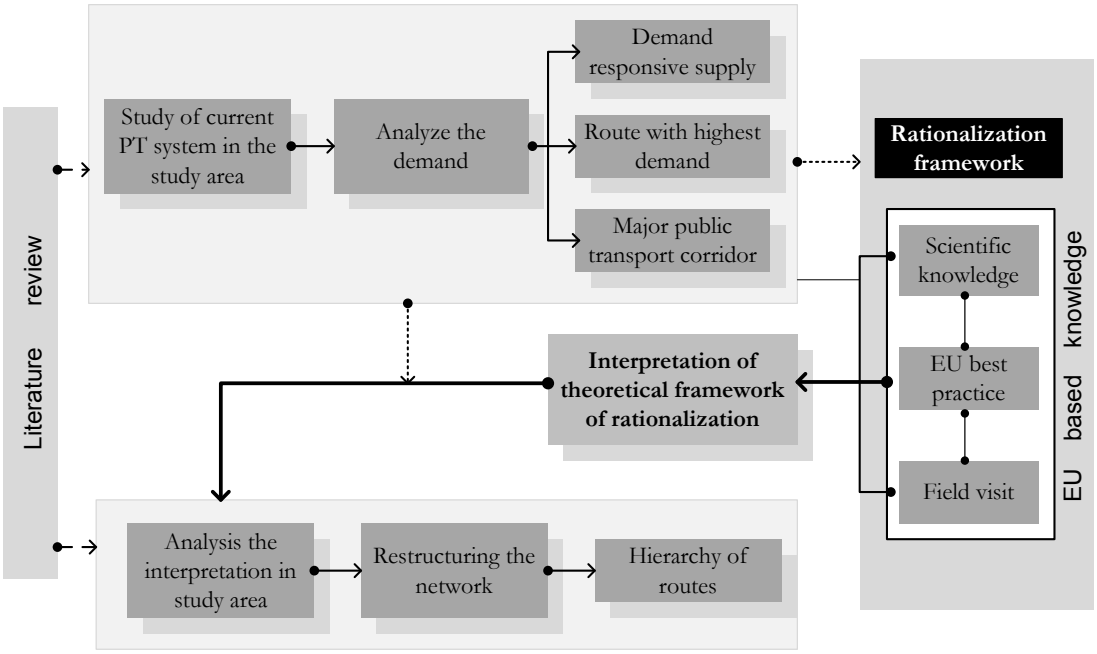

Figure 1-1: Conceptual framework

1.7. Thesis structure

The current research is composed of eight related chapters. Its structure has been organised as the figure below shows:

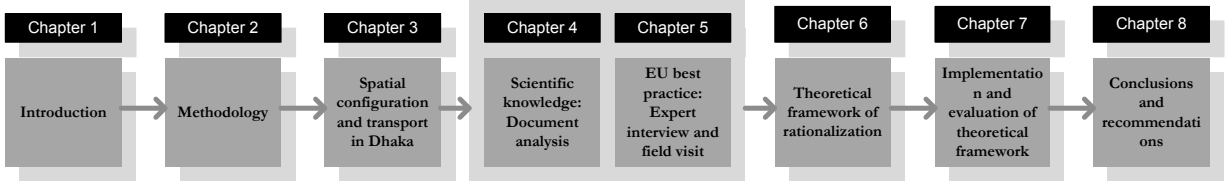

Figure 1-2: Thesis structure

Chapter 1: Introduction

This chapter starts by introducing a transportation bottleneck faced by most motorized cities, congestion. It then briefly outlines the background to the research problem. It defines the research problem, objectives, research questions and conceptual framework in order to achieve set objectives.

Chapter 2: Methodology
This chapter deals with the research methodology where the research process, research design, case study approach, data collection techniques and data processing and analysis are discussed.

Chapter 3: Spatial configuration and transport in Dhaka
Chapter highlights the concerns with Dhaka as the research area narrating an overview of the city, its land use, population and transportation system. Also a brief discussion on the existing situation of public transport challenges and its deficiencies is presented.

Chapter 4: Scientific knowledge: document analysis
This chapter provides a discussion on the importance of public transport planning and the problem faced. Development of sustainable urban transport in reducing congestions and related effects are also discussed. The provision of bus transportation system and its challenges are discussed.

Chapter 5: EU best practice: Expert interview and field visit
This chapter emphasises on experts interview and field visit. Public transport experts are consulted to provide opinions in rationalization of PT and also through field visit to find the example of successful public transport planning.

Chapter 6: Theoretical framework of rationalization
The focus of this chapter is to identify the theoretical framework of rationalization and its significance. The chapter concludes by developing the theoretical framework of rationalization by summarizing scientific knowledge and expert's opinion on successful transport planning.

Chapter 7: Implementation and evaluation of theoretical framework
This chapter describes the implementation of European rationalization concept of public transport design (focusing on routes and their categorization) to the research area Dhaka and finally concludes with the evaluation of few aspects of framework.

Chapter 8: Conclusion and recommendation
This chapter presents the findings and conclusions of research, and suggesting recommendations for future research direction.

2. METHODOLOGY

This chapter gives an overview of the methodological approaches in addressing the research questions of the study. The research design adapted to three phases of research and describes all relevant and required data, including the data sources and methods that are being used. First part elaborates methodological approaches to define rationalization framework of public transport. Second part gives some background on the fieldwork which is intended to capture planning practises in the EU and concluding the chapter to come up with a theoretical framework to rationalize public transport.

2.1. Research methodology

The research methodology employed in this thesis, outlines the steps used to answer the research questions as described in table 1-1. The research design of this study is shown in table 2-1. It presents the data that is required, the sources of data collection and methods applied.

The research has three consecutive phases. The first phase gives problem analysis in which the main problems present in the study area are discussed through literature review and study area inventory. The issues that are looked at are road network conditions, existing bus routes, bus stops, population data, terminals and organizational issues etc., which are linked to the potential travel demand in terms of population density, in order to check the demand responsiveness to supply. To derive the main spatial and non-spatial factors driving public transport problems in Dhaka city the demand/supply mismatch has been studied and reflected on. The main spatial factors like connectivity from north to south or east to west, terminal locations, demand oriented supply of PT etc. but also non-spatial factors like reasons for migration, unawareness of traffic laws, public awareness regarding public transport networks, proper demarcation or signing of all routes, inefficient authorities related to PT etc. have been listed based on literature, telephonic interviews and prior knowledge of the system. These factors complement the spatial analysis. Through analyzing and mapping of the study area, most of the factors (spatial and non-spatial) become visible which worked as a background for the theoretical framework development of the next phase. And also the identification of key public transport expertise which ultimately led to the development of theoretical framework of rationalization is accomplished.

PT systems should be planned in terms of bus routes, stops, capacity etc. but in the study area at hand, the PT planning is one of the oldest plans in South Asian region, which has naturally evolved over the past decades. To rationalize the existing PT routes, examples of cities that went through a rationalization process and concepts and notions of rationalization by PT planners in European cities are needed. So, phase two is to understand the PT theory and rationalization concept in relation to public bus route network with the help of literature and European best practice which is mainly the field work stage. Therefore, formal and informal knowledge is gathered through interview on European best practice and European scientific knowledge regarding PT rationalization. This is done to finally come up with a theoretical framework of rationalization which based on scientific literature, expert interview and visit to one of the example of successful PT practice.

In the final phase of the research, knowledge of PT planners and expert base scientific knowledge have been used to define a theoretical framework of rationalization of PT in the context of the study area. Accordingly a categorization of PT routes and hierarchy of the PT systems have been identified and a proposal regarding bus network improvement has been prepared based on EU experience in the rationalization of public transport. Finally, a proposal regarding bus network improvement has been prepared based on EU experience in the rationalization of public transport and recommendations on PT rationalization in PT planning and policies are given.

The general methods followed to achieve the objective are document analysis, interviews with public transport expertise and a visit to one of the PT planning example in the Netherlands, complemented with data collection, preparation and analysis for Dhaka.

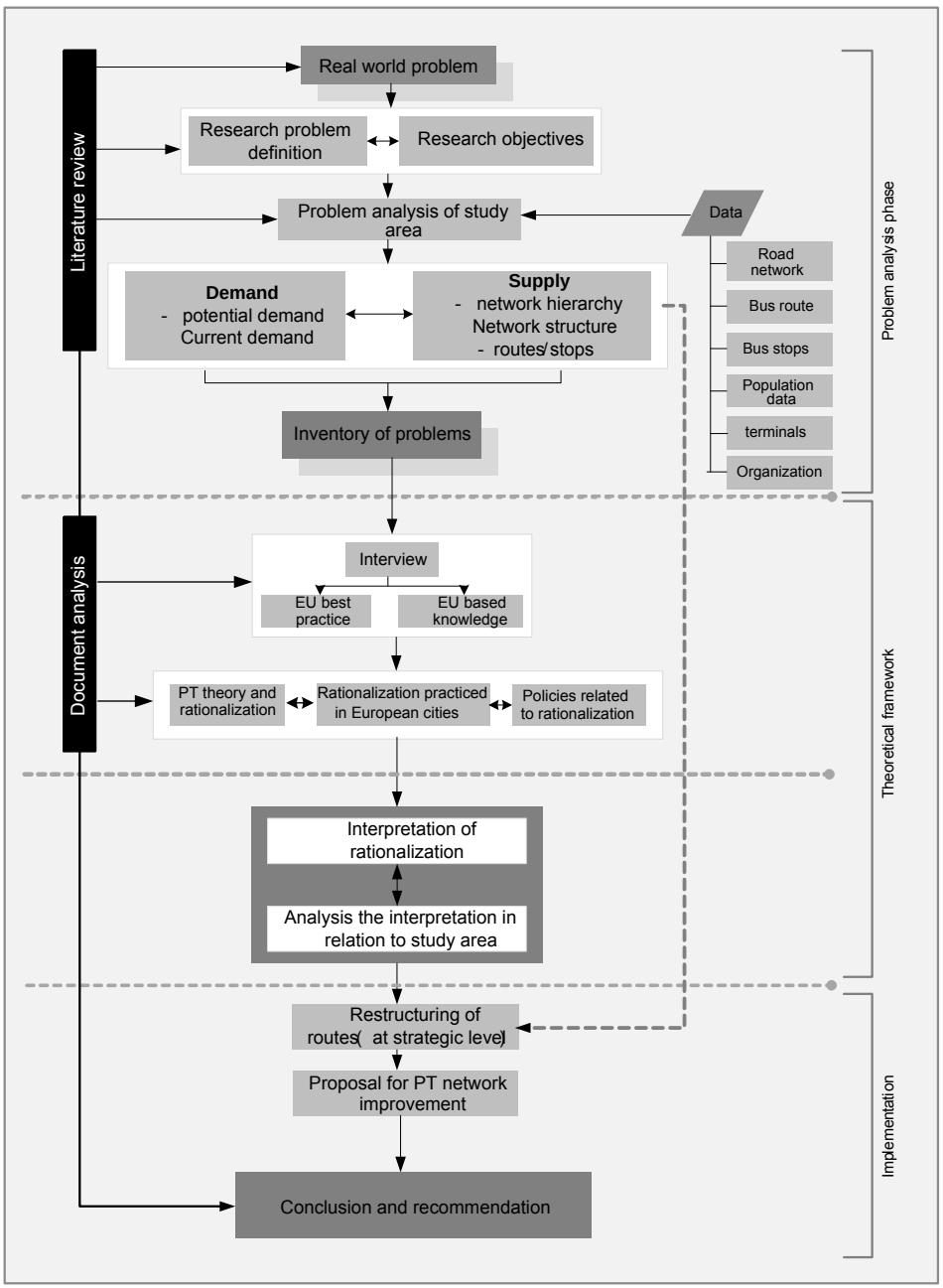

Figure 2-1: Research methodology

2.2. Research design matrix

The research matrix below indicates the required data, their sources and the tools needed to complete the various sub objectives of this research. These are done in achieving the main objective of the research.

Table 2-1: Research design matrix

	Research Questions	Data requirement	Method of data analysis
1.	What kind of route structures exists in the study area?	Relevant literature and bus route information	GIS analysis
	How did the system develop over time (planned development vs. organic development)?	Relevant literature	Literature review
	What is the existing route hierarchy, if any? Can we identify major transport corridor?	Relevant literature and transport data	Literature review and GIS analysis
	How can we analyze and map current public transport travel demand?	Land use and transport data	GIS analysis
2.	What indicators are suitable to analyze and map the mismatch between demand and supply?	Relevant literature and transport data	GIS analysis
	What are the main spatial factors and non spatial factors that influence public transport problem in Dhaka?	Relevant literature	Literature review and GIS analysis
3.	What are the (formal and informal) European procedures for planning and designing PT systems, focusing on route design?	Relevant literature and interview	Literature review
	How is the concept of rationalization in PT design defined and executed?	Relevant literature and interview	Literature review
	What are the best practices of PT rationalization in European cities?	Relevant literature and interview	Literature review
	How would European transport planners rationalize PT systems in a developing city like Dhaka?	Relevant literature and interview	Literature review
4.	What are the planning lessons to be drawn from European PT planners?	Relevant literature and interview	Literature review and GIS analysis
	What are the policy lessons to be drawn from European PT planners?	Relevant literature and interview	Literature review and GIS analysis
	Which lessons need to be operational zed/adjusted for Dhaka?	Relevant literature and interview	Literature review and GIS analysis
	How can the European rationalization concept be implemented for Dhaka?	Relevant literature and interview	Literature review and GIS analysis
5.	What are the planning options to improve the PT system design?	Relevant literature and interview	GIS analysis and discussion
	What policy options can improve the quality of bus service in terms of routes, bus stops and capacity?	Relevant literature and interview	GIS analysis and discussion

2.3. Primary data collection

The primary data collection is mainly dealt with capturing knowledge from established and planned cities in Europe regarding PT, meeting and discussion with public transport experts and scientific knowledge regarding planning and policies for implementation of rationalization concept in the study area.

This phase starts with documentary analysis through literature review of public transport planning and rationalization aspects, in order to identify the rationalization framework. An effort is done to find the gaps between scientific knowledge and practice, whether there is any gap in planning as well as policies and practice. Through interviews with public transport experts, discussion about existing PT scenario of study area and derived their opinions regarding rationalization of PT. Expert's interviews are mainly covered operational aspects, organizational aspects and policy aspects of PT planning.

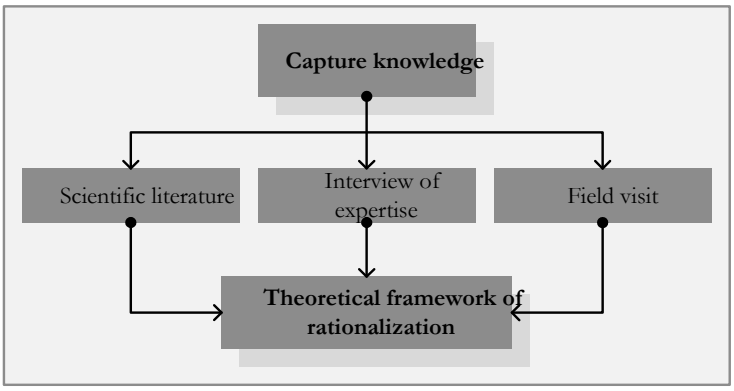

Figure 2-2: Field work framework

The first interview is taken with Mr. Pieter Onderwater, a public transport consultant working with DHV. The discussion is mainly from the operational point of view but there are also some discussions on policy guidelines. The next interview with Mr. Guido Bruggeman, a freelance public transport consultant who previously worked in EBRD (European bank of reconstruction and development) and now he mainly independently worked in different project of EBRD. He did several rationalization projects in Kaunus, Bulgaria and some other cities and most recently in Tajikistan. The discussion is mainly from the organizational point of view but there are also some guidelines on how to achieve an efficient network. The next interview is taken with Mr. Arjan Vermeulen, who is working with HTM, the public transport operator in The Hague, the Netherlands. This discussion is mainly from an operator point of view.

Figure 2-3: Field visit of Almere city (2010), courtesy Parveen Kumar.

Finally the field work finished with a visit of Almere city in the Netherlands which is mainly planned as a traffic leading city. First a presentation was given at the municipality followed by tour through the city centre.

The process is expected to be a loop, where documents lead to more literature, and literature provides more knowledge. Finally through the document analysis, interview and field visit, some lessons of planners' ideas and knowledge to interpretation of rationalization in a theoretical framework have been drawn.

2.4. Secondary data collection

The study is based on both primary and secondary sources of information. Primary data are collected through expert's interview and field visit. Interviews are conducted with key public transport experts, working in different institutions and organizations.

A list of secondary data sources is provided in table 2.1 below. Some of them are digital sources, where as others were hard copies. The bus routes are digitized. The extent of analysis is mainly at Dhaka city corporation (DCC) level.
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Table 2-2: Data set used

Data	Format
Dhaka city ward map	GIS
Metropolitan boundary	GIS
Existing transport network	GIS
Land use map	GIS
Bus route	Hard copy
Bus stops	Hard copy
Population census	Hard copy

2.5. Data processing

The primary and secondary are prepared for analysis. A general procedure is given in this section; however a more detailed procedure to what has done at each phase is given in chapter three and four.

2.5.1. Primary dataset

The information realised from documents, interviews with PT experts and field visit are mainly form the base to establish the theoretical framework of rationalization.

2.5.2. Secondary dataset

Reports, maps and power point presentations are used for references. A personal geo-database is created out of the entire individual transport layer. Also land use shape file, population data are added to relevant layer. The format for the transport network layer (existing road, existing rail) is a shape file in ArcGIS format. The transport network layer is cleaned to ensure that topology is maintained. More so some portions of the transport network layer (vector) is edited. Existing bus routes and bus stops are digitized from the hard copy.

Output from the framework establishing hierarchy of routes are analysed, first considering the existing transport infrastructure then doing same for the proposed backbone network.

2.6. Conclusion

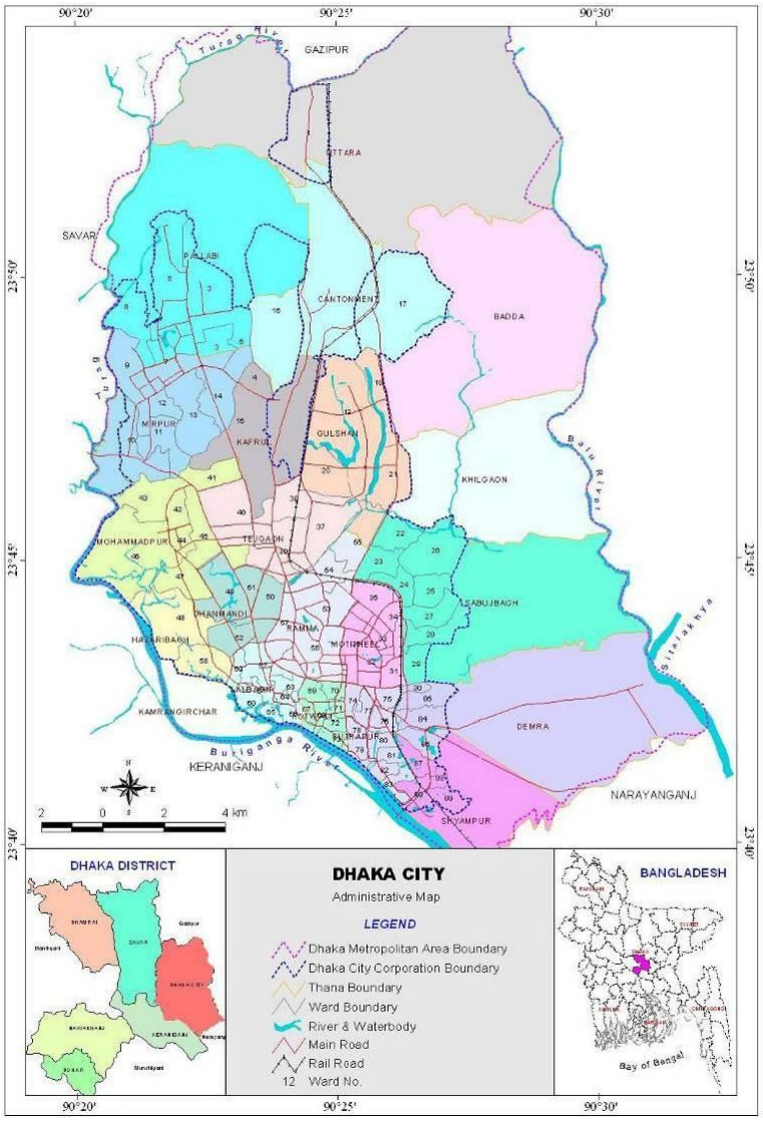
This chapter is complied with describing the thesis methodology. To rationalize public transport in the study area, here derived three phases of methodology to implement PT rationalization approach in study area. Firstly literature review for scientific knowledge of methodology approaches to achieve rationalization of public transport. Secondly it gives an explanation of fieldwork which is interview to experts to capture planning practises in EU and finally is to come up with a theoretical framework to rationalize public transport in the study area.

3. SPATIAL CONFIGURATION AND TRANSPORT IN DHAKA

3.1. Background of the study area: Dhaka city

Dhaka; (formerly known as Dacca, Decca and Jahangir Nagar, under Mughal rule), is the capital of Bangladesh and the principal city of Dhaka District. Dhaka is a mega city and one of the major cities of South Asia. Located on the bank of the Buriganga River, Dhaka, along with its metropolitan area, has a population of over 15 million, making it the largest city in Bangladesh (BBS, 2008). It is the 9th largest city in the world and also among the most densely populated cities in the world. Today it serves as one of the prime centres for culture, education and business in the region. Under Mughal rule in the 17th century, the city was known as Jahangir Nagar and was a provincial capital. The modern city, however, was developed chiefly under British rule in the 19th century, and became the second-largest city in Bengal after Calcutta (presently Kolkata). After the Partition of Bengal in 1905, Dhaka became the capital of the new province of Eastern Bengal and Assam but lost its status as a provincial capital again after the partition was annulled in 1911. After the partition of India in 1947, Dhaka became the administrative capital of East Pakistan, and later, in 1971, the capital of an independent Bangladesh. Historically, the development of Dhaka city started from the southern part, that is, the present "old town" (Pre-Mughal period), then the extension continued toward the west and the north (Mughal and British period). During Pakistan period, the development advanced primarily towards the north and it continued rapidly and in an unplanned way towards every side of the city. The changing pattern of Dhaka City and its population has given in annex 1.

Modern Dhaka is the centre of political, cultural and economic life in Bangladesh. Although its urban infrastructure is the most developed in the country, Dhaka suffers from urban problems such as pollution, congestion, and lack of adequate services due to the rising population. It is also experiencing an increasing influx of people from across the nation; this has made Dhaka the fastest growing city in the world (Wikipedia, 2010). The area of Dhaka mega city is 1,353 km2 of which DCC occupies 276 km2(BBS, 2001). It consists of eight principal thanas –Lalbagh, Kotwali, Sutrapur, Ramna, Motijheel, Paltan, Dhanmondi, Mohammadpur, Tejgaon – and 16 auxiliary thanas – Gulshan, Mirpur, Pallabi, Shah Ali, Turaag, Sabujbagh, Dhaka Cantonment, Demra, Hazaribagh, Shyampur, Badda, Kafrul, Kamrangir char, Khilgaon and Uttara. In total the city has 130 wards and 725 *mohallas*. Dhaka district has an area of 1463.60 square kilometers (565 sq mi); and is bounded by the districts of Gazipur, Tangail, Munshiganj, Rajbari, Narayanganj, Manikganj (Wikipedia, 2010).

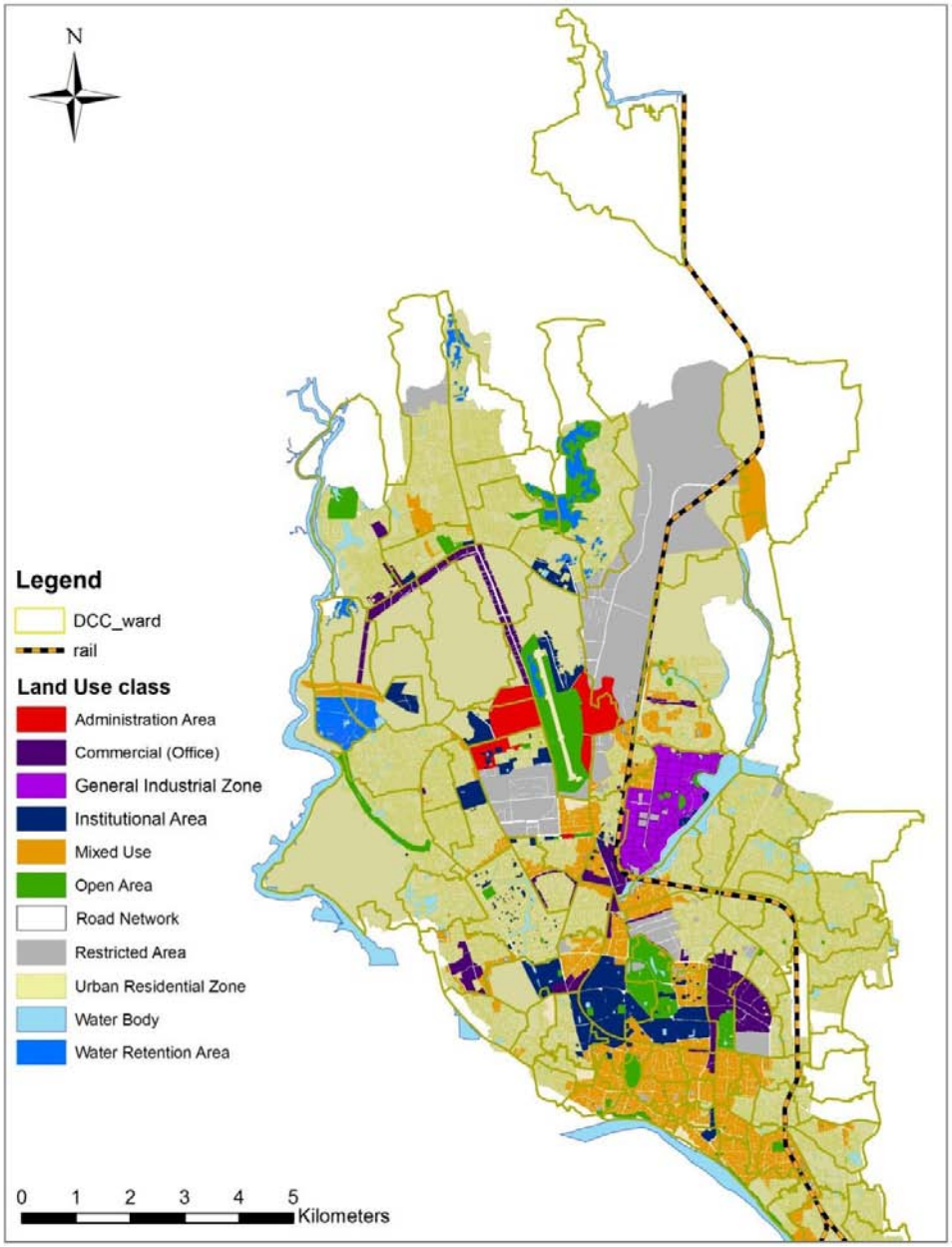


Map 3-1: Location and administrative unit of Dhaka city
Source: Dhaka City State of Environment, 2005

3.2. Land use pattern

Historically, the land use development of the city started from the old town and along the banks of the Buriganga River. Later it expanded towards the north, and the expansion is more or less continued in most of the city areas though the remarkable growth was observed after independence. In fact, after the liberation war, the physical feature of the main city has changed and covered by rapid development both by the government and private sectors. These include development of commercial, industrial, educational, health, communication and residential sectors. Most of the government and non-government administrative headquarters centres control regional, national and international business and trade, industries, housing have been formally and informally established within the DCC area.

The DCC area presently covers more than 25 percent of the total land area of the mega city (BCAS, 2005). Land area under different categories of use is reported differently in various sources. Presently, the city activities spread over approximately 40 km from north to south and 14 km from the east to the west (DCC, 2007).



Map 3-2: Land use of Dhaka city, 2000

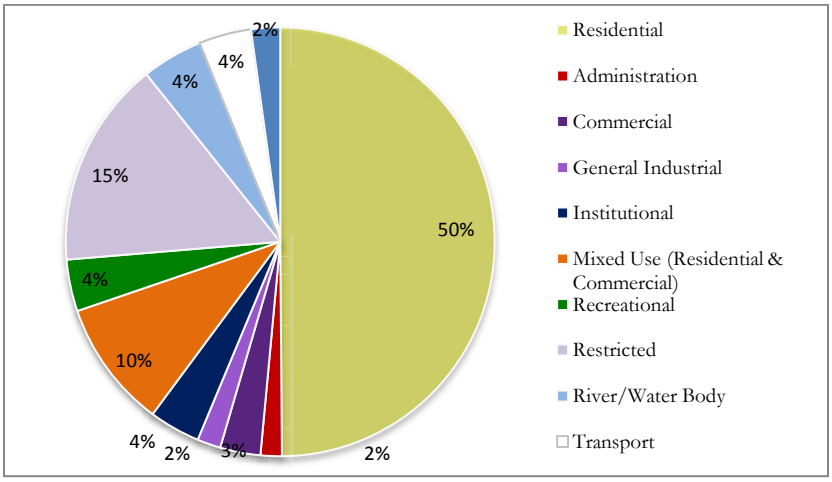


Figure 3-1: Land use distribution

3.3. Population growth trend and density

3.3.1. Population growth trends

Population size, growth by both migration and natural, has already made Dhaka a member of the world mega city family. According to UN Population Report 2007, among the largest 30 cities of the world, Dhaka ranked the 23rd, 20th, 14th and 9th position in the years of 1990, 1995, 2000 and 2005 respectively and expected to be the 4th largest city of the world with a population of 22.015 million by 2015 (UN Population Division, World Urbanization Prospects: The 2007 Revision).

Although Dhaka's area is less than 1% of the country's total land area, it supports about 10% of the total population and about 34% of the total urban population. After the independence of Bangladesh in 1971, the city's population increased rapidly and in 1974 it was about 1.31 million. Population of DCC increased along with the expansion of the city area as tabulated in Table 3-1 which indicates that population growth of DCC area in the period of 1974-1981 was very high with the annual growth rate of about 10.9%. In the following decade, the population growth rate dropped conspicuously. Evaluation of the population increase in the period of 1991-2001 shows an annual growth rate of 3.80% within the DCC boundary.

Table 3-1: Past population of Dhaka city

Census year	Population(Millions)	Annual population growth rate(%)
1961	0.36	-
1974	1.31	9.90
1981	2.82	10.93
1991	3.61	2.49
2001	5.38	3.80

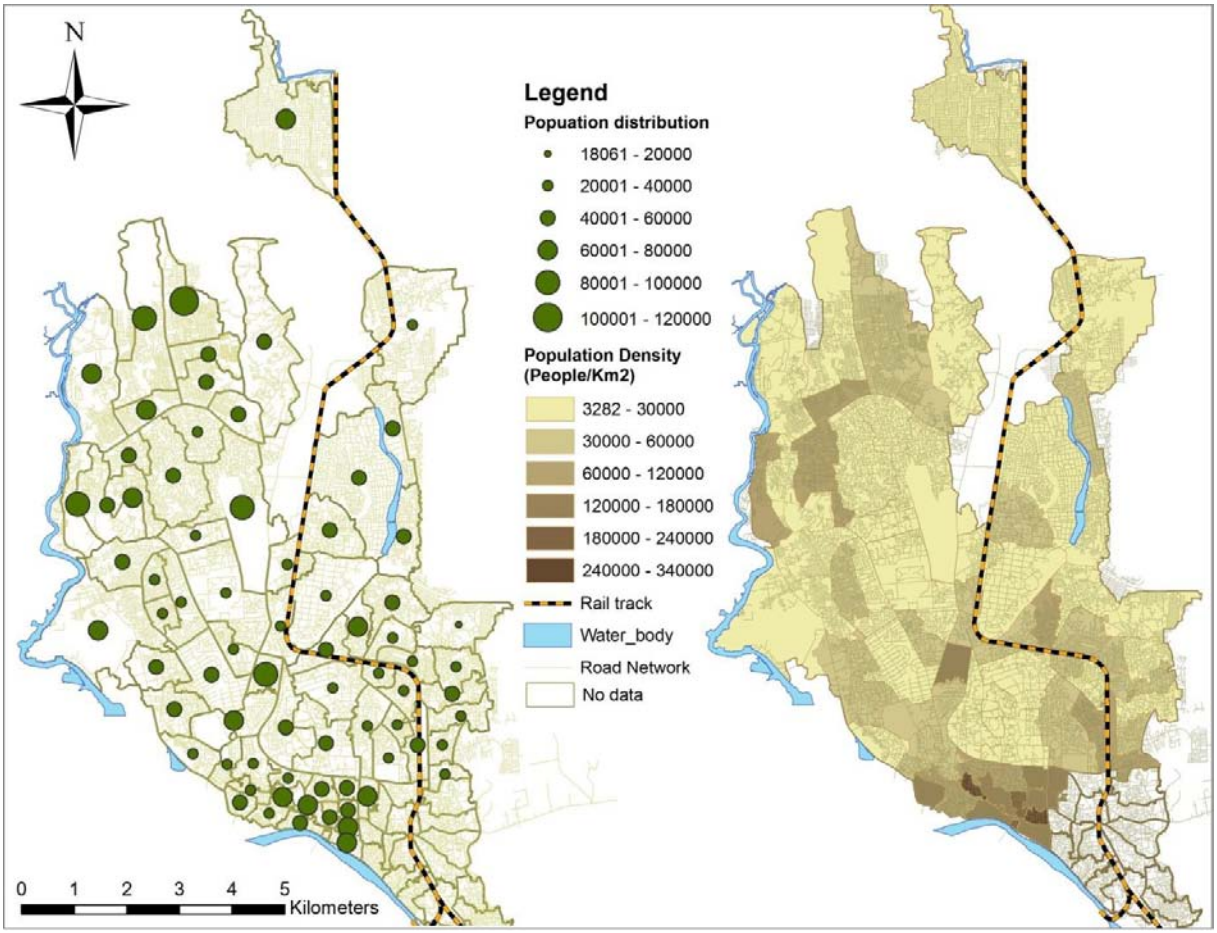
Source: BBS 1997 & 2001

3.3.2. Population density

Dhaka is the fastest growing mega-city in the world, with an estimated 300,000 to 400,000 new migrants, mostly poor, arriving to the city annually. Most migrants come from rural areas in search of opportunities which can provide new livelihood options for millions, translating to improvements in living standards.

Population density of Dhaka mega city was found to be around 5,000 persons/sq. km in 1991 while 7,900 persons/sq. km in 2001. In the year 2004, density is estimated at approximately 8,400 persons/sq. km. However, the population density of DCC area is much higher than that of the mega city area, as in 1991 it was approximately 16,300 persons/sq. km and in 2001 it was 19,500 persons/sq. km. The estimated population density of DCC in 2004 was 21,500 persons/sq. km. In some parts of old Dhaka, the density is even over 100,000 persons per square kilometre (BBS, 2001). With limited availability of flood-free land, further densification of population along with haphazard encroachment of peripheral land of Dhaka seems inevitable.

Increasing trend of population, area and density of Dhaka mega city in different years and population of different thanas of DCC from 1981 to 2001 including old and new thanas are given in Annex 2.



Map 3-3: Population distribution and density of Dhaka city.

Table 3-2: Population density of Dhaka city.

Census year	Dhaka mega city (person/km^2)	DCC (person/km^2)
1991	5,059	16,255
2001	7,918	19,485
2004	8,352	21,521

Source: BBS 1997 & 2001

3.4. Transport in Dhaka city

3.4.1. Overview

Being the administrative, commercial & cultural capital of Bangladesh, the Mega City Dhaka has a major role to play in the socioeconomic development of the country and in the era of regional and sub-regional cooperation. But the existing transportation system is a major bottleneck for the development of the city. Unplanned urbanization, especially poor transportation planning and lower land utilization efficiency, has turned the city into a dangerous urban jungle (M. S. Rahman, 2008) The rapid rise in population along with increased and versatile urban land use patterns has generated considerable travel demand as well as numerous transport problems in Dhaka City. It has resulted in a deterioration of accessibility, level of service, safety, comfort, operational efficiency and urban environment. The population of the Dhaka metropolitan area is expected to reach 36 million by 2024. This additional population will add new

dimensions to the urban fabric of Dhaka in the coming decades. To maintain the economic viability of this City and to keep its environment sustainable, an efficient transportation system is imperative.

The transportation system of Dhaka is predominantly road based and non-motorized transportation (mainly rickshaws) has a substantial share. Although a 37-km long rail-road passes through the heart of the city but it has no contribution to city's transport system. There is a limited use of waterways, especially for freight movements. The existing transportation infrastructure in Dhaka could not bear the current traffic loads. The level of service and options of transport modes are not at all convenient for the passengers and either for the environment (Karim, 1998). Dhaka's transport environment is characterized by mixed-modes transports using the same road space, traffic congestion, delays, mismanagement, conflict of jurisdictions, poor coordination among organizations and increasing environmental problems.

3.4.2. Road network

Established on the banks of the river Buriganga, Dhaka has been increasing in north-south direction. With the expansion of the city, the road network of the city has also been growing time to time. The major roads in the old part of Dhaka have been developed in the east-west direction and major roads in the new part have been developed in the north south direction. The road network of the city had never been planned specifically in cognizance with the well-developed process of trip generation, trip distribution, modal split and route assignment. As a result, an irregular pattern of network, rather than a more efficient pattern such as gridiron or redial-circumferential pattern, has been developed(Ahsan, 1990).

Dhaka's road network is nearly 3000 km (STP, 2004), of which 200 km primary roads, 110 km secondary roads, 50 km feeder roads and rest 2640 km narrow roads, with few alternatives and connector roads and it represents the proportion of road surface to built-up area hardly 7% as against 25% recommended for a good city planning (Quium, 1995). With the exception of some well-planned residential areas, in most of the areas the road network is quite narrow and alignment is poor. Widths of streets, within the old part of Dhaka are narrower than other newly developed parts. There are only a few pedestrian overpass and underpass. At present two flyovers are finished and some others are proposed for construction.

The existing road network in metropolitan Dhaka needs a planned restructuring to support an efficient transport system. This restructuring should be based on standard and functional road classification system, which provides a hierarchy of roads.

3.4.3. Road transport modes

Metropolitan Dhaka has traditionally been served by a wide variety of transport modes. These modes can be broadly classified into two groups, motorized transport (viz. bus, mini-bus, truck, car, auto-rickshaw, auto-tempo, motorcycle etc.) and non-motorized transports (viz. rickshaw, rickshaw van, bicycle, push cart etc.)

Motorized Transport: Estimation from the data provided by 'Statistical Year Book of Bangladesh' reveals that the motor vehicle fleet in Bangladesh is growing as an average rate of 7% per year. But DUTP-II (1998) claims that the vehicle population on road is growing as an average rate of 10% annually.

Non-Motorized Transport*:* Reliable estimate of non-motorized vehicle fleet is more difficult to obtain. DCC limits the number of license issued to rickshaw owners to some 70,000. However, unofficial estimates claim that the number of rickshaws plying in Dhaka city is three times the DCC figure(DUTP-II, 1998).

3.4.4. Terminals

A terminal station is a central location and important traffic generating mode from where buses may originate, terminate or stop over en route to sub serve the over all route network in a given catchments area. It provides passenger amenities and also provides passenger information regarding services. It is an important traffic junction which is a focal point for smooth running of services.

Dhaka is served by three inter-city bus terminals and four BRTC bus depots exist where the terminals are conveniently located with respect to the corridors they serve: Saidabad- Southern Corridor, Mohakhali-Northern Corridor, Gabtoli North-Western Corridor. City Corporation owns the terminals of Dhaka city. While terminals should be the place for passenger boarding and alighting, driver's refreshment and passenger waiting facilities, in Dhaka the main function of the terminal can be described as rather bus depot. Most of the privately owned buses take shelter in the terminals during idle time and as such it remains overcrowded by the idle bus drivers, helpers and union members. All these along with the poor supervision and maintenance practice have made the terminal area as most unwelcome place for the passengers and on duty drivers.

3.5. Existing bus system of Dhaka city

3.5.1. Overview

Existing mass transit system in metropolitan Dhaka is mainly characterized by large bus, mini bus and human hauler/auto-tempo. Bus and minibus routes tend to be concentrated along the limited number of arterial roads, in a generally north-south orientation. Human hauler routes are more dispersed, penetrating narrower roads, and include more east-west linkage.

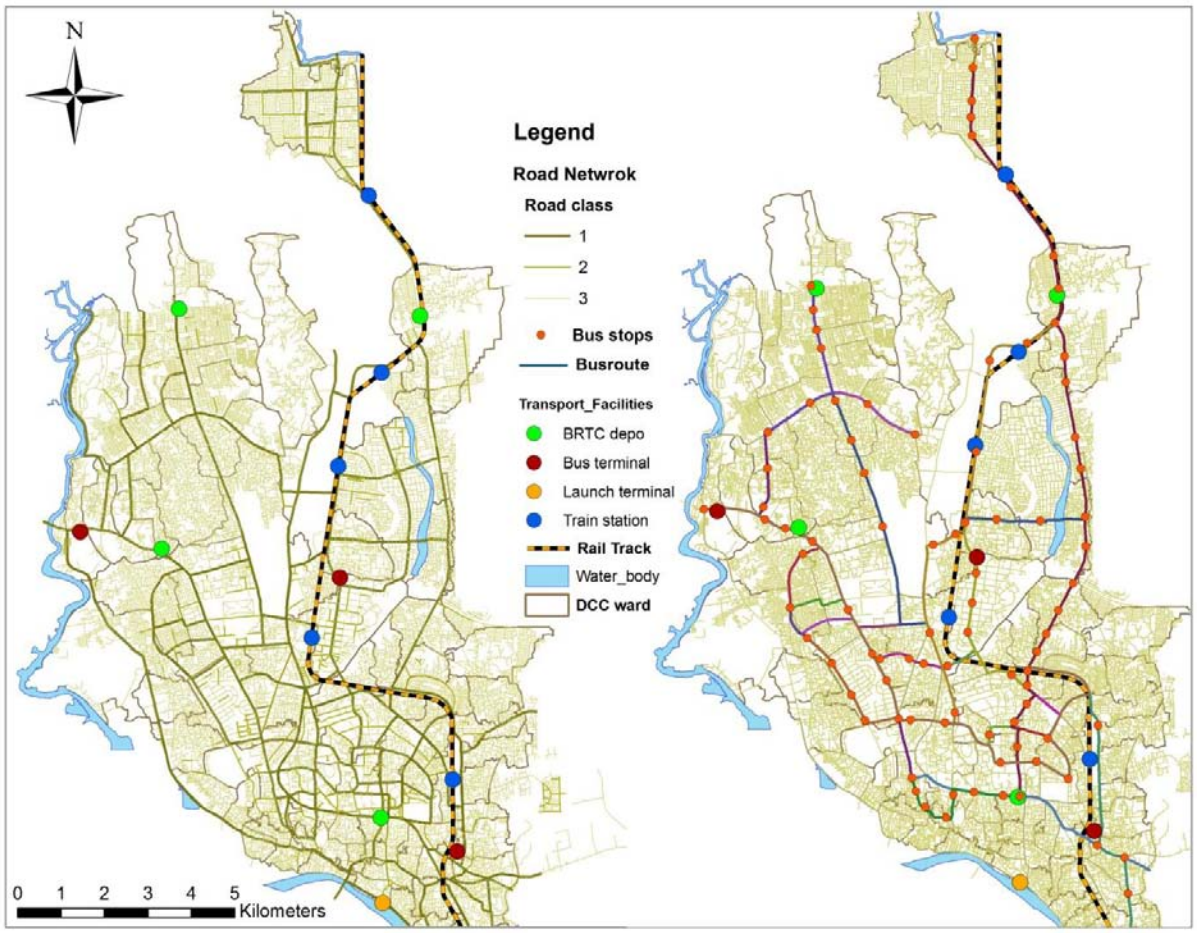
The 2004 Dhaka STP divides buses into several categories: minibuses (41%), microbuses (30%), large buses (13%), auto tempo/laguna maxi (12%), and staff and school buses (4%).

Residents of Dhaka understand the bus system as divided mainly into ticket buses and local buses. Ticket buses have set stoppages on their routes, which can be located by the companies' respective ticket counters. Their fares are collected on the curb side from ticket sellers associated with each private company, and have a single conductor on board who checks tickets at the doorway. Almost all of the large buses are ticket buses. Local buses have stoppages that are unmarked and have on-board fare collection. Local buses can also be boarded and alighted from at any point on the route, at the conductor's discretion. There are a handful of large buses that operate as local buses, but the vast majority of local buses are minibuses.

Buses in Dhaka city are operated both in private and public ways. The private sector is dominating and provides a monopoly service (95% of total bus services) compared to public sector operation. The present bus services provide inefficient, unproductive, and unsafe level of services. Long waiting, delay on plying, overloading, discomfort, and long walking distance from the residence/work place to bus stoppages are some of the obvious problems that confront the users in their daily life.

Today's bus operation in Dhaka is characterized with the existence of 750 individual bus owners. Dhaka city has only around 2500 buses as public transport whilst the current demand is more than 5,000. However, only 1,300 of the existing buses are playing of which less than 200 are of improved quality (G. Rahman, Majumder, & Rana, 1999). Public transport of the city is poor and disorganized with limited coverage (DMDP, 1995). The present mass transit mode in the form of bus transport has not been able to be popular and grow its share of catering demand. The poor institutional and regulatory framework,

reluctance to enforce existing legislation, and lack of enforcement reduce the capacity of existing roads (DMDP, 1995).



Map 3-4: Road network and existing bus route and bus stops of Dhaka city

3.5.2. Bus stop and route location

Though the bus route lists of Bangladesh Road Transport Authority (BRTA) shows a total of 34 routes in Dhaka City, including the sub-routes of different main routes it becomes 46 in total of which 13 routes are not presently in operation (Amin, Rahman, Uddin, & Maniruzzaman, 2005; BRTA, 2002). Majority of the routes are in north–south direction.

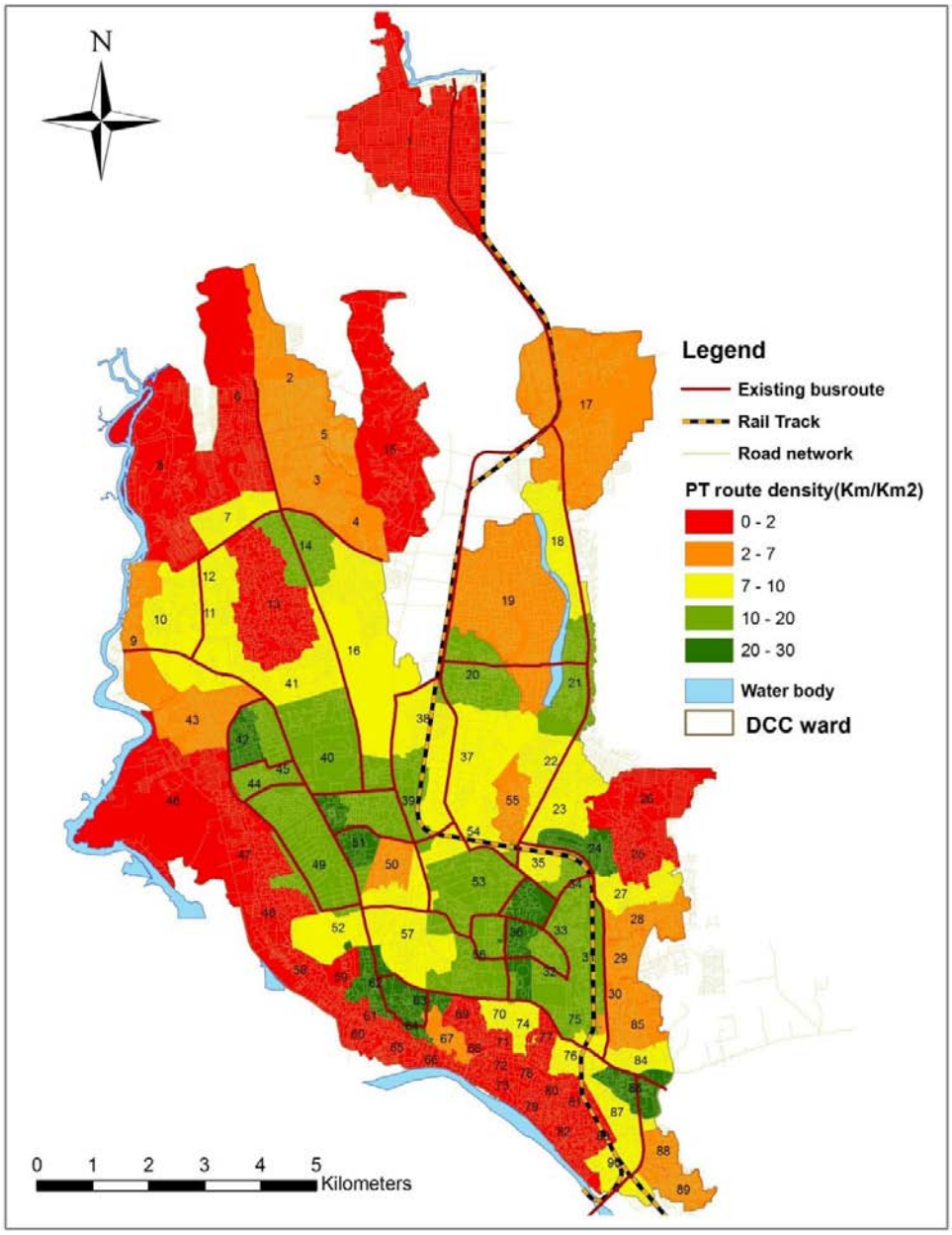
Normally bus stops are attributes of transport services which are designated place where a public transport bus stops for the purpose of allowing passengers to board or leave a bus. Most passengers walk to reach bus stops, and 500 meter is considered a convenient walking distance for human beings (Untermann, 1984). A study on bus routes and stoppages (Amin, et al., 2005) found majority of the bus riders in Dhaka city use a particular bus services for the cheaper fare and walk to or from the bus stop. The study also found that the majority of the stops are not located within a comfortable walking distance. Most of the users have to walk for 15-20 minutes or 1-1.5 km and wait for a period of 20-30 minutes for a bus. Bus/other transit stoppages and the city bus terminals suffer from poor operation and management. Most of the stoppages are in bad condition, e.g., unauthorized use, blocked by parked vehicle and roadside activities and water logging in rainy season. The basic elements of a stoppage such as proper shelter, route information, schedule information and passenger waiting facilities are missing in most of the stoppages.

Buses and other Para-transit vehicles most often stand at a place away from the designated bus stoppage. This creates problem of reduction in effective road width and lack of safety and comfort for transit users.

3.5.3. Spatial analysis of existing bus route structure

PT (bus) route density

One parameter which is used to represent the coverage/distribution of bus service is route density, which shows the number of bus lines between origins and destinations. PT route density is the quantity of bus route lengths divided by their whole service area of the particular road. The denser the bus line is distributed, the more people are expected to choose travelling by bus. Also the denser the route density the shorter the walking distance. Low network density results in the small coverage of routes. According to "Code for Transport Planning on Urban Road" (GB50220-95, 1995), the network density of bus routes planned in urban central area should be a value in the range from 3 km/km2 to 4km/km2



Map 3-5: PT route density per ward in Dhaka city

As shown in the map 3-5, the spatial distribution of bus service is concentrated in central area. The bus lines are dense in central area than peripheral areas. It shows that people of peripheral area have to walk relatively long to reach bus route. From map 3-5 it's also clearly shown that the older part of Dhaka and North western (Mirpur) part, Western suburbs and smaller part of eastern suburb where now new residential area developed, which already mentioned in the analysis of major hotspots are not served by the existing PT system. Here as PT system only include the existing bus system.

Proximity to bus stops

Proximity is an accessibility measure which shows the spatial extent of the service. It measures the closeness of the service to either origins or destinations of people. Proximity of people to the service can be measured using simple buffer analysis based on airline distance. However, this has a limitation that buffering considers only direct path but in reality people walk along road and footpaths to get service at stops. The service area of the bus stops is determined using the network analysis by computing the walking time to bus stops.

However, some assumptions are made to make this analysis is possible. It is assumed that the population is uniformly distributed in the service zones and the walking speed in Dhaka city is assumed to be 4 km/hr. This assumption is based from other studies done earlier.

By computing the service area of each bus stop using the network analyst, the total area within each proximity zone of walking time is determined. Based on proximity analysis results table 3-3 and figure 3-2, about 37% of the total area is covered within 10 minutes walking time to the bus stop. This means, assuming the average walking speed of 4 km per hour, this proportion is covered within a distance close to 500 meters. And rest 63% area are not covered by existing bus stops as mentioned threshold (500 meters). This result clearly mentioned that by the existing bus route 63% of the areas of DCC are not served by the existing bus route and stops.

Table 3-3: Area coverage by proximity to bus stops

Walk time to bus stops(minutes)	Area(%)	Population(%)
0 - 5	11.19	15.19
5 - 10	25.83	20.91
10 - 15	21.99	21.88
15 – 20	17.22	21.53
20 - 30	23.77	14.49

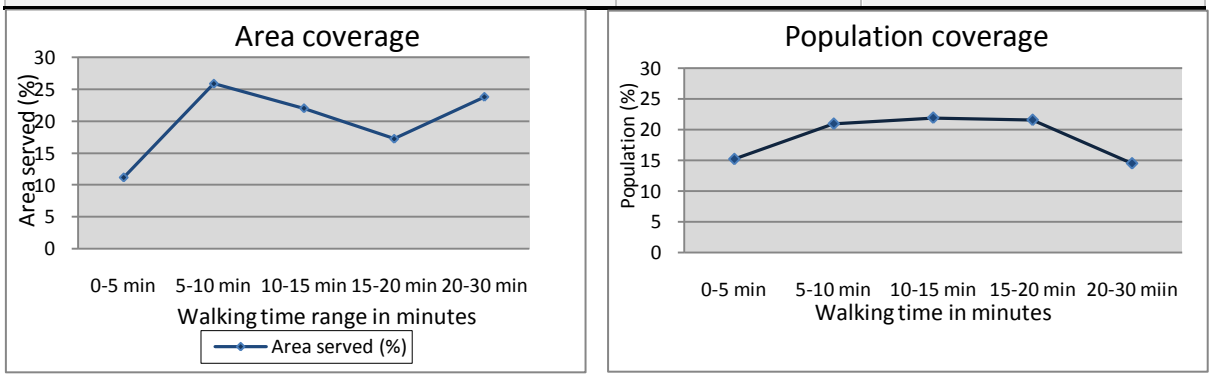
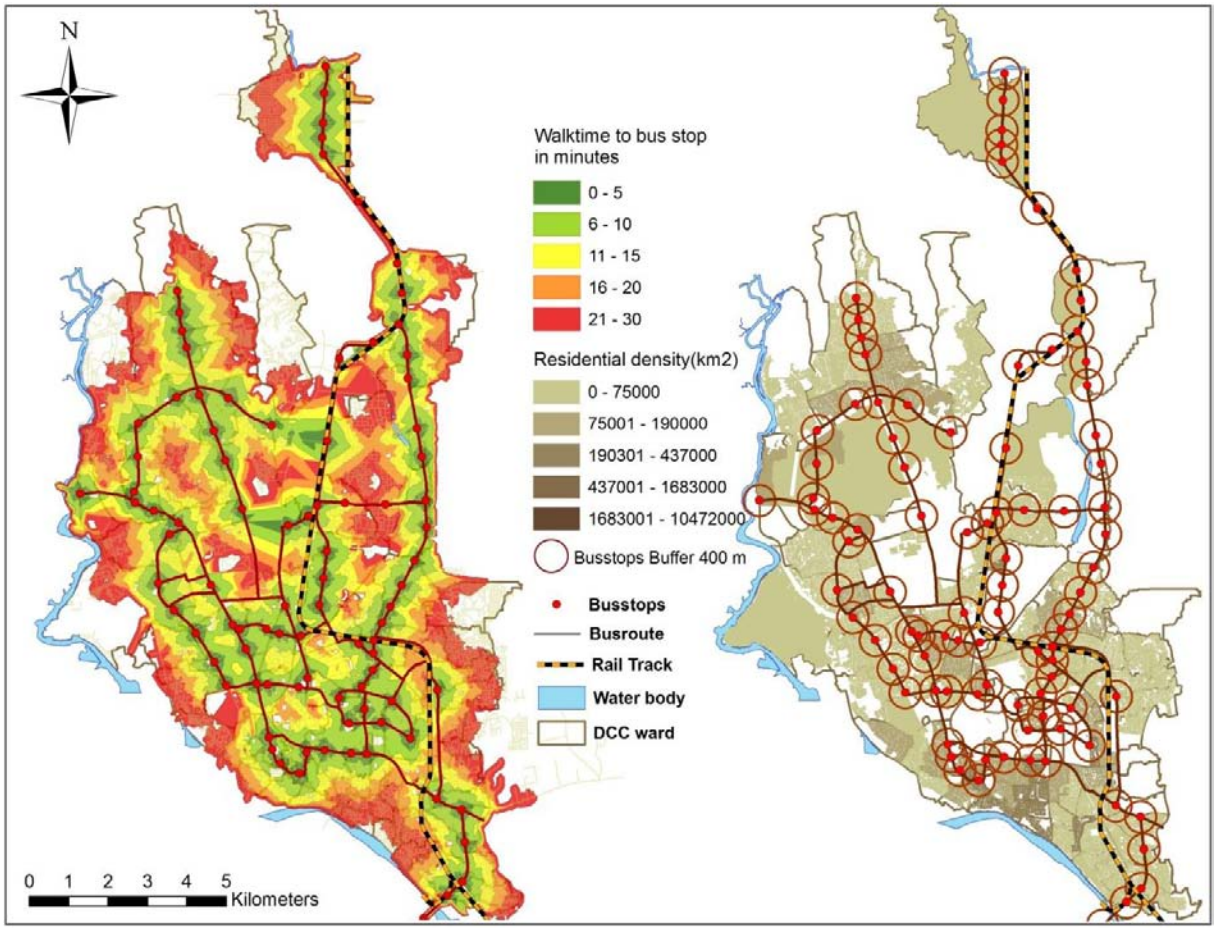


Figure 3-2: Area and population coverage by existing bus stop

And also table 3-3 and figure 3-2 shows the proximity of population to the existing bus stops based on the walking time from their origin to bus stops. It is shown that about 36% of the population can access the bus stop within 10 minutes walk time which is closer to a distance of 500 meter assuming a walking speed of 4 km per hour and nearly 56% of the population walk up to 15 minutes (1000m) to get the bus stop. It also shows that around 44% of the population has to walk more than 15 minutes to get the bus stop.

The buffer coverage is established 400 meters from each bus stop as indicates in Demetsky and Lin (1982). Moreover, the buffer method is widely used in transportation planning, it is simple in calculation. It assumes that walking distance for a transit user accessing a transit stop is the same as the Euclidean distance. However, the actual walking distance is longer than Euclidean distance (Zhao, L. Chow, & et al, 2003) as cited in (Gutierrez & J. C. Garcia-Palomares, 2008).

Acceptable distance is divided into two groups, 1) within 400 meter people willing to walk to access the bus stops, and 2) within 401 -1000 meter people willing to use other mode of transport such us rickshaw, auto rickshaw etc. In the map 3-7 residential density is overlaid with 400 m buffer of existing bus stops to show the coverage of existing bus stops.



Map 3-6: Proximity to existing bus stops and coverage of residential area within 400 meter buffer

3.5.4. Institutional setup

In Dhaka, three separate bodies such as Rajdhani Unnayan Katripakkha (RAJUK), Dhaka City Corporation (DCC) and Dhaka Metropolitan Traffic Police (DMTP) are thought to be responsible for construction of new transport infrastructures, physical maintenance of road elements and management of

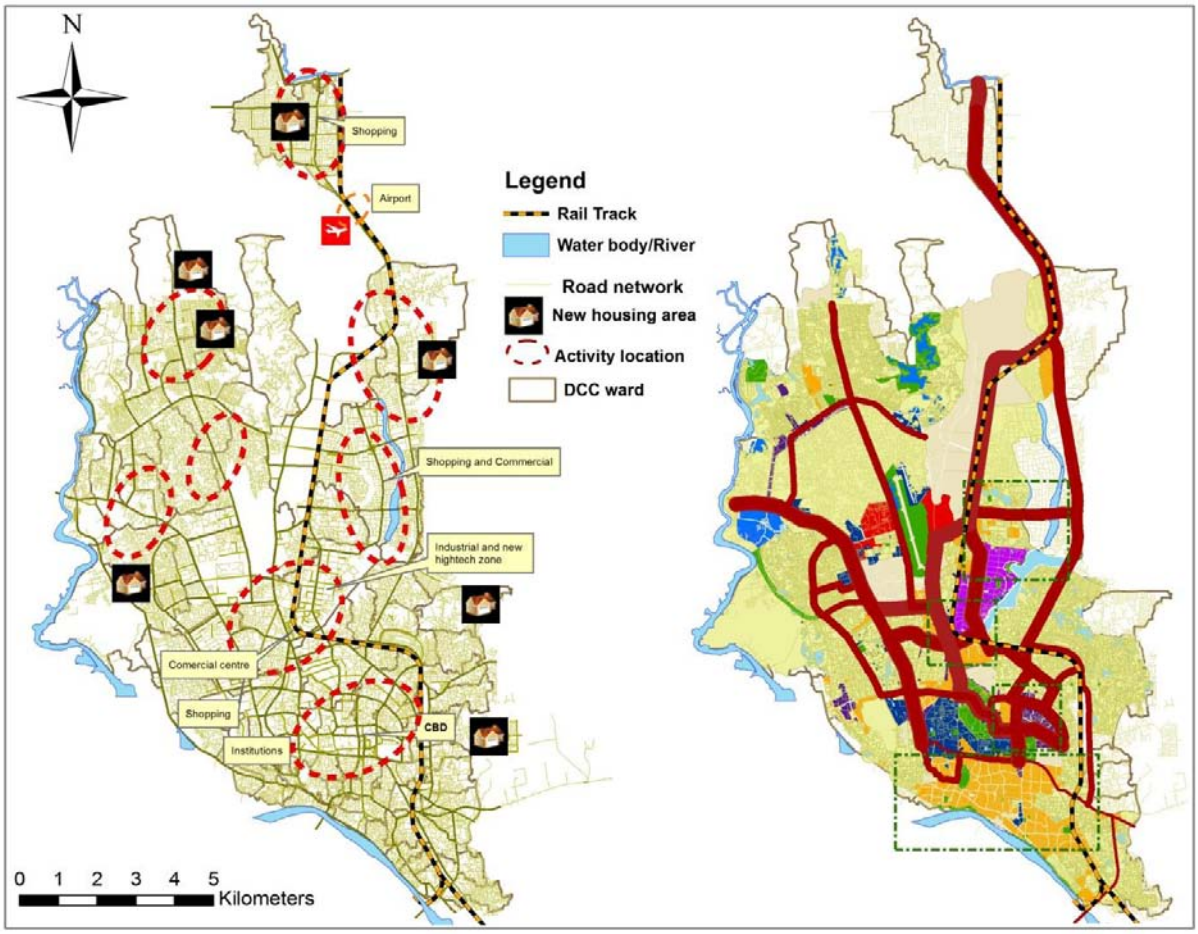
traffic operations respectively. But there is no formal accountable interrelationship among these three agencies. The public sector entity, Bangladesh Road Transport Corporation (BRTC), operates less than 2% of the buses. The overall bus operations are regulated by a number of bodies with overlapping mandates. The Bangladesh Road Transport Authority (BRTA) is empowered to regulate public transport vehicles. The Road Transport Committee (RTC) is appointed by the BRTA to award route permits. The Dhaka Transport Coordination Board (DTCB) plans and coordinates public transport services. The Dhaka Metropolitan Police (DMP) is responsible for enforcing regulations. The Dhaka City Corporation (DCC) is responsible for overall municipal governance and administration. Development partners such as the World Bank have provided support to these authorities in infrastructure development, institutional strengthening and policy support. Other key stakeholders include bus owners (individuals or companies), bus workers, and commuters, owners of other modes of transport, civil society, the media, and politicians.

3.6. Major corridors and hotspots of Dhaka

In order to develop the strategic road network of the city as well as those which could provide major connections to the growth poles/ satellite cities around Dhaka, it is necessary to identify the major arterial road networks of the city which carry most of the North-South and East-West traffic. After a brief analysis of the existing road network and existing situation (Map 3-5) reveals that there are about 5 major North-South corridors whilst several missing links in the East-West direction, which need to be built on a priority basis to provide alternative route for movement .

A corridor of about 5 km, for example, between Khilkhet and Kaptan Bazar, attracts flows of up to 2,300 pcu/hr and heavy public transport flows of almost 40,000 passengers per hour (pph) (Rahmatullah, 2005). The traffic analysis along the Kazi Nazrul Islam Avenue towards Mymenshing Road indicates that this is a heavy traffic demand corridor. In addition, along this corridor particularly high income group of people live and generate private traffic, which are responsible for traffic congestion on these roads. The existing Dhaka-Tongi regional line has all infrastructures from Zia International Airport to Mohakhali rail Crossing. Slight modifications on the existing line and new development from Mohakhali rail crossing to Sadarghat via Farmgate and Motijheel will tremendously increase commuter traffic and ease traffic congestion.

The older part of Dhaka and Mirpur, East and Western suburbs are quite densely populated zones. There the agglomeration of human activities in a small area is so intense that circulation of private vehicle causes recurrent congestion, which no feasible expansion of the street system could eliminate. Commuting a distance of three to four kilometres to certain spots like Gulistan, Motijheel, Old Dhaka, Moghbazar, Malibagh, Gulshan, Banani, Dhanmondi, Science Laboratory, Green Road, Jatrabari, Sayedabad and Mohakhali have become nightmares for city commuters. The traffic problem is also significantly fuelled by the unplanned location of numerous shopping malls, commercial buildings, schools, hospitals and CNG filling stations in various part of the city.



Map 3-7: Major corridors and hotspots of Dhaka city

Figure 3-3: Image of major hotspots and corridors
Source: (Hoque & Choudhury, 2009)

3.7. Traffic congestion in Dhaka city

Traffic congestion is a consequence of disparity between transportation demand and supply. Demand for transportation in urban areas is an increasing phenomenon for the continuous increase in urban population and economic activities lagging behind the transportation supply. As a result, traffic congestion has already become a part of urban transportation system.

The common terms that can be used to describe the present condition of Dhaka City are: congestion, delays, pollution, etc. These are the symptoms of transportation system deficiencies of Dhaka. The population of Dhaka has grown in 50 years from less than a million to over ten million. Now the population is expanding at an average rate of 4.5% (DCC, 2001) annually. Motor vehicle ownership faces a

growth rate of average 10% annually (Monayem, 2001). Intermingle of motorized and non-motorized modes results in a very low speed travel in its streets. With increasing rate of motorization, together with heterogeneous mix of traffic, the road traffic situation of Dhaka is degrading day by day.

The causes of traffic congestion in Dhaka city can be divided into three broad categories. These are site-specific causes, transportation system capacity related causes and planning or policy related causes. The site-specific causes are mainly traffic management related problems. The important manoeuvrings like left turning, through movement along the intersections etc. are often seriously obstructed for the poor quality and in maximum cases absence of traffic management system, uncontrolled parking of both motorized and non-motorized vehicles etc. In many locations of the road network, the effective roadway spaces are reduced by roadside activities, presence of dustbins, hawkers etc. Such reduction in effective roadway spaces in links and intersections creates bottlenecks to traffic flow and causes congestion. The population of the city is increasing day by day but the capacity of the road network is not increasing at the same pace. The lag between increasing travel demand and system capacity is resulting traffic congestion. Another important factor is the uncontrolled increase in rickshaw traffic. As there is no segregation of motorized and non-motorized traffic in the network, the increasing rickshaws are occupying the maximum roadway space and compelling the other modes to move slowly and creating congestion.

The overall transportation system of Dhaka city has not been developed in a planned way rather it has been developed in dynamic response to increasing travel demand. Even there is no definite policy to a sustainable transportation system. Uncontrolled land-use together with increasing migration of rural people towards Dhaka is increasing pressure on transportation system and creating traffic congestion and other related problems.

3.8. Deficiencies in existing public transport system

Current supply of mass transit is much lower than the actual demand. Not only the lack of this supply, there are also many other deficiencies in the existing system of mass transit. Japan Bank for International Cooperation (JBIC) data sources reveal that service deficiencies indicated by users of rickshaw are crowded condition of bus, long waiting time, lack of easy transfer, bus stops are not near from origin, long boarding time. Service deficiencies indicated by bus users are discomfort and congestion. A survey on pedestrians detected service deficiencies in the form of long waiting time, long travel time, lack of comfort, lack of stoppages etc. These deficiencies can be categorized as land use and road limitations, operational weaknesses, and user's points of view.

Land use and roadway deficiencies

1. Limited road space

As in many other cities in the region, systematic bus route planning based on a cycle of monitoring, planning, and implementing adjustments to the network is not in place in Dhaka. Total space occupied by roads and streets of Dhaka Metropolitan City is only 9% of its total space while that of other mega cities cover approximately 25%. Though 9% of road area of the city is available, pavement area is only 6% of total area (RMMS, 2004).

2. Lack of accessible road

In Dhaka city, there is a lack of sufficient accessible road. It is estimated that among the existing road network about half of the road lacks sufficient width to accommodate motorized emergency vehicles. In zone 1, 2, 3 and 7 more than 50% of road is inaccessible to large sized vehicles particularly to public transports. In Dhaka city out of 1286 km road about 821 km of road is found to be accessible (if road width is equal and more than 4.5 m) to motorized vehicles (RMMS, 2004).

3. No road network pattern

As road network of Dhaka City evolved haphazardly without any plan and always to meet short term travel need, the total road network does not show any well defined configuration. Instead, it is expanded eccentrically in the north-south direction and allowing uncontrolled ribbon development.

4. Un-organized and non integrated road network

During last twenty to thirty years, significant road development has been taken place to cope with sudden transformation of the city from provincial town to the capital of the country. But most of the transport developments have been driven by ad hoc considerations having no explicit focus on analysis of existing demand or future requirements. As a result, the road network of the city is not organized and integrated in terms of connectivity.

5. Absence of east west continuous road

Present public transport problems are the lack of integration between land use and transport system. In the city, there is not a single continuous main road in east-west direction. The road, which are existing in this direction all are formed as a connecting road or link road. Therefore, vehicle cannot move thoroughly in that direction. Absence of east-west connection has become the major problem for the entire road network of Dhaka. Presently, such requirements are meeting by relatively narrow and poorly aligned roads, which are far beyond to meet the existing demand in terms of capacity, speed and level of service.

6. Lack of bus lay on roads

There is very few designated place for bus stoppage in road side of Dhaka city. Most of the bus stop in road side haphazardly with competition attitude and alighting and boarding passenger dangerously. This makes always crowed on road side and influence pedestrian to move on road as well as decreases the effective width of the carriage way.

Operational deficiencies

1. Mixed operation in major roads

Road network of Dhaka city is characterized by mix traffic system. All types of vehicles, both motorized and non-motorized vehicles are in operation on each and every road, except some NMT restricted routes. Where, all types of vehicles are played on the road, majority of road spaces occupied by rickshaw. Because of the presence of non motorized vehicles, travel speed is significantly reduced for motorized vehicles and a huge congestion occurred. Even where non-motorized vehicles are restricted, the majority of road space is occupied by three wheeler vehicles.

2. Low roadway capacity and speed

Due to the complex mixture of motorized and non-motorized traffic and non-lane based movement over the Dhaka city road network, the capacity & speed of vehicles has abruptly decreased. The capacity of road lane and speed of the transport mode are very low compared to other capital cities in the world. That is how the city is facing huge traffic congestion at everywhere of the Dhaka city.

3. Absence of bus priority measure

Public transport is currently not given any priority over other vehicle types and road users. Various forms of bus priority ranging from traffic signal priority measures and bus lanes to possibly dedicated bus-ways should be considered for application in Dhaka. There is no bus only routes or segregated bus lane on roads.

4. Poor maintenance and surface condition of roads

The surface conditions of most of the roads are very poor. The surface of the roads are not smooth, as a result, journey through vehicles on such roads is not comfortable. Because of the absence of periodic maintenance of the roads, a lot of potholes exist on the surface of the roads. Rain water is stored in these potholes and surface becomes worst. Travel on such roads is very much risky and accidents may occur on such roads. If vehicles are operated continuously on such roads, vehicle's parts may damage.

5. Road space occupied other than traffic

Most of the roads are not fully used by traffic. Presence of dustbin on roads is very common in Dhaka city. This significantly reduces the effective road width for traffic use. Road spaces are also occupied by hawkers and retailer traders. In many places, construction materials for building are placed on the road. These cause reduction in effective road width and make the road unsafe for vehicles. Again, on-street parking also reduces road spaces and hinders smooth flow of traffic.

6. Fragmented ownership

Buses, which are main mass transit system in Dhaka, are operated by government authority and by privately. The BRTC, which operates under immunity from regulation by licensing authorities, owns a total of 306 buses operating on 15 routes in Dhaka. BRTC does not actually operate the buses, but sub-contracts out the operations to private operators. The main problem of privately operated bus services is that buses are owned by a large number of operators and also numerous small operators (Figure 3-3). There are many operators who have only 2 to 3 buses and some private bus operators have 30 or more buses. Multiple operators competing in same route, often leads to competition which results in results in inefficient road use (Figure 3-3).

7. Deficient and improper place of bus terminal

All terminals are poorly designed with respect to terminal system requirements. Many components of the system are totally absent along with some basic amenities. Utter disorder in using the terminal space, lack of management and indiscipline of drivers and passengers are other reasons for congestion all those inter-city bus terminals. Fulbaria Road is the main terminus for intra-urban buses, which also experiences extreme congestion, mainly induced by buses lying over the whole road haphazardly and absence of terminal facilities. Moreover, there is an acute shortage of bus stands with adequate facilities throughout the city (except recently introduced Premium/BRTC services). Hence buses frequently stop here and there affecting smooth flow of traffic. Besides this there are so many deficiencies in regulatory measure like poor loading and unloading, on street ticket counter etc.

8. Non coordinated transport system

The existing modes and sub-modes (bus-water-rail-NMT) are acting independently of each other. STP survey data shows that as a primary travel mode for all trips, only 31% are made by public transport of which most of trips are completed by using bus. Travel share of other transit system viz. rail and water are very insignificant. Nearly 70% of all trips are made either by walk, rickshaw or non-transit modes etc (DITS, 1994). It is to be mentioned here that the peak hour commuter movement of Dhaka city is mainly road based. Other alternative travel systems viz. rail and water has inherent weakness, as they are not aligned with the inner city commuter movement paths.

9. Absence of automated and integrated traffic signals

There are about 1932 nos. of signal lights points all over the streets of Dhaka City. The operational and maintenance cost of these lights is about 4 cores Taka. But this huge cost goes almost in vein, because in most of the cases the lights are not functioning now. The traffic police control the flow with the hands. In some cases traffic signals are found to be obscured by hoarding, billboards, branches of trees etc. (JBIC, 2000).

10. Poor interface provisions

Deficiency in the provisions of interface is largely responsible for much of the operational problem of the city's transportation system. Passengers of buses require adequate and efficient facilities for changing mode to reach their ultimate destination. Most of them are served by rickshaws, baby taxis, tempos for this purpose. But bus and these modes are hardly linked and appropriately designed for efficient integrated services. Often a large swarm of rickshaws remain standing in bus-stands blocking the way for buses to move forward or come closer to the footpath. Again there provision for baby taxis, tempos, taxi-cabs to park properly and collect passengers from buses and thereby creating a chaotic situation at most of the bus stoppages in the city.

Deficiencies from user point of views

Most of the existing bus services are uncomfortable, inconvenient, and unsafe for the passengers. Most of the buses are owned privately and they operate it completely from commercial point view. They seek more and more profit and don't care about passengers' facilities. They always compete with other buses to pick up the passengers from route and try to get the pick up spot first and to do so; they often cause safety problems for passengers. During off peak hour, they wait for long time at bus stops to full the bus and cause a huge delay for passengers to get their destinations. There are many other difficulties for the people who are using the buses such as:

1. Lack of passenger information

Passenger information, in terms of route maps, schedules, or service time coverage, is virtually non-existent. Furthermore, most buses are not identified by route number. Some are identified with display boards showing the origin and destination of the route. For the majority of buses in the city, however, passengers rely either on familiarity with the route, or on the instructions shouted out by the bus conductor/helper while the bus slows down or stops at bus stop.

2. Inadequate bus stops

Bus shelters in Dhaka are generally absent, or, where provided, are generally unused (at least by bus passengers) and often in a derelict condition. Passengers waiting for buses do so in poor conditions unprotected from wind, rain, and sun or passing vehicles. Passengers waiting for buses in Dhaka generally do not have access to bus shelters, passenger information, shelter from weather, or any other facilities.

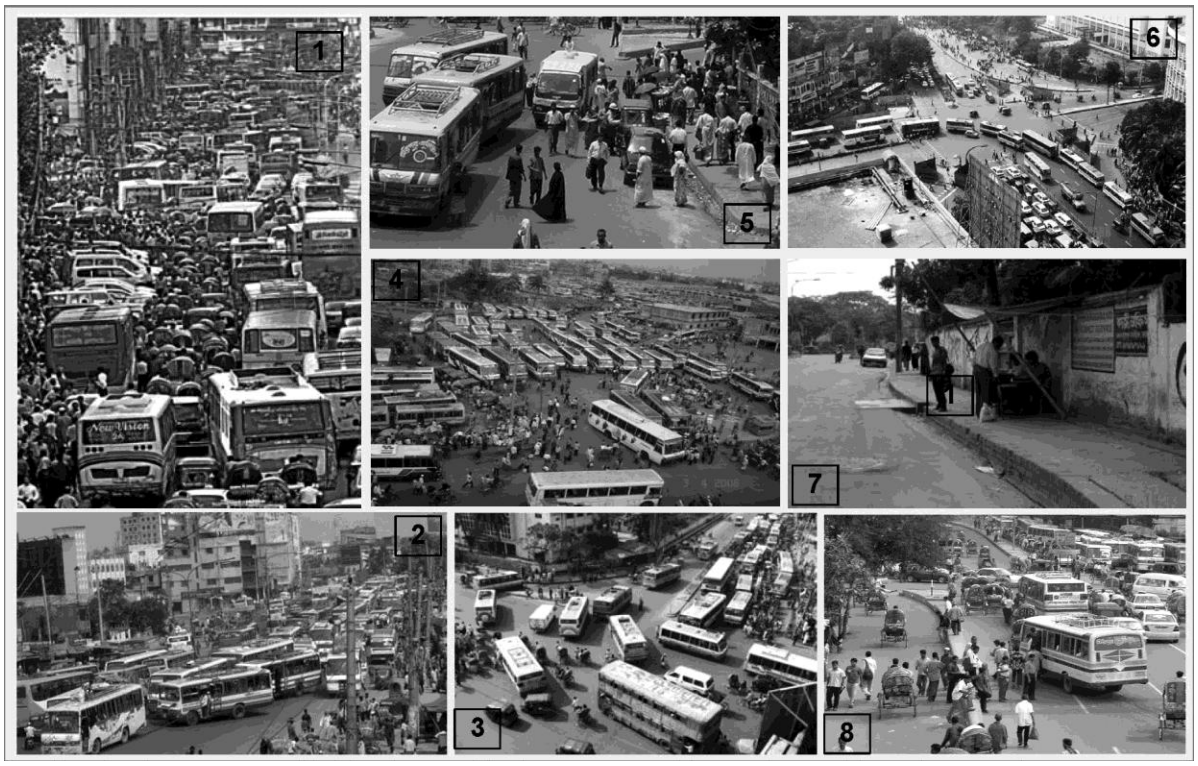


Figure 3-4: Deficiencies of existing bus system
Source: (Hoque & Choudhury, 2009)

1. Mixed operations in major roads.
2. Inefficient road use.
3. Fragmented ownership.
4. Numerous small operators.
5. No proper bus stops.
6. Multiple operators competing in same route

7. Inadequate bus stops.
8. Safety issue.

3.9. Conclusion

In conclusion, Dhaka is an over densely populated city and its transport system is mainly road based with mostly non-motorized vehicles (predominantly rickshaw). Dhaka is experiencing lots of traffic congestion and a great lack of traffic management. Very few studies dealt with mass transit system in the metropolitan area. There has been no study dedicated to overcome the situation. Tools and methods for assessing the performance of a road network are the first requirement of transport planners. Standard procedures to procure information about the impact of changes in road network is deemed important in providing guidelines for future policies investments and improvements in the existing road network. Although DITS and DUTP dealt a little about the transportation system performance, they concentrated on Greater Dhaka. The real hindrance to smooth traffic as experts look at it does not lie in inadequate roads. Dhaka's unplanned growth, a Dhaka-centric development of the country, the lack of east-west connecting roads, unplanned construction inside the city, increased number of private transports, the lack of mass transit are some of the contributory factors to these problem. At the same time the poor traffic management, increasing number of rickshaws, lack of parking space and pedestrian walkways and reluctance to use of foot over-bridge make travelling more difficult on the streets.

4. SCIENTIFIC KNOWLEDGE: DOCUMENT ANALYSIS

This chapter explores scientific knowledge on public transport planning and design, particularly focusing on public bus transport, public transport rationalization, and best practises of EU based public transport planning including bus rapid transit systems. The focus of this chapter is to identify the theoretical framework of rationalization and its significance, based on document analysis and best practice examples from EU planning practice. The chapter concludes with a framework of rationalization.

4.1. Background on public transport planning

4.1.1. Importance of public transport planning

White (2002) defines 'public transport' as all modes available to the public irrespective of ownership. The importance of public transport services in a successful transport system is widely recognized (Nash 1982; May and Roberts, 1985) cited by (Murray & Davis, 1998). It provides mobility to those who cannot drive their own car, helps in creating and maintaining liveable communities, relieves traffic congestion and assures long term sustainability in terms of resource consumption and the environment (David et al.) cited by (Paul, 2001). It can also provide a very efficient means of moving large number of people in order to meet demand throughout the city(Armstrong-Wright et al, 1987).

As the demand for transport is increasing, the need for sustainable modes becomes more evident. The need of more plentiful and efficient public transport becomes very essential as a step to reduce traffic congestion which is mainly caused by private modes. Public transport modes are regarded as city friendly as they provide space efficiency. The most important benefit of a good public transport is that it reduces the need and desire of private vehicle ownership to some extent and hence can massively reduce the amount of motorized travel (Barter & Raad, 2000).

However existing public transport capacities (in developing countries) do not satisfy the demand. The quality of travel on public transport is poor, roads are badly maintained and managed and in most cases there is no hierarchy in the routes. Despite the advantages of using public transport, there is an increasing trend in the use of private cars in developing cities due to the poor public transport network.

4.1.2. Access and Accessibility: A concept and tool for public transport planning

The growing and expanding urban metropolitan regions are well connected to the provision of adequate and appropriate transportation services. An expanding urban population requires access to business activities, education, employment and recreational opportunities. The location of these services and the provision of adequate transportation infrastructure, such as freeways, mass transit, and parking accommodation, is the essence of urban planning. The transportation system has a great influence and impact on regional patterns of development, economic viability, environmental impacts, and on maintaining socially acceptable levels of quality of life(Murray, R. Davis, R.J. Stimson, & Ferreira, 1998).

Access to public transport can be defined as the opportunity for commuters to use the transport system. It can be defined in terms of the proximity to commuters or the cost of using the services(Murray, et al.,

1998). The cost of using the service can be in terms of the fares incurred in using public transport. When costs are set very high, the transport becomes inaccessible to the people in the society. Accessibility of bus services in terms of proximity on the other hand look at how close the bus stops are from the commuters either in terms of the physical distance or time. Further, providing access for disabled people to public transport is not an isolated endeavour: it is a crucial part of a quality approach to public transport services, which ensures that all passengers are provided with a high standard of public transport. Significant attention is being placed on strategic and operational analysis of public transportation systems in order to make transit more desirable and to increase utilization.

In urban planning, accessibility is used frequently in explanations of the growth of cities, the spatial location of facilities and functions and their relative position within the entire land use structure whereas in public transport planning context, accessibility is the measure of transport systems ability to provide low cost service (either in monetary value or time) to overcome the distance between two points (Handy & Niemeier, 1997). Therefore, in public transport planning accessibility is a major factor that has to be considered, hence an important tool for analyzing transport and traffic policies. Accessibility allows the interactions of people with land use along certain transport mode.

Suitable access to public transit is typically characterized as a reasonable walk under normal conditions. Demetsky and Lin (1982) indicate that most transit firms consider 400 meters an acceptable walking distance. Such standard suggests the notion of coverage, where a given location (home, place of employment, school, shopping center, park, etc.) is suitably serviced by a stop if it is within the stipulated access distance. Stop spacing optimization has received considerable attention in transit planning(Furth & A.B. Rahbee, 2000; Saka, 2001). This component of operational planning has a direct impact on travel time/speed accessibility. Most urban regions have established standards for the spacing of transit stops. Ammons (2001)states that stop spacing standards of 200–600 meters for bus systems are common.

An operational level concern in transit planning focuses on the spatial efficiency of service coverage. For bus-based systems, a number of solutions are possible, such as improved routing, express services, integrated hub systems, and minimizing the number of stops along routes. Routes with fewer stops have faster travel speeds as well as less associated operational costs (Furth & A.B. Rahbee, 2000; Levinson, 1983; Saka, 2001; Wirasinghe & N.S. Ghoneim, 1981).

The bus-oriented transit management and planning must address both expanding service coverage and increased efficiency of routes. However, public transit will not be successful unless travel speeds are more competitive with private vehicles. If a regional goal is to increase public transit utilization, it is essential that service coverage redundancy be minimized (in order to decrease transit travel times) and new services be established in emergent population growth areas. Strategic planning to support this should facilitate appropriate policy development as well as enable planners to assess and monitor the status of existing or proposed transit systems.

4.1.3. Public bus transport

Public bus transport has been seen to be a sustainable (economical, environmental and social) transport in the urban areas which has the potential of competing with private automobiles (Tiwari, 2002). Compared to other public transports such as rail and trams, it has a low cost of investment since it uses the same road and only on rare cases that extensions need to be done to the road. Because of its public nature, it become accessible to all in the community and has less harmful to the environment.

Public bus transport can cause a reduction in the congestion levels on the roads. This is achieved by the large occupancy nature of public bus as compared to the use of private automobiles. The large occupancy nature of the public bus means that it can transport more people at the same time as compared to private automobile, reducing the road space used per person per trip thus reducing congestion (M. G. Badami, 2005). The amount of energy used per person for the trip is also reduced (Martens, 2004). The reduction in the energy use may lead to the reduction in air pollutant from fossil fuels such as carbon dioxide, nitrate oxides and other green house gases(Banister, 2008).

There are many types of bus systems, including three basic types of roadway bus systems are:

- Buses that operate in general traffic, with no priority,
- Buses that receive limited priority, such as bus lanes and at traffic signals,
- Buses that operate on dedicated infrastructure such as bus ways, with minimal interaction with general road traffic.

Whether or not dedicated roadway infrastructure is available, bus systems can benefit from a variety of technological and street design measures. These include traffic-signal prioritization, better bus shelters, fewer stops, special ticketing systems, improved information systems for riders and potential riders and better pedestrian and bicycle access to stations. They can also benefit from the deployment of better buses, with features such as low floor access (or raised platforms at floor level), larger capacity, more comfortable seating, smoother ride, and better acceleration.

4.2. Network planning and design

Network planning and design can be a decisive factor for public transport success. High quality public transport that is able to replace car use as a significant measure to create a more sustainable and environment friendly city region on a long-term basis. In most urban regions in the developed world, this is a major concern of transport policy. Therefore, solutions for public transport systems that are able to be a competitive alternative to the motor car for urban travel are needed. This is a far-reaching quality ambition, which means that it is difficult to find practical examples that fully live up to the expected level of quality for all components of the public transport system.

The HiTrans Best Practice Guide discusses a number of aspects of public transport network planning in cities, including the planning process, the need for good understanding of user requirements and travel demand factors, project assessment and, most thoroughly, institutional and political factors. Good practice in public transport planning requires awareness of this dichotomy of thinking about how the transport system should be developed; finding the right balance between demand and supply oriented planning. The choice of balance should reflect the major ambitions and objectives for public transport.

The key to public transport success in the competition with the motor car lies in good network planning and development. Having the right network planning philosophy as well as applying the right network design principles can stand between outstanding success and complete failure for public transport. The main practical recommendation is to use all available planning means to create a simple high frequency integrated network for all modes and services with high quality infrastructure, vehicles and service operations. This should form a public transport structure that is fixed and stable enough to form the backbone of urban land-use planning and development.

4.3. Mass rapid transit systems: The instrument to solve the transport crisis

'Mass Rapid Transit' (MRT) is a term used to describe modes of urban public transport (both road and rail based) that carry large volumes of passengers quickly. It comprises a spectrum of modes of urban public transport that use specific fixed-track or exclusive and separated use of a potentially common-user road track. A well designed Mass Transit System has the potential to reduce traffic congestion and also become the single most powerful tool to consolidate the trends of urban growth, become the key engine to create new satellite cities, renew blighted urban areas and dispersing the extremely dense city centre (Khan, 2010). The role and form of MRT of course depends upon the city context, its size, income level, asset base, institutions, existing transport systems and other cultural and behavioral factors and attitudes. Mass Rapid Transit is a form of public transport which is organized to transport large numbers of people at speed through the city. Common 3 mass rapid transit systems are, Bus Rapid Transit (BRT), Light Rail Transit (LRT) and Heavy Rail Metro (Metro). Table 4-1 summarizes the key features of the MRT options.

Table 4-1: Key features of MRT systems

Characteristics	Bus rapid transit (BRT)	Light rail transit (LRT)	Metro
Current applications	Widespread in Latin America & some developing cities	Most European & North American cities	Most developed cities & few large developing cities
Segregation	At grade	At grade	Mostly elevation or underground
Space requirement	2-4 lanes from existing road	2-3 lanes from existing road	Little impact on existing road if elevated or underground
Impact on traffic	Depends on policy and design	Depends on policy and design	Reduces congestion
Public transit integration	Problem with Para transit	Often difficult	Excellent
Initial cost (US$ million/Km)	0.5 – 15	13 – 50	15 – 30 at grade 30 – 75 elevated 60 – 180 underground
Implementation time	Short	Medium	Long
Interaction with land development	Good	Very good	Excellent
Fuel	Mainly Diesel/CNG/LPG	Electricity	Electricity
Air pollution & noise	Considerable	Low	Low
Capacity (Pass./hr/direction)	10 – 35,000	12 – 30,000	60,000+
Speed (Km/hr)	17 – 20	20 – 25	30 - 80
Traffic accident	Minor	Minor	No
System image & passenger attraction	Good	Very good	Excellent

Source: GTZ, 2005; World Bank, 2001 & 2002

Implementing a BRT system may require taking road space away from other vehicles. But even if existing roadway space is given over to a BRT line, there is often an improvement in traffic flow, both from a reduction in the number of vehicles on the road and from removing buses that may have been slowing traffic when stopping to pick up passengers. Light rail systems may also require use of existing roadway space. Metros typically have little impact on existing roadway capacity and therefore may increase the overall capacity of the transport network substantially more than most bus systems. However, if one of the goals of adding a mass transit line is to encourage modal shifts away from personal vehicles, this may be encouraged by the removal of some roadway capacity.

4.3.1. Bus rapid transit (BRT)

Bus Rapid Transit (BRT) is a form of customer-oriented transit combining stations, vehicles, planning, and intelligent transport systems elements into an integrated system with a unique identity, usually uses dedicated Right of Way (ROW), which may be either bus-ways (involving physical segregation of the track) or bus-lanes (using painted lines to demarcate the ROW). BRT systems usually include additional design and operational features to increase passenger capacity, such as well-designed bus stops, organized operations, efficient collection methods and clearly defined corridors. These days, BRT concept is becoming increasingly utilized by cities looking for cost-effective transit solution. BRT systems are designed with an objective to swiftly, efficiently and cost-effectively move more people rather than private vehicles. BRTS attempts to address the deficiencies of the earlier public transport system by providing a rapid, high quality, safe and secure transit options.

BRT systems can compete with rail systems in many respects, including movement of passengers per hour, and are much less expensive to build. BRT systems can be built incrementally as funds allow, which is more difficult to do with rail systems. BRT systems also may have the advantage of flexibility – depending on design, some routes can be modified relatively easily after being built – while rail systems tend to be inflexible after completion. Allocating dedicated roadway infrastructure for bus systems can also make more room for bus stops, elevated platforms, and rapid bus boarding using multiple bus doors. In fact, several BRT systems use bus "stations" rather than bus stops, with fare payment occurring at the station entrance. These features are an important part of the successful BRT systems in cities such as Curitiba and Bogota.

The following are some of the elements of a good BRT system:
Running ways: BRT can operate in broad variety of physical and operating environments, but as much segregated, dedicated running way as possible.

Figure 4-1: Different running ways of BRT
Source:(World Bank, 2009)

Stops, Stations and Terminals:

- Station spacing should be 0.5 to 2 Km and integrated with surroundings
- The structure should be permanent, substantial and weather protected.
- Should be equipped with passenger information and need to have safe pedestrian and bike access.

Figure 4-2: Different example of BRT stops
Source:(World Bank, 2009)

Vehicles

- Variety of sizes through 27 Meters.
- Conventional buses or specialized BRT
- Environmentally friendly

Fare collection

- Needs to facilitate fast, efficient multiple stream boarding. It can be off-board (preferred) or on-board multi-point payment.
- Integrated with but may not be the same as for local bus system

Service Plan

- All-day, week frequent service. Maximum interval 5-10 minutes in peak hour and off-peak interval 10 minutes.
- Integrated with rest of transit system
- Simple network structure. Minimum variations (less than 4 distinct BRT routes preferred), easy to understand
- Develop service plan based on market, physical and operating environment

All-day, all-(limited) stops trunk line (e.g., Mexico City, Beijing, Curritiba, Jakarta, Istanbul).

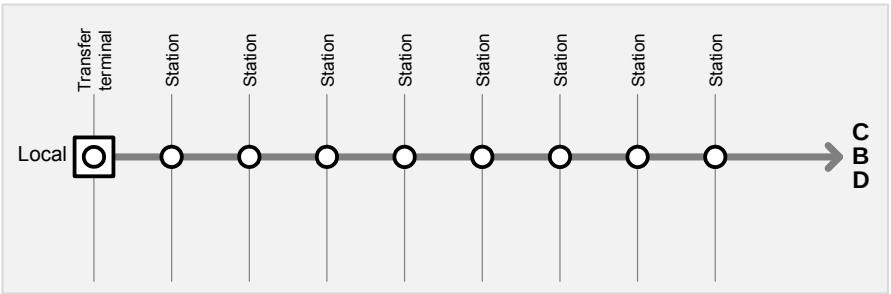


Figure 4-3: Design of BRT line (opt 01)
Source:(World Bank, 2009)

Base: All-day, all-stops trunk line (e.g., Bogota)

Overlay: Peak-only or all-day express services

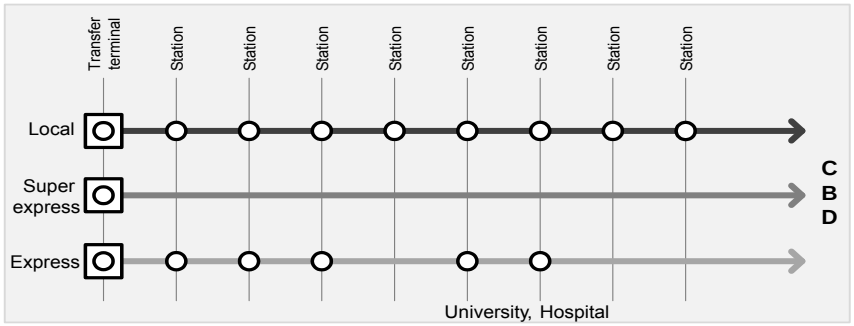


Figure 4-4: Design of BRT line (opt 02)
Source:(World Bank, 2009)

4.3.2. Light rail transit (LRT)

Light Rail Transit (LRT) provides high-quality, high-speed, and environmentally friendly public transit service on established trunk corridors linking major trip generators, regional centers, and county cores. Successful LRT service generates high levels of rider ship, is time-competitive with the automobile, accommodates higher capacity than Bus Rapid Transit (BRT), and costs less than heavy rail transit. LRT is a premium, accessible, and convenient service capable of attracting and promoting development and investment around stations and along corridors. LRT characterized by its ability to operate single car or short trains at ground level, aerial structures, in subways, or occasionally in streets, and employs a fully segregated, but uses less massive equipment & infrastructure. LRT is the modern version of the tram or streetcar or trolley in many locals and has better images over bus ways. Since the end of the nineteenth century urban planners around the world have used light rail systems as the key component of mass transit networks to shape the urban growth of entire regions by the means of creating satellite townships.

LRT is only operational in a few developing cities – notably Tunis, Shanghai, Hong Kong, Kuala Lumpur, Putra, Manila, Istanbul and Mexico City. Recent examples of LRT systems in developing cities include the elevated Putra and monorail systems in Kuala Lumpur, Tren de la Costa of Buenos Aires and Shanghai's Pearl Line.

4.3.3. Metro

Metros, often designated as true heavy rapid transit, use fully segregated, and grade-separated track in central areas, the track may be elevated although the most common international term is for subway or underground. They employ very advanced control systems that allow high-frequency operations, and the trains are made up of multiple units of high-capacity 'heavy' cars. They can provide high levels of service (speeds and frequency) having the highest theoretical capacity, although they are also the most expensive form of MRT system. Metros in developing cities carried about 11 billion journeys in 2000, more than twice the ridership of commuter rail and more than four times the rider ship of LRT systems (GTZ, 2005). Metro systems are being developed or expanded in several developing cities, such as Bangkok, Santiago de Chile, Kuala Lumpur, Delhi, Mumbai, Kolkata, Sao Paulo, Buenos Aires, Mexico City, Cairo, Dubai, Ankara, Manila, Beijing, Shanghai, Taipei, Hong Kong and many other parts of the world. There is extensive metro activity and substantial future activity is under planning or underway in many cities.

4.4. Major considerations of PT planning in European cities

The definition of 'successful public transport' depends on the goals that have been set when implementing measures. Successful public transport systems in Europe have managed to serve commuters, shoppers and car-less people, while also combining high service levels with good cost recovery.

Broadly there are three types of public transport systems observed in Europe: public monopoly, where the service is provided by a publicly owned organisation; a tendering regime, where companies (private or public) are awarded the right to operate services following an open call for tenders in which stipulated levels of service are given; and deregulation, where private companies compete directly on the road. In the deregulated (or privatised") regime there is normally scope for the public transport authority or local authority to subsidise services that it considers socially necessary, and that would not otherwise be provided by the commercial operators(ECMT, 2004).

Transport policies in the Europe are mainly aimed at two main goals, one is improved accessibility (to and from inner cities or important economic destinations) and environment (amenity, quality of life, traffic safety)(Maas, 1998). These goals should be reached through less car usage and more use of modes that are better for the environment (public transport, cycling, walking). From the research of the practice in a number of European urban regions, especially Western Europe it has emerged that a stronger position for public transport, together with a related increase in public transport usage, is the result of a number factors, namely:

a) Strategic vision;
b) Organization;
c) Quality.

Since growth in the use of public transport, improvement in the degree of self-financing in public transport or an increase in public transport's share of the modal split is often the result of a combination of factors, it is not easy to determine the effects of specific policies or measures. In practice, governments and public transport companies should try to implement as many as possible of the elements that are explained under those factors in order to reach a successful public transport system.(Maas, 1998)

a) Strategic vision;

Integration of transport policy and spatial planning:

The development of traffic and transport policy in general and public transport policy in particular, has to proceed with spatial planning. For example, in Oberhausen (Germany) the construction of a new shopping and entertainment centre was combined with the restructuring of public transport, in which the construction of a 'high quality public transport track' and the introduction of trams had played a major role. A year after the opening of the new centre and the new public transport network there has already been a 40% increase in public transport usage. In Strasbourg (France) too, the introduction of the tram and the restructuring of the whole public transport system were combined with a spatial reorganization of the city centre. Experiences in Freiburg (Germany) too, show that there is a lot to gain when transport policy and spatial planning are being integrated. New residential areas should be made accessible by public transport. Thus planning of public transport should be done in the context of city centre renovation or planning of new residential areas and office districts.

Integration of policies for public and individual modes of transport

Supporting policy towards making car use less attractive or even physically impossible forms an important part of transport policy to increase public transport usage. For this, local authorities have to develop a vision on an integrated policy for public transport and car traffic and have to apply this policy consistently. An integrated policy on both public and individual modes of transport should be developed, with the objective of decreasing car use and at the same time providing a good alternative transport mode. This

push-policy on car use can result in parking policy (charges for parking, traffic volume control on parking, P+R), and barring (through) traffic from the city centre (car-free city centres). Strasbourg (France) is an example of a city where the integrated vision on traffic and transport has been very important: through car traffic has been barred from the city centre, and public transport has achieved an important place in the municipal policy.

Public transport plan

Public transport has to function as an interconnected whole; it cannot simply be a loose collection of services, with one provider not knowing what the next provider is supplying and with no physical connection between one service and another. The various modes of transport must all form part of one transport system, each performing its own function. It is clear from the systems implemented that there is a strong tendency to think in system levels and hierarchies. There is always one transport system which is intended to operate as the backbone, subordinate system levels have the function of taking passengers to and from this system. In principle, it does not matter which system operates as the backbone. What really matters is the underlying plan and the specific issues and structures; the right system will then emerge by itself. It is important that there are good transfer stations and transfer arrangements.

Political courage and creativity

A good strategic vision should result in political courage and creativity. For implementing strong push-policy for cars, there should be political support. Politicians have the courage to implement these measures and, if needed, to make large investments in public transport in order to solve the traffic problems in the urban environment. Making compromises, as often at practices, should be avoided.

b) Organization;

Cooperation and planning on a regional scale

Regional integration or cooperation is important for the public transport 'product' as it is offered to the passenger. Thinking more in regional rather than in local terms can result in better coordination with regard to both services and fares. In Germany the need for this has been recognized for many years: the municipalities within a region are combined in a Verkehrsverbund or transport authority which works to coordinate public transport. It has already been shown that this has resulted in improved transport services (regional public transport without additional stops and repeated changes, and an integrated fare structure) and, as a consequence, an increased demand for public transport.

Introduction of competition

Introduction of competition can contribute to the success of public transport. In Stockholm (Sweden) and Copenhagen (Denmark) cost recovery ratios are increasing and levels of subsidy are decreasing. The government tenders the operation of public transport, with the objective to reduce the total costs. Different cases show that competition and the 'social function' of public transport can go hand in hand. Competition does not have to mean that the market is totally free. Governments are still able to set rules for a certain level of quality.

Financing public transport

Concerning financing the operation of public transport, the local or regional government should consider giving the public transport company a financial incentive. By giving a financial incentive to the operating company, a certain level of cost recovery, ratio or subsidy level can be reached. In many countries the company receives a fixed amount of subsidy. When the public transport company works more efficiently and reaches a higher cost recovery ratio, even profit can be made.

c) Quality of public transport

Availability

A frequent service means that it does not matter so much if a vehicle is missed. If frequencies are very high public transport is in effect continuously available, connections are guaranteed, and waiting times are very short. In that way, public transports can approach the major advantage of the private car it is always available. It is not a realistic aim to achieve a five-minute frequency everywhere, but a service at ten minute intervals (and 15-minute intervals off-peak) is the least that can be expected in urban public transport. In Vienna (Austria) the U-Bahn comes once every five minutes, and in Lille the metro actually runs at one-minute intervals at peak periods. In Oberhausen too, a tram or bus comes along every 90 seconds on the central high quality track (which is over 8 km long). These are examples of high-frequency availability that clearly contributes to the demand for public transport in these places.

Journey times and reliability

To be able to compete with the car, the whole journey by public transport must be speedy. For this to be the case, public transport must run quickly and should not stop unnecessarily. It is also important that public transport runs to timetable. In any case a low speed in the city centre is not a problem if it is solved by high speeds on free tracks in the outer areas. In Strasbourg the speed of trams on the city centre route is 25 km/hr, because of the pedestrian zone and the stops involved. However, the tram reaches speeds of up to 70 km/hr on the route outside the city centre. The tram has a fully dedicated track and has priority at junctions along the whole route, resulting in a high level of reliability. It also benefits the trams overall speed.

Accessibility

Accessibility means physical accessibility, with safe obstacle-free routes to the stops and properly equipped stops. Good physical accessibility is important both for the vehicles and for the stops or stations. Entry to the vehicles must be on the same level as the platform. Where stations or stops are not at street level, lifts and escalators provide for easy accessibility. A good stop is properly equipped with all the necessary facilities in logical positions. This is generally common in newly constructed transport systems at present.

Travel convenience/comfort

Comfort begins at the stop, which has to give shelter from wind and weather. If a high level of comfort is provided during the journey (large seats, spacious layouts, information on transfer possibilities during the journey, no rocking or jolting) it is possible to put the time spent on the vehicle to good use, a great advantage by comparison with the car. Here the driver's driving style and the dimensions and construction of the vehicle and the track are very important.

Safety and security

Safety is taken as covering both technical safety and social safety. In the countries of Europe there is usually no lack of technical safety, but social safety is a more difficult problem to solve. The stations or stops and the routes leading to them have to be arranged in such a way as to remove the feeling of social insecurity and also to reduce the chance of socially undesirable behaviour taking place.

A great deal of attention has been paid to design and safety, particularly in the automatic metro system because it is underground. The stations are open in order to let in as much daylight as possible. Art also forms part of the stations' design, while advertising posters have deliberately been excluded as these can provoke vandalism (graffiti). For that reason, mobile staffs are present, in the form of guards at the stations and guards or inspectors on the vehicles, as well as surveillance cameras in the stations. It is also possible to communicate with the control room using the communications system available at all stations and on all vehicles, so that the people there can call upon the mobile staff and police, fire service or ambulance, if necessary.

Service and information

Passenger information is important, it is a great help to passengers if the stops are announced and adequate information is given on arrival and departure times and any disruptions. Good route plans showing transfer points are important, and in some cases information is also available on computer diskette. The regional public transport authority in the region around Cologne provides clear, recognizable passenger information in many forms. A good example of this in Oberhausen, where signs with dynamic

passenger information have also been placed on the (pedestrian or cycle) approach routes. This means that an approaching pedestrian can see whether he should run to catch the bus.

Affordability

The price paid for the journey by public transport is an important factor for competition with the car. Experience in various countries has shown that the level of fares can be a good instrument for encouraging people to make use of public transport. It has been found that the price for (regional) public transport must not he higher than the parking and fuel costs for using a car. Many regions have introduced a monthly ticket that gives unlimited access to all the public transport in a very large region. Regional fare and tariff integration is also an important factor in pricing policy. The charges for parking and using public transport (P+R, park and ride) have to be integrated into the tariff structure.

4.5. Transit systems requirement

Vuchic (2005) discussed transit system requirement, which consists of requirements for three types of stakeholders, i.e. passengers, operator, and community. Table 4-2 shows these types and their indicators.

Table 4-2: Transit system requirements

Passenger	Operator	Community
Availability	Area coverage	Service quality
Frequency	Reliability	Passenger attraction
Punctuality	Cycle speed	System costs
Speed / travel time	Capacity	Reliability in emergencies
Comfort	Flexibility	Social objectives
Convenience	Security and safety	Environmental impact
Security and safety	Cost	Energy consumption
User costs	Passenger attraction	Long range impact
	Side effects	

Passenger requirements typically relate to availability, punctuality, speed/travel time, comfort, convenience, and safety of transit services. Availability describes whether people can indeed access the system both spatially (when the transit stop is close enough to be reached) and temporally (if the transit facility is available when it is needed)(Vuchic, 2007). Hence, not only access time is important, but also whether the destination can be reached, how long the trip takes, etc. The frequency is the number of vehicles operating at one route. Punctuality is usually described as the on-time performance of a transit route. The speed, or in fact travel time, is probably the most important factor concerning passenger satisfaction. A comfortable transit can be described using many variables, among which walking environment, attractive stations, temperature and ventilation. Convenience emphasizes the choice of people for a certain transport mode and the information they have about the transit mode. Safety from a passenger point of view could perhaps best be described as the absence of accidents. However also the perception of safety (how likely is an accident going to happen) might influence people's opinion on safety.

Transit operator requirements typically relate to area coverage, reliability, cycle speed/line capacity, flexibility, safety and security, and passenger attraction, as they are all geared to maximizing paying passenger demand. Area coverage is usually defined by a five minute (primary) and ten minute (secondary) accessibility circle. Reliability is strongly correlated with the change of failure and the punctuality as described in the passenger requirements section. Cycle speed / Line capacity is the time it takes to make a complete run on a certain route, which, in case of a straight line, from A to B and back to A. The cycle speed is of great influence on the operators' cost, because on faster routes, fewer vehicles are needed.

Flexibility, a system is regarded flexible, when it can change either in space or in schedule without any (or with minor) expenses. Safety and security are more or less the same as the safety and security from a passenger's point of view. Passenger attraction is the total number of people that use the public transport system.

Community requirements are more social and relate to service quality / passenger attraction and social objectives. Service quality / Passenger attraction is therefore defined as the area coverage, whereas the passenger attraction remains the same as in the transit operator requirements. Social objectives can be set at different requirements, for instance area coverage and availability.

4.6. Rationalization from a scientific point of view

Rationalization is a process of making something seem consistent with or based on certain reasons, criteria and scientific study. It also means systematic organization. The concept of rationalization can also be defined as a structured process to increase the effectiveness with a maximize use of resources. Rationalization in terms of road infrastructure or systems can be achieved in a various ways, by establishing hierarchy of routes, optimize bus stops locations, proper integration of motorized and non motorized transport etc. Eppell, V. A. T., J. M. Bunker, et al. (2001) describes rationalization in terms of road hierarchy one of the important tools used for road network and land use planning. They further describe each roadway in terms of its function such that appropriate objectives for that roadway can be set and appropriate design criteria can be implemented. These objectives and design criteria are aimed at achieving an efficient road system whereby conflicts between the roadway and the adjacent land use are minimized and the appropriate level of interaction between the roadway and land use is permitted. The introduction of road hierarchy expands the use of the road hierarchy as a tool for a broad spread of uses ranging from network/land use planning to asset management

4.7. Translation of scientific knowledge

Based on the literature review and document analyses on the various aspects of PT planning, a framework for rationalizing public transport system has been developed. The ultimate aim is to develop a theoretical framework from scientific knowledge and European PT planning practice (through expert's interview). But this translation of scientific knowledge is mainly derived from"Urban transit operations, planning and economics, Vukan R. Vuchic" which is mainly North American perspective and also tried to find out that whether there are same issues discussed in European PT planning practice and North American PT planning practice. The aspects of this framework already discussed in this chapter earlier.

In context of Vuchic, mainly four components of PT planning were discussed and they are operations and network, organization, economics and system planning. Some of the issues also discussed in section 4.6, major considerations of PT planning in European cities. But issues like integration of policy and spatial planning, safety, environment, comfort are ignored in this framework which discussed in European planning practices.

The first and most important aspect discussed in Vuchic that is of operations and network. To achieve an efficient network it is necessary to ensure proper service provision, sufficient capacity and speed. Regarding service provision there should be proper integration of network, frequency, travel time and scheduling. Ownership, proper regulation, information for passengers and management are the key notions of proper organizational setup. These notions are interrelated and without integration of these aspects are impossible to achieve rationalization in terms of PT planning. Economics is the third component discussed in Vuchic book and fares, finance, performance and marketing are sub aspects in

relation to ensure proper economics towards achieving rationalization. The final component is system planning, which is very much related to the operations and network. There should be proper planning procedure, demand consideration and also to review the planning time to time which ensure and effective and efficient system planning. This further influences the efficiency of network.

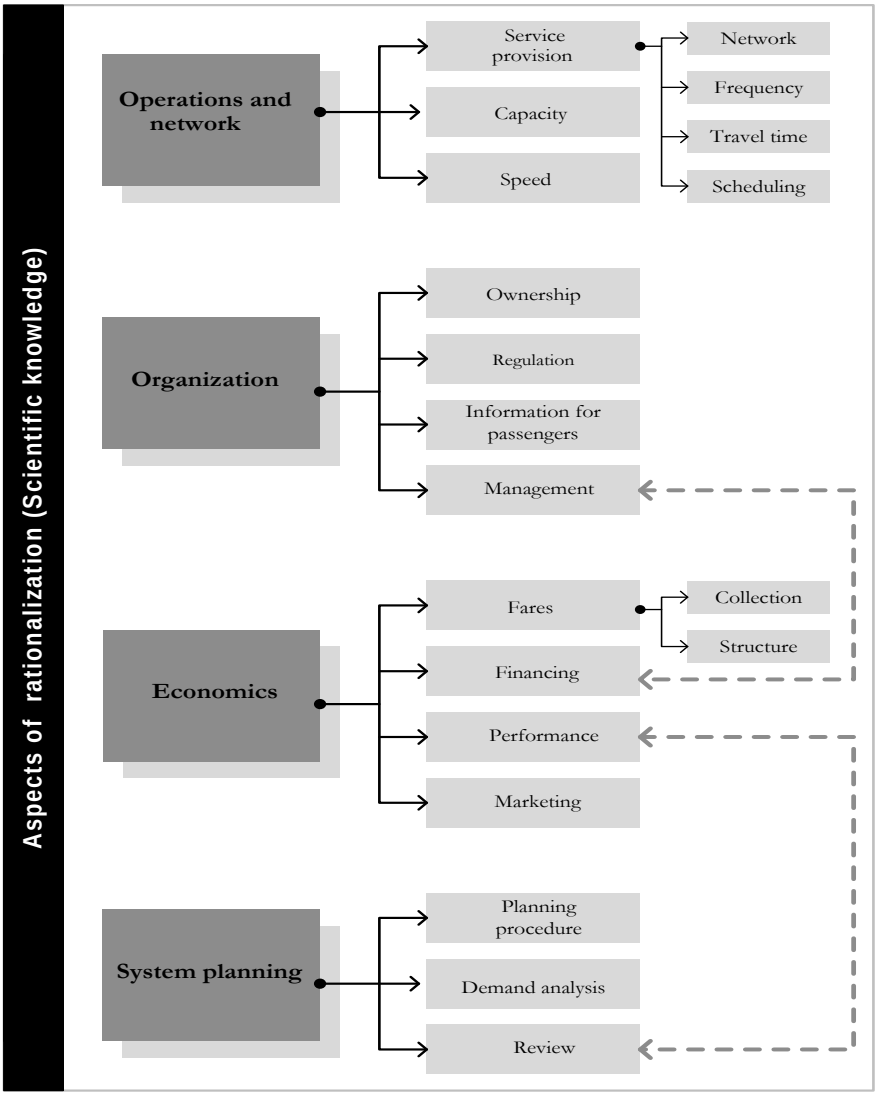


Figure 4-5: Framework translated from scientific knowledge

4.8. Conclusion

Main discussion of this chapter explores public transport planning and design aspects of rationalization. Importance of public transport planning, rationalization concept, mass rapid transit (MRT) system and various modes of MRT, features and facilities of different MRT systems, various tools to design public transport systems and finally aspects of rationalization of PT systems are derived through all these literature review. These all discussions have contributions towards achieving rationalization. Based on the several literatures and specifically of Vuchic's rationalization aspects are developed at the end which is used further to compare with the experts opinion.

5. EU BEST PRACTICE: EXPERT INTERVIEWS AND FIELD VISIT

This chapter emphasises on the expert's interview and a field visit to Almere city in The Netherlands. Public transport expert's interviews are conducted to provide their opinions in aspect of rationalization PT. Through the field visit in Almere a European city is used to study an example of public transport planning. The focus of this chapter is to identify the theoretical framework of rationalization and its significance, from expert's opinion. The chapter starts by describing expert's interview mainly focusing on the aspect of rationalization. Later a description of the field visit in Almere city is included. At the end of this chapter, a theoretical framework of rationalization is derived by summarizing expert's opinions.

5.1. Experts interview

The fieldwork is mainly based on taking interviews of public transport experts, working with different institutions and organizations. These interviews aimed at covering operational aspects, organizational aspects and policy aspects of PT planning based on the literature review. The first interview is taken with Mr. Pieter Onderwater, a public transport consultant working at DHV (at the time). The discussion is mainly from the technical aspects covering operational point of view but there also some discussions on policy guidelines. The next interview is taken with Mr. Guido Bruggeman, a freelance public transport consultant who previously worked in the EBRD (European bank of reconstruction and development) and now he mainly independently works in different projects of EBRD. As such he did several rationalization projects in Kaunus, Bulgeria and some other cities and most recently in Tajikistan. The discussion is mainly from the organizational point of view but there also some discussions on how to improve the network and its implication on organizational aspects. The next interview is taken of Mr. Arjan Vermeulen, (who used to work in HTM), the public transport operator in The Hague, the Netherlands. The discussion is mainly from the operator perspective.

The purpose of the interviews is to capture knowledge from established and planned cities in Europe regarding planning and policies of PT and discussion with public transport experts about existing PT scenario of study area for implementation of rationalization concept. And derived their opinions regarding rationalization of PT. Expert's interviews are mainly covered operational aspects, organizational aspects and policy aspects of PT planning.

5.1.1. Views from technical expert

The first interview is taken with Mr. Pieter Onderwater, where both of my supervisors Dr. Ir. M.H.P. Zuidgeest and Ing. F.H.M. van den Bosch was present in the same meeting. The discussion is mainly from the operational point of view but there also some discussions on policy guidelines. The major points are discussed are as follows:

- Types of rationalization besides network planning: There are several ways to rationalize PT system but in Europe mainly focused on economic rationalization and organizational rationalization.

- The main two goals in public transport to achieve rationalization:
  First one is equity in order to provide public transport to every citizen.
  And second is accessibility to ensure the full coverage of public transport.
- Geometric design: Geometric design comprises of the following points,
  - Organizational
  - Finance
  - Network
  - Regulating capacity, frequency and schedule.

From the discussion five major aspects of rationalization are derived. The translation from the interview into a framework is shown in Annex 3. Below there is a brief discussion of various aspects and sub aspects of the framework that seem the most important are given:

Network: To achieve proper and efficient network in order to rationalize public transport it is necessary to first establish hierarchy of routes in terms of backbone (BRT) network and feeder network. The backbone should be served by separate bus ways or dedicated routes and it should be characterized by high capacity, speed and frequency. Internal/ feeder route can be served by minibus, also sometimes by metro and train. Also the terminal location plays an important role towards achieving a proper network. It can be in central location where most of the routes will pass like CBD or other demand location. Few other points also came out from the discussion like the importance of speed, capacity and frequency which are an integral part of network and can be achieved by hierarchy, separate bus lanes, dedicated route or closed all other traffic except bus in certain routes.

Organization: The second aspect is organizational structure which comprises of government role, fare structure, scheduling and regulatory body. Government role is one of the important sub aspects of organizational structure. Strong monitoring must be there to provide efficient and effective regulation. Government should always play an important lead role as a regulatory body. Also maintain the fare structure and maintain proper scheduling. Development and implementation of appropriate policy is one of major functions of government role

Economics: This includes combination of fare structure, bidding procedure and economical viability. It is also necessary to maintain proper fare structure by the regulatory body. Invitation of bidder is one of the good options to maintain good management and government will play a strong role through the bidding process. So there is strong relationship between government and private management in economical aspects of rationalization. Good governance and institutional framework is needed to rationalize PT system.

System planning: Without proper system planning it's impossible to rationalize public transport system. And these can be achieved by integration of spatial planning through proper demand analysis and by ensuring proper network planning and infrastructure. These all are interrelated to each other.

Spatial planning ⟶ PT demand ⟶ Network planning ⟶ Infrastructure

Finance: The final aspect of rationalization is the role of proper finance. There should be proper subsidy for the operator which is very common in most of the European cities. And also need to pay attention in setting fare structure. This can be solved in various ways like fare based on distance or by zone.

In this discussion mainly operational aspects are come out but also some other issues like safety, environment, integration of different mode are discussed which are not covered in Vuchic theory. There

are several policy guidelines also like major corridor need to restricted by few operators, provide proper regulation regarding parking and licensing etc.

5.1.2. Views from international expert

Mr. Guido Bruggeman, a freelance public transport consultant who previously worked with EBRD (European bank of reconstruction and development) and is now working independently for several projects of EBRD. He did rationalization projects for several cities as given Kaunus, Bulgeria and most recently in Tajikistan. The discussion is mainly from an organizational point of views. Some of the issues regarding network improvement are also discussed in the meeting. Derived lessons from the interview are demonstrated into a framework. Through discussion with Mr. Bruggeman, It was found that there are mainly five aspects or components of rationalization which are discussed below:

The role of government: Government can be local or transport authority but should take the lead. Role of Government in the transport sector will be limited to the implementation of a national and social framework including:

- Development and implementation of appropriate policy, legal and regulatory functions;
- Planning and monitoring programs, as well as the mobilization of funds;
- Supervision and increased efficiency of transportation systems, including tariffs and taxes collected by public enterprises and private monopolies; and
- Licensing of transport services to ensure compliance with safety rules and regulations for environmental protection.
- Public transport regulation
- Regulation should cover:
  - Fares
  - Service levels: frequency, hours, accessibility
  - Service quality: reliability, crowding
  - Vehicles: access, comfort, safety, emissions

Institutional and regulatory framework: Institutional functions are as follows

- All frameworks need regulation
  - Set rules of conduct and operation
  - Enforce rules
- Effectiveness of regulations
  - Regulations are meaningless without enforcement
  - Incentives can assist compliance
- Traffic management, including parking
- Traffic law enforcement
- Integrated ticketing system
- Coordination
  - Planning
  - Investment
  - Management, operations

Network: The network should be planned in a systematic way and to start from the scratch if necessary. By establishing hierarchy this systematic approach can be achieved. Terminal locations also play very important role in order to achieve proper network. There should be a hub located in the city centre.

In hierarchy of route, the network should be based on 3 layers. Each layer has a dedicated function with specific service characteristics and operated by different type of buses (large, medium and small size).

Table 5-1: Network hierarchy

Layer	Location	Level of service
1 Backbone network	Main corridors	Very fast, high frequency and high capacity
2 Internal network	Areas not served by backbone	Normal speed, normal frequency and normal capacity
3 External network	Direct line to other districts	Fast, medium or low and normal or low capacity

Contract: It is necessary to have a proper agreement between a competent authority and a public service operator. Contract can act as an efficient tool when route are assigned to the operators. It can be achieved by proper tendering. Public service contract (PSC) came out from the discussion which can act as the driving force.

Finance: Finance is the most important issue towards achieving rationalization. Without proper plan it's difficult to organize finance. And PSC can act as tool for finance.

The major focus is on the role of government and public service contracts (PSC). According to the discussion PSC can act as a major tool to arrange finance. And above all there should be long term transport policy which is essential to achieve rationalization.

5.1.3. From operator point of view

The next interview is taken of Mr. Arjan Vermeulen, who is working with HTM, the public transport operator in The Hague, the Netherlands. The discussion is held mainly from an operator perspective. The following important points came out of the discussions:

- The strategy for public transport (regional based): the main strategy for public transport provision is that it should be integrated with spatial planning. According to him low demand should be serve by bus and high demand need to serve by tram. Another important aspect is to establish hierarchy. He also suggested not building feeder route in parallel to the backbone.

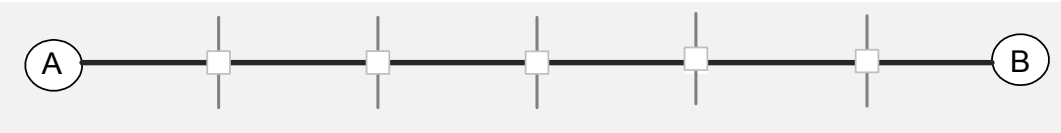


Figure 5-1: Design of BRT and feeder route (example)

- Network: Proper network can be achieved in a various way, for example, by establishing free bus lane, changing network in relation to demand, by improving infrastructure and by achieving proper speed

- Terminal locations: Terminal location act as a hub. But it's not necessary to be in the center. The location need to ensure changing of every mode is possible.

- Organization: Proper organizational structure comprise of Government role, monitoring, fare structure, subsidy and tender.

5.1.4. Translation of interviews into framework

Based on above three interviews, a framework for rationalizing public transport systems has been developed. The ultimate aim is to develop a theoretical framework from scientific knowledge and expert's interview.

This framework has been developed in several consecutive phases. Firstly the interviews are conducted and the discussions are organized under main aspects of rationalization according to the experts own views on main components of rationalization. The second step is to develop a framework from each of the interviews. Finally, the three frameworks have been combined into one framework considering main aspects of rationalization which are commonly came out from the discussion of the experts. After combining these three expert's opinions, the framework has been derived that covered operational, policy and operator perspectives (the process from experts interview has been demonstrated in Annex 3).

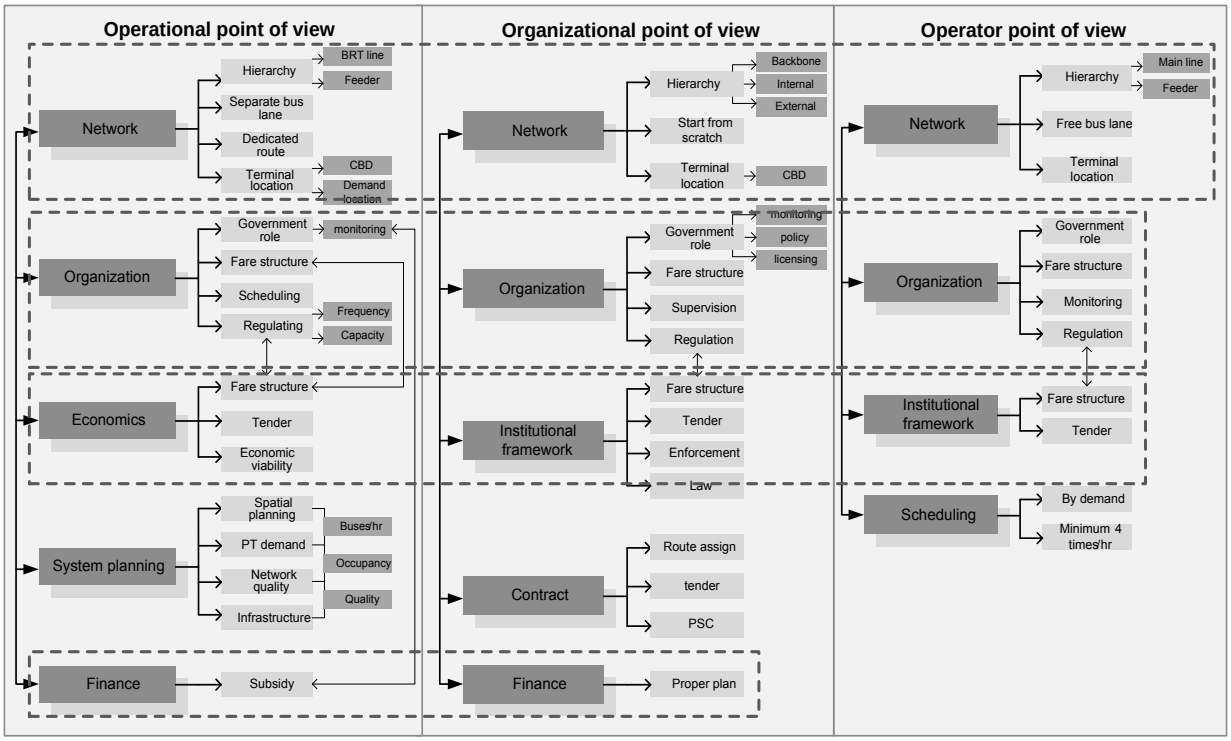


Figure 5-2: Translation of interview

The ultimate framework mainly explores five main components of rationalization. Under these five main components there are several sub components also mentioned which already discussed in this chapter. Through framework of scientific knowledge, expert interviews and field visit explored the gap between theory and practice if it exists. The overall theoretical framework of rationalization of PT planning explored in chapter six.

5.2. Field visit

The purpose of the field visit is to capture knowledge from established and planned city in Europe regarding planning and policies of PT, for implementation of rationalization concept in the study area. In this regard the city of Almere is visited which is one of the good example of integrated public transport planning and land use planning. But Almere is a completely new designed city where as the Dhaka is already an established city.

Almere

The city of Almere is situated north of Amsterdam, the Netherlands. It is planned and developed as a completely new settlement in the early 1970s. Almere is the youngest city designed thirty years ago on land reclaimed from the sea. It is the largest municipality in the province Flevoland with more than 180 thousand people (7 July 2008), and the 8th largest city in the Netherlands with a yearly growth of about 6,000 inhabitants. In 2010 the city has approximately 200,000 inhabitants. In October 2007, the city council of Almere made agreements with the national government to expand the population of the city to 350,000 inhabitants by 2030.

Almere is located in the polder of Southern Flevoland. It is the most western municipality of the province Flevoland. It borders with Lake Marken in the west and north, Lelystad in the northeast, Zeewolde in the east, and Lake Gooi in the south. The municipality of Almere comprises the districts Almere Stad, Almere Haven, Almere Buiten, Almere Hout, Almere Poort (under construction) and Almere Pampus (design phase) which has shown in map 5-1.

Spatial structure:

The main concept for the spatial structure (Figure 5-3) is to maintain the city as

- Green and Blue
- Low density
- Public transport will be the leading

Transport system:

Public transport (bus lanes and railway) and bike are the key elements of the Almere city transport system. The traffic infrastructure in Almere is recognisable because of its separate infrastructure for cycles (which have separate cycle paths), cars and buses (In Almere the buses drive on a separate bus lane). There are also shortcuts for bus and bike which is a sustainable solution. Terminal of Almere city serve both for rail and bus which act as a mulimode hub of the city.

Almere is connected to the motorways A6 and A27. The A6 motorway is just over 100 kilometres in length and it connects the A1 motorway at interchange, and with the A7 motorway at the interchange, is approximately 109 kilometres towards Utrecht. The map of transport network is shown in map 5-1. Almere was connected to the national railway system in 1987. Almere currently has five railway stations. In Almere there are 10 bus lines which service the urban area. Besides the local bus lines there are regional bus lines to Hilversum, Zeewolde, Harderwijk, Schiphol, Amsterdam and Amstel etc.

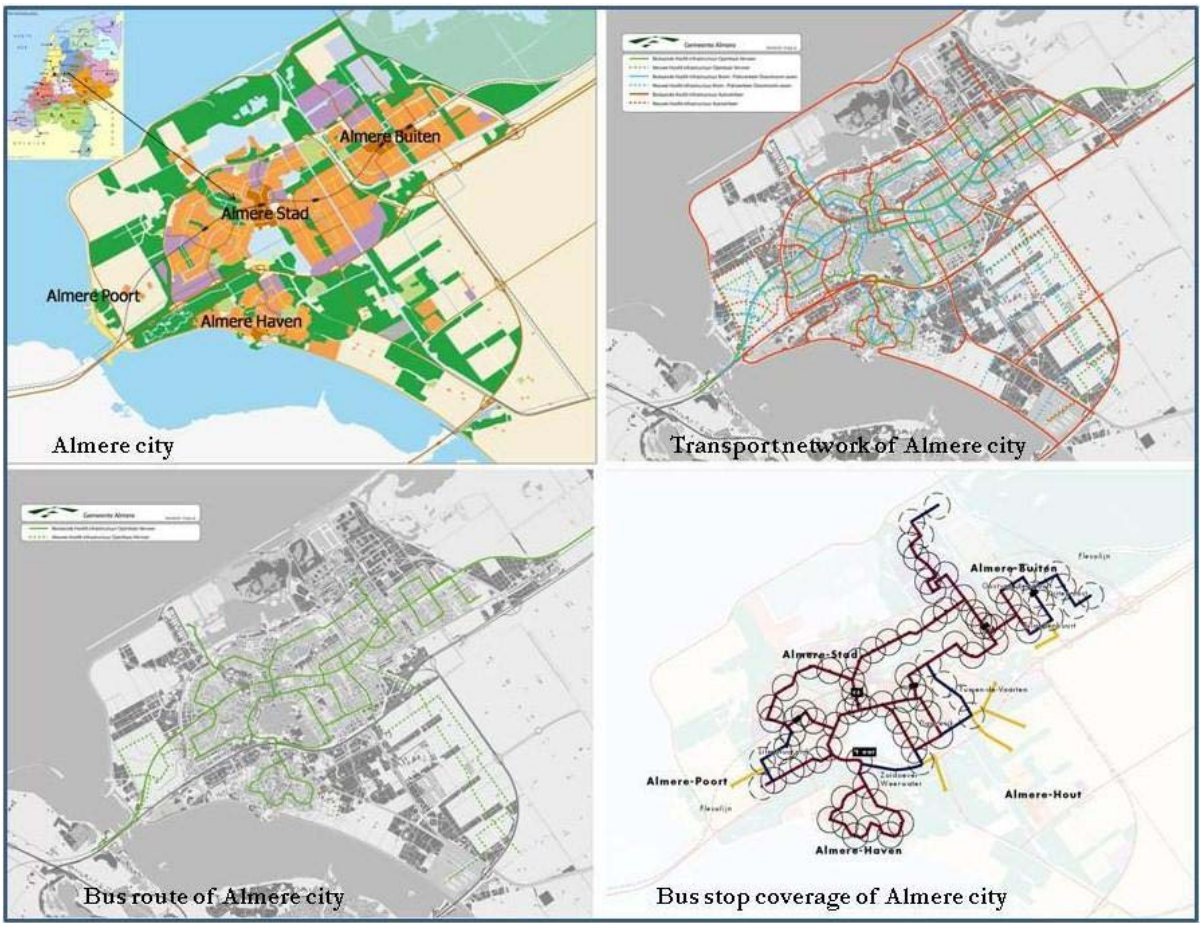
Public transport

From the start of the development of Almere public transport was an integral part of the plans and the city is designed on basis of public transport systems. Buslanes are the central element and city is build around them. The bus lanes are dense and crisscrossing the city (i.e. From one district via the city centre/central Station to another district). But car owner has to travel longer distances in order to encourage dwellers for using public transport. The route for car designed around the urban areas and there is no direct routes between urban areas. In the city centre there are also provision for parking

facilities for car and bicycle. Almere has an excellent local public transport system (MAXX), which is very well integrated with the railway system. On the11th of November 2004 the city of Almere awarded the trophy for most innovative PT practice in the Netherlands.

Figure 5-3: The concept of spatial structure of the city

Figure 5-4: Segregated infrastructure and terminal of Almere city



Map 5-1: Almere region and overview of its transport system
Source: Presentation of Mr. Boris Buffing, Almere municipality.

Main features of the public bus system of Almere city are as follows:

- The public transport buses in Almere use an extensive network of dedicated bus lanes. The total one way length is 105 km. The buses have priority at all intersections.
- The majority of houses and businesses are within 400 meters of a bus stop.
- The average speed of the bus system is 26 km per hour which comparable with light rail. One of the aims of the Maxx-concept is to minimize boarding time in order to increase the average speed.
- The service has a high (7.5 to 10 minute) frequency six days a week.
- The rolling stock has a low floor and is very accessible for wheelchairs and baby carriages.
- Moreover, the buses are equipped with an information display, camera supervision and a system for announcing stops.
- Customers pay the special Maxx tariff of 2 Euros with which they may travel 1.5 hours. There are also multiple trip tickets available. Maxx has a so-called "open boarding regime".
- Passengers can board through all available doors. For this purpose special sensors are installed with which the doors can be opened from the outside by waiting passengers. In quiet hours, these sensors are shut down for safety and security reasons; with passengers getting in at the front of the vehicle.
- There are ticket validation machines inside the buses. Due to the open boarding regime, the average speed of the buses has increased by 13 per cent to an average speed of 26 kilometers per hour. Extra supervisors are deployed to ensure that all passengers buy a ticket.

Nowadays in Almere city almost 20% travels are by bus and within Almere there are almost no traffic jams and no problems with pollution. Despite of this advantage there are some limitations also. The whole segregation of infrastructure has some negative effect. The total segregation of bike/pedestrians, car and bus are not safe enough especially during dark hours around tunnels (Figure 5-4: Separate bike lane).

5.3. Conclusion

From the above discussions of rationalization, based on scientific knowledge and expert's opinions, it is quite clear that the main aspects of rationalization are to some extent similar. But after analysing the expert's interview there are some points or sub aspects which are yet not documented. For example in Vuchic theory there are hardly any discussions on establishing hierarchy and also on the importance of terminal locations which according to planning practice are quite important aspects. Also about the integration of transport policy and spatial planning are missing.

6. THEORETICAL FRAMEWORK OF RATIONALIZATION

This chapter provides the theoretical framework of rationalization and its significance, as derived from scientific knowledge, expert's opinions and a field visit. The chapter starts by describing the basic requirements of public transport, the basic elements of PT planning strategy based on literature and experts opinion. Finally it concludes with the theoretical framework of rationalization of PT planning.

6.1. Basic requirements for public transport

Public transport is vital for most cities in the world. Cities like Moscow, New York, Shanghai and Hong Kong would look completely different if they would not have their extensive public transport systems. Public transport provides mobility for the society, especially during rush hours when many citizens travel from home to work or vice versa. Not only the large cities but also intermediate cities (roughly between 100,000 and 400,000) need to have a good working public transport system for healthy economic, social and ecological circumstances. The main goal of public transport is to ensure:

- Equitable mobility.
- Economic development of urban areas;
- An attractive alternative for private car user.

Based on the discussions in chapter four and five, specifically major considerations of PT planning in European cities and the transit system requirements and experts opinion, come up with the following basic requirements for public transport. By combining passenger, operator and community perspective these basic requirements are set out.

Public transport should comply with the basic requirements that are explained in table 6-1.

Table 6-1: Basic requirements for PT

Attractive	Safe	Efficient	Affordable	Sustainable
Comfortable	Safe vehicle	Clear network hierarchy	Affordable for passengers	Environmentally sustainable
Reliable	Safe infrastructure	Efficient organisation and management	Affordable for operators	Socially sustainable
Fast	Safe stops	Competitive	Affordable for municipality	Financially sustainable
Understandable	Safe drivers	Effective legalization		

Attractive public transport: Comfortable, reliable, fast, understandable and integration are major five aspects which can make public transport attractive. By modern vehicles, ensuring sufficient capacity and seating availability public transport can be comfortable. Regular service and proper travel time can make public transport reliable. High frequencies, segregated infrastructure, speed and direct connections make public transport attractive. All these aspects of attractive public transport are summarized in table 6-2.

Table 6-2: Requirements of attractive PT

Attractive public transport	
Comfortable	Modern and attractive vehicles Sufficient capacity and seating availability
Reliable	Services at regular intervals Reliable travel times
Fast	High frequency Direct connections Commercial travel speed competitive with private cars Segregated infrastructure in busy city center Smooth transfers between lines
Understandable	Logical route network User friendly Extensive passengers' information at public transport stops, stations, internet and via mobile phone (call centre / SMS)
Integration	Coordinated routes and timetables

Safe public transport: Public transport should be safe in terms of vehicle, infrastructure, bus stops, and stations and also by ensuring proper trained driver. The ways to achieve safe public transport are described below:

Table 6-3: Requirement of safe PT

Safe public transport	
Safe vehicle	Modern and safe vehicles meeting (inter)national safety standards Strict adherence to bus maintenance requirements
Safe infrastructure	Well maintained roads Geometric design standards compatible with standard or large buses' turning and dimensions
Safe stops	Safe and comfortable stops Bus bays at important stops
Safe stations	Well designed bus bays and parking areas to avoid conflicts between buses or with passengers Sheltered waiting areas for the passengers
Safe drivers	Trained drivers Active safety management that monitor drivers' safety records

Efficient public transport: To ensure efficient public transport need to establish clear network hierarchy, proper organization and management, competitive market and sound finance mechanism.

Table 6-4: Requirement of effective PT

Efficient public transport	
Clear network hierarchy	Network design with clear distinction between route types. No "in-the-market" competition and only "for the market" competition. Vehicle technology and capacity compatible with the routes function. Well maintained roads.
Efficient organization and management	Professional public sector authority with capabilities to design efficient network structure and to procure services with tender services. Central control monitoring with real time dispatching and adjustment capabilities. Professional companies management with modern personnel and equipment procurement procedures. Regular surveys to identify passenger needs and demand.
Competitive	Competitive environment aimed to get "value for money".

Sound financing mechanism	Multi year service contract agreement between operators and public sector with built-in revenues. Secure mechanism for upgrading fares and tariffs. Public sector financing of discounts for special population groups.
Effective legalization	Consideration of operators rights and obligations.

Affordable public transport: Public transport needs to be affordable not only for passengers also for the public transport operators, for municipality and also for the community. Below there is brief discussion to achieve affordable public transport:

Table 6-5: Requirement of affordable PT

Affordable public transport	
Affordable for passengers	Minimum single fare competitive with alternative transport options. Variety of ticketing options (transfer, daily, monthly, seasonal) to make affordable multi-trips and transfers. Discount system for special population groups.
Affordable for operators	Income should cover Operation and Maintenance costs as well as fleet renewal and modernization. Revenue risks should be minimized for the operators. Contracts should allow multi-year planning. Operating conditions and commercial speed should improve to increase revenues per bus.
Affordable for municipality	Subsidies (if any) should be transparent, kept to minimum and should be stable over the years. Service should be regular and continuous without interruption.
Affordable for community	Accessibility to public transport should be granted to all urban locations and to all population groups. Public sector investments should be based on benefit-cost considerations.

Sustainable public transport: Public transport should be sustainable in terms of environmentally, socially and financially. Following are the requirements for sustainable public transport:

Table 6-6: Requirement of effective PT

Sustainable public transport	
Environmentally sustainable	Buses should power with low emission engines complying to the environmental standards. Public transport should be attractive enough to shift passengers from private cars. Accessibility to public transport should make maximum use of non-motorized modes (walking and bicycles).
Socially sustainable	Public transport should be available in all parts of the city. Public transport should have a contribution to the concept of a livable city. City centre should reserve most space for public transport, cycling and walking and less for (space consuming) car traffic.
Financially sustainable	Financial resources to be made available by to improve urban passenger transport on a long term basis. Long term service contracts should be signed to ensure service and financial stability. Service contracts should provide sound mechanisms for fare updates and for service cost update.

While integrating scientific knowledge and expert's opinion it comes in front that, in literature different components of rationalization discussed separately but not as categorized components of rationalization where as in planning practice (expert's opinion) it is quite clear. Also in literature most of the planning solutions are referred for the newly planned cities where as in expert's opinion especially in operational point of view, the suggestions are mainly for the existing established cities.

6.2. A theoretical framework of rationalization

The ultimate aim is to develop a theoretical framework from scientific knowledge and expert's interview. The main aspects of this framework are already discussed in chapter four and five. After combining scientific knowledge, expert's opinion which mainly covers the operational, policy and operator perspective and experience from field visit, a combined theoretical framework of rationalization has been developed.

This framework mainly explores five main components of rationalization which are network, system planning organization, institutional framework and finance. Under these components there are several sub aspects also mentioned. Although all the aspects are closely connected but network and system planning are closely interlinked whereas organization, institutional framework and finance are influence each other.

To get an efficient network it's necessary to establish hierarchy, separate way or dedicated route, ensure proper terminals location and service provision. Already in chapter four and five different ways of establishing hierarchy by categorizing routes are discussed according to backbone, feeder and also by external or direct routes towards surroundings. Backbone network can be established by any form of mass transit like BRT, LRT, and Metro; depends on city size and demand. Also backbone network can be achieved by the combination of BRT, LRT and Metro. It effects the service provision in terms of achieving enough capacity, by reducing travel time and by increasing speed. Also by designing separate bus ways or dedicated bus lane can increase the service provision and act as an integral part of establishing hierarchy. Terminal location plays a major role towards ensuring an efficient network. It can also play as a hub where all types of modes interchange is possible.

System planning is another component of rationalization framework which is closely related to network. It has three main sub aspects namely spatial planning, demand analysis and infrastructure. Spatial planning and demand influence each other which in long run influence the network. Also proper infrastructure can ensure efficient network. It is necessary to provide proper infrastructure in relation to spatial planning as new land use always generate demand. So proper system planning will increase towards achieving the efficient and effective network and vice versa.

Organization is one of major aspects of rationalization. This mainly consists of four sub aspects namely government role, system integration, and management and involve of public sector. Government has strong role in monitoring, licensing and providing policies. System integration and management also play major role towards ensuring proper organizational set up. It is also necessary to involve public sector in relation to achieve rationalization.

Tendering, enforcement and law are the sub aspects of institutional framework which is the fourth component of rationalization. Strong enforcement, proper tendering and effective law ensure proper institutional framework. Institutional framework is closely interlinked with organizational set up.

The final component is finance which has two sub aspects fare structure and subsidy. Fare structure plays a major role. According EU planning practice subsidy is one of the important aspects for rationalization. Proper plan can ensure the subsidy.

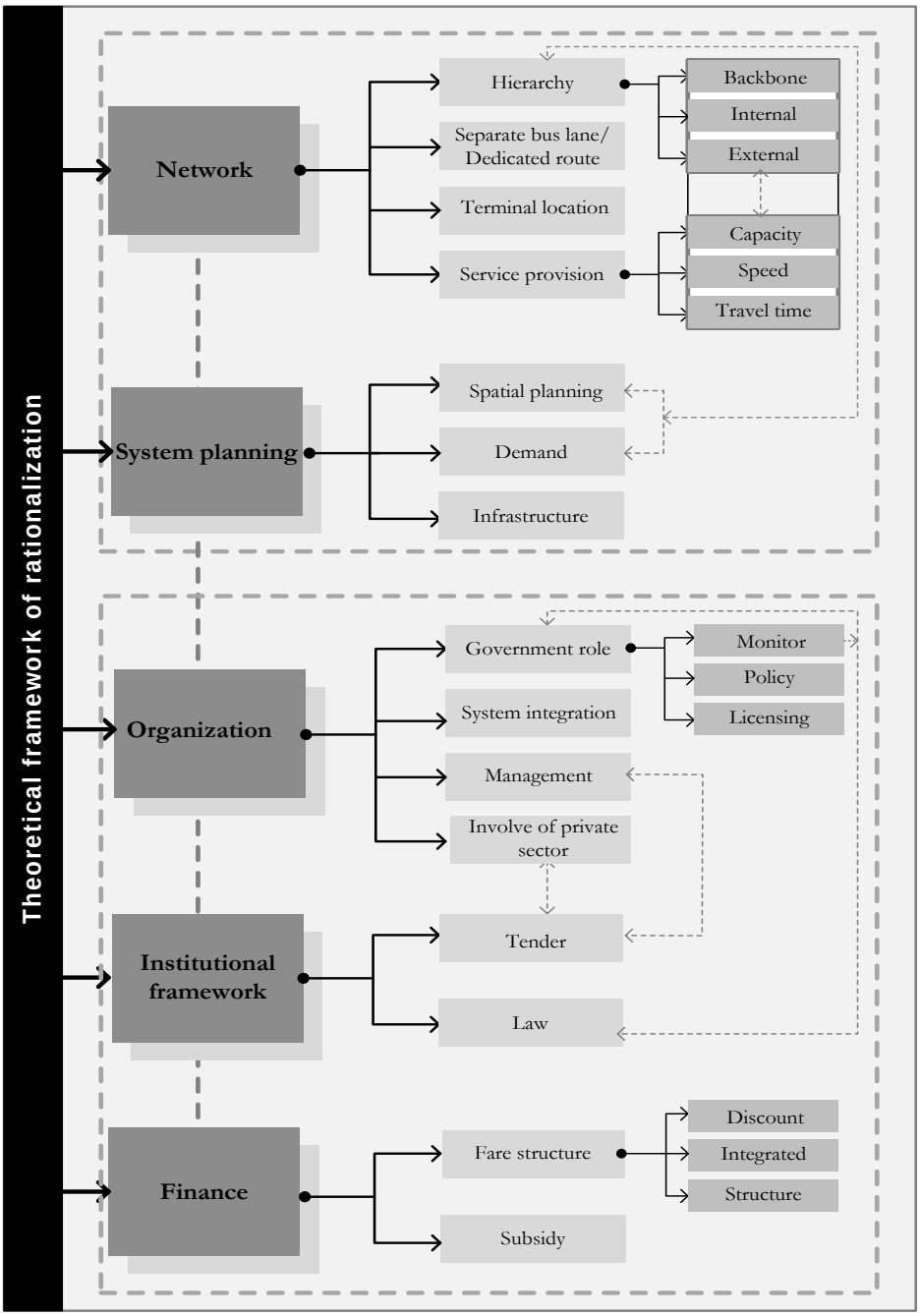


Figure 6-1: Theoretical framework of rationalization

6.3. Conclusion

The overall theoretical framework is explained in this chapter. This framework is derived from mainly two aspects which are scientific knowledge and expert's opinion. This framework mainly explores five main components of rationalization which are network, system planning, organization, institutional framework and finance. All the components regarding the theoretical frameworks are closely connected and interlinked with each other. In this chapter also discusses the basic requirements of public transport system. Based on this theoretic framework, a proposal on rationalization of public transport system is prepared for study area which is discussed in Chapter 7.

7. IMPLEMENTATION AND EVALUATION OF THEORETICAL FRAMEWORK

The previous chapter resulted in a rationalization framework. This chapter describes the implementation of this framework for Dhaka PT situation (focusing on routes and their categorization) and finally concludes with the evaluation of the frameworks' network component and recommends policy guidelines.

7.1. Implementation of rationalization framework to study area, Dhaka

The public transportation system in Metropolitan Dhaka is not only performing below standard as compared with other capital cities but it has also reached a crisis point that requires immediate attention. An intensive effort is needed from all concerned to resolve the city's transportation problem. The overall design of the public transport systems both public and private transport need to be re-planned and re-constructed.

In the previous chapter the rationalization framework explores five main aspects of PT system design. This framework mainly discussed five aspects and under every aspect there are several sub aspects also mentioned. In the following sections implementations of these aspects and sub aspects of rationalization framework are discussed in relation to study area. But due to the data and information limitations, not all the sub aspects can be discussed.

In order to guide the implementation of framework in the study area, there should be a set of clearly defined objectives. The following are the guiding objectives:-
(a) Develop an efficient public transport system.
(b) Strengthen institutional, policy and regulatory framework;
(c) Prepare long-term urban transport plan to cope with future growth of the city in coordination with future land-use planning for the capital area; and
(d) Improve road safety and environment.

7.1.1. Network

According to the rationalization framework, towards a better and effective public transport the first and most important aspect is to ensure an efficient and effective PT network. Towards this, the first step is to establish hierarchy of routes. The highest hierarchy should have a separate lane or dedicated route. There is a significant influence of service provision (that is ensuring capacity, proper speed and travel time) and terminals location on achieving proper network. Below there is a brief discussion on these aspects to implement in study area.

1. **Establishing hierarchy of PT routes:**

The network should have a certain logical hierarchy for PT routes. A new network and service concept has designed consisting of **3 layers**. Each layer has a dedicated function with specific service characteristics. This hierarchy will be achieved by establishing backbone network, internal network and external network in study area as already explained in table 5-1.

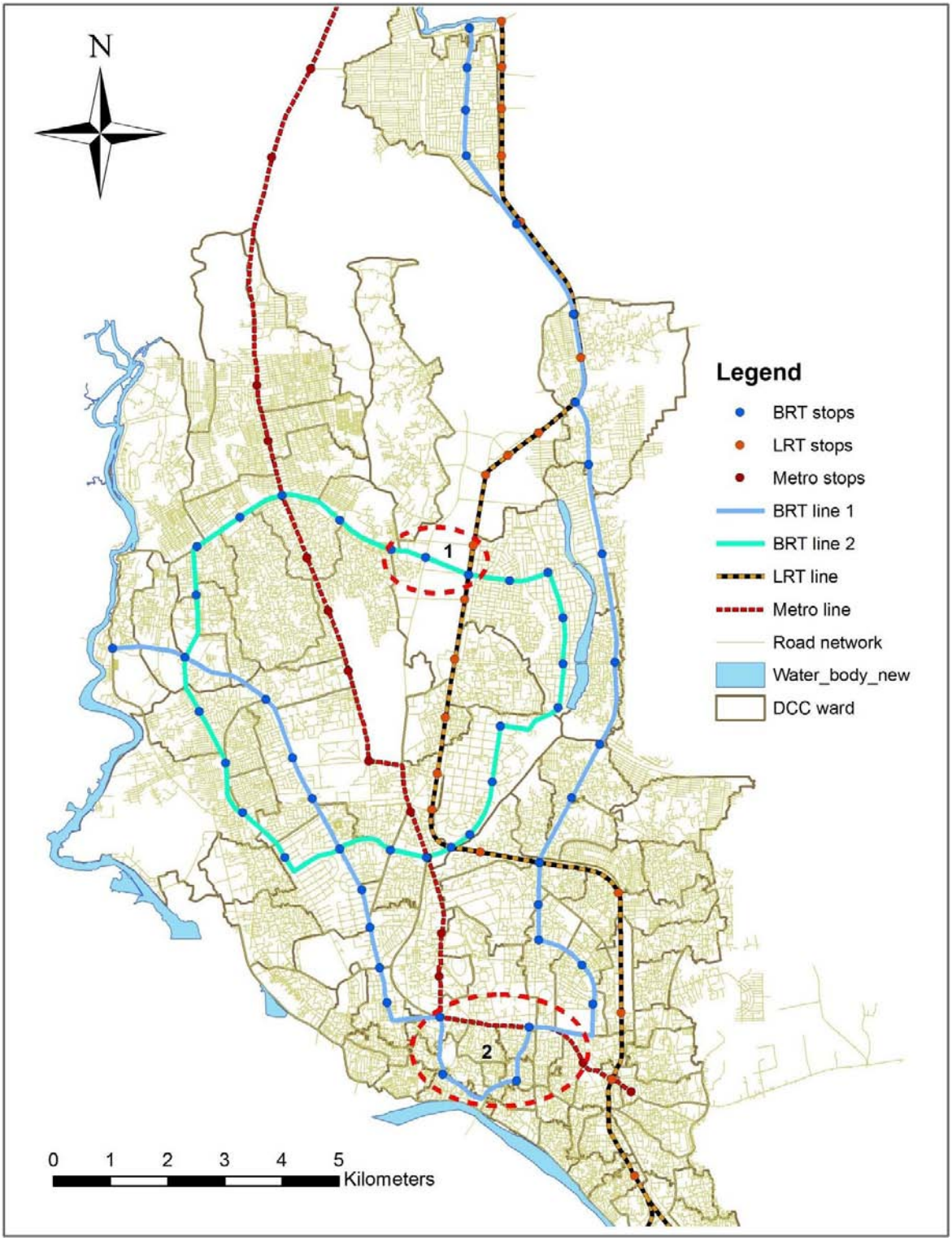
Backbone network:
The backbone network (1st layer) consists of services on the main corridors in Dhaka. The backbone lines provides a high operational speed (high vehicle speed, relative long distances between stops and short dwelling times at bus stops) and have a high frequency. On the backbone network regular big buses (capacity between 60 and 80 passengers per vehicle) will operate. Based on the major hotspots and major corridors (discussed in chapter three) 4 backbone networks are proposed in the study area. Among these 4 backbone network two will be served by BRT line, one by LRT line and another will be served by metro line which already in planning (elevated).

Within large metropolitan areas like Dhaka with a population of over 10 million, it is unsuitable and uneconomical to operate only one exclusive public transportation system (Ahsan, 1990). From this viewpoint introduction of improved mass transit is important.

BRT: The first backbone is a proposal for a Bus Rapid Transport (BRT) system. There will be two BRT lines on identified major corridors, one is in north south direction and another one is in east west direction based on the analysis of demand and major hotspots, but with separate designated lane exclusive to bus system. The main characteristics of these BRT lines will be:

- Create a new network of bus routes along selected axes of movement. For these routes, keep the left/central lane free as dedicated route for special and designated buses;
- No vehicles will ply on the dedicated routes.
- Frequency of buses will be high, with service every 10 to 15 minutes in peak and 20 to 25 minutes during off peak hour;
- Construct specially designed bus stops for faster transfer and passenger loading;
- Large (articulated) buses will ply on these routes in order to carry maximum passengers (all small vehicles such as tempos and human haulers will have to be eliminated).

LRT: A large city, like Dhaka, especially when it reaches a stage where the concentration of travel demand cannot be efficiently handled by the road-based system, the development of an urban rail system becomes essential. From the experience of other mega cities, it can be said that road network alone can not satisfy the need for transportation of such a large city. To cope with the problems of increasing transportation demand, traffic congestion, deteriorating environmental quality, and inadequate traffic safety measures Light Rail Transit can be a probable solution. Considering its potential, LRT proved a suitable solution to the present transportation need of Dhaka City as already an existing rail track is passing in the heart of the city. Rail-based mass rapid transit system along with efficient bus service can resolve the high transport demand in Dhaka. And also we know that the best solution is to have the city train system 'on ground', not over or under. Constructing and operating an extensive new underground or elevated rail network will be an extremely complex, expensive and time consuming for a developing city like Dhaka and in the perspective of rationalization it would be efficient if we can able to use existing resources. So there is a potential of developing an integrated transport and urbanization scheme by upgrading the existing railway network and connecting it to a backbone network of new BRT routes of public transport for the greater Dhaka region.
Metro: The third network of the backbone is a proposal to develop some 20.8 kilometres of Metro system which will be elevated from the ground. It has been proposed in the STP plan that the METRO system will be developed which incorporated in this proposed backbone network. This line will run from Uttara to Saidabad via Mohakhali, Sonargoan Hotel and Motijheel should be up. As already mentioned, a study of rationalization it's logical to include existing plan and that corridor already identified as demand corridor in existing situation analysis in chapter three. That's why in this backbone network this proposed metro is included.

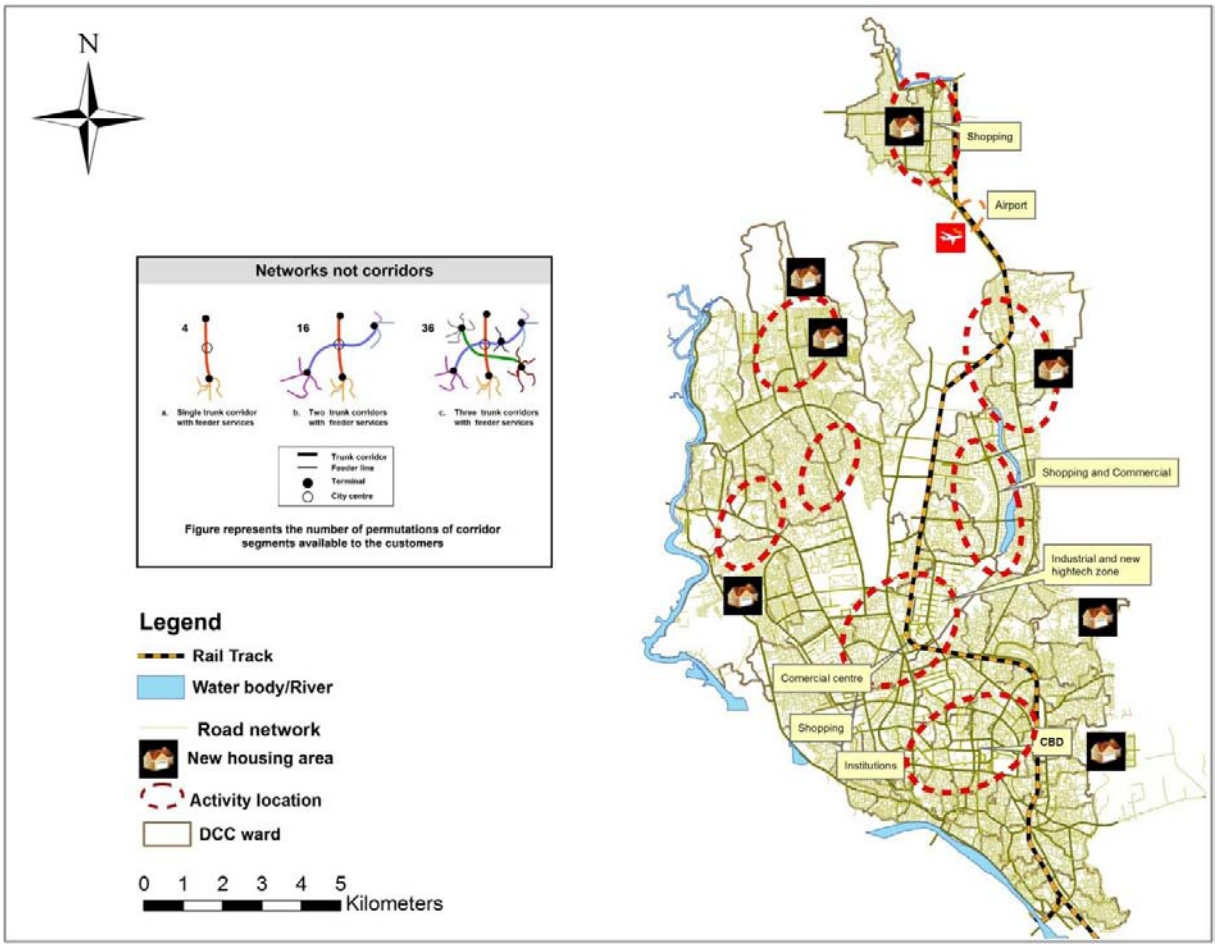


Map 7-1: Proposed Backbone network

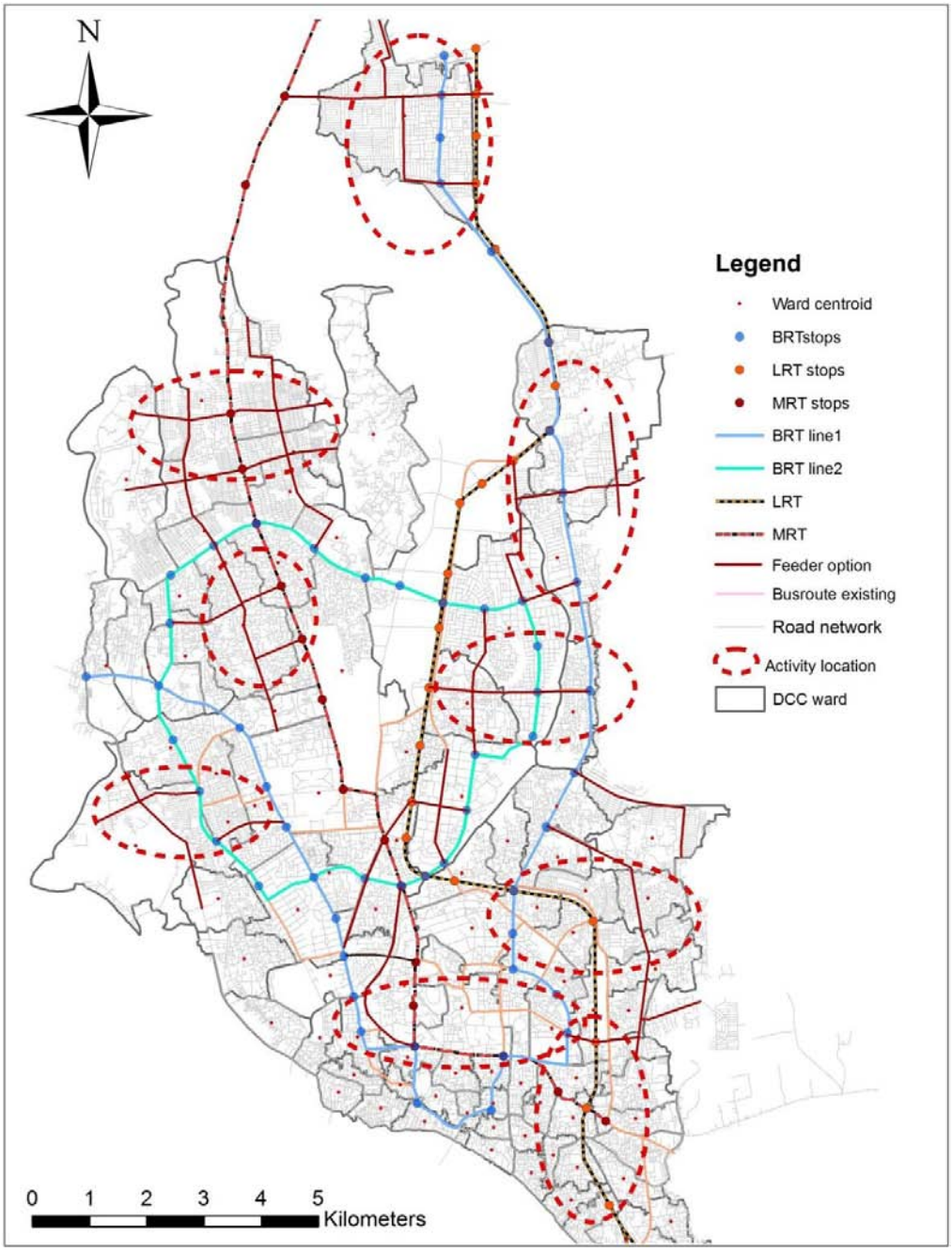
In the context of low income developing country, dedicated bus lanes and light rail transits seem to be the most realistic solutions for the urban transportation problem of metropolitan Dhaka. Once the system is in place, it is expected that people would not be interested to use their private cars anymore. The city and the economy will get tremendous relief from the vehicle pressure and reduction of fuel related pollutants respectively. The majority of the people could have easy access to them.

Internal network/Feeder route:

The internal network (2nd layer) consists of services to the areas that are not served by the backbone network. In general, the internal network services will serve the internal areas of Dhaka. The internal network will provide services with a normal speed with an interval between 7 and 15 minutes during peak hours and between 10 and 30 minutes during the day. On the internal network mini buses (capacity between 20 and 30 passengers per vehicle) will operate. Some of the existing bus route will operate as a feeder route as those routes are not served by the Backbone network. Due to the time limitations and data in-availability of origins and destinations, demand locations, the feeder route is only conceptually solved. Based on the previous analysis about major hotspots/major demand location the location of feeder routes are following the concept located (indicative) and shown in maps 7-2 and 7-3.



Map 7-2: Location of feeder route (conceptual).

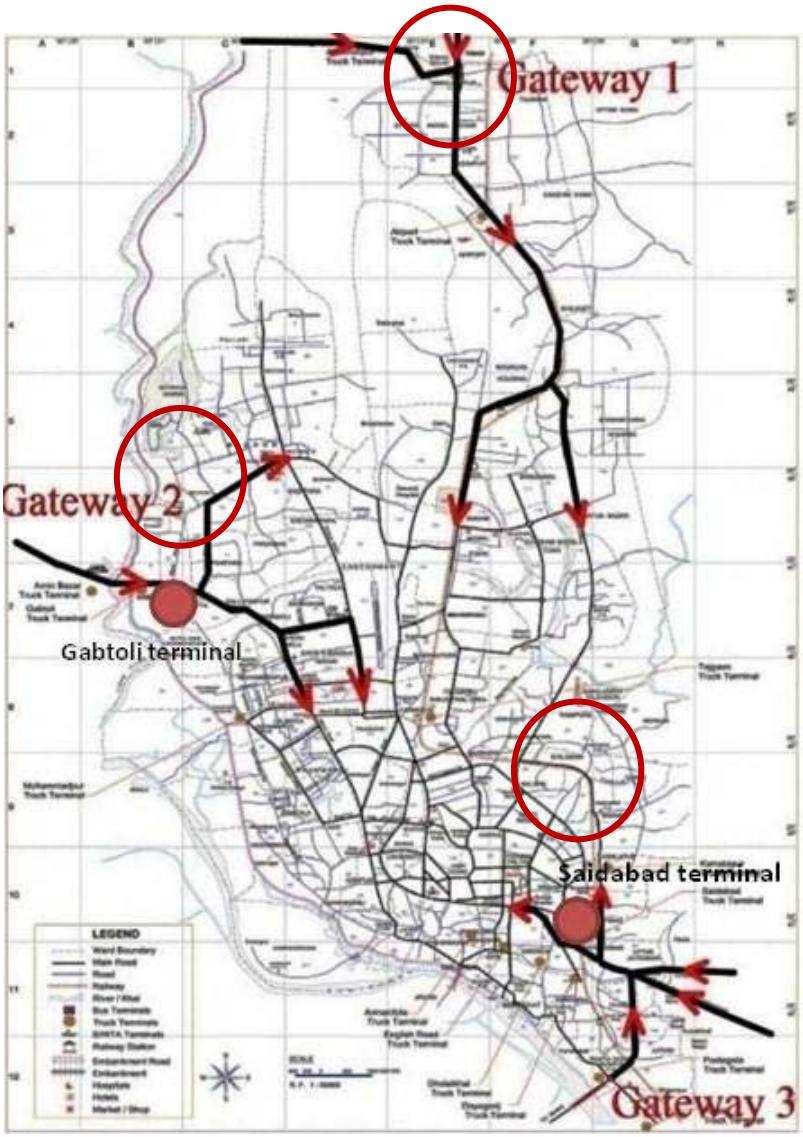


Map 7-3: Feeder route layout (option)

External network:

Geographically the location of Dhaka is in the centre of the country and there are three gateways connecting the city with adjacent cities/villages/ as shown in map 7-4. As a result a lot of vehicle related traffic passes through the city creating anonymous pressure on city roads. That's why it's really necessary to differentiate these inter-district connections from city's own PT system. This external network (3rd layer) consists of direct fast services to different towns in the Dhaka district. Distances of lines are much longer than the internal network and depending on travel demand; frequencies will vary from 15-30 minutes in peak hour till 30-60 minutes during the day. Connections from the external network to the backbone network can be made either on Saidabad bus terminal (for southern corridor) or for some lines

at the Gabtoli bus terminal (north western corridor). Outskirt connection from Dhaka is beyond the scope of study and due to the data limitations it's not possible to show the proposed external network.



Map 7-4: Dhaka city map showing three gateways
Source: (Hoque & Choudhury, 2009)

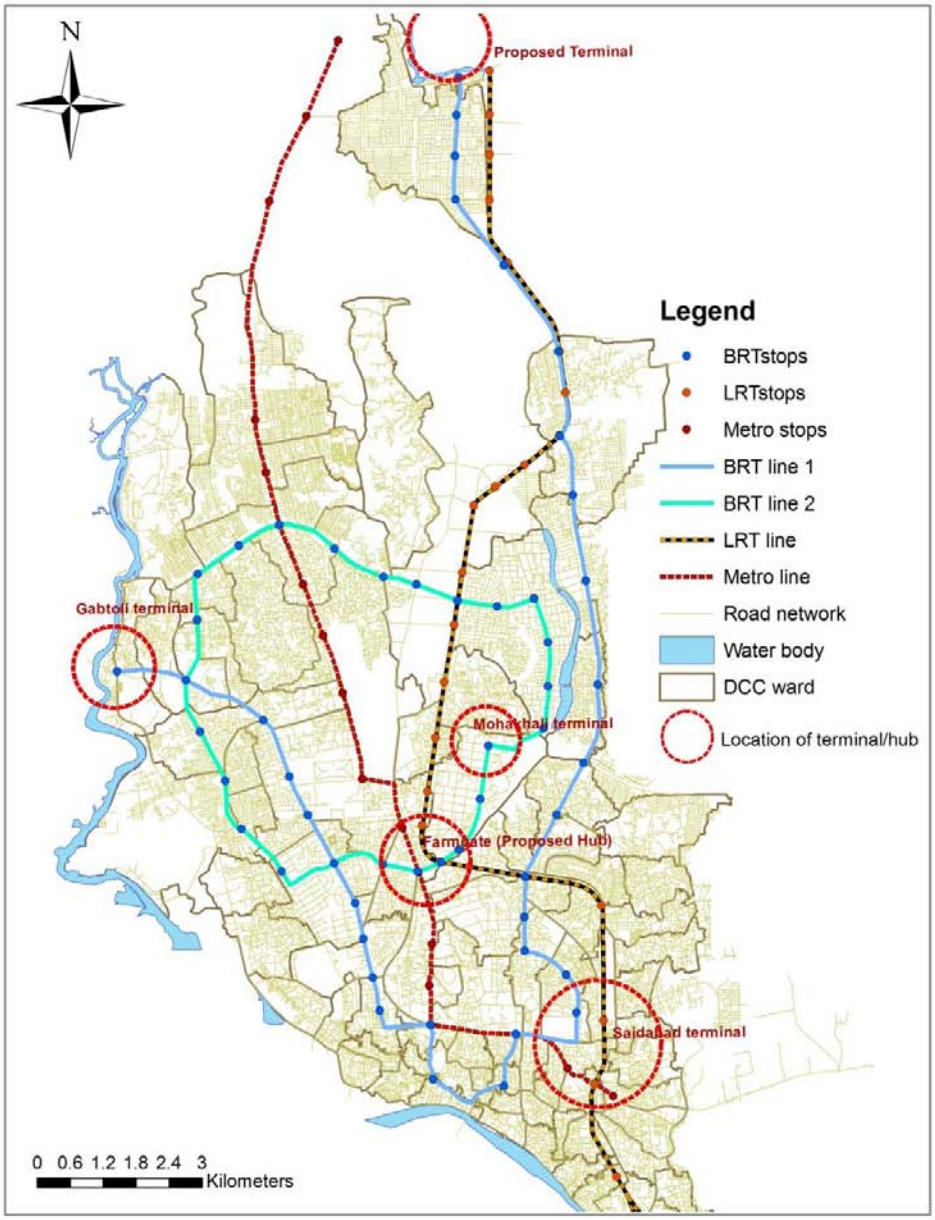
2. Dedicated lanes/Separate bus ways:

Three aspects of geometric design viz. exclusive bus lane, location and design of bus stops, and non-motorized vehicle lane are essential for system efficiency of BRT (Tiwari, 2006). Creating exclusive lanes for buses minimizes conflicts with other vehicles and therefore improves bus movements. The basic changes required in the proposed BRT lines include provision of a segregated bus way. Then, at least one lane can be reserved for buses, while the other two can be for cars, and other motor vehicles. Exclusive bus lanes can be provided either as curb-side lanes or central lanes physically segregated from the rest of the traffic (Tiwari, 2006). The central lanes of a corridor have minimum conflict with turning vehicles or slow moving vehicles. There is least probability that the volume of turning traffic from innermost lane will come in conflict with it. Most successful BRT systems use the centre lanes (Hook, 2004). These central lanes will be reserved for buses. In centrally placed bus lane layout the bus lanes for both directions are separated by a median. Bus shelter can be on the right or on the left; but, putting station in the middle consumes less road space and eases transfers (Hook, 2004). In the proposed BRT corridors it is possible

to have segregated bus ways except the old Dhaka area where it's needed to be dedicated lane. The area is shown in map 7-1. The limitation of this dedicated route will be that it will limit other vehicles to use that road and it is also necessary to redesign the traffic system of this area. One way is to solve by restricting some road by one way traffic.

3. Terminals and stops location:

Saidabad and Gabtoli terminal will be serve the south and north-west corridor and because of its central location Mohakhali terminal can also serve the route. But at the location of Farmgate a hub needs to create where BRT and LRT come together which is shown in map 7-5. It is necessary to establish an interchange station at this location. In Almere city the terminal acts as a multimode terminal for rail and bus and transfer point for mode shift (bicycle - PT and car - PT). Keeping this in mind there is a possibility to create a multimodal terminal, as Saidabad terminal and Kamalapur rail station are almost together.



Map 7-5: Location of terminals (existing and proposed)

From the discussion in chapter four, the standard spacing for BRT stops vary from 0.5km to 2 km. In the proposed two BRT lines, the stops need to be located accordingly. Only a few existing stops can be adapted but they also need some modifications (permanent structure, sitting facilities, information display et.) and better facilities. Leading for the locations of the stops are the potential demand at those like a new residential area, a location of a major facilities. So BRT stop spacing will not be always within 500 meter, varies from 500 meter to 1.5 km. Bus stops need to be located at designated points only on the major roads, with locations for boarding and alighting passengers.

For the proposed LRT the existing railway stations at Airport, Cantonment, Banani, Tejgaon, Kamalapur must be expanded to function as multimodal exchange nodes. New such stations will have to be constructed at the intersections of key roads and railway tracks at Mohakhali, Maghbazar, Panthapath and Rampura Road.

7.1.2. System planning

Satellite cities are planned after carefully analyzing the present and future land use patterns and density, ecosystems, utility and road infrastructure, presence of growth magnets such as industry, commerce, institutional facilities, other urban amenities, and travelling time from key urban nodes. The integration of transportation planning and land use planning in the context of the development of metropolitan Dhaka is critical. The only realistic approach for the successful control of growth of development involves an active commitment to policies involving transportation and land use planning. It is essential to recognize that the size, growth rate and distribution of the density of metropolitan Dhaka have a crucial impact on the dependence on transit. Land use planning and transportation planning interact between themselves to determine development patterns. The two are so interconnected that they need to be considered simultaneously. To achieve integration between these two it is necessary to create a unified authority that will be responsible for the planning of both land use and transportation systems whereas the two functions are currently separated. But the creation of a new authority will not be enough; also most essentially needed is the political will and determination of the government.

7.1.3. Organization

Plan, program, and finance and implement such an important transportation system would need an effective organizational set up. A good organizational set up can only be possible by strong government role. Government should play a major role on monitoring, implementing policy and licensing as well as need to monitor fare structure also. Government need to introduce policies on congestion pricing system for specific areas for example Motijheel, Gulshan, Farmgate area, in order to control vehicle traffic at specific hours of the day. The Government should revise the present system of vehicle registration in order to eliminate the possibility of vehicles which are non-roadworthy obtaining a certificate to operate. The Government should encourage the private sector to establish trained technicians to undertake the vehicle testing program under license from the BRTA and need to review the existing system of issuance of driving licenses. The Government needs to ensure that the drivers are trained, skilful, and aware of traffic rules and medically fit to obtain a driving license. Computerise the parking violation records of drivers and cars and introduce demerit penalty point system both for car and drivers.

System integration is important in terms of physical facilities e.g. terminals, exclusive bus lanes, ticketing, infrastructure, parking and services e.g. network structure, schedule coordination. The greatest efficiencies in operating transportation systems are achieved when different modes can act together whereas in Dhaka the existing modes and sub modes act independently. The systems need to be planned so that all modes of transport are integrated. There should be proper integration between all modes of backbone network and

also with the backbone to the feeder in terms of fare integration, scheduling and also by creating a common hub. The new systems will need to use whatever resources they have available in order to enhance the existing services and to provide for increasing demand in the future.

Involve of private sector has an important role on organizational issue. Developing city like Dhaka it is very necessary to have proper public private partnership. There are many advantages possible to gain by involving private sector in the provisions of infrastructure and operations.

7.1.4. Institutional framework

The institutional capacity is known to be weak in the Dhaka Metropolitan Area, so it is important to ensure that the enabling legislation for the executing agencies is enacted, lines of responsibility are clearly defined and key staff appointments are made. There is a need to ensure that the current legislative conditions are suitable for the encouragement of private sector investment. There will need to be an independent review of current laws to ensure fairness on behalf of the private investor and protection for the Government. The Government will should provide an open and transparent bidding procedure to create fare competition within the bidding procedures.

In the absence of a properly maintained database, the authorities in Dhaka face another special problem in respect of the assessment of actual number of registered motor vehicles and the identification of ownership of these vehicles. As a result the law enforcing authority finds it difficult to locate and penalize the owners and drivers of the vehicles which violate the traffic rules. The Government need to provide the funds and other measures which will be needed to establish and maintain an up to date data base of both vehicles and drivers. The data base will be managed by BRTA but will be accessible to law enforcing agencies and safety engineers.

7.1.5. Finance

This new system will require investment in infrastructure to improve the existing roads, provide stations and fare collection gates and equipment. In order to finance the implementation of recommended backbone network required for the development of Metropolitan Dhaka, there are a range of possible options including creating a user charges system and providing equitable subsidies in the right manner and at as low a level as possible. There is a need to encourage loan financing from major international agencies. The private sector will also need to play a vital role in the promotion of private public partnerships.

The program could be run as a totally public sector venture or as joint public and private sector initiative. The joint public sector -private sector initiatives could include majority contributions from a donor agency, central government, City government to say 60 per cent to 75 per cent of the cost of the program. The privatization of public transport has moderated the concentration of market structure and has lead to improved frequencies and service levels in many European countries.

There is a need to introduce some form of easier fare structure in Dhaka city. This will not be easy under this existing weak institutional framework. An innovative but easily understandable mechanism need to be developed for the integration of fares between different type of backbone and feeder and also to develop the provision of a common ticketing system to allow free movement between different modes. This is also necessary to apply different strategies like discount fare for senior citizen, child etc. The fare structure will take account the length of trip and the type of service provided. Also the fare structure needs to be revised

periodically to adjust for justifiable cost increases. Government need to take proper initiative to maintain this and to ensure an equitable fare structure for passengers.

7.2. Evaluation of rationalization framework

In the previous section the implementation of framework in Dhaka is discussed, though it's not yet established that this framework specifically the hierarchy of network will improve the existing situation or not. To come up with this conclusion it's necessary to evaluate the network. But as already mentioned due to the limitations of data availability it's not possible to assess the backbone and feeder network both. In spite of this limitation it is attempted to evaluate the proposed (backbone) network on the base of a few indicators.

1. Key features of proposed backbone network:

The key features of the proposed backbone network summarized in table 7-1. It is mainly derived from the table 4-1 in chapter four.

Table 7-1: Key features of proposed Backbone network

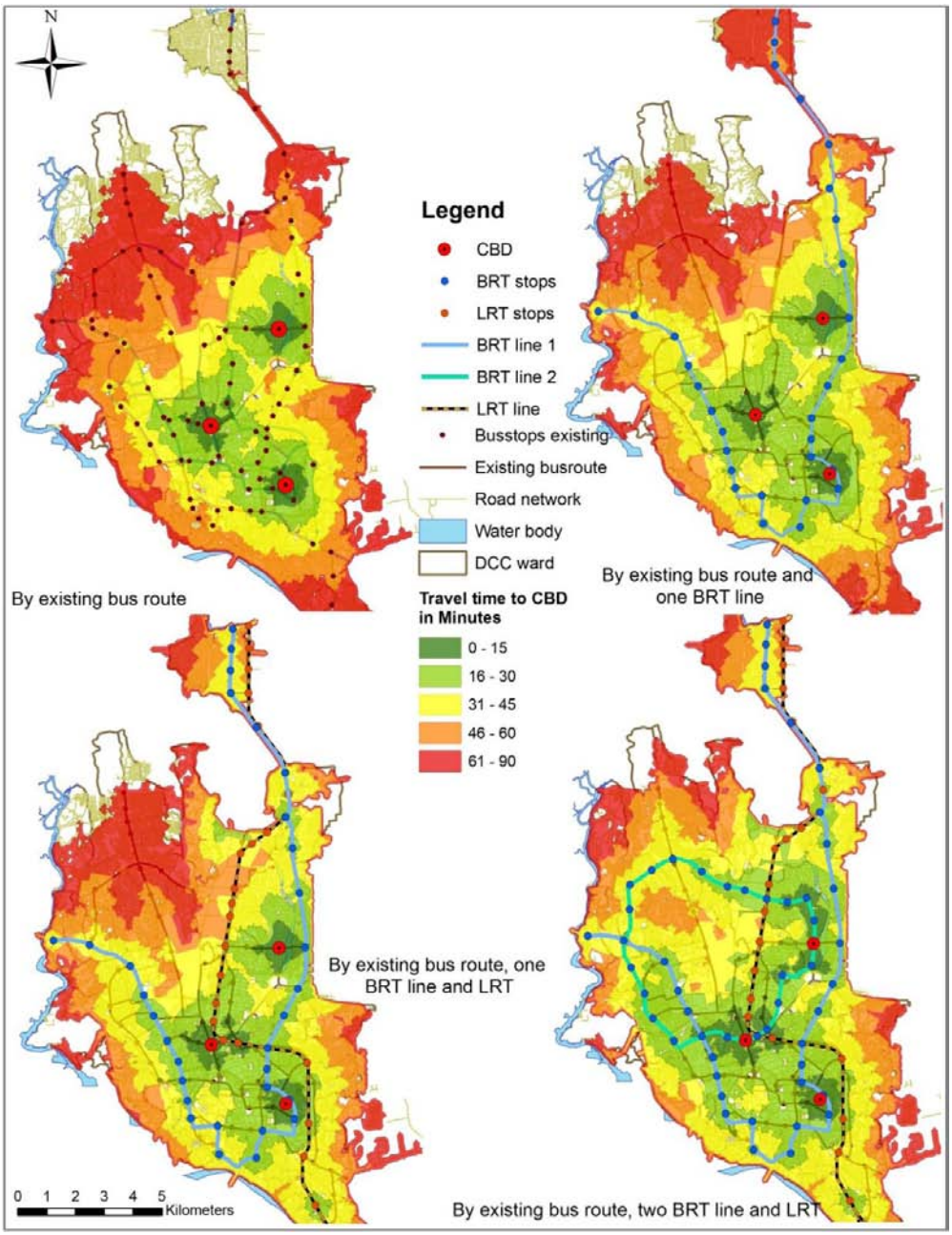
Passenger	Proposed backbone network		
	BRT	LRT	Metro (source: JICA)
Segregation	Segregation / dedicated lane	Existing track	Elevated
Space requirement	1 lane from existing road	1 or 2 lanes from existing track	Little impact on existing road
Public transit integration	Integrated with feeder & Para transit	Integrated with BRT stops, feeder & Para transit	Integrated with BRT stops, feeder & Para transit
Implementation time	Short	Medium	Long

2. Access to CBD:

Access is the process associated with getting to and departing from the stops or stations. It is important that transport services are efficient and reliable as compared with an acceptable level of accessibility to transport facilities. Most public transport users access bus stops by walking, particularly in urban areas. Such access is typically perceived in spatial terms as the physical proximity to transit stops or stations. The significance of access is that the more people that reside and/or are employed in close proximity to transit, the greater the likelihood that the service will be used (Murray et al, 1998). Actually, accessibility to transit is a critical issue from a point of view both of sustainable mobility and of sustainable accessibility (Javier Gutierrez, 2008).

As the city is growing, residential areas started to develop outside the CBD. People tend to live outside city center and commute daily to the CBD for work. Using a bus system to commute is expected to reduce the traffic volume on main roads. One of the indicators to analyze the accessibility to the CBD is the travel time from each bus stop to the CBD. In this analysis three CBD's are defined, one is Motijheel area which is the main commercial centre of the city, second is Framgate area which is the second commercial centre of the city and third is Gulshan area which is newly developed commercial centre. The world average commuting time is 40 minutes, one way for work. Here 30 to 45 minute is used as threshold to define how long commuting time should take place. Travelling within this timeframe is regarded. It is assumed that all people work in one of the Central Business Districts (CBD). The analysis is execute sequentially, first using the existing bus then followed by adding one by one the backbone network (one BRT, LRT, two BRT and finally with MRT) to see the effect of the additions gradually (Map 7-6). In

figure 7-1 it is clearly visible that how the accessibility is increased by adding backbone network. And finally from map 7-7 it is clear that accessibility to CBD is increased by adding the four backbone network, most of the area is covered within the time threshold (45 minutes).



Map 7-6: Accessibility to CBD by existing bus route, two BRT line and LRT line.

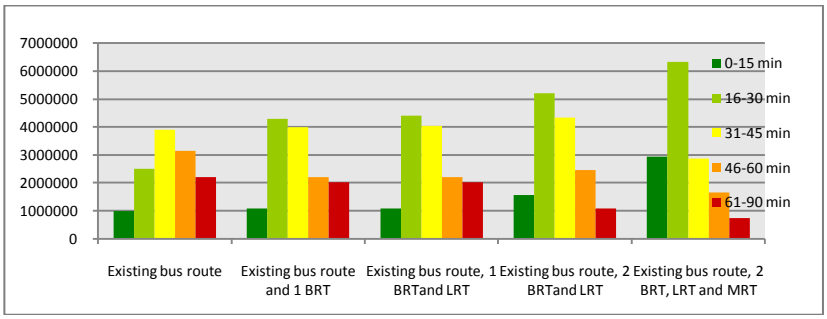
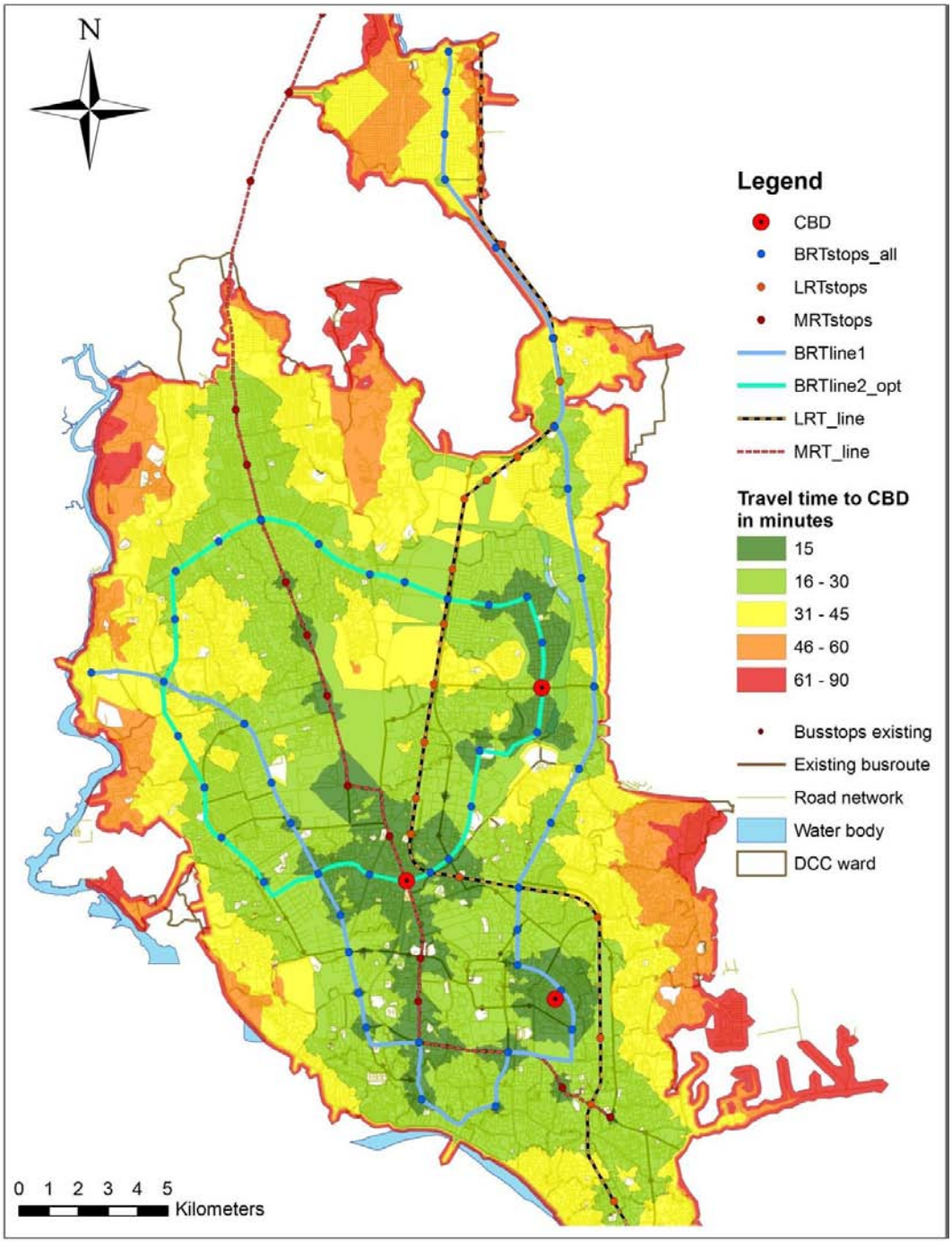


Figure 7-1: Population covered within the travel to CBD



Map 7-7: Accessibility to CBD by backbone network

The similar analysis but based on industrial area, major government health facilities and major institutions has been executed and are shown in Annex 4.

3. Service provision of existing bus route and proposed backbone network:

Service provision of existing bus route and proposed backbone network are summarized in table 7-2. Three main characteristics that are travel speed, capacity and frequency, of existing bus route and proposed backbone network are compared in this table.

Table 7-2: Service provision of existing bus route and proposed backbone network

Characteristics	Existing bus	Proposed backbone network		
		BRT	LRT	Metro (source:JICA)
Travel speed	8 Km/hr	15 Km/hr	30 Km/hr	35 Km/hr
Capacity (person)	30 to 45	60	500 to 1000	1778
Frequency	15 to 30 min (No defined frequency)	10 – 15 min (peak hr) 20 – 25 min (off peak)	10 – 15 min (peak hr) 20 – 25 min (off peak)	3 min 20 seconds

7.3. Some policy guidelines and recommendations

In the expert's interview and also in European planning considerations, beside main components of rationalization, there is several policy guidelines also provided. Considering experts critical comments and also by reviewing documents regarding policy issues in study area, below there are few policy guide lines and recommendations are provided towards achieving rationalized public transport system in Dhaka city.

1. Rationalise and harmonise the existing private sector buses into a number of limited companies and allocate major routes to one of these different companies. Each route will be served by only one company under a strictly set of rules and regulations. These would include number and types of buses to be used on each routes, frequencies of operation, fares to be charged, etc. No other buses or other companies will be allowed to ply on the designated routes.

2. The Government needs to implement a policy that removes the inefficient competition between modes.

3. The Government should identify those areas of the city and the expanded development where there will be a policy of emphasizing public transport access over private vehicle access.

4. Parking control should be the responsibility of the municipalities who will administer it through a central parking control office. The office will retain its own staff and will employ parking wardens to monitor space usage and issue tickets to violators. It is preferred that this aspect be undertaken by the private sector and the Government will enact such rules as will make this possible. And also need to provide and build as many parking-only structures (not mixed with other commercial uses) as possible on all major arterial roads of the city.

5. There should be investigate means whereby subsidies can be allocated to the poor and needy in order to make the transportation system affordable to all. Public transport of all kinds need to be planned and designed or adapted so as to provide some facilities in the vehicles so that disabled persons can access the vehicles and ride on them in comfort. The bus stations, terminals, railway stations and motor launch landing stations will be re-planned to provide proper facilities for disabled persons so that they do not encounter any impedance to movement.

6. Non-motorized transport will be prevented from operating on many sections of arterial highways and especially at intersections. Rickshaws will be encouraged and assisted to ply on the lanes and narrow roads to serve local neighbourhood demands and to provide feeder services from the neighbourhoods to the main line rapid transit stops.

7. Bicycles need to be recognized as a mode of transport and separate lanes and crossings will be provided within the city in order to make bicycle journeys safe and pleasant.

8. The Government need to enact a pedestrian policy to ensure the construction of properly designed and continuous pedestrians with well-defined and maintained pedestrian routes in the city, the provision of pedestrian crossing facilities giving the pedestrian priority over all other traffic and the prohibition of unauthorised encroachment on the footpath by street vendors and others.

9. The Government will initiate a comprehensive review of the existing laws and regulations as they apply to private sector investments and will amend the laws such that they provide equitable ways to enter into contracts between the parties.

The formulation of the most efficient plan and organizational set up will not be enough, is most essentially needed is the political will and determination of the Government.

8. CONCLUSION AND RECOMMENDATION

The objective of this chapter is to conclude the study and give recommendations. It is composed in three main sections. First, conclusive remarks from the scope of study are given. Second the limitation of achieving answers through analysis of all research questions is given. Finally recommendations are given for further research from this study.

8.1. Conclusion

In drawing conclusion of this study, the research objective which is to study rationalization of public transport; particularly public transport system design (routes and their categorization) in Dhaka, Bangladesh, based on European public transport planning tradition and best practices is evaluated against the findings and the observation.

- Analyzing existing public transport situation of Dhaka city.

Dhaka is over densely populated city and its transport system is based on mainly road systems and it's related to the traffic congestion and traffic management. The study shows that current public bus provision was inadequate in relation to the demand. The present bus services (operated under as many as 750 individual ownerships) provide inefficient, unproductive, and unsafe level of services. Long waiting, delay on plying, overloading, discomfort, and long walking distance from the residence/work place to bus stoppages are some of the obvious problems that confront the users in their daily life. In peak hours they very often load and unload in unspecified stops.

The real hindrance to smooth traffic as experts look at it does not lie in inadequate roads. Dhaka's unplanned growth, a Dhaka-centric development of the country, the lack of east-west connecting roads, unplanned construction inside the city, increased number of private transports, the lack of mass transit are some of the contributory factors to these problem. At the same time the poor traffic management, increasing number of rickshaws, lack of parking space and pedestrian walkways and reluctance to use of foot over-bridge make travelling more difficult on the streets.

Also transport service in Dhaka has several deficiencies resulting from a combination of factors - physical, developmental and institutional-cum-policy framework-related which lead to lower efficiency, higher transport costs, longer waiting & travel time, discomfort and more significantly, "transport unreliability" with major adverse consequence for the economy & environment. Rapid population growth, the absence of planning control and poor economic conditions has contributed to the lack of organization on the public rights-of-way. There is also a high level of operation disorder, which significantly diminishes the efficiency and effectiveness of the existing transport systems.

- Derive a theoretical framework from European scientific knowledge, planning practices and example of European PT planning

By integrating scientific knowledge and discussions with European PT planning experts and an example of PT planning, a theoretical framework on public transport rationalization is derived. This framework is mainly captured from main two aspects which are scientific knowledge and expert's opinion through

interviews. This framework explores five main components of rationalization which are network, system planning, organization, institutional framework and finance. All about the components regarding the theoretical frameworks are closely connected and interlinked with each other.

From the scientific knowledge and expert's opinion it is quite clear that the main aspects of rationalization to some extent are similar. But after analyzing expert's interview it has confronted that there are some points or sub aspects which yet not documented. For example in Vuchic theory there are hardly any discussions on establishing hierarchy and also on the importance of terminal locations which according to planning practices are quite important aspects. Also about the integration of transport policy and spatial planning are missing.

- Establish this theoretical framework to Dhaka and draw planning and policy lessons.

After analyzing the existing situation it is clear that without a collaborative Mass Rapid Transport (MRT) system the roads of Dhaka City will not be able to cope with the growing vehicles and expanded passengers in the near future and the whole transportation system will collapse. So establishing the theoretical framework where one of the major components is to ensure proper network by proper mass rapid transit system is one way to solution the existing PT problem of Dhaka city. An integrated transport scheme with BRT, LRT and metro to achieve hierarchy are already discussed in the previous chapter along with the other components of theoretical framework. This will be two BRT lines on grade on existing roads, but with separate designated lane exclusive to bus system. The existing railway stations and road intersections at Tongi, Airport, Cantonment, Banani, Tejgaon, Kamalapur and Naranyanganj must be expanded and rebuilt to function as multimodal exchange nodes. New such stations will have to be built at the intersections of the key roads and railway tracks at Mohakhali, Maghbazar, Panthapath and Rampura Road. Also feeder route need to integrate with the backbone system.

To overcome these increasing transportation burdens and to meet the transport needs of residents and to promote desirable patterns of land use in Greater Dhaka over the next decades it is necessary to change the existing policies. However, organizational supports and infrastructure development needed to meet the demand of the mobility of the urban dwellers.

Establishment of this theoretical framework (chapter-7) to the study area are shown in this study which will be useful to transportation planners, urban planner and policy makers in development of present PT crisis and congestion of Dhaka city. Hopefully, hierarchy of routes and future proposed feeder access accordingly will help to PT Planner and experts to influence the performance of public transportation systems of Dhaka.

8.2. Study limitation

In the course of this research, some limitations are encountered:

- Limitation on the existing situation analysis of the study area

The main limitation of this research regarding the analysis of the study area is the reliance on secondary data and the inability to commence fieldwork in the study area, hence its not possible to check all data correct or not. Since it is not possible to conduct an extensive survey in study area required for this study, in the analysis it is necessary to rely on assumption and own knowledge. Although the researcher lives in the study area it is quite impossible to have complete understanding and information about the entire study area.

Another limitation is the lack of spatial data covering the entire area of study which limits the scope of the spatial analysis and a better understanding of existing situation of study area. Also regarding data limitations, the data used for DCC is in GIS format but the population information used in analysis is collected from paper sources. There is a slight difference in ward sizes used in GIS format vs ward sizes collected from paper sources and keeping this in mind the further analysis is carried out.

As data and information collected from relevant organizations and published reports, many of the relevant organizations and reports show the different figure of the same data for the same period. Therefore, some of the data are incorporated based on assumption. Also data that have been used in this report from different sources may have some inaccuracies. Sometimes they are not trustworthy like data have been used from the internet sources (website), which may not be very reliable. These may lead to inaccuracies in analysis. Sufficient updated data are not available for all priority issues and most of the data are used not recent data.

- Limitation on the theoretical framework approach

The theoretical framework is mainly based on scientific knowledge, expert's opinion and one of the examples of EU planning practice. In this regard there are also few limitations, in capturing scientific knowledge several documents are analysed but the framework mainly derived from Vuchics book which mainly covered operational aspects. There are also few guide lines regarding planning issues but policy guidelines are missing. Regarding experts interview it is initialized to cover all the expertise of PT planning including operational, organizational, institutional and operator point of views. But due to expert's unavailability and time limitations it is not possible to cover academician's points of view. Also another limitation is about one of the example of European PT planning practices. Bearing in mind that the city neither in same size nor generate same demand the analysis is carried out.

- Limitation on the assessing the framework

Due to data limitation only the first component of framework implemented and evaluated in the study area, in the rest of the components suggested guidelines but not implemented. Also the theoretical framework implemented in the study area could not be assessed quantitatively and qualitatively due to lack of data for doing so. This has been identified as a recommendation for future research.

8.3. Further research

This thesis reflects an initial step to the development of a theoretical framework to rationalize transport system from European knowledge and practice and how to implement this framework in a developing city like Dhaka with various constraints of land use and transport development. However further research in this field is required.

Firstly there is an emerging need to analyse existing PT situation of the study area with a detail survey which is able to integrate other factors within its analysis. The existing situation analysis used for this study had a lot of limitation in term of data on cost (travel cost, fare cost, reliability of mode, safety and travel information).

Secondly further study is required in defining the theoretical framework to be able to capture rationalization in public transport planning. Further study can be done aimed at revealing consequences of theoretical framework. Further study can focus on capturing expert's opinion, to cover all the aspects of PT planning and also increase the number of expert's interview.

Thirdly the implementation of framework needs to be evaluated both qualitatively and quantitatively. Also in this study the entire population is treated as equal, no competition is considered in term of education and income level. Evaluating accessibility by taking into account the diversity in the socio-economic structure of the society would result in more accurate results.

Finally in this research, while implementing the framework in Dhaka the cost benefit issue are not included in the analysis due to the limitation of data. Further study can be done by considering this issue.

LIST OF REFERENCES

Ahsan, H. M. (1990). *A Study of Mass Transit in Metropolitan Dhaka*. BUET, Dhaka.

Alterkawi, M. M. (2006). A Computer Simulation Analysis for Optimizing Bus Stops Spacing: The Case of Riyadh, Saudi Arabia. *Habitat International, 30*(3), 500-508.

Amin, M. S. R., Rahman, M. M., Uddin, M. Z., & Maniruzzaman, K. M. (2005). State of Public Transport:An Analysis of Bus Routes and Stoppages of Dhaka City. *Jahangirnagar Planning Review,, 3*, 93-104.

Ammons, D. N. (2001). *Municipal Benchmarks: Assessing Local Performance and Establishing Community Standards* (2nd ed.): Thousand Oaks: Sage.

Armstrong-Wright et al. (1987). *Bus services: Reducing cost, Raising standards*: The world bank.

Badami, M. G. (2005). The urban transport challenge in India - Considerations, implications and strategies. *International Development Planning Review, 27*(2), 169-194.

Badami, M. G., & Haider, M. (2007). An Analysis of Public Bus Transit Performance in Indian Cities. *Transportation Research Part A: Policy and Practice 41*(10), 961-981.

Banister, D. (2008). The Sustainable Mobility Paradigm. *Transport Policy, 15*(2), 73-80.

Barter, P., & Raad, T. (2000). *TAKING STEPS: A community action guide to people-centred, equitable and sustainable transport*: The SUSTRAN network.

BBS. (2001). *Statistical Year Book of Bangladesh,* : Dhaka Reproduction Documentation and Publication Wing, BBS.

BBS. (2008). *Statistical Year Book of Bangladesh*: Dhaka Reproduction Documentation and Publication Wing, BBS.

BCAS. (2005). *Dhaka City State of Environment: 2005*: Report for Department of Environment, Ministry of Environment and Forests.

Beirão, G., & SarsfieldCabral, J. A. (2007). Understanding Attitudes towards Public Transport and Private Car: A Qualitative Study. *Transport Policy 14*(6), 478-489.

BRTA. (2002). *Statistical List of Route Permit of Bus and Minibus in Dhaka City*. Dhaka: Bangladesh Road Transport.

Button, K., & D. Hensher. (2001). *Handbooks in transport 3*: Handbook of transport systems and traffic control.

DCC. (2001). *"Ward Details"*: Annual Report of Dhaka City Corporation.

DCC. (2007). Dhaka Profile: City Growth- Area and Population. from http://www.dhakacity.org/html/dhaka_profile.html

DDC. (1998). *Dhaka Urban Transport Plan Phase II Consultancy Draft Final Report (Volume III): Environmental Action Plan (EAP)*: Development Design Consultants (DDC) and Mott MacDonald and PPK prepared for the Ministry of Transport, Government of Bangladesh.

DDC. (1998). *Dhaka Urban Transport Plan Phase II Consultancy Draft Final Report (Volume III): Environmental Action Plan (EAP)*: Development Design Consultants (DDC) and Mott MacDonald and PPK prepared for the Ministry of Transport, Government of Bangladesh.

Demetsky, M. J., & Lin, B. (1982). "Bus Stop Location and Design.". *Transportation Engineering Journal of ASCE, 108,* , 313–327.

DITS. (1994). *"Dhaka Integrated Transport System (DITS)"*. Dhaka: Dhaka Transport Coordination Board (DTCB).

DMDP. (1995). *Dhaka Structure Plan 1995-2015*: Dhaka Metropolitan Development Plan, RAJUK.

DUTP- II. (1998). *Draft Final Report,* . Dhaka.: Prepared by PPK, Mot MacDonald and Development Design Consultant (DDC), .

DUTP. (1998). *Draft Final Report, Prepared by PPK*. Dhaka: Mot MacDonald and Development Design Consultant (DDC), .

ECMT. (2004). *Improving access to public transport*.

Eppell, V. A. T., J. M. Bunker, & et al. (2001). *A four level road hierarchy for network planning and management*. Paper presented at the 20th ARRB Conference, Melbourne.

Furth, P. G., & A.B. Rahbee. (2000). "Optimal Bus Stop Spacing Through Dynamic Programming and Geographic Modeling.". *Transportation Research Record, 1731*, 15-22.

GB50220-95. (1995). *Code for Transport Planning on Urban Road*. Beijing: Ministry of Construction of the People's Republic of China.

Gutierrez, J., & J. C. Garcia-Palomares. (2008). Distance-measure impacts on the calculation of transport service area using GIS. *Environmental and Planning B : Planning and Design 2008*(35), 480-503.

Gwilliam, K. M. (2002). *Cities on the Move: A World Bank Urban Transport Strategy Review*. Washington D.C., : World Bank Publications.
Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: an explanation of issues and alternatives. *Environment and Planning A, 29*(7), 1175-1194.
Hook, W. (2004). *Maximizing the Air Quality Benefits of Bus Rapid Transit*. Paper presented at the BAQ Conference 2004.
Hoque, M. S., & Choudhury, C. F. (2009). *Mass Transit System in Dhaka City*. Paper presented at the Workshop on Future Direction of Dhaka Urban Transport.
Ingram. (1998). Patterns of metropolitan development: what have we learned? *Urban studies, 35*(7), 1019-1035.
JBIC. (2000). *Study on the Improvement of Transportation and Environment in Dhaka*: Japan Bank for International Cooperation.
Karim, M. M. (1998). *Engineering, Regulatory, and Financial Options for Mass Transit in Metropolitan Dhaka*: Government of the People's Republic of Bangladesh.
Khan, S. I. (2010). Mass rapid transit for Dhaka: The last ray of hope. *The Daily Star*. Retrieved from http://www.thedailystar.net/newDesign/news-details.php?nid=134581
Levinson, H. S. (1983). "Analyzing Transit Travel Time Performance.". *Transportation Research Record, 915,* , 1–6.
Maas, C. J. v. d. (1998). *Successful public transport in urban regions: A European study on policy and practice*.
Mackett, R. L. (2001). "Policies to Attract Drivers out of their Cars for Short Trips. *Transport Policy, 8*(4), 295-306.
Martens, K. (2004). The Bicycle as a Feedering Mode: Experiences from Three European Countries. *Transportation Research Part D: Transport and Environment, 9*(4), 281-294.
Monayem, M. A. (2001). *Evaluation of Traffic Operation Conditions on Two Urban Arterials in Metropolitan Dhaka.* BUET
Dhaka.
Murray, & Davis. (1998). Public Transportation Access. *Transportation Research Part D: Transport and Environment, 3*(5), 319-328.
Murray, R. Davis, R.J. Stimson, & Ferreira. (1998). "Public Transport Access.". *Transportation Research D 3*, 319–328.
Nagari, A. T. M. H. (2001). *Strategic Transport Planning for Dhaka Metropolitan Area*.
Newman, P., & Kenworthy, J. (1999). *Sustainability and Cities: Overcoming Automobile Dependence*. Washington, DC: Island Press.
Palmner, C., Astrop, A., & al., e. (1996). Attitudes and Travel Behavior of Households in Pune, India. International Symposium on Infrastructure of the Future. Bangalore, India. *Transport Research Laboratory*.
Paul. (2001). Transport research and information network. *Journal of transport geography, 9*, book reviews: 75 - 81.
Quium, A. S. M. (1995). *Dhaka Metropolitan Development Plan, Review of Structures, and Urban Area Plans, Sub Sector: Transport*. Paper presented at the Dhaka Metropolitan Development Plan,.
Rahman, G., Majumder, M. K., & Rana, B. (1999). *State of Air Pollution in Bangladesh.*: Forum of Environmental Journalists of Bangladesh (FEJB).
Rahman, M. S. (2008). Future Mass Rapid Transit in Dhaka City: Options, Issues and Realities. *Jahangirnagar Planning Review, 6*, 69-81.
Rahmatullah, M. (2005, 22 March 2005). *Strategic Transport Plan for Dhaka*. Paper presented at the Proceedings of the seminar on Contemporary Planning Issues, URP Seminar Series, Department of URP,
Jahangirnagar University.
RMMS. (2004). *Road Maintenance and Management System (RMMS)*. Dhaka: Dhaka City Corporation (DCC).
Rodrigue, J.-P., Comtois, C., & al, e. (2009). *The Geography of Transport Systems, Second Edition*. New York, : Routledge.
Saka, A. A. (2001). "Model for Determining Optimum Bus-Stop Spacing in Urban Areas." *Journal of Transportation*
Engineering 127, , 195–199.
Santhakumar. (2003). Transportation system management for Madurai city using GIS. Retrieved from http://www.gisdevelopment.net/application/utility/transport/mi03189.htm

Scott, D., Novak, D., & al, e. (2006). Network robustness index: A new method for identifying critical links and evaluating the performance of transportation networks. *Journal of Transport Geography, 14*(3), 215-227.

STP. (2004). *"Strategic Transport Plan(STP) for Dhaka, Final Report, 2006"*: Dhaka Transport Coordination Board.

Tiwari, G. (2002). Urban Transport Priorities: Meeting the Challenge of Socio-economic Diversity in Cities, a Case Study of Delhi, India *"Cities", 19(2)*, 95-103.

Tiwari, G. (2006). *Safer Infrastructure Design of Bus Rapid Transit System in Asian Cities.* . Paper presented at the Proceedings of International Conference on Road Safety in Developing Countries, Bangladesh University of Engineering and Technology (BUET).

TranSafety, I. (1998). Strategies for solving urban transportation problems in developing countries. *Road management and engineering journal*.

Untermann, R. K. (1984). *Accommodating the Pedestrians*. New York: Van Nostrand Reinhold.

Vuchic, V. (2007). *Urban transit Systems and Technology: system and technology*. Wiley.

White. (2002). *Public transport: its planning, management and operation.* London: Newyork, spon press.

Wikipedia. (2010). from http://en.wikipedia.org/wiki/Dhaka

Wirasinghe, S. C., & N.S. Ghoneim. (1981). "Spacing of Bus-Stops for Many to Many Travel Demand.". *Transportation Science*
15, , 210–221.

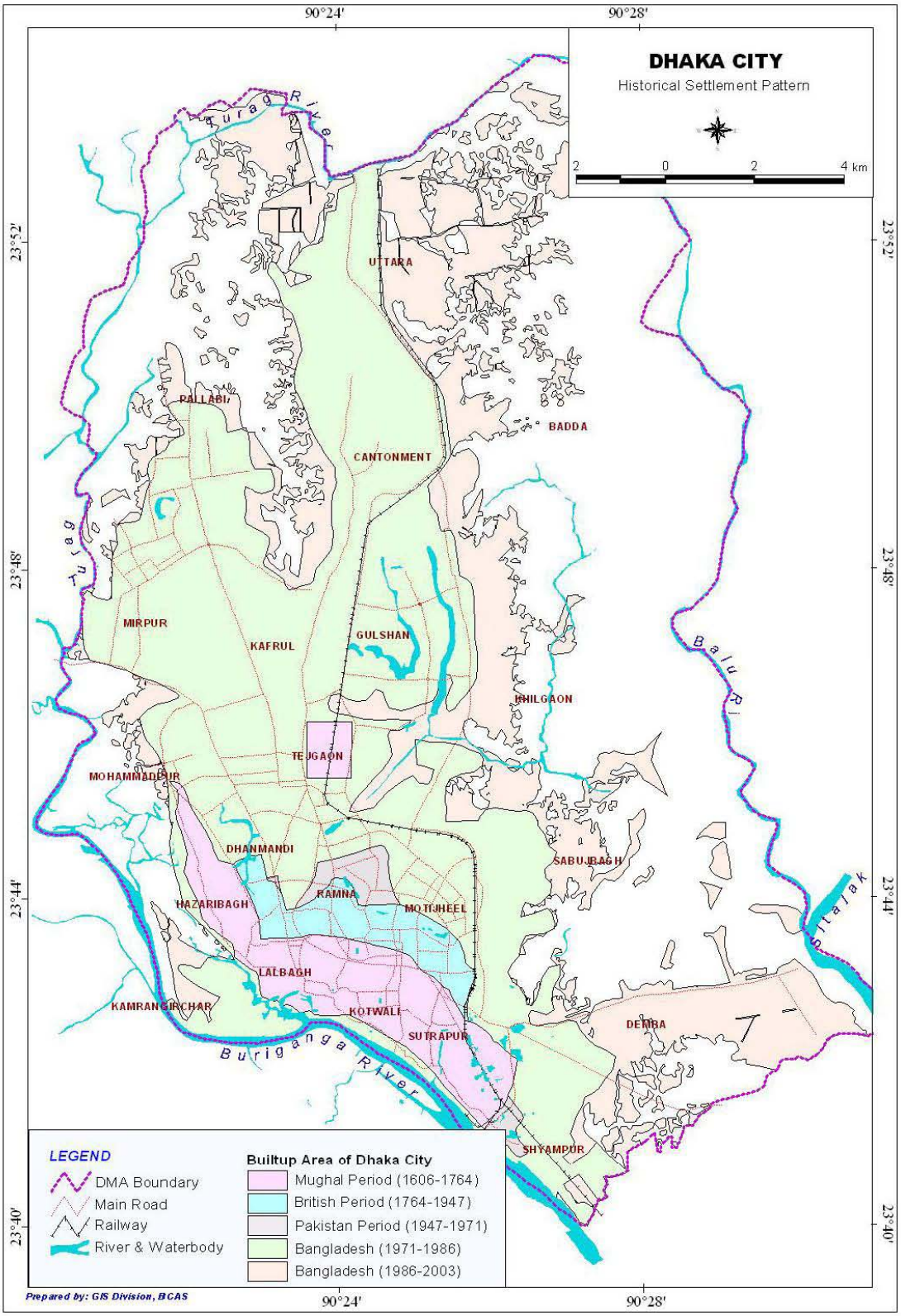
World Bank. (1996). *Sustainable Transport: Priorities for Policy Reform*. Washington DC: World Bank.

World Bank. (2009). *Bus Rapid Transit (BRT) Primer.* Paper presented at the Workshop and Training on Urban Transport Planning and Reform, Baku.

Zhao, F., L. Chow, & et al. (2003). Forecasting transit walk accessibility: a regression model alternative to the buffer method. *Transportation Research Board Annual Meeting*.

Zuidgeest. (2005). *Sustainable urban transport development: A dynamic optimisation approach.* University of Twente, Enschede, The Netherlands.

ANNEX 1: DHAKA CITY DEVELOPMENT



Map 8-1: Historical settlement pattern of Dhaka city.
Source: Dhaka City State of Environment, 2005

ANNEX 2: DHAKA CITY POPULATION GROWTH TRENDS

Table 8-1: Increasing trend of total population, area and density of Dhaka Mega City

Year	Area ($Km^{2)}$	Population	% increase of population over the preceding years	Density (per Km^2)
1951	85.45	411,279	-	4813.09
1961	124.45	718,766	74.76	5775.54
1974	335.79	2,068,353	187.76	6159.66
1981	509.62	3,440,147	66.32	6750.41
1991	1352.82	6,844,131	98.95	5059.16
2001	1352.82	10,712,206	56.51	7918.43

Source: BBS, 1991 & 2001

Table 8-2: Increasing trend of population of DCC based on Thana

No	Thana	Area Km^2	Year		
			1981	1991	2001
1	Gulshan	10.29	215329	281000	190720
2	Cantonment	14.36	116166	191000	147960
3	Lalbag	4.08	294659	402000	335040
4	Mirpur	14.22	347416	338000	577440
5	Mohammadpur	12.14	219406	316000	456300
6	Dhanmondi	6.23	142762	202000	263560
7	Tejgaon	8.89	186118	221000	301680
8	Motijheel	4.95	343821	224000	270840
9	Ramna	7.71	119299	195000	255940
10	Kotwali	1.93	188626	210000	261360
11	Sutrapur	3.99	307501	307000	352580
12	Demra (part)	31.10	326123	521000	421540
13	Sabujbagh (part) Estd. In 1988	6.74		355000	299820
14	Uttara (part) Estd. In 1988	58.85		146,000	351140
15	Hajaribagh Estd. In 1998	5.89			135060
16	Kamrangirchar Estd. In 1998	3.68			143560
17	Pallabi Estd. In 1993	17.96			440180
18	Kafrul Estd. In 1998	8.85			295880
19	Badda (part) Estd. In 1998	49.85			359380
20	Khilgaon Estd. In 1998	20.26			341800
21	Shaympur (part) Estd. In 1998	10.94			376340
22	Airport Estd. In				

Source: BBS, 1983; 1991 & 2001

ANNEX 3: THE PROCESS OF TRANSLATING INTERVIEW

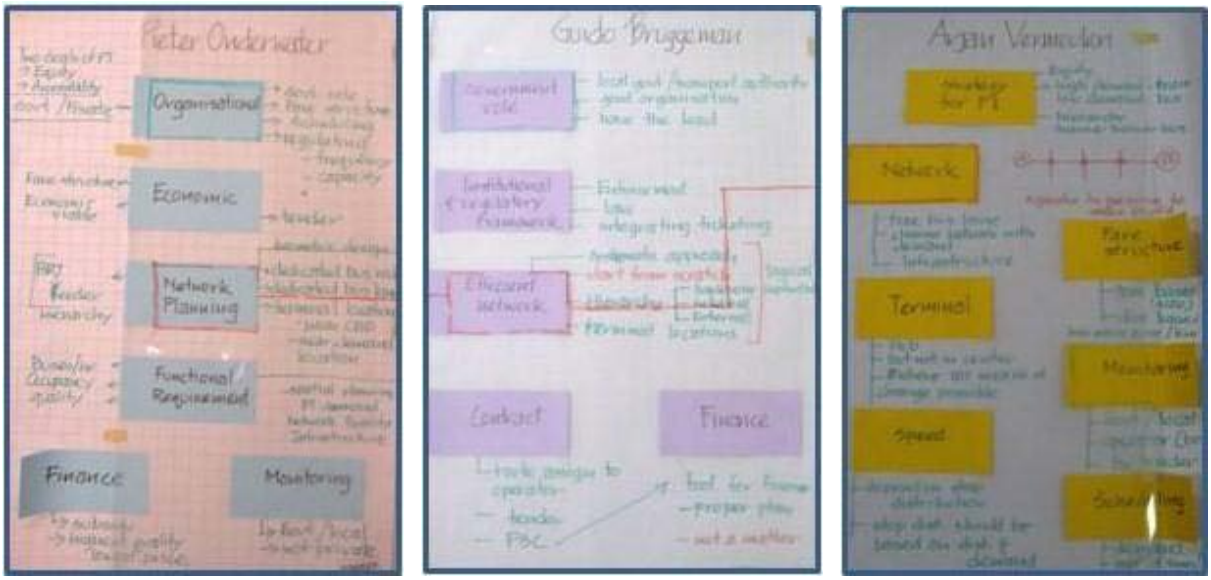


Figure 8-1: First step of translating interview

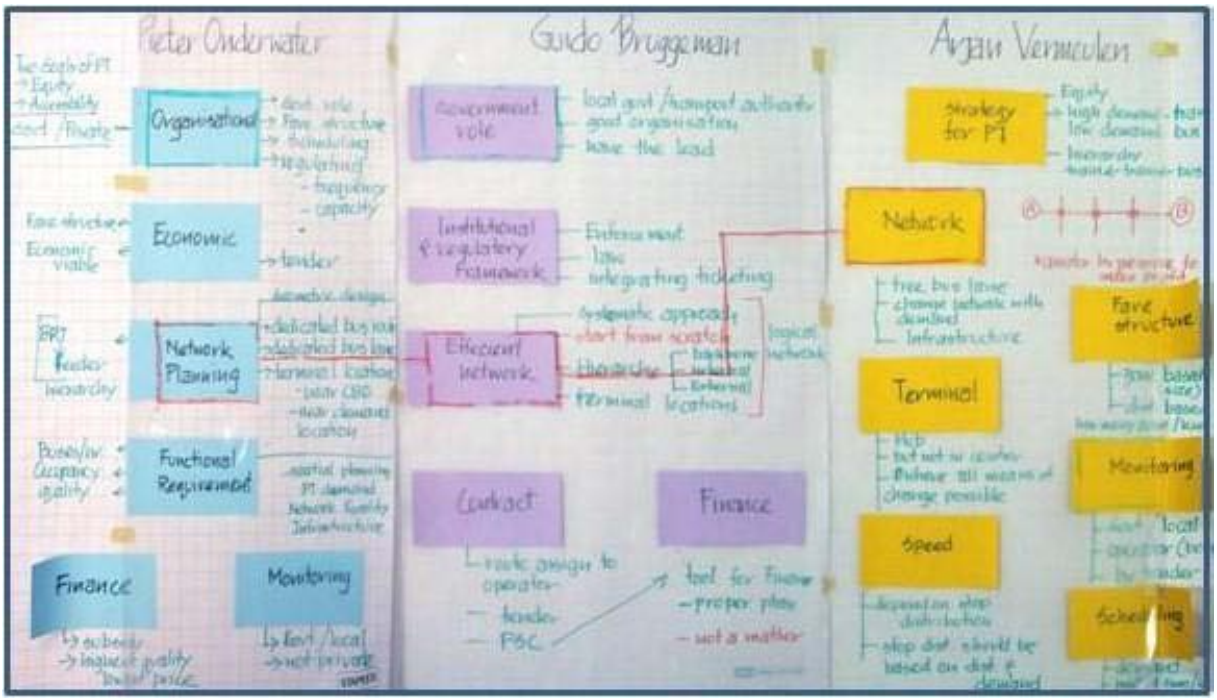
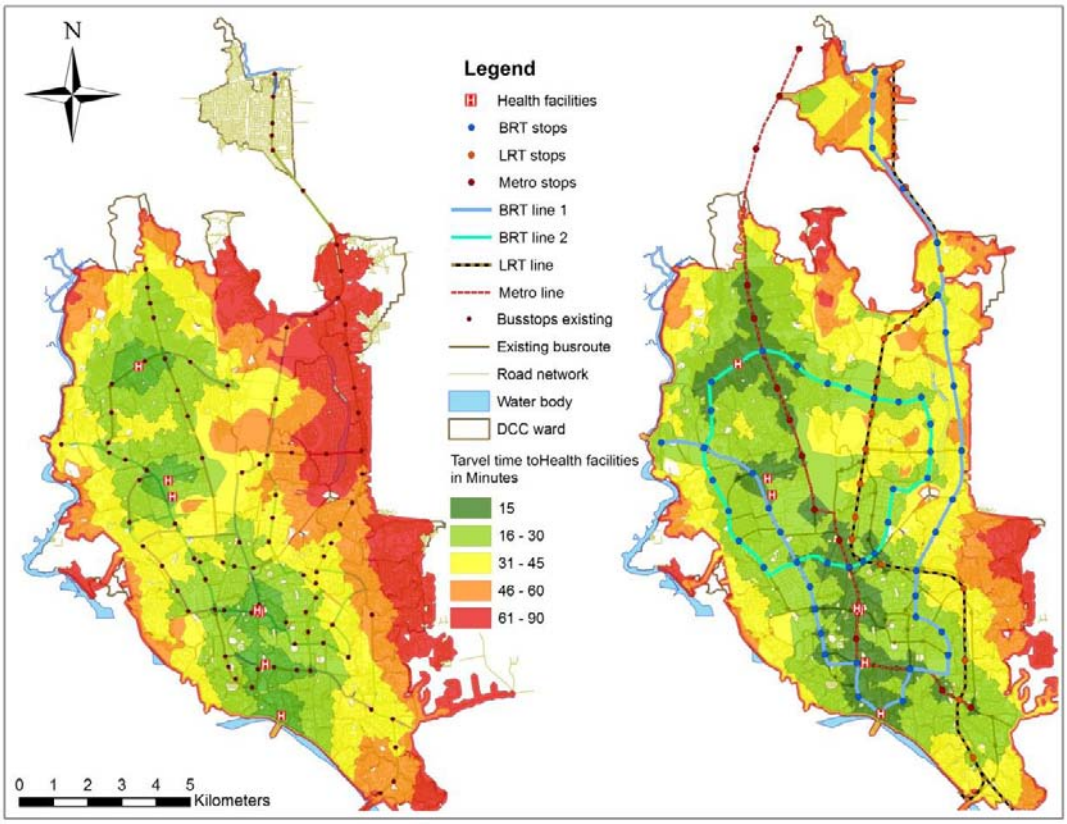
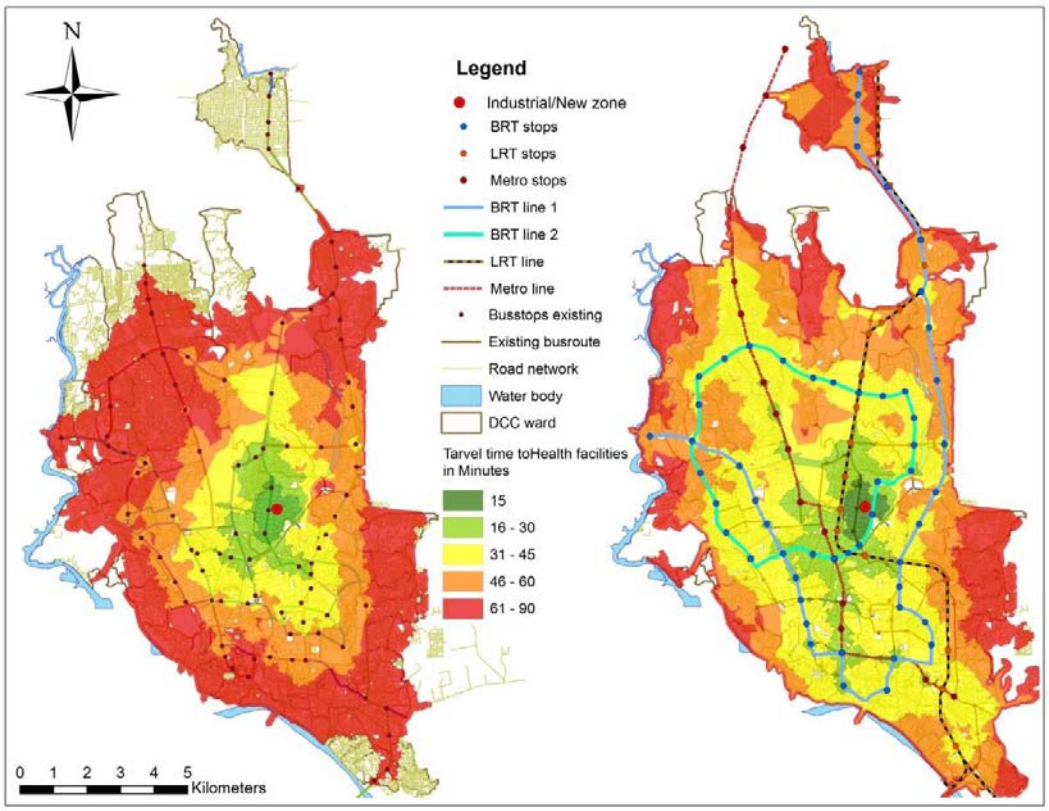


Figure 8-2: Second step of translating interview

ANNEX 4: ACCESSIBILITY ANALYSIS BY PROPOSED BACKBONE NETWORK



Map 8-2: Accessibility to major health facilities by existing bus route and proposed backbone network



Map 8-3: Accessibility to industrial zone by existing bus route and proposed backbone network