STUDY OF NOISE HAZARD IN BUS INTERIOR IN DHAKA CITY

A Thesis

by

Md. Riyajul Haq Munsi

MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

Department of Civil Engineering

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Submitted to the Department of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka in partial fulfillment of the requirements for the degree

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CERTIFICATE OF APPROVAL

The thesis titled "Study of Noise Hazard in Bus Interior in Dhaka City" Submitted by Md. Riyajul Haq Munsi, Roll No: 0412042505, session: April, 2012 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of M.Sc. Engineering (Environmental) on 03 January, 2015.

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DECLARATION

It is hereby declared that except for the contents where specific references have been made to the work of others, the studies contained in this thesis are the result of investigation carried out by the author. No part of this thesis has been submitted to any other University or other educational establishment for a degree, diploma or other qualification.

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Md. Riyajul Haq Munsi

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Dedicated

to

my mother

ABSTRACT

The problem of urban mass transit noise pollution is universal and in the past few decades it has grown to the point that it has become a major concern for both the public and the policy-makers. Dhaka is one of the most heavily populated metropolitan cities of the world with significant commuter flows. The scenario of bus interior noise level in Dhaka city has got worse due to very old bus engine, weak physical condition of buses and poor maintenance of bus fleet. The awareness regarding the noise hazards of mass transportation in Dhaka city almost absent due to limited research work on occupational noise hazard related to mass transit networks.

Continuous noise level measurements were carried out approximately for a total of 39 hours in 29 buses on almost all bus routes in Dhaka city. Noise indices L_{10}, L_{50}, L_{90} and L_{eq} were estimated from measured noise levels for 29 bus trips. Stair graphs of L_{eq} were portrayed for 29 bus trips and also for selected 9 bus routes in Dhaka city. The noise indices L_{90} varied between 65.8 dBA (Azmiriglori bus) to 77.3 dBA (Midway bus) and L_{50} ranged between a minimum of 72.9 dBA (BRTC AC bus) to a maximum of 82.2 dBA (Dipon transport and Konok Poribahan). The maximum L_{10} (90 dBA) was experienced in Shatabdi poribahan whereas minimum (79 dBA) was experienced in BRTC AC bus. Three kinds of noise maps were constructed for Dhaka city bus routes to visualize overall bus interior noise hazard scenario and to identify hotspots of noise pollution in Dhaka city bus routes. The maximum average equivalent continuous noise level (88 dBA) was found in Mirpur-12 to Mirpur-10 route segment whereas the minimum average equivalent continuous noise level (77 dBA) was found in Kakrail to Shatrasta route segment.

Noise exposure metrics were calculated to obtain an understanding regarding the nature of the noise exposed as well as to provide comparison with the permitted noise exposure levels as per National Institute for Occupational Safety and Health (NIOSH) guidelines. After correction for working shift, the range of noise exposure was found to be ranging from 79.8 dBA (Azmiriglori bus) to as high as 92.9 dBA (Dipon transport bus). The shift length of 24 buses exceeded the permitted shift length as per NIOSH guidelines whereas for 5 buses the shift length did not exceed NIOSH guidelines. Nine buses among 29 buses exceeded Noise Dose as per NIOSH guidelines. According to NIOSH guideline the most severely noise polluted bus services were BRTC bus, Dipon transport and Konok Poribahan. Experienced Noise Exposure Levels (L_{EX}) in

BRTC bus, Dipon Transport and Konok poribahan bus were 91.5dBA, 92.9dBA and 90.8dBA respectively. For these noise exposure levels the permitted shift length according to NIOSH guidelines are 1.78 hours, 1.3 hours and 2.1 hours respectively but actual average shift length for these buses were 14.4 hours. The lowest L_{EX} (79.8 dBA) and the lowest Noise Dose (31%) were found in Azmiriglori bus which operates on Sadarghat to Abdullapur route. From this study significant influence of bus velocities, age of bus engine, number of intersection on specific bus routes, types of engine and impact of outside noise levels were found on bus interior noise level.

Findings of this research work showed that level of noise hazard in bus transportation in Dhaka city urban area is high enough to adversely affect the health and productivity of bus driver and conductor as well as its residents. With the rapidly growing rate of infrastructural development, unplanned urban land-use change and weak transportation system it is almost certain that problem of bus interior noise pollution will soon assume a critical dimension and will be a cause of increasing concern for both public and responsible policy-makers.

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List of Abbreviation

NIHL = Noise Induced Hearing Loss

NIOSH = National Institute of Occupational Safety and Health

OSHA = Occupational Safety and Health Administration

EU = European Union

WHO = World Health Organization

EPA = Environmental Protection Agency

REL = Recommended Exposure Limit

DoE = Department of Environment

TWA = Time Weighted Average

ND = Noise Dose

RMS = Root-Mean-Square

dB = decibels

SEL = Sound Exposure Level

PSEM = Personal Sound Exposure Meter

ANSI = American National Standards Institute

SPL = sound pressure level

BRT = Bus Rapid Transit

BRTC = Bangladesh Road Transport Corporation

CNG = Compressed Natural Gas

RTV = Rural Transport Vehicles

GPS = Global Positioning System

STP = strategic transport plan

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Noise has always been an important environmental problem. In ancient Rome, rules existed as to the noise emitted from the ironed wheels of wagons which battered the stones on the pavement, causing disruption of sleep and annoyance to the citizenry. In Medieval Europe, horse carriages and horse-back riding were not allowed during night time in certain cities to ensure peaceful sleep for inhabitants. However, the noise problems of the past are incomparable with those of the modern society. An immense number of cars, motorcycles, trucks and other motorized vehicles crises-crosses developing cities, day and night. In comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on humans and of dose-response relationships as well as a lack of defined criteria. While it has been suggested that noise pollution is primarily a "luxury" problem for developed countries, exposure to noise is often higher in developing countries, due to densities, poor planning and construction. The effects of the noise are just as widespread and the long term consequences for health are the same. In this perspective, practical action to limit and control the exposure to environmental noise are essential. Noise pollution in large developing cities is an insidious issue. In such noisy cities, many people seem to have become accustomed to the higher noise levels that underpin their daily activities. Yet in a city such as Hong Kong, for example, noise is the most common cause of complaints. Of the 23678 environmental complaints received by the Hong Kong Environmental Protection Department in 2010, 29% were noise related (Jaecker-Cueppers, 2011).

Noise is present in every human activity, and when assessing its impact on human well-being it is usually classified either as occupational noise (i.e. noise in the workplace), or as environmental noise, which includes noise in all other settings, whether at the community, residential, or domestic level e.g. traffic, playgrounds, sports, music (Mangalekar et al, 2012). Noise pollution is a significant environmental problem in many urban areas and one of the most important occupational risk factors both in industry and transportation. Many of the industries are associated with noise, such as steel industry, automobile industry, dyeing industry, agriculture, electronics, pharmaceutics, military, construction work, cement factories and transportation (Nadir et al, 2011). Noise pollution is recognized as a major problem for the quality of life in urban areas all over the world. Because of the increase in the number of cars and industrialization, noise pollution has also increased. Noise in cities, especially along main arteries, has reached up disturbing levels. Residences far from noise sources and near silent secondary roads are currently very popular. People prefer to live in places far from noisy urban areas (Ozer et al, 2009). Noise is considered one of the most common occupational hazards worldwide and the relationship between exposure to high levels of noise and Noise Induced Hearing Loss (NIHL) is well understood (NIOSH, 1998). In general, a pattern of exposure to any source of sound that produces high enough levels can result in temporary hearing loss. If the exposure persists over a long period of time, this could lead to permanent hearing impairment (ANSI, 1996). NIHL has a profound physiological and social impact on affected individuals which eventually affects work performance, efficiency and reduces the quality of life. Additionally, noise pollution can cause annoyance and aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects (Hossain et al 2013). Noise control measures are being considered as part of an overall strategy to help improve the quality of life of urban dwellers. One important source of urban noise is related to mass transit networks, which include buses, subways, light rail, commuter rail and other transportation systems (Gershon et al, 2006).

Noise pollution continues to pose a major health threat for Bangladesh, especially in cities and particularly in Dhaka city. Much discussion has occurred in the media over the many serious environmental problems that Bangladesh faces which includes water and air pollution, harmful effects of polythene bags etc. Although it is mentioned occasionally, noise pollution has not received serious attention in the past. Recent studies show high levels of noise in various points in the urban centers of Dhaka, Sylhet and Khulna. To many Dhaka residents, it may be considered more of a necessary aggravation than a serious problem that can be addressed. Noise pollution is not only an aggravation, but also a serious risk. The WHO and GoB have established guidelines and standards for maximum allowable levels of noise above which people are harmed; it is widely known that in many parts of Dhaka city, those levels are regularly exceeded. People of Dhaka city mostly suffer from the bad effects of noise pollution. Dhaka is one of the most heavily populated metropolitan cities of the world with significant commuter flows. It has a large public transportation system engaging a significant number of work forces. There are different kinds of public and private buses plying within the city and the total number of buses in Dhaka city approximately 7100. Each bus engages 2–3 persons as driver, conductor and cleaner. Approximately 16 million people now live in the capital city where traffic congestions are a regular phenomenon in almost every road. This traffic congestion is the root cause of noise pollution as most of the motor vehicles especially buses, mini-buses and trucks have hydraulic horns and the drivers are trained to honk continuously till they get their ways clear. Other reasons for honking that creates noise pollution include reckless driving, overtaking and drivers lack of knowledge on the impact of noise pollution. Moreover, use of brick-crushing machines in the locality and abuse of loudspeakers are other causes of noise pollution. The noise emitted from the engine, gear, clutch, hydraulics horn, accelerator, brake, etc. during operation of the bus are the main noise sources within and outside the bus (Mukherjee et al, 2003). There is lack of data due to limited research work on occupational noise hazard related to mass transit networks. It is widely suggested that people working in bus transportation system may be suffering from NIHL and related ailments. To our knowledge, no research has been conducted in Bangladesh to realistically estimate the magnitude of occupational noise exposure levels for bus transportation system in Dhaka city.

1.2 OBJECTIVES OF THIS STUDY

The specific objectives of the study are:

- To assess the internal noise environment of buses in Dhaka city through continuous noise level measurement along bus routes.
- To determine the severity of noise hazard from the point of view of bus operators and passengers through various noise level metrics and comparison with occupational health and safety guidelines.
- To determine whether the physical characteristics of the vehicle (bus type, age of engine), geometric features of the road (no of intersections in a one-way trip) and trip characteristics (trip duration, average travel time in a single one way trip) have any bearing on the average noise level experienced in a particular trip.
- To identify hotspots of noise pollution on the road map of Dhaka city.

The probable outcome from this research would be

- To provide a better understanding regarding the possible impact of noise on bus operators and the huge number of travelling people of Dhaka city availing bus services inside the city every day.
- To generate awareness regarding the noise hazards of mass transportation in Dhaka city.

1.3 OUTLINE OF METHODOLOGY

To complete this research work and to achieve all the mentioned objectives, the following activities were undertaken:

- Continuous noise level measurements were carried out on most of the local bus routes of Dhaka City using a datalogging noise level meter. Measurements were carried out under normal operating conditions—i.e., loaded with passengers (but avoiding rainy conditions, weekends or holidays) during peak hours of the day.
- Measurements were carried out over the entire length of a one-way trip of the selected routes. Noise levels were recorded in decibels (A-weighted) at 30-second intervals. Noise level meter was placed at the rear of driver and close to ear of the helper.
- During noise level measurements a GPS (etrex-10) was used to acquire relevant trip characteristics data such as trip distance, road segment distance, moving average velocity, overall average velocity, total travel time, stopped time and maximum trip velocity. Numbers of intersections for single one-way trip were counted during noise level measurement.
- The recorded data was downloaded in a computer and postprocessed using MATLAB and Microsoft office Excel to calculate different noise level metrics (Equivalent continuous noise level, Noise Dose, working shift noise exposure) for comparison with NIOSH guidelines.
- The noise level metrics for bus routes, relationship between average noise level and average trip velocity, graphical representation of noise intensity-duration relationship will eventually make a profile of interior noise for the bus transportation system in Dhaka city.

1.4 ORGANIZATION OF THE THESIS

This thesis paper is mainly comprised of five Chapters. Chapter one is Introduction which contains background, Objectives of the present research and Outline of the Methodology.

Chapter two is Literature Review which presents a brief discussion on previous research work conducted on occupational noise exposure in working people and noise pollution of mass transit system. This chapter also presents discussion about aspects of noise, sources of mass transit noise, the nature and scale of impacts of noise, basic noise calculation methods and transportation system and noise pollution studies in Dhaka city.

Chapter three describes the methodology followed to complete this research work.

Chapter four contains result and discussion. This chapter describes the cumulative noise distribution, stair graphs and noise hazard map. This chapter also describes comparison of noise pollution level with NIOSH guideline, Effect of the physical characteristics of the vehicle (bus type, age of engine, bus size), geometric features of the road (no of intersections in a one-way trip) and trip characteristics (trip duration, average travel velocity in a single one way trip) on the experienced average noise level in bus transportation system.

Chapter five provides the conclusion and recommendations for future work.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

The main objective of this study was to investigate and determine the interior noise profile of bus transportation system of Dhaka city. This chapter presents aspects of noise, basic noise calculation, sources of mass transit noise. This chapter presents a brief discussion on previous research work conducted on occupational noise exposure levels or noise pollution in mass transit system. The results of previous studies were analyzed to identify the needs for further investigation works for improvement of knowledge in this area.

2.2 ASPECTS OF NOISE

2.2.1 Description of noise and noise pollution

Noise is derived from the Latin word "nausea "implying 'unwanted sound' or 'sound that is loud, unpleasant or unexpected. Noise, commonly defined as unwanted sound, is an environmental phenomenon to which we are exposed before birth and throughout life. Noise can also be considered an environmental pollutant, a waste product generated in conjunction with various anthropogenic activities. Under the later definition, noise is any sound- independent of loudness- that can produce an undesired physiological or psychological effect in an individual, and that may interfere with the social ends of an individual or group. These social ends include all of our activities – communications, work, rest, recreation and sleep.

Patterns of noise may be qualitatively described by one of the following terms: steady-state or continuous; intermittent; and impulse or impact. Continuous noise is an uninterrupted sound level that varies less than 5 dB during the period of observation. An example is the noise from a household fan. Intermittent noise is a continuous noise that persists for more than one second that is interrupted for more than one second. A dentist's drilling would be an example of an intermittent noise. Impulse noise is characterized by a change of sound pressure of 40 dB or more within 0.5 second with duration of less than one second. The noise from firing a weapon would be an example of an impulse noise (Davis and Cornwell, 2012). Noise pollution, human-created noise harmful to health or welfare. Transportation vehicles are the worst offenders, with aircraft, railroad stock, trucks, buses, automobiles, and motorcycles all producing excessive noise. Construction equipment, e.g., jackhammers and bulldozers also produce substantial noise pollution. Noise intensity is measured in decibel units. The decibel scale is logarithmic; each 10-decibel increase represents a tenfold increase in noise intensity. Human perception of loudness also conforms to a logarithmic scale; a 10-decibel increase is perceived as roughly a doubling of loudness. Thus, 30 decibels is 10 times more intense than 20 decibels and sounds twice as loud; 40 decibels is 100 times more intense than 20 and sounds 4 times as loud; 80 decibels is 1 million times more intense than 20 and sounds 64 times as loud. Distance diminishes the effective decibel level reaching the ear. Thus, moderate auto traffic at a distance of 100 ft (30 m) rates about 50 decibels. To a driver with a car window open or a pedestrian on the sidewalk, the same traffic rates about 70 decibels; that is, it sounds 4 times louder. At a distance of 2,000 ft (600 m), the noise of a jet takeoff reaches about 110 decibels—approximately the same as an automobile horn only 3 ft (1 m) away.

Subjected to 45 decibels of noise, the average person cannot sleep. At 120 decibels the ear registers pain, but hearing damage begins at a much lower level, about 85 decibels. The duration of the exposure is also important. There is evidence that among young Americans hearing sensitivity is decreasing year by year because of exposure to noise, including excessively amplified music. Apart from hearing loss, such noise can cause lack of sleep, irritability, heartburn, indigestion, ulcers, high blood pressure, and possibly heart disease. One burst of noise, as from a passing truck, is known to alter endocrine, neurological, and cardiovascular functions in many individuals; prolonged or frequent exposure to such noise tends to make the physiological disturbances chronic. In addition, noise-induced stress creates severe tension in daily living and contributes to mental illness. Noise is recognized as a controllable pollutant that can yield to abatement technology. In the United States the Noise Control Act of 1972 empowered the Environmental Protection Agency to determine the limits of noise required to protect public health and welfare; to set noise emission standards for major sources of noise in the environment, including transportation equipment and facilities, construction equipment, and electrical machinery; and to recommend regulations for controlling aircraft noise and sonic booms. Also in the 1970s, the Occupational Safety and Health Administration began to try to reduce workplace noise. Funding for these efforts and similar local efforts was severely cut in the early 1980s, and enforcement became negligible.

2.2.2 Sources of road noise

Noise associated with road development and traffic has four main sources (Jaecker-Cueppers 2011):

1. Propulsion noise of vehicles
2. Interaction between vehicles (especially tries) and road surface.
3. Driver behavior and
4. Construction and maintenance activity.

Vehicle noise

Noise on roads is caused by engine of the vehicles, its exhaust, horn, brakes, transmission, suspension, and is greatest during acceleration, on upward slopes, during engine breaking, on rough roads, and in stop-and-go traffic conditions. Poor vehicle maintenance is a contributing factor to this source. It generally increases with the engine speed and depends therefore on the vehicles speed and gear selection.

Road/tire noise

Noise from the contact between tires and pavement contributes significantly to overall traffic noise. There are two important mechanisms of noise generation:

- The roughness of the road surface causes vibrations of the tires leading to sound radiation;
- The compression and relaxation of the air in the tire profiles in the contact area lead to aerodynamic noise; so called "air-pumping".

Road/tire noise of modern cars driving with constant speed above 30 km/h is dominant in inner urban situations. The noise level depends on the type and condition of tires and pavement. Road/tire noise is generally greatest at high speed and during quick breaking.

Driver behavior

Drivers contribute to road noise by driving with high engine speed, by using their vehicles, horns, by playing loud music, by shouting at each other, and by causing their tires to squeal as a result of sudden braking or acceleration.

Construction and maintenance

Road construction and maintenance generally require the use of heavy machinery, and although these activities may be intermittent and localized, they nevertheless contribute tremendous amounts of sustained noise during equipment operation (Jaecker-Cueppers, 2011)).

Noise from the motors and exhaust systems of large trucks provides the major portion of highway noise impact, and provides a potential noise hazard to the driver as well. In the city, the main sources of traffic noise are the motors and exhaust systems of autos, smaller trucks, buses, and motorcycles. This type of noise can be augmented by narrow streets and tall buildings, which produce a "canyon" in which traffic noise reverberates. The noise from locomotive engines, horns and whistles, and switching and shunting operations in rail yards can impact neighboring communities and railroad workers. For example, rail car retreads can produce a high-frequency; high-level screech that can reach peak levels of 120 dB at a distance of 100 feet which translates to levels as high as 138 or 140 dB at the railroad worker's ear. In Dhaka vehicles create 95 decibel. Microphones about 100 dB(A) , scooters 80-90 dB (A) and trucks or buses 92 to 94 dB (A) (DoE,1998).

2.2.3 The nature and scale of impacts (Belojevic, 2008)

Health effects of noise and Societal Economic Costs of Noise Pollution

Noise health effects are the health consequences of elevated sound levels. Elevated workplace or other noise can cause hearing impairment, hypertension, ischemic heart disease, annoyance, and sleep disturbance, Changes in the immune system and birth defects have been attributed to noise exposure. In many developed nations the cumulative impact of noise is sufficient to impair the hearing of a large fraction of the population over the course of a lifetime. Noise exposure also has been known to induce tinnitus, hypertension, vasoconstriction, and other cardiovascular adverse effects. Beyond these effects, elevated noise levels can create stress, increase workplace accident rates, and stimulate aggression and other anti-social behaviors. The most significant causes are vehicle and aircraft noise, prolonged exposure to loud music, and industrial noise. In Norway, road traffic has been demonstrated to cause almost 80% of the noise annoyances reported (http://www.ssb.no/english/subjects/01/sa_nrm/arkiv/nrm2006/kap10-noise.pdf).

There may be psychological definitions of noise as well. Firecrackers may upset domestic and wild animals or noise-traumatized individuals. The most common noise-traumatized persons are those exposed to military conflicts, but often loud groups of people can trigger complaints and other behaviors about noise. Infants are easily startled by noise. The social costs of traffic noise in EU22 are more than €40 billion per year, and passenger cars and Lorries (trucks) are responsible for bulk of costs. Traffic noise alone is harming the health of almost every third person in the WHO European Region. One in five Europeans is regularly exposed to sound levels at night that could significantly damage health. Noise also is a threat to marine and terrestrial ecosystems.

Hearing loss

The mechanism of hearing loss arises from trauma to stereocilia of the cochlea, the principal fluid filled structure of the inner ear. The pinna combined with the middle ear amplifies sound pressure levels by a factor of twenty, so that extremely high sound pressure levels arrive in the cochlea, even from moderate atmospheric sound stimuli. Underlying pathology to the cochlea are reactive oxygen species, which play a significant role in noise-induced necrosis and apoptosis of the stereocilia. Exposure to high levels of noise have differing effects within a given population, and the involvement of reactive oxygen species suggests possible avenues to treat or prevent damage to hearing and related cellular structures. The elevated sound levels cause trauma to cochlear structure in the inner ear, which gives rise to irreversible hearing loss. A very loud sound in a particular frequency range can damage the cochlea's hair cells that respond to that range, thereby reducing the ear's ability to hear those frequencies in the future; however, loud noise in *any* frequency range has deleterious effects across the entire range of human hearing. The outer ear (visible portion of the human ear) combined with the middle ear amplifies sound levels by a factor of 20 when sound reaches the inner ear.

Effect of Age

Hearing loss is somewhat inevitable with age. Though older males exposed to significant occupational noise demonstrate significantly reduced hearing sensitivity compared to non-exposed peers, differences in hearing sensitivity decrease with time and the two groups are indistinguishable by age 79 (Rosenhall et al, 1990). Women exposed to occupational noise do not differ from their peers in hearing sensitivity, although they do hear well than their non-exposed male counterparts. Due to loud music and a generally noisy environment, young people in the United States have a rate of impaired hearing 2.5 times greater than their parents and grandparents, with an estimated 50 million individuals with impaired hearing estimated in 2050 (Schmid, 2007). In Rosen's work on health effects and hearing loss, one of his findings derived from tracking Maaban tribesmen, who were insignificantly exposed to transportation or industrial noise. This population was systematically compared by cohort group to a typical U.S. population. The findings proved that aging is an almost insignificant cause of hearing loss, which instead is associated with chronic exposure to moderately high levels of environmental noise.

Cardiovascular effects

Noise has been associated with important cardiovascular health problems. In 1999, the World Health Organization concluded that the available evidence suggested a weak correlation between long-term noise exposure above 67-70 dB(A) and hypertension. More recent studies have suggested that noise levels of 50 dB(A) at night may also increase the risk of myocardial infarction by chronically elevating cortical production. Fairly typical roadway noise levels are sufficient to constrict arterial blood flow and lead to elevated blood pressure; in this case, it appears that a certain fraction of the population is more susceptible to vasoconstriction. This may result because annoyance from the sound causes elevated adrenaline levels trigger a narrowing of the blood vessels (vasoconstriction), or independently through medical stress reactions. Other effects of high noise levels are increased frequency of headaches, fatigue, stomach ulcers, and vertigo.

Stress

Research commissioned by Rockwool, a UK insulation manufacturer, reveals in the UK one third (33%) of victims of domestic disturbances claim loud parties have left them unable to sleep or made them stressed in the last two years. Around one in eleven (9%) of those affected by domestic disturbances claims it has left them continually disturbed and stressed. More than 1.8 million people claim noisy neighbors have made their life a misery and they cannot enjoy their own homes. The impact of noise on health is potentially a significant problem across the UK given that more than 17.5 million Britons (38%) have been disturbed by the inhabitants of neighboring properties in the last two years. For almost one in ten (7%) Britons this is a regular occurrence. The extent of the problem of noise pollution for public health is reinforced by figures collated by Rockwool from local authority responses to a Freedom of Information Act (FOI) request. This research reveals in the period April 2008 - 2009 UK councils received 315,838 complaints about noise pollution from private residences. This resulted in environmental health officers across the UK serving 8,069 noise abatement notices, or citations under the terms of the Anti-Social Behavior (Scotland) Act. Westminster City Council has received more complaints per head of population than any other district in the UK with 9,814 grievances about noise, which equates to 42.32 complaints per thousand residents. Eight of the top 10 councils ranked by complaints per 1,000 residents are located in London.

Annoyance

Because some stressful effects depend on qualities of the sound other than its absolute decibel value, the annoyance associated with sound may need to be considered in regard to health effects. For example, noise from airports is typically perceived as more bothersome than noise from traffic of equal volume. Annoyance effects of noise are minimally affected by demographics, but fear of the noise source and sensitivity to noise both strongly affect the 'annoyance' of a noise. Even sound levels as low as 40 dB(A) (about as loud as a refrigerator or library) can generate noise complaints and the lower threshold for noise producing sleep disturbance is 45 dB(A) or lower (Walker et al. 1998). Other factors that affect the 'annoyance level' of sound include beliefs about noise prevention and the importance of the noise source, and annoyance at the cause (i.e. non-noise related factors) of the noise. For instance, in an office setting, audible telephone conversations and discussions between co-workers were considered to be irritating, depending upon the contents of the conversations. Many of the interpretations of the level of annoyance and the relationship between noise levels and resulting health symptoms could be influenced by the quality of interpersonal relationships at the workplace, as well as the stress level generated by the work itself. Evidence for impact on annoyance of long-term noise versus recent changes is equivocal. Estimates of sound annoyance typically rely on weighting filters, which consider some sound frequencies to be more important than others based on their presumed audibility to humans. The older dB(A) weighting filter described above is used widely in the U.S., but underestimates the impact of frequencies around 6000 Hz and at very low frequencies. The newer ITU-R 468 noise weighting filter is used more widely in Europe. The propagation of sound varies between environments; for example, low frequencies typically carry over longer distances. Therefore different filters, such as dB(B) and dB(C), may be recommended for specific situations. Furthermore, studies have shown that neighborhood noise (consisting of noise from neighboring apartments, as well as noise within one's own apartment or home) can cause significant irritation and noise stress within people, due to the great deal of time people spend in their residences. This can result in an increased risk of depression and psychological disorders, migraines, and even emotional stress. In the workplace, noise pollution is generally a problem once the noise level is greater than 55 dB(A). Selected studies show that approximately 35% to 40% of office workers find noise levels from 55 to 60 dB(A) extremely irritating. The noise standard in Germany for mentally stressful tasks is set at 55 dB(A), however, if the noise source is continuous, the threshold level for tolerability among office workers is lower than 55 dB(A). One important effect of noise is to make a person's speech less easy to hear. The human brain compensates for background noise during speech production in a process called the Lombard effect in which speech becomes louder with more distinct syllables. However, this cannot fully remove the problems of communication intelligibility made in noise.

Child physical development

The U.S. Environmental Protection Agency authored a pamphlet in 1978 that suggested a correlation between low-birth weight (using the World Health Organization definition of less than 2,500 g (~5.5 lb) and high sound levels, and also high rates of birth defects in places where expectant mothers are exposed to elevated sound levels, such as typical airport environs. Specific birth abnormalities included harelip, cleft palate, and defects in the spine (EPA, 1978). According to Lester W. Sontag of the Fells Research Institute (as presented in the same EPA study): “There is ample evidence that environment has a role in shaping the physique, behavior, and function of animals, including man, from conception and not merely from birth. The fetus is capable of perceiving sounds and responding to them by motor activity and cardiac rate change." The effects of noise exposure are highest when it occurs between 15 and 60 days after conception, a period in which major internal organs and the central nervous system are formed. Later developmental effects occur as vasoconstriction in the mother reduces blood flow and therefore oxygen and nutrition to the fetus. Low birth weights and noise were also associated with lower levels of certain hormones in the mother. These hormones are thought to affect fetal growth and to be good indicators of protein production. The difference between the hormone levels of pregnant mothers in noisy versus quiet areas increased as birth approached. In a 2000 publication, a review of studies on birth weight and noise exposure note that while some older studies suggest that when women are exposed to >65 dB aircraft noise a small decrease in birth weight occurs, in a more recent study of 200 Taiwanese women including noise dosimetry measurements of individual noise exposure, the authors found no significant association between noise exposure and birth weight after adjusting for relevant confounders, e.g. social class, maternal weight gain during pregnancy, etc.

Cognitive development

When young children are regularly exposed to levels of noise that interfere with speech, they may develop speech or reading difficulties, because auditory processing functions are compromised. Children continue to develop their speech perception abilities until they reach their teens. Evidence has shown that when children learn in noisier classrooms, they have a more difficult time understanding speech than those who learn in quieter settings. In a study conducted by Cornell University in 1993, children exposed to noise in learning environments experienced trouble with word discrimination, as well as various cognitive developmental delays. In particular, the writing learning impairment known as dysgraphia is commonly associated with environmental stressors in the classroom. The effect of high noise levels on small children has been known to cause physical health damages as well. Children from noisy residences often possess a heart rate that is significantly higher (by 2 beats/min on average) than those of children from quieter homes (Belojevic, 2008).

2.3 ACCEPTABLE LIMITS OF NOISE

To combat the hazards of noise pollution, standardization and fixation of tolerance limits of noise pollution is essential. The acceptable noise levels for different areas recommended by Bangladesh Department of Environment (DoE) are as shown in Table 2.1.

Table 2.1: Acceptable Noise Level for Different Areas (NPCR, 2006)

Description of area	Noise level (L_{eq}) in dBA	
	Day Time	Night Time
i) A sensitive area where quietness is of primary importance such as schools, hospitals, mosques etc.	50	40
ii) Residential areas	55	45
iii) Mixed areas, which are, used as residential areas as well as commercial and industrial purposes.	60	50
iv) Commercial areas	70	60
v) Industrial areas	75	70

- Day time shall mean from 6:00 am to 9:00 pm
- Night time shall mean from 10:00 pm to 6:00 am
- L_{eq}: It is energy mean of the noise level over a specific period.

2.4 NIOSH GUIDELINES FOR NOISE EXPOSURE AND NOISE DOSE IN WORKPLACE

The National Institute for Occupational Safety and Health (NIOSH) recommends the following standard for promulgation by regulatory agencies such as the occupational safety and health administration and the mine safety and health administration to protect workers from hearing losses resulting from occupational noise exposure. The NIOSH recommended exposure limit (REL) is 85 decibels, A-weighted, as an 8-hr time-weighted average (85 dBA as an 8-hr TWA).Exposures at and above this level are considered hazardous (NIOSH, 1998)

The average of different exposure levels during an exposure period. For noise, given an 85 dBA exposure limit and a 3 dB exchange rate, the time-weighted average (TWA) is calculated according to the following formula:

$$TWA = 10.0 \times \text{Log}\,(D/100) + 85$$

Where, D = dose

When the daily noise exposure consists of periods of different noise levels,the daily dose (D) shall not equal or exceed 100, as calculated according to the following formula:

$$D = [C_1/T_1 + C/T_2 + \ldots.. + C_n/T_n] \times 100$$

Where, C_n = total time of exposure at a specified noise level and T_n = exposure duration for which noise at this level becomes hazardous.

The daily dose can be converted into an 8-hr TWA according to the formula that mention above.

Table 2.2: NIOSH Guidelines for Noise Exposure in Workplace (NIOSH, 1998)

Exposure Level dBA	Exposure Time
80	25 hours 24 minutes
81	20 hours 10 minutes
82	16 hours
83	12 hours 42 minutes
84	10 hours 08 minutes
85	08 hour
86	06 hours 21 minutes
87	05 hours 02 minutes
88	04 hours
89	03 hours 10 minutes
90	02 hours 31 minutes
Upto 140	< 1 second

Table 2.3: OSHA Guidelines for Noise Exposure in Workplace (OSHA, 1983)

Duration per day, Hours	Sound level Exposure dBA
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

Table 2.4: Daily Noise Dose as an 8-hr TWA (NIOSH, 1998)

Noise Dose(%)	dBA as 8-hr TWA
20	78.0
30	79.8
40	81.0
50	82.0
60	82.8
70	83.5
80	84.0
90	84.5
100	85.0
110	85.4
120	85.8
130	86.1
140	86.5
150	86.8
170	87.3
200	88.0
250	89.0
300	89.8
350	90.4

2.5 NOISE MEASUREMENT TECHNIQUES & INSTRUMENTS

Noise measurement is an important diagnostic tool in noise control technology. The objective of noise measurement is to make accurate measurement which gives us a purposeful act of comparing noises under different conditions for assessment of adverse impacts of noise. Noise measuring devices typically use a sensor to receive the noise signals emanating from a source. The sensor, however, not only detects the noise from the source, but also any ambient background noise. Thus, measuring the value of the detected noise is inaccurate, as it includes the ambient background noise. Different types of instruments are available to measure sound levels and the most widely used are sound level meters. A sound level meter or sound meter is an instrument that measures sound pressure level, commonly used in noise pollution studies for the quantification of different kinds of noise, especially for industrial, environmental and aircraft noise. A sound level meter consists basically of a microphone and an electronic circuit including an attenuator, amplifier, weighting networks or filters and a display unit. The microphone converts the sound signal to an equivalent electrical signal. The signal is passed through a weighting network which provides a conversion and gives the sound pressure level in dB. The instructions lay down by the noise level meter manufacturers shall be followed while using the instruments (Subramani et al. 2012).

Three kinds of sound measuring instruments are used to measure continuous noise level. They are the "conventional" sound level meter, the integrating-averaging sound level meter, and the integrating sound level meter. The standard sound level meter can be called an exponentially averaging sound level meter as the AC signal from the microphone is converted to DC by a root-mean-square (RMS) circuit and thus it must have a time-constant of integration; today referred to as the time-weighting. Three of these time-weightings have been internationally standardized, 'S' (1 s) originally called Slow, 'F' (125 ms) originally called Fast and 'I' (35 ms) originally called Impulse. Their names were changed in the 1980s to be the same in any language. I-time-weighting is no longer in the body of the standard because it has little real correlation with the impulsive character of noise events (http://webstore.iec.ch/preview/info_iec61672-1%7Bed1.0%7Den_d.pdf). The output of the RMS circuit is linear in voltage and is passed through a logarithmic circuit to give readout linear in decibels (dB). This is 20 times the base 10 logarithm of the ratio of a given root-mean-square sound pressure to the reference sound pressure. Root-mean-square sound pressure being obtained with a standard frequency weighting and standard time weighting. The reference pressure is set by International agreement to be 20 micro Pascal's for airborne sound. It follows that the decibel is in a sense not a unit; it is simply a dimensionless ratio—in this case the ratio of two pressures. An exponentially averaging sound level meter, which gives a snapshot of the current noise level, is of limited use for hearing damage risk measurements; an integrating or integrating-averaging meter is usually mandated. An integrating meter simply integrates—or in other words 'sums'—the frequency-weighted noise to give sound exposure and the metric used is pressure squared times time, often $Pa^2 \cdot s$, but $Pa^2 \cdot h$ is also used. However, because sound was historically described in decibels, the exposure is most often described in terms of sound exposure level (SEL), the logarithmic conversion of sound exposure into decibels.

A common variant of the sound level meter is a noise dosimeter (dosimeter in American English). However, this is now formally known as a personal sound exposure meter (PSEM) and has its own International standard IEC 61252:1993 (OSHA, 1983).

A noise dosimeter (American) or noise dosemeter (British) is a specialized sound level meter intended specifically to measure the noise exposure of a person integrated over a period of time; usually to comply with Health and Safety regulations such as the Occupational Safety and Health (OSHA) 29 CFR 1910.95 Occupational Noise Exposure Standard or EU Directive 2003/10/EC.

This is normally intended to be a body-worn instrument and thus has a relaxed technical requirement, as a body-worn instrument—because of the presence of the body—has a poorer overall acoustic performance. A PSEM gives a read-out based on sound exposure, usually $Pa^2 \cdot h$, and the older 'classic' dosimeters giving the metric of 'percentage dose' are no longer used in most countries. The problem with "%dose" is that it relates to the political situation and thus any device can become obsolete if the "100%" value is changed by local laws. Today, one of the most common devices in use is a miniature PSEM called by many manufacturers a 'dose badge', or some similar name, as it is so small and lights that it somewhat resembles a radiation badge. These tiny devices have the three advantages that not only do they not affect the sound field, but they are so small that they do not interfere with the worker in any way and his work pattern does not change; as well, having no microphone cable, they should have a lower risk of failure, by the cable 'catching on machinery' (OSHA, 1983).

ANSI standards divide sound level meters into two "classes". Sound level meters of the two classes have the same functionality, but different tolerances for error. Class 1 instruments have a wider frequency range and a tighter tolerance than a lower cost, Class 2 unit. This applies to both the sound level meter itself as well as the associated calibrator. Most national standards permit the use of "at least a Class 2 instrument". For many measurements, there is little practical point in using a Class 1unit; these are best employed for research and law enforcement. Similarly, the American National Standards Institute (ANSI) specifies sound level meters as three different Types 0, 1 and 2. These are described, as follows, in the Occupational Safety and Health OSHA Technical Manual TED01-00-015, Chapter 5, OSHA Noise and Hearing Conservation, "These ANSI standards set performance and accuracy tolerances according to three levels of precision: Types 0, 1, and 2. Type 0 is used in laboratories, Type 1 is used for precision measurements in the field, and Type 2 is used for general-purpose measurements. For compliance purposes, readings with an ANSI Type 2 sound level meter and dosimeter are considered to have an accuracy of ±2 dBA, while a Type 1 instrument has an accuracy of ±1 dBA. A Type 2 meter is the minimum requirement by OSHA for noise measurements, and is usually sufficient for general purpose noise surveys. The Type 1 meter is preferred for the design of cost-effective noise controls. For unusual measurement situations, refer to the manufacturer's instructions and appropriate ANSI standards for guidance in interpreting instrument accuracy (OSHA, 1983).

2.6 NOISE MEASUREMENTS

Frequency weighting

In almost all countries, the use of A-frequency-weighting is mandated to be used for the protection of workers against noise-induced deafness. The A-frequency curve was based on the historical equal-loudness contours and while arguably A-frequency-weighting is no longer the ideal frequency weighting on purely scientific grounds, it is nonetheless the legally required standard for almost all such measurements and has the huge practical advantage that old data can be compared with new measurements. It is for these reasons that A-frequency-weighting is the only weighting mandated by the international standard, the frequency weightings 'C' and 'Z' being optional fitments. Originally, the A-frequency-weighting was only meant for quiet sounds in the region of 40 dB sound pressure level (SPL), but is now mandated for all levels. C-frequency-weighting however is still used in the measurement of the peak value of a noise in some legislation, but B-frequency-weighting - a half way house between 'A' and 'C' has almost no practical use. D-frequency-weighting was designed for use in measuring aircraft noise, when non-bypass jets were being measured and after the demise of Concord, these are all military types. For all civil aircraft noise measurements A-frequency-weighting is used as is mandated by the ISO and ICAO standards.

Equivalent continuous Noise level (L_{eq})

Sound exposure level—in decibels—is not much used in industrial noise measurement. Instead, the time-averaged value is used. This is the time average sound level or as it is usually called the 'equivalent continuous sound level' has the formal symbol L_{eq} Formally, L_{eq} is 20 times the base 10 logarithm of the ratio of a root-mean-square A-weighted sound pressure during a stated time interval to the reference sound pressure and there is no time constant involved. To measure L_{eq} and integrating-averaging meter is needed; this in concept takes the sound exposure, divides it by time and then takes the logarithm of the result.

Short Equivalent continuous Noise level (L_{eq})

An important variant of overall L_{eq} is "short L_{eq}" where very short L_{eq} values are taken in succession, say at 1/8 second intervals, each being stored in a digital memory. These data elements can either be transmitted to another unit or be recovered from the memory and re-constituted into almost any conventional metric long after the data has been acquired. This can be done using either dedicated programs or standard spreadsheets. Short L_{eq} has the advantage that as regulations change, old data can be re-processed to check if a new regulation is met. It also permits data to be converted from one metric to another in some cases. Today almost all fixed airport noise monitoring systems, which are in concept just complex sound level meters, use short L_{eq} as their metric, as a steady stream of the digital one second L_{eq} values can be transmitted via telephone lines or the Internet to a central display and processing unit. Short L_{eq} is a feature of most commercial integrating sound level meters—although some manufacturers give it many different names. Short L_{eq} is a very valuable method for acoustic data storage; initially, a concept of the French Government's Laboratories' National d'Essais (ref 1), it has now become the most common method of storing and displaying a true time history of the noise in professional commercial sound level meters. The alternative method which is to generate a time history by storing and displaying samples of exponential sound level has too many artifacts of the sound level meter to be as valuable and such sampled data cannot be readily combined to form an overall set of data.

Peak sound pressure level (LC_{pk})

Most national regulations also call for the absolute peak value to be measured to protect workers hearing against sudden large pressure peaks, using either 'C' or 'Z' frequency weighting. 'Peak sound pressure level' should not be confused with 'MAX sound pressure level'. 'Max sound pressure level' is simply the highest RMS reading a conventional sound level meter gives over a stated period for a given time-weighting (S, F, or I) and can be many decibel less than the peak value. In the European Union the maximum permitted value of the peak sound level is 140 dB(C) and this equates to 200 Pa pressure. The symbol for the A-frequency and S-time weighted maximum sound level is LAS_{max}. For the C-frequency weighted peak it is LC_{pk} or $L_{C,peak}$.

Figure 2.1: Integrating-averaging sound level meters (IEC, 2002).

2.7 REVIEW OF NOISE DESCRIPTORS

The Occupational Health and Safety Regulation requires that the noise exposure be reported for all workers exposed to sound levels in excess of L_{EX} = 85dBA. Often the measurements alone are insufficient to produce an accurate value for L_{EX}. The measured results may require to be combined with other data or it may be subjected to some corrections (e.g. for shift length or artifacts which may have intruded upon the measurement).

With occupational noise, we are concerned with workers' noise exposure. In the Occupational Health and Safety Regulation, a worker's noise exposure is expressed as:

- The daily energy-averaged sound level (L_{EX} in dBA)
- Peak sound level in dBA.

Equivalent continuous noise level L_{eq}

L_{eq} is the equivalent steady sound level of a noise energy-averaged over time. Because occupational noise is often a complex signal, the noise level needs to be averaged over a minimum sample time. The sampling time can be as short as a few- 4 -minutes if the noise signal is steady or repetitive over a short cycle; some jobs could require a full day's monitoring. Whatever the actual duration, it should be representative sample of the entire exposure. If the activity is not typical of the shift then either more sampling is required when the condition is fulfilled or corrections to measurements may be required.

Noise exposure level (L_{EX})

L_{EX} is the noise **ex**posure level. L_{EX} is useful as a single number measure of the noise exposure in decibel form. L_{EX} is the sound level, energy-averaged over 8 hours, which would give the same daily noise exposure dose as the varying noise over atypical full shift. It is closely related to the Leq which is actually the measured quantity. In fact, L_{EX} could be regarded as being the measured Leq with a small correction. Thus:

$$L_{EX} = L_{eq} + \text{correction for shift length,}$$

Where the correction is given by the chart below. The shift time correction to L_{eq} is zero when the shift duration is 8 h.

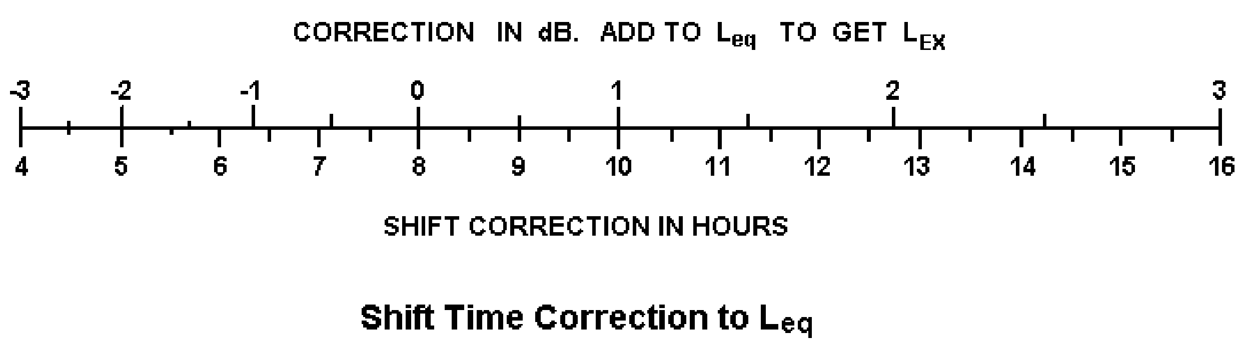


Figure 2.2: Correction for Shift Length to get L_{EX}
(Source: Work Safe BC, 2007)

L_{EX} of Non-standard Work Patterns

To obtain the appropriate L_{EX} correction for shift L_{eq} that depart from the standard hours/day, 5 days/week work pattern, the shift shall be assumed to have equivalent daily duration equal to the higher of:

• One-fifth of the average number of hours worked per week, or

• The average number of hours worked per month divided by 21

Noise Dose

Noise dose is another single descriptor for noise exposure. Noise dose may be given in terms of a value relative to unity or 100% of an “acceptable” amount of noise. As with L_{EX}, it’s easier to see that a noise dose of 160% (87 dBA for 8 h) exceeds the permissible 100% dose (85 dBA for 8 h). Also, noise calculations can be made simpler by using noise dose values instead of sound levels in decibels.

Note: In NIOSH guidelines an exposure to sound level 85 dBA for 8 hours = 100% noise dose.

The statistical measures (L_N) concept

The parameter L_N is a statistical measure that indicates how frequently a particular sound level is exceeded. If, for example, we write L_{40} = 72 dBA, then we know that 72 dBA was exceeded for 40 percent of the measuring time.

2.8 TRANSPORTATION SYSTEM OF DHAKA CITY

The transportation system of Dhaka city is predominantly road based. Although there is a limited use of waterways along the river Buriganga within the metropolitan area the rail and water transport is almost absent as the city’s public transport. The city has no mass transit system like metrorail or bus rapid transit (BRT) systems. However, the government is planning to have BRT systems in three major corridors and metro rail in one corridor. As in other Asian cities, the majority of trips in Dhaka are served on public transport and non-motorized transport modes (NMT) or Para-transits because a significant numbers of people are poor who cannot afford personal vehicle. As the fare of NMT (such as rickshaws) or other para-transits are more expensive than the bus fares; most of the people are heavily dependent on public transport for their travel. The STP (2005) stated that the modal share of trips on public transport in Dhaka is about 44%. Bus services are playing the dominant role in providing public transport facilities of the city. If only the mechanized transports are considered, the buses run the highest passenger-km per day. Although the bus provides highest passenger-km travel, the modal share of bus in terms of person-trips is comparatively low; hence there is a considerable scope of improvement of modal share of bus by improving bus service in Dhaka city. However, the number of passengers in public transport has been increasing continuously during the last 20 years. The bus fleets operating in Dhaka are mainly standard buses and minibuses. According to the strategic transport plan (STP 2005), it is estimated that there are around 7100 buses in Dhaka. Only 1,300 of them are plying of which less than 200 are of improved quality. Even though the government owned Bangladesh Road Transport Corporation (BRTC) provides bus services in few routes; the private sector is dominating the sector, which constitutes more than95% of the total public transport, and often act like a syndicate providing monopolistic service. Furthermore, due to lack of proper planning, management and maintenance, the bus services in Dhaka is in an unsatisfactory situation. Dhaka, being a city with very less car ownership rate and poor economy needs cost-effective public transport systems and services. Thus, bus service should be the spine of transportation for the city. However, various researches claimed that the present bus services are inefficient, unproductive, and unsafe due to long waiting time, delay on plying, long boarding time, overloading, discomfort, long walking distance from the residence/work place to bus stoppages, and so on. (Rahman and Nahrin, 2012).

2.9 NOISE POLLUTION IN DHAKA CITY

2.9.1 Status of Noise Pollution in Sensitive Areas of Dhaka City

In Bangladesh noise pollution (also termed as sound pollution) is a major health hazard. In fact, due to noise pollution millions of people in Bangladesh are exposed to a number of health risks - from deafness to heart attack. On city streets noise pollution can be caused by hydraulic horns of vehicles, microphones and cassette players. The hydraulic horns used by buses, trucks and scooters in the crowded city streets are dangerous for human being. The horns especially cause serious damage to children. Experts say, if a child below three years of age hears a horn emitting 100 dB of noise from a close range, he or she might lose his or her hearing power. A child's health may also be adversely affected by loud sounds from the radio, television, cassette players and microphones, the sound of mills and factories and loud noise. Another survey of DoE shows that noise pollution has increased in different parts of Dhaka City. This survey mainly covered sensitive area where quietness is of primary importance such as schools and hospitals. They experienced noise level at sensitive areas exceeding acceptable limit of noise (see Table 2.5). But, in Bangladesh, little has been done so far to reduce noise pollution (DoE, 1998).

Table 2.5: Observed noise level at sensitive area of Dhaka city (DoE, 1998)

Sensitive area such as School & Hospitals	Experienced Noise level (dBA)		Acceptable limit of noise (dBA)	
	Day	Night	Day	Night
Shaheen School	83	74	45	35
Motijheel Government High School	83	79	45	35
Dhanmondi Government Boys School	80	75	45	35
Azimpur Girls' College	80	74	45	35
Tejgaon Girls' College	75	67	45	35
Bangabandhu Sheikh Mujib Medical University	82	74	45	35
Dhaka Medical College Hospital	80	69	45	35
Mitford Hospital	76	73	45	35
Shishu Hospital	72	69	45	35

2.9.2 Traffic Noise Levels at Different Locations in Dhaka City

Noise emission is one of the major concerns for a mega city like Dhaka. A large civil-structured project is being implemented in Dhaka, which was known as Jatrabari-Gulistan flyover. A study was carried out by Hassan and Alam, (2013) to focus variation of traffic noise level at different intersections during construction period and normal period. Main focus of this research was concentrated to record and analyze noise levels in major intersections located at the study area as well as key entities, such as hospitals, educational institutions; religious institutions etc. for both day and night and seven days of a week. Average noise level was found 92.7 dBA at Jatrabari intersection during construction period and 86.6 dBA during normal period. To compare the noise level during operation phase and construction phase two other similar civil structured projects, Khilgaon and Kuril flyover were selected and same operation was carried out. In this regard, noise related parameters such as L_{eq}, L_{10}, L_{50}, and L_{90} have been estimated from field observations of noise levels. It was observed that at all locations; noise level remained far above the acceptable limit. From this study it is observed that average noise level at every location varies within the range of 80-90 dB(A) which far exceeds the acceptable limit of 60 dB(A) set by DoE, Bangladesh considering the road side as mixed area. In most places minimum sound level also exceeds the acceptable limit. From the noise prediction of noise for different construction equipment it is clear that noise level is within the limit at a distance far away from source but it is really high in the nearby areas. It is also observed that noise level is closely related to the volume of traffic, traffic flow condition, speed, tire and pavement types, and characteristics of vehicles and so on but in this study they have not carried out any investigation to proof that observation.

2.9.3 Status of Noise Pollution in Mixed Areas of Dhaka City

Uncontrolled noise of Dhaka city has made a serious and vulnerable situation for the dwellers. Mixed areas are used in multidimensional ways so the degree and intensity of noise pollution is often higher. In this regard, a research by Haq et al. (2012) to explored the nature and vulnerability of noise pollution in mixed areas as well as to realize its impacts. This study put an effort to determine the level of noise pollution and its zone of influence to know how far noise is affecting the socio-environment of the study area. From this study it can be seen that the highest average noise level at every location of study area varies within the range of 82-87 dB(A) which far exceeds the acceptable limit of 60 dB(A) set by DoE, Bangladesh considering the road side as mixed area. It is also observed that the lowest average noise level at every location of study area varies within the range of 71.3 – 76.7 dBA. The highest experienced average noise level found in that study at Banglamotor intersection while lowest experienced average noise level found at Ruposhi Bangla road intersection. It is observed that noise level remains higher at morning (9 am to 11 am) and evening (5 pm to 8pm), remains low at noon (12 pm to 4 pm). Noise level reaches at pick in evening (5 pm to 8 pm).Noise level increases at morning, as it is the beginning of office hours. This study reveals the current status of noise pollution as well as vulnerability due to it but this study has not discussed about source of noise pollution and also did not presents any observation about possible impact of traffic noise on experienced average noise level in this study area.

2.10 PREVIOUS STUDY ON MASS TRANSIT NOISE POLLUTION

2.10.1 Exposure to noise inside transit buses

In both the industrialized and the non-industrialized world, traffic noise is a major environmental concern for residents of cities. With continuing urbanization, car ownership, roadway capacity expansion, and the steady growth of traffic volume, ever-increasing numbers of urban residents will be exposed to rising traffic noise pollution in future years. Urban dwellers directly expose to noise inside bus transportation system. Koushki and Ali, (2001) conducted a study that designed to quantify noise pollution levels inside transit buses in Kuwait. It also presents the results of a passenger attitude study concerning the exposure and impact of noise. In this research, noise levels were measured, for the first time, inside 115 random transit buses, operating on 12 sample representative routes during the daily commuting hours in Metropolitan Kuwait. The measured noise levels and the computed noise pollution level all indicated that the noise levels inside transit buses were generally high. Equivalent continuous noise level ranged between a minimum of 68.2 (dBA) and a maximum of 106.7 (dBA) for an overall sample mean of 79.0 (dBA). Nearly 65% of riding passengers were annoyed with the noise inside the bus, of which nearly 34% were `very much' annoyed.

Noise from outside sources (traffic, commercial, construction, etc.), significantly contributed to noise pollution levels inside buses. To examine the validity of this point, a three-way cross classification analysis was performed on the data. The affects of noise from outside sources (traffic noise and other noises) was very significant on those measured inside the bus. For example, the measured noise levels inside the Volvo buses, operating on different routes, varied from a low of 70.5 (dBA) to a high of 79.5 (dBA) on commercialized route. Similar variations in the inside noise levels were found in the Ikarus and the Tata buses operating on different routes, but this findings are not enough evidence to verify that the Noise from outside sources significantly contributed to noise pollution levels inside buses. There are many reasons behind the variation of noise inside transit buses such as age of bus engine, velocity of bus, road condition and traffic flow. For that reason there is need to further investigation to examine the validity of this point.

A research was carried out by Nadir et al. (2011) in Kerman, in southeast Iranto evaluate the exposure levels of Kerman city public transportation bus drivers to noise. In this study eighty public transportation buses in the streets of Kerman, Iran in 2010 were randomly sampled during week day business hours and in each driver noise exposure was measured for 10 minutes according to the standard methods. The noise exposure was measured in 4 different models of buses. All of the buses were 7 or fewer years old. There was no significant difference in the noise produced by the 4 models. The measurements were similar ranging from 65.9 dBA to 79 dBA. The noise levels measured in these buses for the drivers were under the 85 dBA threshold for speech frequencies, and less than 85 dBA for the passengers; it will probably not cause hearing or other health related problems. This study indicates the highest amount of experienced noise exposure level was 79 dBA and the lowest amount of experienced noise exposure level was 65.9 dBA.

To evaluate the noise level exposure of noise levels to which the bus drivers in Curitiba, Brazil a study was conducted by Zannin et al. (2003). Two measurements were taken inside 25 buses, the first close to the driver and the second at the back of the bus. The normalized exposure levels were all over 65 dBA in all cases making the work environment uncomfortable according to the Brazilian Legislation for Ergonomics. The year of manufacture and the location of the engine are relevant factors in determining the noise inflicted on drivers. They found noise dose below 50% for all bus drivers except for two bus drivers. In this study they mentioned that the year of manufacture and the location of the engine are relevant factors in determining the noise inflicted on drivers but they have not shown any correlation to examine the validity of this point.

A research work was done by Mukherjee et al. (2003) to investigate exposure of drivers and conductors of special state buses in Kolkata, India to noise. This exposure study was undertaken for state special buses over three routes. Each route was studied at least three times. The noise exposures of driver alone are estimated for two seasons—winter (January–February) and summer (May)—during 2000 over a period of two weeks. The first trip exposure levels on all routes were found to vary between 79.5 and 86.3 dBA. The noise exposures of drivers on route 3 exceeded the recommended standard of 85 dBA in second trip whereas on route 2, the exposure levels exceeded on the third trip. However, the maximum values of Leq were always above the permissible level on all the routes. Drivers mostly perform 2–3 trips per work-shift and in most cases after the third trip noise exposure levels exceeded prescribed levels. Comparing routes, it was found that the condition of the selected buses played a role along with busy and congested roads. There is no significant difference in Leq between summer and winter although the minimum values for noise exposure in summer were slightly higher than winter. This research has not discussed factors that influence on interior noise pollution level in buses.

A research was carried out by Portela and Zannin, (2010) in Brazil to evaluate noise pollution levels and analyzed factors that influence noise levels in urban buses. Noise exposure was evaluated in 80 buses of four models whish were conventional, speedy, micro and articulated. For best possible comparison of models, 20 vehicles of each model were chosen randomly. In this study the highest experienced equivalent continuous noise level (80.2 dBA with standard deviations 2.3 dBA) was found in conventional buses whereas lowest equivalent continuous noise level (75.1 dBA with standard deviations 2 dBA) found in speedy buses. Measurements taken in this study indicated that conventional, micro and articulated buses (most of which have a front-engine design) produce higher noise levels may be due to the fact that engine is located near driver and also near the point of measurement. Analysis of various bus models revealed significant difference among four engine configurations of buses. Thus, engine configuration in different locations in bus influence L_{eq}, demonstrating that drivers who work with rear-engine vehicles are exposed to lower noise levels than those who work in buses with front-engine design. In this study, researcher mainly focused on bus sized but they have not analyzed other many factors that influence noise levels in buses such as velocity of bus.

An investigative work was done by Anyogita et al. (2002) to examine the levels of noise and its spectral characteristics in CNG driven vehicles on roads of Delhi. Measurements of noise and its spectral characteristics were made inside various types of transport running on Compressed Natural Gas (CNG) fuel in Delhi. Noise indices L_{10}, L_{50}, L_{90} and L_{eq} were estimated from the measured noise levels for vehicles in neutral gear, slow speed (speed 420 km/h) and under free flow (speed 530 km/h) conditions. It is found that background levels, when averaged over all speeds, are maximum in Rural Transport Vehicles (RTV) followed by Buses, Auto-rickshaws and Taxis. With increase in the speed, noise levels are appreciably enhanced except in the case of auto-rickshaws where the increase is moderate. The study reveals significantly lower noise levels inside CNG driven public modes of transport compared to those found in an earlier survey inside diesel and petrol driven vehicles.

2.10.2 Study of mass transit noise pollution in different cities

A Study of Riders' Noise Exposure on Bay Area Rapid Transit Trains in San Francisco was carried out by Dinno et al. (2011) to characterize transit noise and riders' exposure to noise on the Bay Area Rapid Transit system. They made 268 dosimetry measurements on a convenience sample of 51 line segments. This study provides evidence of levels of hazardous levels of noise exposure in all three dosimetry metrics. L_{eq} and L_{max} measures indicate exposures well above ranges associated with increased cardiovascular and psychosomatic health risks. L_{peak} indicate acute exposures hazardous to adult hearing on about 1% of line segment rides and acute exposures hazardous to child hearing on about 2% of such rides. Of the 268 noise dosimetry measurements of L_{eq},60 (22%) were above 85 dBA and six recorded L_{peak} levels exceeded 120 dB, the World Health Organization's (WHO) guideline threshold for hearing impairment in children. Besides, three reported L_{peak} levels exceeded 140 dB, the threshold for hearing impairment in adults used by both the National Institute of Occupational Health and Safety and the WHO. In this study, dosimetry measures were modeled using linear and nonlinear multiple regression as functions of average velocity, tunnel enclosure, flooring, and wet weather conditions and presented visually on a map of the BART system. The number of observations is overlaid on each line segment, except those with a single measurement. Figure 2.3 presents noise map for rapid transit trains.

This study indicated that average velocity had different effects on three dosimetry measures and equivalent continuous noise level (L_{eq}) increased linearly with average velocity. An environmental survey of noise levels of the New York City transit system was conducted by Dinno et al. 2011. Over 90 noise measurements were made using a sound level meter. Average and maximum noise levels were measured on subway platforms, and maximum levels were measured inside subway cars and at several bus stops for comparison purposes. The average noise level measured on the subway platforms was 86 dBA. Maximum levels of 106, 112, and 89 dBA were measured on subway platforms, inside subway cars, and at bus stops, respectively.

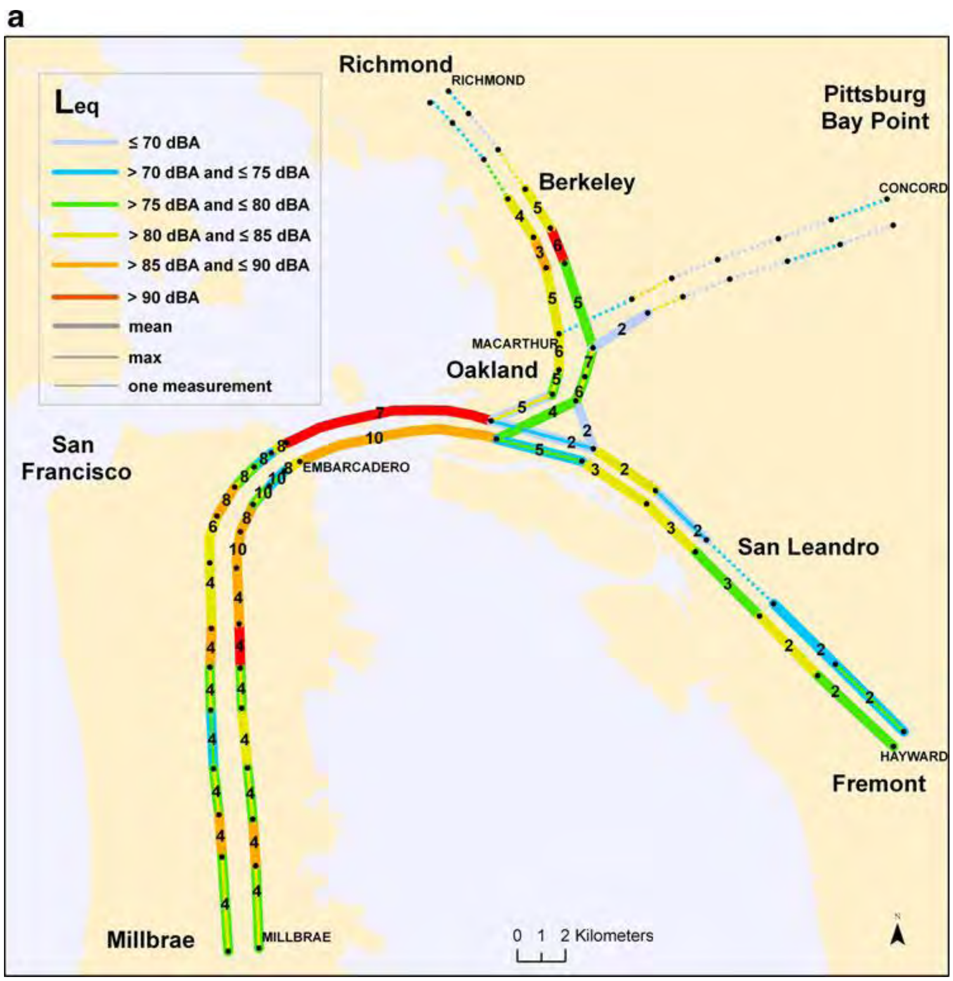


Figure 2.3: Map of mean and maximum L_{eq} (dBA) for rapid transit trains in San Francisco (Dinno et al. 2011)

These results indicate that noise levels in subway and bus stop environments have the potential to exceed recommended exposure guidelines from the World Health Organization (WHO) and U.S. Environmental Protection Agency (EPA).

Another environmental survey of Passenger exposure to noise at transit platforms in Los Angeles was conducted by Schaffer, (2012). In this study noise measurements were carried out on the 16 transit platforms in the study area.

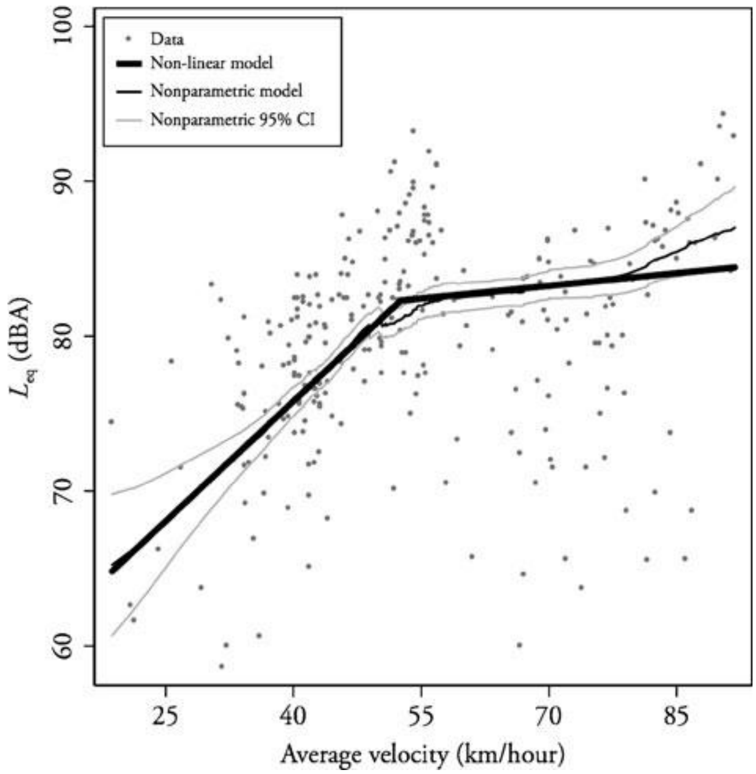


Figure 2.4: Effect of average velocity on L_{eq} for rapid transit trains (Dinno et al. 2011)

This study indicated experienced average noise level ranged between 80.8 to 88.1 dBA and maximum measured noise level was 92.9 dBA whereas minimum experienced noise level was 76.1 dBA. This study also presents that traffic is moving faster and making more noise. Limitations of this Study were the data collected for this study was not comprehensive. The readings did not capture a full range of variation in traffic speeds at many stations, so it was not possible to determine the effects of traffic speeds on noise at each station.

A study was carried out by Ozer et al. (2009) in the city of Tokat, Turkey to evaluate noise pollution levels caused by vehicles. Noise measurements were taken in the evening to determine noise pollution all over the city as motorway transportation noise. The equivalent sound levels (L_{eq}) were measured at 65 points, between 17 and 19 p.m. in the city. High noise levels on these streets were observed throughout the city. At fifty of sixty-five measurement points (76.9%), noise values exceeded 65 dB(A), limit value according to Statistical analysis revealed that, there were significant differences in noise levels among the streets. This study has revealed that even in Tokat one of the small-sized cities, noise pollution has reached serious levels, showing that the noise has become one of the major environmental problems of the country to be urgently overcome.

A Study of Noise Pollution in Kolhapur City, Maharashtra, India was conducted by Mangalekar et al. (2012) to monitor existing noise pollution levels in Kolhanpur City**.** In this study, continuous monitoring of noise levels (L_{eq}) dB A was carried out for three days in the month of December, 2011 at six different sites within the Kolhapur city. On the basis of location these sites were grouped into industrial, commercial, residential and silent zones respectively. The results showed that there is an enhanced pressure of noise at all sites due to increase in number of vehicles and facilities of transportation. All the sites under study showed higher sound level than the prescribed limits of Central Pollution Control Board (CPCB) of India.

A research work was done by Mishra et al. (2010) to evaluate and analysis of traffic noise along bus rapid transit system corridor in Delhi. Based on this study, it is concluded that traffic noise caused by heavy traffic flow condition on the main BRTS corridor is significant and exceeding the national CPCB standards. Due to heavy traffic volume, traffic noise is also increasing at this particular corridor. In response to this, noise abatement measures have been proposed to curb the noise pollution in the vicinity of the concerned transport corridors. These measures mainly include construction of noise barriers and adopting traffic mitigatory measures.

Balashanmugam et al. (2013) discussed the results obtained in a study on assessment of noise pollution in Chidambaram town. The data obtained was used to compute various noise parameters, namely equivalent continuous level (L_{eq}), Noise pollution level (L_{np}), Noise climate (NC), Percentile noise levels (L_{10}, L_{50}, L_{90}).The comparison of the data shows that the noise levels at various locations of the Chidambaram town are more than the permissible limits. Vehicular traffic and air horns are found to be the main reasons for these high noise levels. This study examines the problems of reduction of individual's efficiency in his/her respective working places because of road traffic noise pollution in Chidambaram due to rapidly growing vehicular traffic.

Debnath et al. (2012) reported the results obtained in a research on Analysis of Heavy Vehicular Noise Pollution in Nagaon Assam, India. It is found that in all places noise level exceed maximum value of minimum level of pollution and creating an environment with high level noise pollution and the study proves that Nagaon district is highly affected by noise pollution. It is found that the loaded trucks, sand carrying trucks, Public Buses and other heavy vehicles are moving freely in the town causing high voltage noise. This study implied that natural vegetation, if high enough, wide enough, and dense enough, can decrease roadway traffic noise to some extents.

A study was carried out by Dursun et al. (2006) in Turkey. In this investigation, direct effect of architectural peculiarity on noise pollution was found and threshold level of 65 dBA was exceeded all the region measured. Noise source factors were mainly transportation vehicle, architectural faults, usage of the non isolated materials in the construction, vehicle horns and music, conditioning systems of some industrial work yards, machine stroke noise, on the other hand project or faulty material for road surface noise can also be included in noise source. This investigation showed that there is a relationship between the noise level and traffic and also disordered city plan with the reference of measurements from 366 sampling point. Threshold level of 65 dBA was exceeding the most of measurement points. Another point in this investigation is road width which was affecting noise level increment. Two streets with different widths but same vehicle numbers were compared, wide streets have less noise production with having large place of distribution, no horn nor high engine sound on unblocked road, but there was echo in large surface between the opposite buildings on the road..The vehicle type is another factor affecting the traffic source noise level too. Each vehicle produces noises in different levels and the vehicle type in the traffic is a valuable parameter for noise levels on the roads.

An Analysis of noise pollution in Tirupur, India city was conducted by Keerthana et al. (2013). Results obtained in this study shows that the whole city is affected heavily by noise pollution more during the evening hours when compared to morning hours and in almost 90% of the area prevailing noise level is more than the ambient noise level. It has been found that in many areas the noise level prevailing averages around 85 db at 90% of the busy points of the city. Most of the noise is generated only due to horns of vehicles like rickshaws, buses, wagons & trucks etc.

To determine the level of traffic noise in the city of Karachi a study was conducted. The Maximum level of noise was 110 dB (A), recorded from Autorickshaw & Motorcycles (without silencers) and Minibuses. Maximum noise was observed during the peak rush hours. The mean values of noise level in the commercial and residential areas were 95.75dB (A) and 60 dB (A) respectively. Karachi is facing an enormous problem of exceedingly high levels of traffic noise, which is significantly higher than all the available international data.

An environmental noise study in the city of Caceres, Spain was conducted by Morillasa, and Escobar (2002). In the overall analysis of the results, 90% of the measurements were higher than 65 dBA, and always above 55 dBA, showing that, even for a city this small in size and of a non-industrial type, traffic noise is a major pollutant. The results showed there to be a clear relationship between urban noise due to traffic and the traffic volume, and also an acceptable linear correlation between L_{10} and L_{eq}.

A comprehensive study was conducted by Ali and Tamura, (2003) in Greater Cairo, Egypt to quantify present road traffic noise level, monitor noise level with restriction and percentage of annoyance with road traffic noise level. Measurements of road traffic noise levels in Greater Cairo indicate that noise levels in the city are higher than those set by Egyptian noise standards and policy to protect public health and welfare in residential areas (L_{eq}=80 dBA and higher were recorded, while maximum permissible level is 65 dBA). Restrictions were introduced to improve environmental conditions including: (i) a ban on horns, (ii) a ban on horns and trucks, (iii) a ban on horns, trucks and noisy buses. Equivalent noise levels (L_{eq}) were measured before and after these restrictions. The equivalent noise level was considerably reduced by the bans. The degree of annoyance was measured by means of questionnaire. The results showed that there was a strong relationship between road traffic noise levels and the percentage of highly annoyed respondents. There is a strong relationship between road traffic noise level and the percentage of respondents feeling ‘‘highly annoyed’’. By increasing road traffic noise levels, the percentage of respondents feeling ‘‘highly annoyed’’ is also increased.

Ayaz and Rahman, (2011) were conducted a study to assess of roadway noise level in Dhaka city. From this study it was found that the maximum value of the 48 points ranged from 62-99 dB, the average value ranged from 47-91 dB and the minimum value of the 48 points ranged from 17-84 dB. Analysis showed that 2% places had maximum noise level within acceptable limit for working day and holiday. On the other hand 2% places had average noise level within acceptable limit for working day and 10% places had average noise level within acceptable limit for holiday. However, 10% places had minimum noise level within acceptable limit for working day whereas 20% places had minimum noise level within acceptable limit for holiday. There exists a constant level of pollution resulting from unbounded movement of traffic throughout the city due to commercial, social, educational, recreational and other activities and thus results the alarming level of pollution both at working day and holiday. Figure 2.5 shows that among 48 places Sonar Tori Building was only within acceptable limit (<70 dB) in case of average noise level for working day.

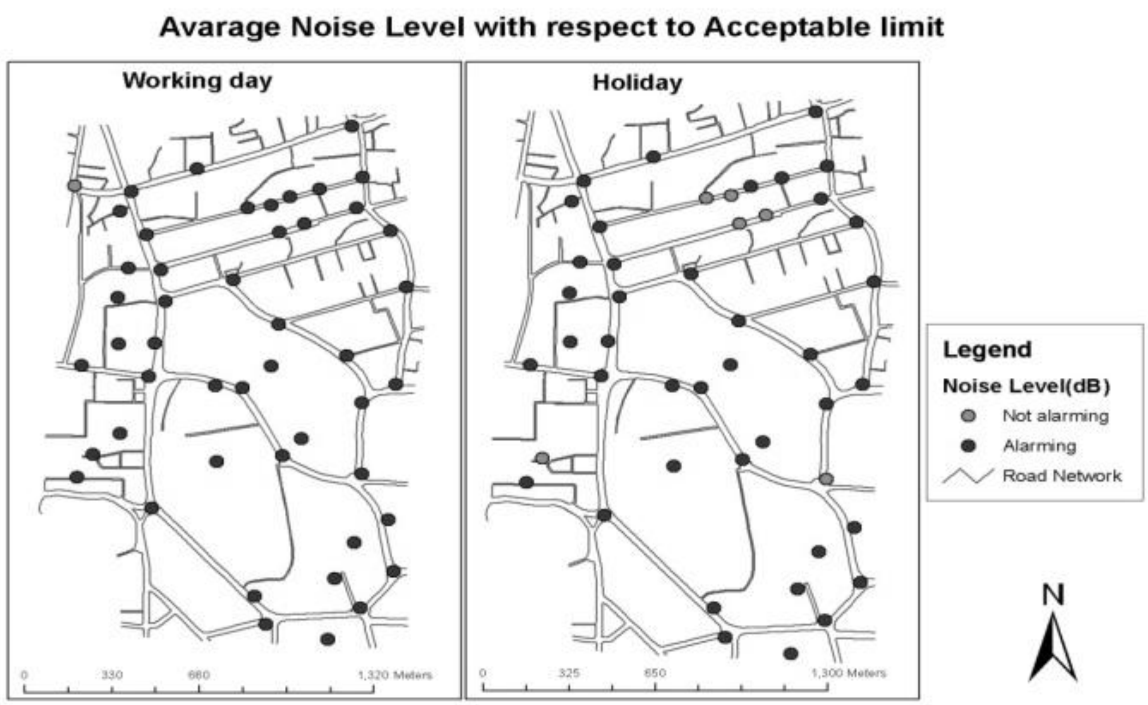


Figure 2. 5: Alarming and Non-alarming Areas with respect to Average Noise Level in Dhaka city (Ayaz and Rahman, 2011)

Till now only one study has been conducted by Hossain et al. (2013) to assess interior noise exposure level of bus driver and helper in Bangladesh. In this study they only measured continuous noise level in five bus routes among the 60 different buses plying on different routes within Dhaka city. They reported that in the bus routes, all the noise levels were above the guideline values ranging from 86 dBA to as high as 89.2 dBA. In this study they calculated equivalent continuous noise level for entire trip. To carry out thorough investigation on interior noise hazard level in buses, there is a need to calculate noise exposure level in several route segments for every entire-length of trip. Besides, in this study they did not carry out any investigation on factors that influence interior noise level in buses. That is why it is necessary to conduct a comprehensive research on interior noise hazard level of buses in Dhaka city.

2.11 SUMMARY

A review of related literature shows that over the years numerous studies of urban traffic noise have been conducted. Several studies have addressed the quantification of outdoor noise pollution levels. The impacts of urban traffic noise on the health and welfare of exposed individuals have also been studied by many researchers worldwide. A significant amount of work has also focused on monitoring noise pollution levels at indoor locations adjacent to busy roadways. However, the quantification of noise pollution levels inside vehicles especially in bus transportation system has received little attention from the researchers (Koushki and Ali, 2001; Nadir et al. 2011; Zannin et al. 2003; Mukherjee et al. 2003; Portela et al. 2011; S. Anyogita et al. 2002). To our knowledge, no research has been conducted in Bangladesh to realistically estimate the magnitude of occupational noise exposure levels for bus transportation system in Dhaka city in a comprehensive manner. This research represents the first study of noise inside bus transportation system in Dhaka city.

CHAPTER 3
METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology adopted to carry out this research work. This chapter mainly contains three sections namely routes selection, data collection and basic noise calculation. Routes selection section presents the procedure of transit buses selection, bus routes selection and describes the selected bus routes. The data collection section describes the procedure of data collection. A data logging noise level meter was used to carry out continuous noise level measurement on every selected bus trips, and GPS (Etrex-10) was used to collect trip distance, moving velocity, moving time and stopped time. Basic noise calculation section contains the description of noise level metrics such as Equivalent Continuous Level (L_{eq}), Noise Exposure (L_{EX}), Noise Dose and how these metrics are calculated for the current study.

3.2 ROUTES SELECTION

Dhaka, the capital of Bangladesh is located at 23°42′0″North and 90°22′30″East. The area of the city is 153.84 sq.km (59.4 sq mi) in City Corporation and 590 sq. km (227.8 sq mi) in metropolitan. There are 4, 12,540 registered motorized vehicles with 1, 05,636 registered motor car. Besides, there are about 500,000 registered rickshaws in the city. The actual number of rickshaws would be two to three times higher than the registered rickshaws (Mahmud et al, 2002).

The main objective of this research work was to determine the internal noise environment of bus transportation system of Dhaka city. To achieve this main goal, most of the bus routes of Dhaka city had to be covered. To select starting and end point for most of the trips, seven locations were considered which are Azimpur bus station, Abdullapur bus station, Gabtoli bus station, Sadarghat bus station, Jatrabari, Mirpur and Motijheel. These seven locations are situated at the periphery of the Dhaka City corporation area that are shown in the Figure 3.1. The selection of these seven locations as a starting or end points helped to make sure to cover most of the bus routes of Dhaka city corporation area. As of April 2009, there were 39 different routes of bus service in Dhaka approved by DMTRC (Rahman and Nahrin, 2012). However, almost each of these routes has a variety of service options. According to Dhaka bus map approximately 60 different bus services company are plying within Dhaka city. Dhaka bus map (Figure 3.2 and

3.3) has been followed to select bus routes and bus services for this research purpose. In order to determine the interior noise environment of bus transportation system and to assess the noise exposure level of the bus drivers and conductors, 29 different bus services were selected for noise level measurements which are presented in Table 3.1.

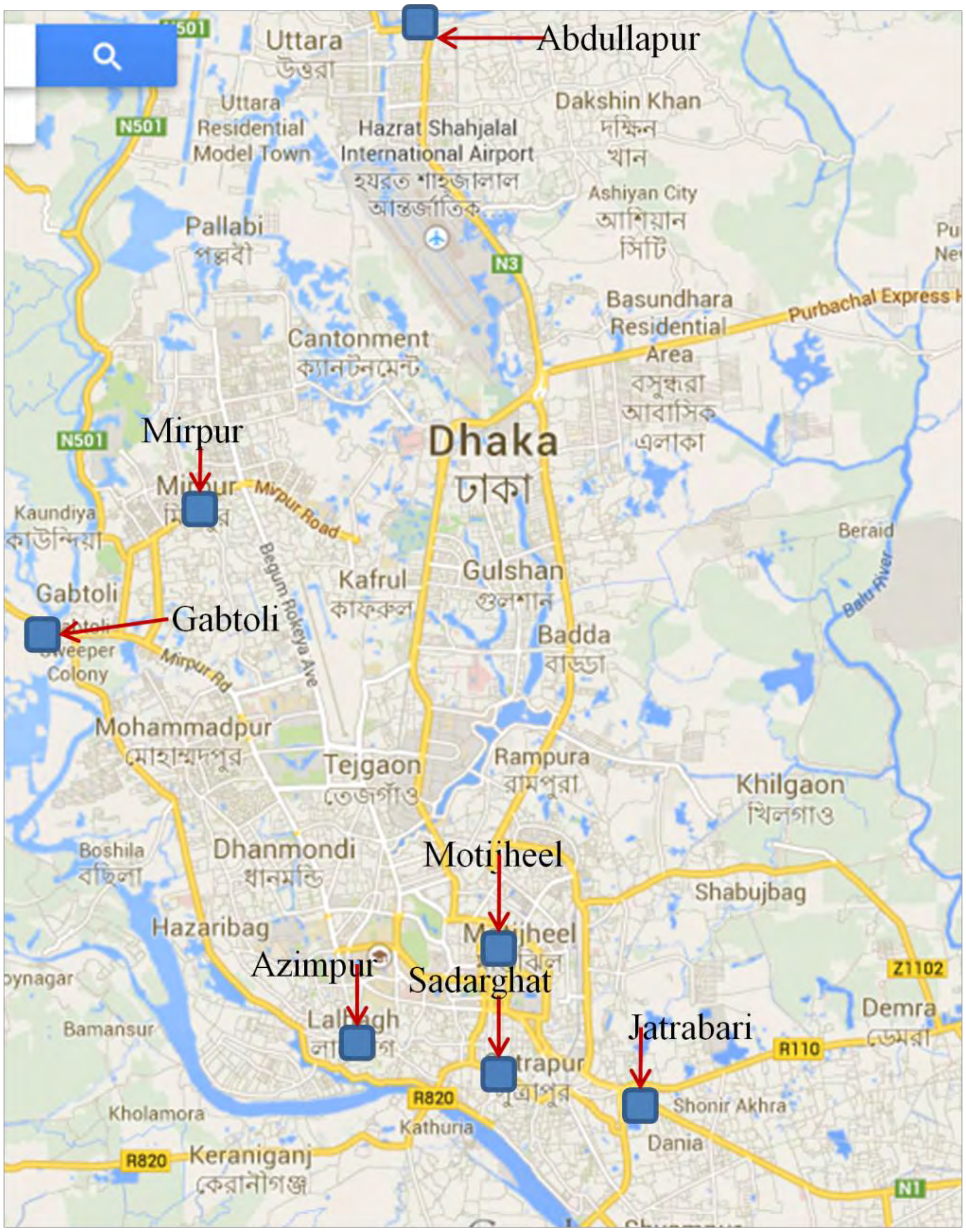


Figure 3.1: Selected seven locations as a starting or end points (Source: Google map)

Table 3.1: Details of the 29 Selected Bus Routes

Bus Company	Origin	Intermediate Stoppage	End Point	Trip Distance (km)
3 no local bus	Abdullapur	Azompur, Airport, Khilkhet, MES, Banana, Jahangirgate, Bijoysarani, Farmgate, Kawranbazar, Sahabagh and Pressclub	Gulistan	21.4
7 no local bus	Gabtoli	Technical, Kollanpur, Shishumela, Asadgate, Kolabaghan, Sciencelab, Katabon, Sahabagh, Pressclub and Gulistanmajar	Sadarghat	13.2
Ashirbad	Azimpur	Nilkhet, Sciencelab, Asadgate, Shishumela and Technical	Mirpur-1	9.7
Azmiri glori	Sadarghat	Bongshal, Gulistan, Kakrail, Mowchak, Moghbazar, Shatrasta, Nabisco, Mohakhali, Banani and MES	Abdullapur	21.5
Bangole Motors	House-building	Airport, Kuril, Banani, Jahangirgate, Agargaon and Shishumela	Kollanpur	19.4
Bikolpo	Azimpur	Nilkhet, Sciencelab, Asadgate, Khamaebari, Bijoysarani, Agargaon, Mirpur-10 and Mirpur-11	Mirpur-12	13.5
BRTC	Mirpur-12	Mirpur-11, Mirpur-10, Shawrapara, Agargaon, Bijoysarani, Farmgate, Kawranbazar, Shahabagh, Pressclub and Zeropoint	Motijheel	15
BRTC AC	Motijheel	Gulistan, Pressclub, Shahabagh, Kawranbazar, Farmgate, Bijoysarani, Mohakhali, Banani, MES, Khilkhet, Airport and Azompur	Abdullapur	22.6
BRTC Double Decker	Abdullapur	Airport, Khilkhet, MES, ECB chottor, Kalshi, Pallobi, Mirpur-10, Mirpur-1 and Technical	Gabtoli	20.3
Dipon Transport	Motijheel	Pressclub, Shahabagh, Katabon, Sciencelab and Jigatola	Mohammad pur	8.8
Dishari Poribahan	Mirpur-1	Technical, Shyamoli, Asadgtae, Farmgate, Kawranbazar, Shahabagh and Pressclub	Gulistan	12.3
Falgoan	House-building	Airport, Khilkhet, Bashundara, Nutonbazar, Uttar badda, Moddo Badda, Rampura, Malibagh, Mowchak, Shantinagar, Kakrail, Shahabagh and Sciencelab	Azimpur	21.4
Jatrabari Poribahan	House-building	Airport, Khilkhet, Banani, Mohakhali, Satrasta, Moghbazar, Mowchak and Razarbagh	Jatrabari	22.8
Konok Poribahan	Abdullapur	Azompur, Airport, Khikhet, ECB Chottor, Kalshi, Pallobi and Mirpur-10	Mirpur-1	16.7
Midway	Taltola	Kamolapur, Arambagh, Motijheel, Polton, Pressclub, Shahabagh, Katabon, Sciencelab and Jigatola	Mohammad pur	15.3

Bus Company	Origin	Intermediate Stoppage	End Point	Trip Distance (km)
Moitri Poribahan	Motijheel	Bonghabazar, Zeropoint, Pressclub, Shatrasta, Katabon, Sciencelab and Jigatola	Mohammad pur	8.8
New Dhaka Link	Azimpur	Nilkhet, Kolabaghan, Asadgate, Shyamoli and Technical	Mirpur-1	9.4
New Vision	Mirpur-1	Technical, Shyamoli, Asadgate, Farmgate, Kawranbazar, Shahabagh, Pressclub and Palton	Motijeel	13.3
Nishorgo	Azimpur	Nilkhet, Sciencelab, Mohammadpur, Asadgate, Shishumela, Agargaon, Kazipara and Mirpur-10	Mirpur-14	16
Probati Bonosri	Gulistan	Zeropoint, Bijoysarani, Shantinagar, Moghbazar, Shatrasta, Mohakhali, Banani, Khilhet and Airport	Abdullapur	19.9
Salsabil	Jatrabari	Mughda, Bashabo, Malibagh, Rampura, Moddo Badda, Nuton Bazar, Bashundara, Khilkhet and Airport	Abdullapur	21.8
Shuprobat	Sadarghat	Gulistan, Bijoysarani, Shantinagar, Malibagh, Rampura, Moddo Badda, Nuton Bazar, Bashundara, Khilkhet and Airport	Abdullapur	20.9
Shotabdi poribahan	Mirpur-14	Mirpur-10, Mirpur-1, Technical, Shyamoli, Asadgate, Mohammadpur, Jigatola, Sciencelab, Shahabagh, Pressclub and Zeropoint	Motijheel	19.8
Shuchona poribahan	Nilkhet	Asadgate, Fermgate, Bijoysarani, Jahangirgate, Banani, MES, Khilkhet and Airport	Abdullapur	21
Transilba	Mirpur-1	Technical, Shishumela, Asadgate, Sciencelab, Katabon, Shahabagh, Pressclub, Palton, Gulistan, Motijheel and Ittifakmor	Jatrabai	20
Turagh	Jatrabari	Maniknagar, Bashabo, Malibagh, Rampura, Moddo Badda, Nuton bazaar and Bashundara	Abdullapur	21.8
VIP	Azimpur	Nilkhet, Sciencelab, Asadgate, Khamarbari. Farmgate, Bijoysarani, Jahangirgate, Banani, MES, Kuril, Khilkhet, Airport and Azompur	Abdullapur	21.6
Winner	Nilkhet	Sciencelab, Kolabaghan, Panthopath, Kawranbazar, Shatrasta, Mohakhali, Gulistan, Moddo Badda and Nuton baza	Kuril	16.5
Cantonment mini service	Mirpur-14	Shadinota chottor and Shoynic club.	Kakoli	2.6

Figure 3.2: Dhaka Bus Map, Source: www.urbanlaunchpad.org/alpha

Figure 3.3: List of Dhaka city Bus Services Source: www.urbanlaunchpad.org/alpha

3.3 DATA COLLECTION

To complete this study, Continuous noise level measurements were carried out on most of the local bus routes of Dhaka City. For this purpose, a data logging noise level meter (Model number HD-600) was used. Noise level measurements were carried out over the entire length of a one-way trip of the selected bus routes. To ensure recording of actual noise level inside bus transportation system of Dhaka city, Continuous noise level measurements were carried out under normal operating conditions—i.e., loaded with passengers (but avoiding rainy conditions, weekends or holidays) during working hours of the day (9:00 AM to 7:00 PM). Measurements were not done during holidays due to the low traffic and low number of buses plying on the streets. To assess the noise exposure level of Driver and Helper of the bus, noise measurements were carried out by placing the noise level meter near the ear level of the Driver and Conductors. Noise measurements were done continuously during a one-way trip from origin to destination. There are different kinds of public and private buses plying within the Dhaka city and most of the buses could be classified in two categories. One is small sized buses that have around 35 seats and the other is large sized buses that have around 65 seats. In the small sized buses noise measurements were carried out by placing the noise level meter at the rear of bus driver and in large sized buses noise measurement were carried out at the rear of bus helper that shown in Figure 3.4. Noise levels were recorded in decibels (A-weighted) at 30-second intervals. The Noise level meter also recorded average noise level, minimum experienced noise level and maximum experienced noise level for entire trip. When bus reached the end point (destination) of the route noise level recording was stopped; the recorded data was later downloaded in a personal computer and post-processed in Microsoft Excel and MATLAB.

Besides, during noise level measurements a GPS (Etrex-10) was used to acquire relevant trip characteristics data such as trip distance, road segment distance, moving average velocity, overall average velocity, total travel time, stopped time and maximum trip velocity. Number of intersections for single one-way trip was counted during noise level measurement.

After finishing the noise level measurement for a one-way trip a discussion with the bus operators and drivers was carried out to understand other relevant information such as number of driver and conductor working in a specific bus, number of buses, number of seats in a specific bus, age of buses, number of trips per day and manufacturer name for specific bus models.

Figure 3.4: Noise measurement was carried out at the rear of bus driver and close to the ear of helper

Figure 3.5: View of Large sized bus (left) and small sized bus (right)

Figure 3.6: View of external condition of Salsabil bus (left) and view of internal condition of Konok porobahan (right)

3.4 BASIC NOISE CALCULATION

Temporally recorded noise data is not useful to compare with any standard value and we cannot understand from recorded data that the noise level is making any threat to human health. Besides, the Occupational Health and Safety Regulation require that the noise exposure be reported for all workers exposed to sound levels in excess of 85dBA. Most noises contain a mixture of sounds with different frequencies. In order to correctly determine the characteristics of a noise, it is necessary to determine the Equivalent Continuous Noise Level. Often the measurements alone are insufficient to produce an accurate value for L_{EX}. The measured results may require to be combined with other data or it may be subjected to some corrections. For that reason some basic noise calculation are necessary to analyze the temporally recorded noise data. Some noise level metrics calculated in this study are discussed below.

3.4.1 Equivalent Continuous Level (L_{eq})

The equivalent continuous equal level can be applied to any fluctuating noise level. It is that constant noise level that, over a given time, expends the same amount of energy as the fluctuating level over the same time period. L_{eq} is the equivalent steady sound level of a noise energy-averaged over time. Because occupational noise is often a complex signal, the noise level needs to be averaged over a minimum sample time. The sampling time can be as short as a few-4 -minutes if the noise signal is steady or repetitive over a short cycle; some jobs could require a full day's monitoring. Whatever the actual duration, it should be a representative sample of the entire exposure. Equivalent continuous noise level can be calculated from the following equation (1) and equation (2).

$$L_{eq} = 10\, log \frac{1}{t} \int_0^t 10^{L(t)/10}\, dt \; \ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where, t = the time over which L_{eq} is determined, $L(t)$ = the time varying noise level in dBA and L_{eq} = Equivalent Continuous Noise Level.

A series of discrete samples of L(t) have to be taken. This modifies the expression to:

$$L_{eq} = 10\, log \sum_{i=1}^{i=n} 10^{L_i/10}\, t_i \quad \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where n = the total number of samples taken, L_i = the noise level in dBA of the ith sample and t_i = fraction of total sample time (Davis and Cornwell , 2012).

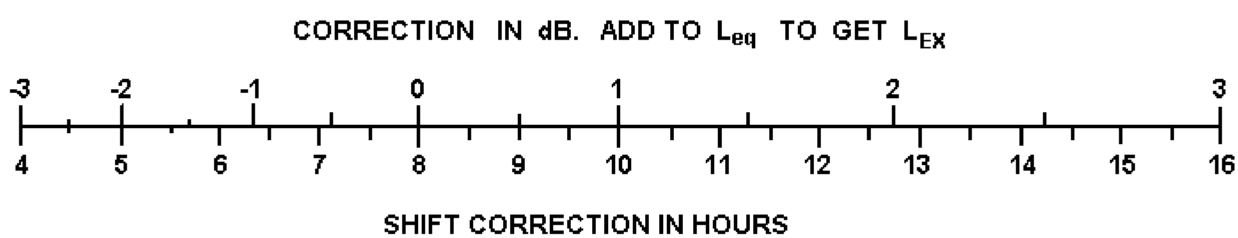
In this study overall equivalent continuous noise levels were calculated over the entire length of a one-way trip. Besides, equivalent continuous levels were also calculated between selected road segments. Every one-way trip divided into several road segments. For example, 3 no local bus operates on Abdullapur and Gulistan route which is divided into twelve road segments which are as follows: Abdullapur-Azompur, Azompur-Airport, Airport-Khilkhet, Khilkhet-MES, MES-Banani, Banani-Jahangirgate, Jahangirgate-Bijoysarani, Bijoysarani-Farmgate, Farmgate-Kawranbazar, Kawranbazar-Sahabagh, Sahabagh-Pressclub and Pressclub-Gulistan.

3.4.2 Noise Exposure Level & Noise Dose

L_{EX} is the noise exposure level. L_{EX} is useful as a single number measure of the noise exposure in decibel form. L_{EX} is the sound level, energy-averaged over 8 hours, which would give the same daily noise exposure dose as the varying noise over typical full shift. It is closely related to the L_{eq} which actually measured. In fact, L_{EX} could be regarded as being the measured L_{eq} with a small correction.

Thus: $L_{EX} = L_{eq}$ + correction for shift length (Work Safe BC, 2007)

where the correction is given by the chart below.



Shift Time Correction to L_{eq}

In Dhaka city most of the Drivers and Helpers work approximately 18 hours (6:00AM to 12:00PM) in a day and they generally work four days per week.

According to NIOSH guideline, to obtain the appropriate L_{EX} correction for shift L_{eq} that depart from the standard hours/day, 5 days/week work pattern, the shift shall be assumed to have equivalent daily duration equal to the higher of:

One-fifth of the average number of hours worked per week or

The average number of hours worked per month divided by 21 (Work Safe BC, 2007).

The shift time correction to L_{eq} is 2.5 dBA for Dhaka city bus Drivers and Helpers, because the shift duration is 14.4 hours. $[18 \times 4 = \frac{72}{5} = 14.4\ hrs]$

Along with the L_{EX} the Noise dose can be assessed. Noise dose is another single descriptor for noise exposure and may be given in terms of a value relative to unity or 100%. An exposure to sound level 85 dBA for 8 hours corresponds to a 100% noise dose which is termed as an "acceptable" amount of noise according to the NIOSH guidelines. Also, noise calculations can be made simpler by using noise dose values instead of sound levels in decibels. For example, in discussing noise exposures, it is more convenient to see that a noise dose of 160% (87 dBA for 8 h) exceeds the permissible 100% dose (85 dBA for 8 h) (NIOSH, 1998). Noise dose can be calculated using the following equation (3).

$$ND = 100 \times \frac{T}{8} \times 10^{\frac{L_{eq}-85}{10}}\ \% \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, L_{eq} = A-weighted, sound level linearly energy averaged over T hours and

T = shift length or sampling time, in hours.

According to NIOSH guideline to control occupational noise exposure, worker exposures are less than the combination of exposure level (L) and duration/shift length(T) as calculated by the following formula (NIOSH, 1998):

$$T\ (min) = \frac{480}{2^{(L-85)/3}} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3.5 CALCULATION OF SEGMENT WISE DISTANCE AND VELOCITY OF BUS

Segment wise distance and travel velocity of bus were calculated for all the 29 bus routes with the help of GPS. Trip duration between two road segments was determined with the help of the noise level meter. Travel velocity of buses on selected road segments were calculated from measured distance and time. Trip distance, moving average velocity, overall average velocity, moving time, stopped time and maximum trip velocity for an entire trip were recorded by GPS.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 INTRODUCTION

Continuous noise level measurements were carried out in 29 different buses in Dhaka city. Cumulative noise distribution and stair graphs of equivalent continuous noise level were plotted to present internal noise environment of buses in Dhaka city. Noise map of Dhaka city bus transportation system was constructed to present overall noise hazard scenario in buses. The hotspots of noise pollution in Dhaka city bus routes were identified from this noise map. Besides, different relationship curves were plotted to determine whether the physical characteristics of the vehicle (bus type, age of engine, bus size), geometric features of the road (no of intersections in a one-way trip) and trip characteristics (trip duration, trip distance and average travel velocity in a single one way trip) have any bearing on the average experienced noise level.

4.2 INTERIOR NOISE ENVIRONMENT IN DHAKA CITY BUS TRANSPORTATION SYSTEM

4.2.1 Noise intensity - duration relationship

Temporal noise levels data have been collected in 29 different bus trips in Dhaka city. There was significant variation of noise level in 29 different bus trips due to variation of bus routes, bus types, bus engine, velocity of buses and other many factors. One objective of this study was to determine the internal noise environment in bus transportation system in Dhaka city. In order to define the internal noise environment and characterize the noise level in different buses in Dhaka city, cumulative noise distributions were constructed from the temporal noise profiles. These distributions indicate the percentage of time a certain noise level is equaled or exceeded within the sampling time in the bus interior. Besides, noise indices L_{90}, L_{50}, L_{10} are also shown in Cumulative distribution curve. The parameter L_N (L_{90}, L_{50} and L_{10}) is a statistical measure that indicates how frequently a particular sound level is exceeded. If, for example, we write L_{40} = 72 dBA, then we know that 72 dBA was exceeded for 40 percent of the measuring time. Here Cumulative Noise Distribution profile for 7 number local bus that operates on Gabtoli to Sadarghat route was described that shown in Figure 4.1. From this curve it can be seen that 74 dBA noise level equaled or exceeded 90% of sampling time, 79.6 dBA noise level equaled or exceeded 50% of sampling time and 84.3 dBA noise level equaled or exceeded 10% of sampling time in the bus interior. Similar cumulative noise distribution curves for the 29 buses were constructed under the current study which are presented in appendix A.

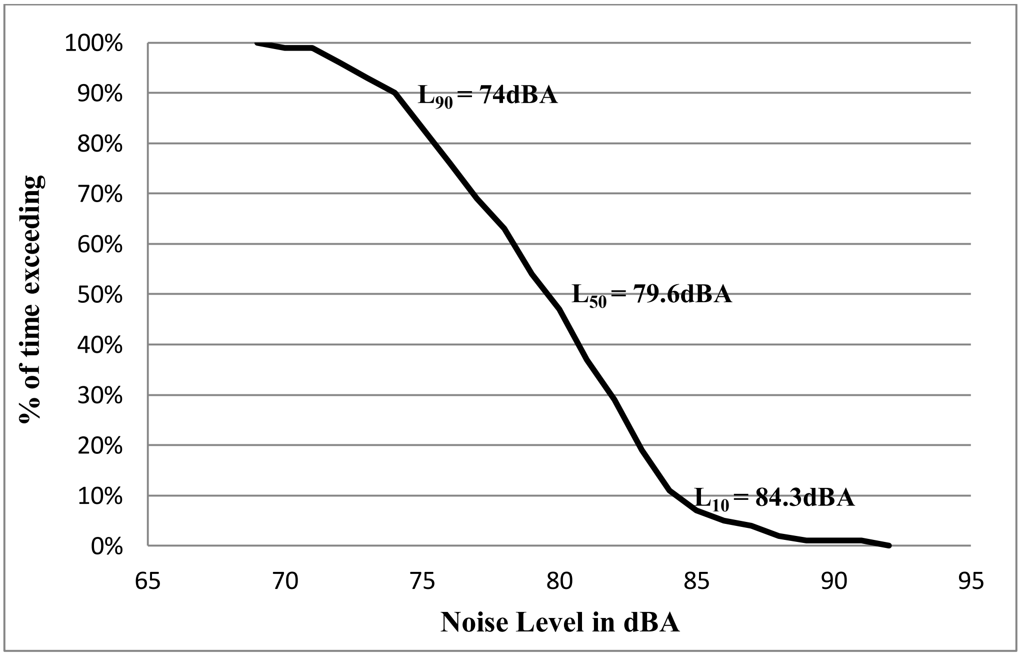


Figure 4.1: Noise Intensity – duration relationship for 7 no. local bus

The cumulative noise distribution curves of 29 buses are shown combinedly in figure 4.2. From this figure it can be seen that most of the cumulative noise profiles are roughly within the ranges defined by the profiles of Dipon transport and BRTC AC bus. The maximum L_{90} (77.3 dBA) was found in Midway bus that operates on Taltola to Mohammadpur route whereas the minimum L_{90} (65.8 dBA) was found in Azmiriglori bus that operates on Sadarghat to Khilkhet route. The average value of L_{90} was found 71.8 dBA with a standard deviation of 3.1 dBA. The maximum L_{50} (82.2 dBA) was experienced in Dipon transport and Konok poribahan whereas the minimum L_{50} was 72.9 dBA that was experienced in BRTC AC bus which operates on Motijheel to Abdullapur route. The standard deviation and average value of L_{50} were 2.5 dBA, 78 dBA respectively. The maximum L_{10} (90 dBA) was experienced in Shatabdi poribahan which operates on Mirpur-14 to Motijheel route whereas the minimum L_{10} (79 dBA) was experienced in BRTC AC bus which operates on Motijheel to Abdullapur route. The standard deviation of L_{10} was 2.5 dBA and average of L_{10} was 84.5 dBA. Noise level metrics were calculated from interior noise measurements in Dhaka city for 29 different bus services are shown in table 4.1. The highest equivalent continuous noise level (90.4 dBA) was found in Dipon transport bus and the lowest

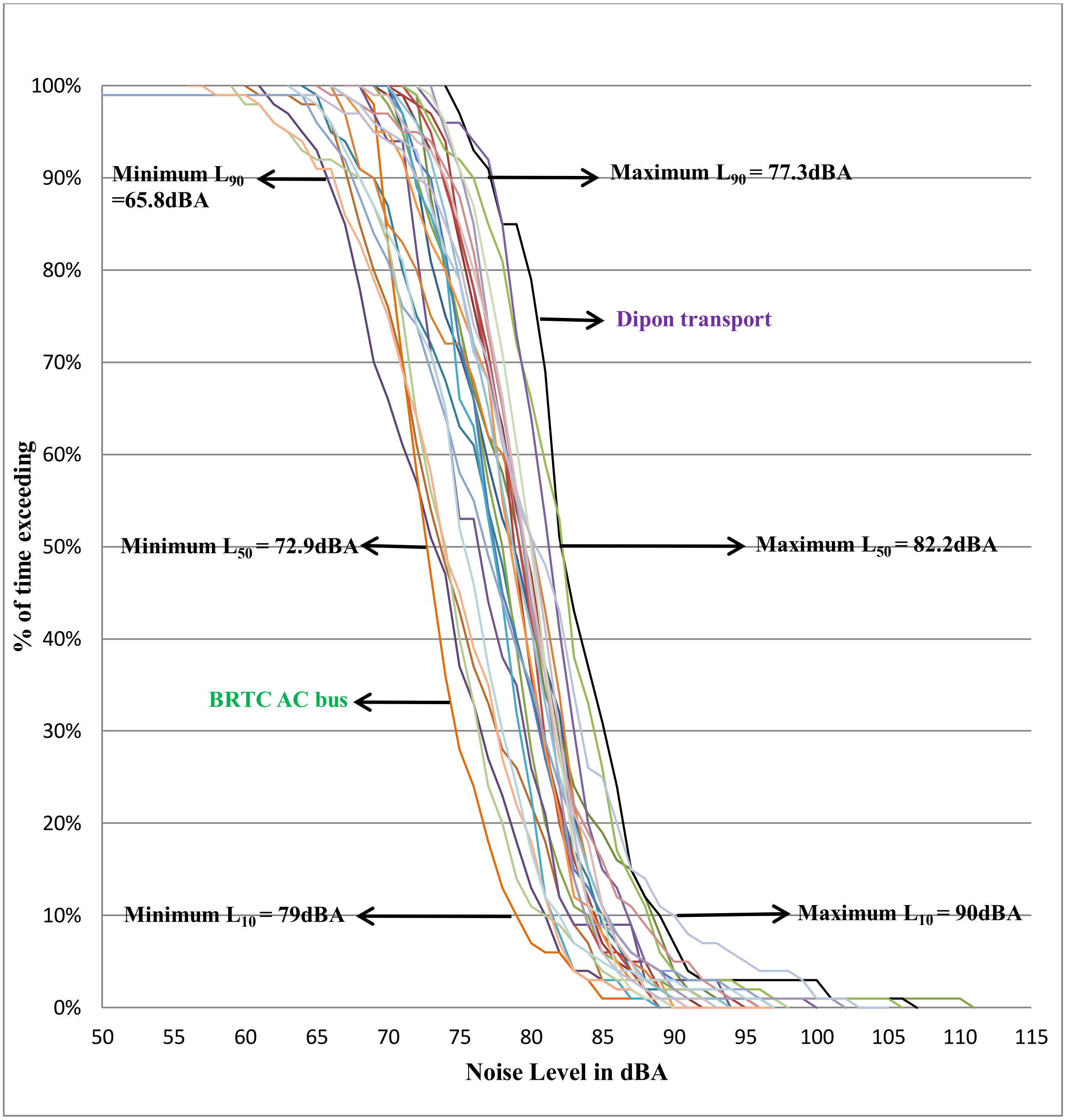


Figure 4.2: Combined Noise Intensity - duration relationship for the 29 buses

equivalent continuous noise level (77.3 dBA) was found in Azmiriglori bus. Besides, the lowest minimum experienced noise level was experienced in New vision bus which was 49.3dBA and the highest maximum experienced noise level was found in BRTC bus which was 111 dBA. The highest average noise level (83.1 dBA) was experienced in Dipon transport that operates on Motijheel to Mohammadpur route.

Table 4.1: Noise level metrics calculated from interior noise measurements in Dhaka city for 29 different bus services

Bus Company	L_{min} in dBA	L_{avg} in dBA	L_{max} in dBA	L_{90} in dBA	L_{50} in dBA	L_{10} in dBA	L_{eq} in dBA
3 no local bus	69.8	78.5	92	72	78.7	85.2	81.3
7 no local bus	69.3	79.3	91.5	74	79.6	84.3	81.3
Ashirbad	71.8	79.6	95.8	72.8	79.2	88.5	83.7
Azmiri glori	61	73.1	89.6	65.8	73.2	81	77.3
Bangole Motors	64.2	77.1	93.7	69	77.7	84.8	81
Bikolpo	60.1	74.6	89	67.2	73.7	82.6	78.4
BRTC	69	78.1	111	72	78	84	89
BRTC AC	68.2	73.6	95.2	69.5	72.9	79	77.6
BRTC Double Decker	70.6	79.2	94.7	74.4	78.9	84.5	81.8
Dipon Transport	74.9	83.1	106.4	77.2	82.2	89	90.4
Dishari Poribahan	66	78.3	96	69	80.1	85.3	82.5
Falgoan	69	78.5	109	73	77.4	85	86.9
Jatrabari Poribahan	70.8	79	88.8	73.8	79.2	83.8	80.8
Konok Poribahan	71.1	82	105.8	76	82.2	88.2	88.3
Midway	72.2	81.4	99.9	77.3	81.2	86.7	83.6
Moitri Poribahan	68.7	77.2	88.8	71.9	77.4	81.5	78.9
New Dhaka Link	66.3	78.2	89.3	71.5	78.6	84.3	80.6
New Vision	49.3	76.8	101.2	67.4	76.8	85.3	83
Nishorgo	65.4	79.9	95.2	74.3	79.5	87.5	83.6
Probati Bonosri	59.4	74.1	97.2	68	74	81	80.6
Salsabil	73	79.8	101.5	75.2	79.5	83.8	83.8
Shuprobat	70.2	79.1	93.3	73.4	78.8	85.3	81.7
Shatabdi poribahan	66.1	80.9	104.6	72.4	80.3	90	88.8
Shuchona poribahan	56.2	75.3	96.7	66.2	73.9	81.4	79.6
Transilba	67.7	79.5	90.9	74	79.6	85.3	81.7
Turagh	72.2	79.9	89	75.3	80	85	81.2
VIP	63	78.9	92	72	80.1	84.2	81.3
Winner	63	75.6	96	68	75.4	82	81
Cantonment mini service	68.7	76.9	93.7	71.4	76.3	82.6	81.1

4.2.2 STAIR GRAPHS FOR SELECTED BUS TRIPS

Stair graph of equivalent continuous noise level (L_{eq}) was portrayed for every selected bus trip to portray the interior noise pollution level of different buses in different route segments of Dhaka city and Equivalent continuous noise levels were calculated in selected route segments for every selected bus trip. These stair graphs show the relative level of equivalent continuous noise levels in buses in selected route segments. The hotspots of noise pollution in the Dhaka city bus routes can be identified from these stair graphs. These stair graphs also show approximate distance between two route segments. The highest segmentwise bus interior L_{eq} (100 dBA) was experienced in the 1.2 km long Mirpur-10 to Mirpur-11 route segment in BRTC bus whereas the lowest segment wise bus interior L_{eq} (77.3 dBA) was found in the 1 km long Shahabagh to Kawranbazar and 2.5 km long Mohakali to Banani route segments in BRTC AC bus. For example, Stairs graph for Salsabil bus that operates on Jatrabari to Abdullapur route is shown in Figure 4.3. From this stair graph it can be seen that the highest equivalent continuous noise level (91 dBA) was experienced in the 1.8 km long Nuton Bazar to Bashundara route segment and the lowest equivalent continuous noise level (78 dBA) was experienced in the 1.2 km long Mughda to Bashabo route segment. Similar stair graphs were portrayed for all the 29 bus trips which are presented in appendix A.

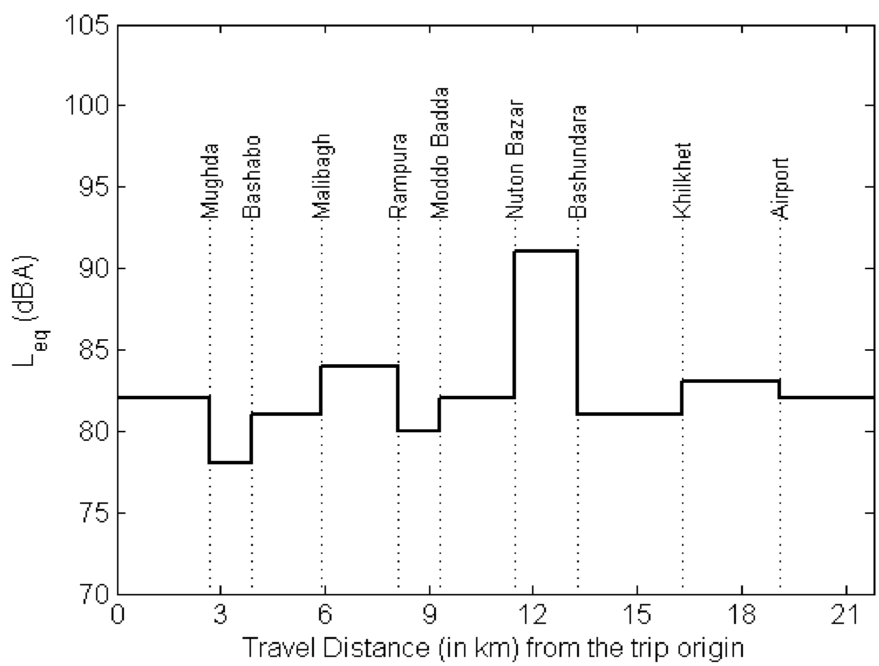


Figure 4.3: Stair graph for Salsabil bus trip

4.3 INTERIOR NOISE HAZARD LEVEL OF BUSES IN DHAKA CITY BUS ROUTE

The survey data of 29 bus services was consolidated into nine major routes to portray the interior noise hazard level in buses along specific bus routes. These routes were divided into several route segments. Since Continuous noise level measurements were carried out several times on almost every route segment, the arithmetic average of equivalent continuous noise level (L_{eq}) was taken to denote the average noise exposure in the corresponding route segment. To present the interior noise hazard scenario in buses in nine bus routes, L_{eq} bar diagram and stair graphs of equivalent continuous noise level (L_{eq}) were constructed for these nine bus routes. Figure 4.4 to Figure 4.11 represents equivalent continuous noise level (L_{eq}) bar diagram and stair graphs of nine major Dhaka city bus routes. Details of the nine bus routes are presented in Table 4.2.

Table 4.2: Details of the 9 selected bus routes

Bus Route	Origin	Intermediate Station	End Point
Route 1	Abdullapur	Airport, Khilkhet, Banani, Farmgate and Shahbag	Sadarghat
Route 2	Jatrabari	Khilgaon, Malibagh, Rampura, Moddobadda, Nutonbazar, Khilkhet and Airport	Abdullapur
Route 3	Abdullapur	Airport, Khilkhet, MES, Pallobi, Mirpur-10, Mirpur-1 and Technical	Gabtoli
Route 4	Gadtoli	Technical, Shyamoli, Asadgate, Sciencelab, Shahbag	Sadarghat
Route 5	Mirpur-12	Mirpur-10, Agargaon, Farmgate, Shahbag	Motijheel
Route 6	Mirpur-14	Mirpur-10, Mirpur-1, Technical, Shyamoli, Asadgate, Sciencelab, Shahbag, Motijheel amd Komolapur	Taltola
Route 7	Azimpur	Kolabaghan, Kawranbazar, Shatrasta, Mohakhali, Gulshan-1, Moddobadda and Nutonbazar	Kuril
Route 8	Sadarghat	Kakrail, Moghbazar, Shatrasta, Mohakhali, Banani, Khilkhet and Airport	Abdullapur
Route 9	Mirpur-1	Technical, Shyamoli, Asadgate, Sciencelab, Shahbag, Motijheel and Ittifakmor	Jatrabari

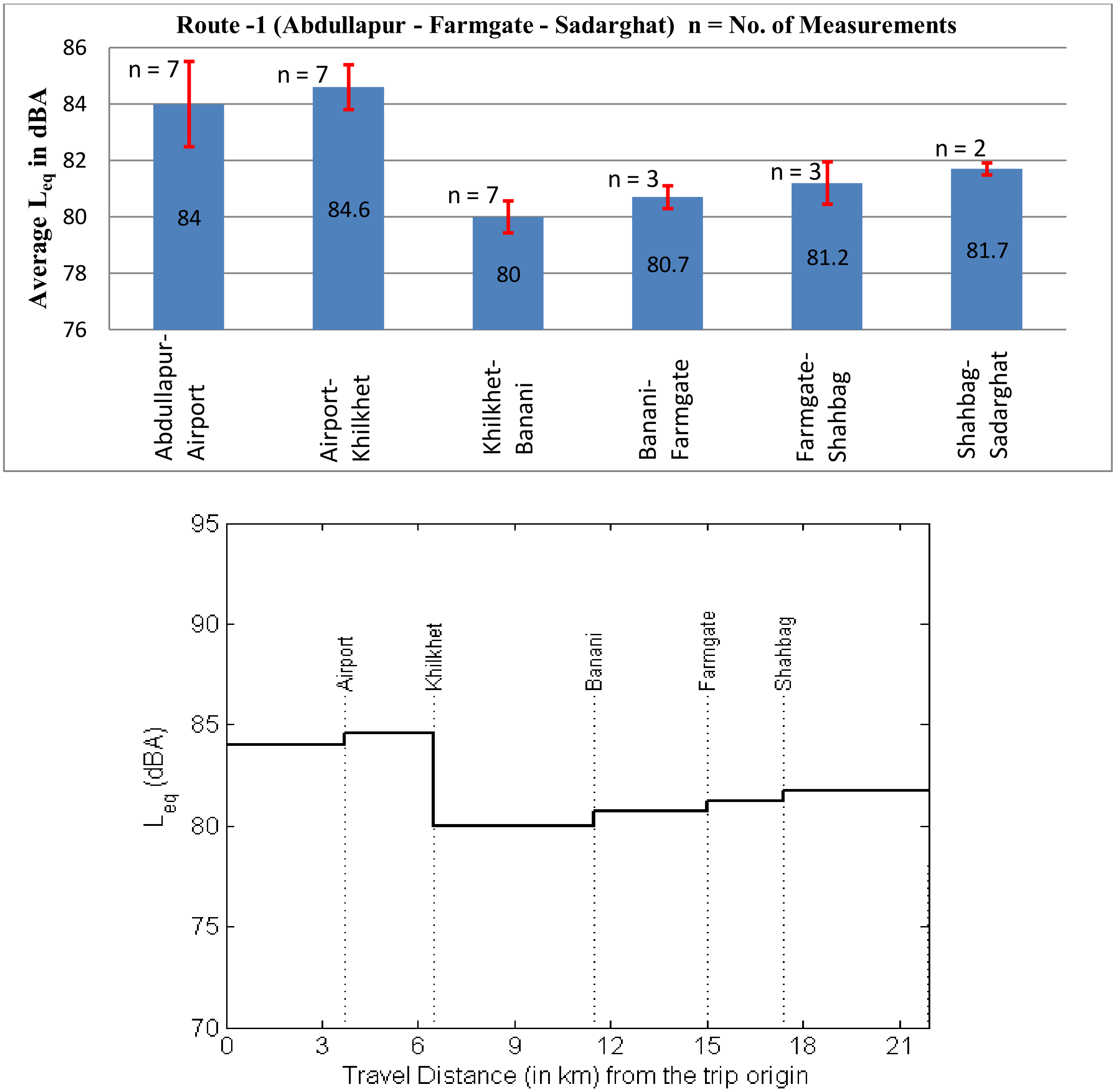


Figure 4.4: L_{eq} Bar diagram and Stair graph for Route -1

Figure 4.4 represents the relative bus interior noise hazard scenario for Abdullapur to Sadarghat bus route. In this route the highest average equivalent continuous noise level (84.6 dBA) was experienced in the 2.8 km long Airport to Khilkhet route segment whereas the lowest average equivalent continuous noise level (80 dBA) was found in the 5 km long Khilkhet to Banani route segment. The intensity of traffic is significantly low in the 2.8 km long Khilkhet to Airport route segment, that is why bus drive with high velocity in this route segment. The highest average L_{eq} was found in the khilkhet to Airport route segment due to high velocity of bus. On the other hand bus drive slowly and often remain stopped in the Khilkhet to Banani route segment due to high intensity of traffic and traffic signal. For this reason the minimum bus interior L_{eq} was found in this route segment.

The relative bus interior noise hazard level is shown for entire length of Jatrabari to Abdullapur route by the Figure 4.5. The lowest equivalent continuous noise level (80.7 dBA) was experienced in the 1.3 km long Rampura to Moddobadda route segment.

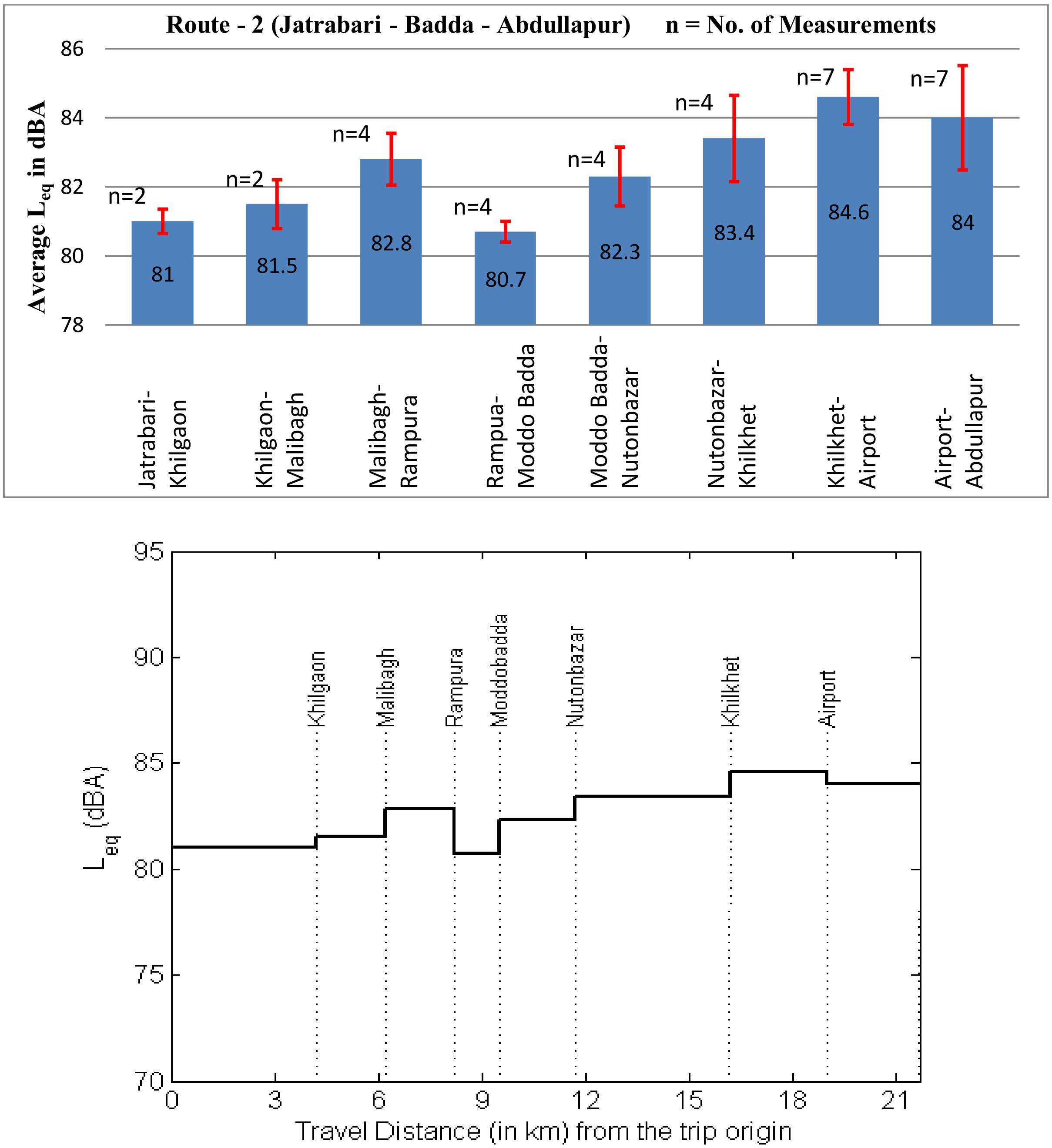
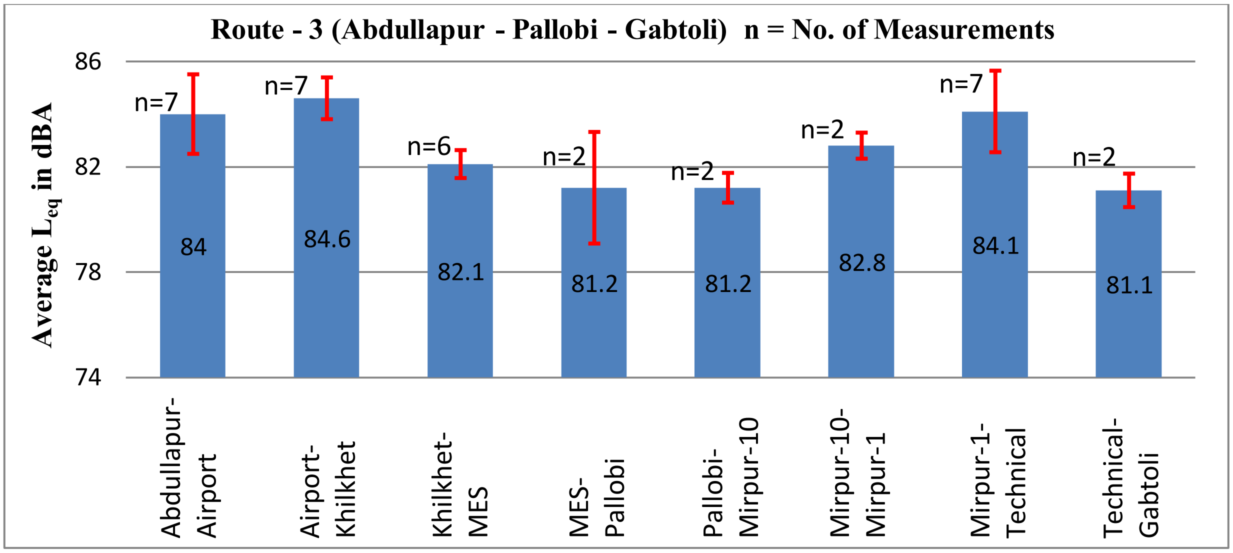


Figure 4.5: L_{eq} Bar diagram and Stair graph for Route -2

Figure 4.6 represents the relative bus interior noise hazard level for Abdullapur to Gabtoli route. From this figure it can be seen that the minimum equivalent continuous noise level (81.1 dBA) was found in the technical to Gabtoli route segment. Traffic movement is significantly low in this route segment because it is situated at the periphery of the Dhaka City corporation area.



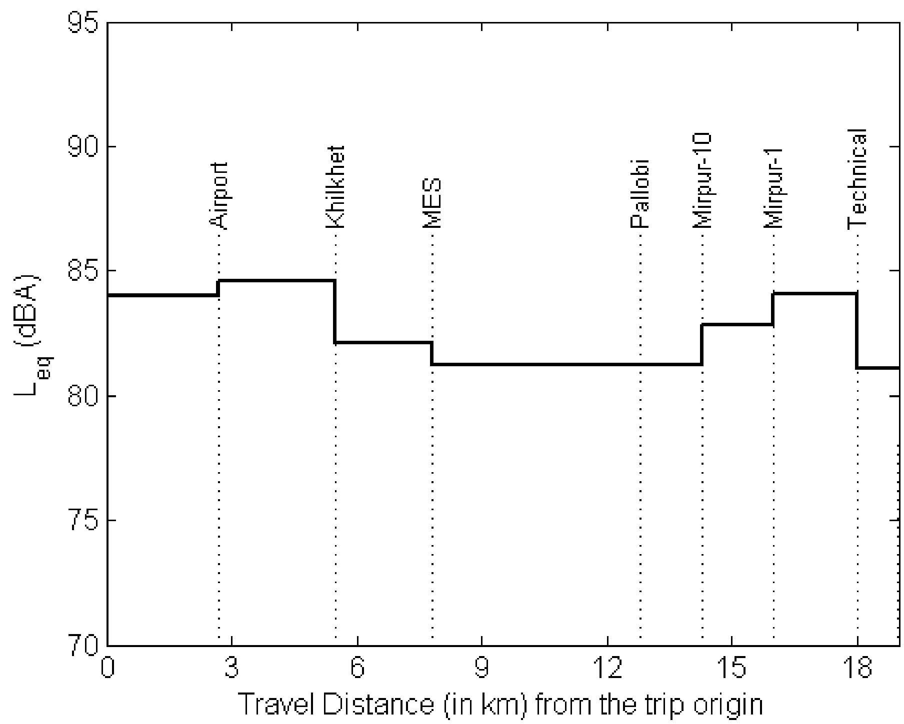


Figure 4.6: L_{eq} Bar diagram and Stair graph for Route -3

The bus interior noise level for entire length is presented for Gabtoli to Sadarghat route by the Figure 4.7. From this figure it can be seen that the highest equivalent continuous noise level (84 dBA) was experienced in the 1.9 km long Shyamoli to Asadgate route segment. The experienced equivalent continuous noise level in the Technical to Shyamoli route segment was approximately similar to Shyamoli to Asadgate route segment may be due to the route geometry (major intersections) of Technical to Shyamoli route segment is also similar with route geometry of Shyamoli to Asadgate route segment.

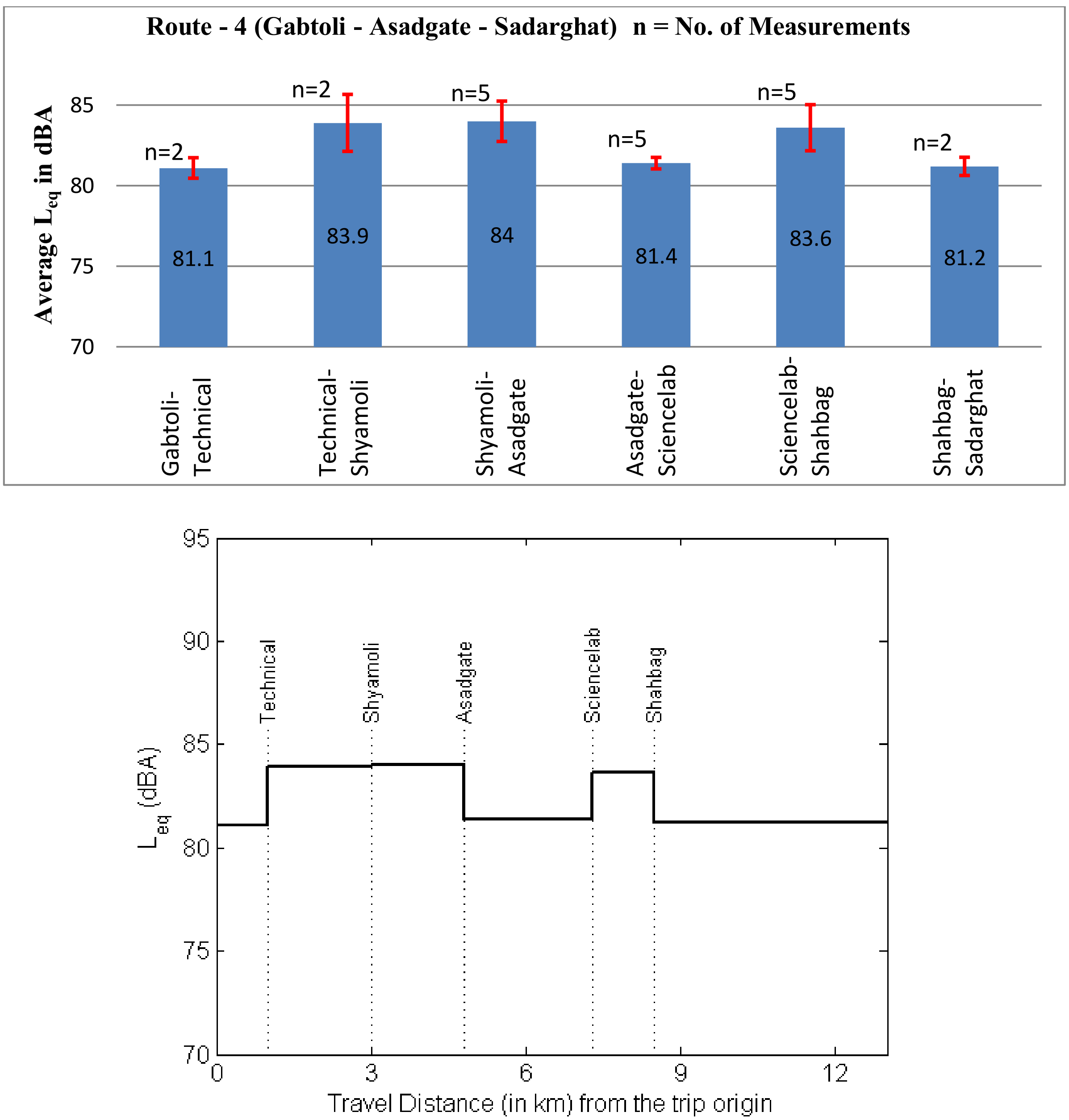


Figure 4.7: L_{eq} Bar diagram and Stair graph for Route -4

The highest experienced bus interior average equivalent continuous noise level (84.8 dBA) for entire length was found in the Mirpur-12 to Motijheel route (Figure 4.8) may be due to the some busy routes intersections (more congestion rate and mixed area) such as Mirpur-10, Farmgate, Shahabagh and Motijheel are situated in this route, most of the buses run in this route are larger in size and effect of non motorized vehicles.

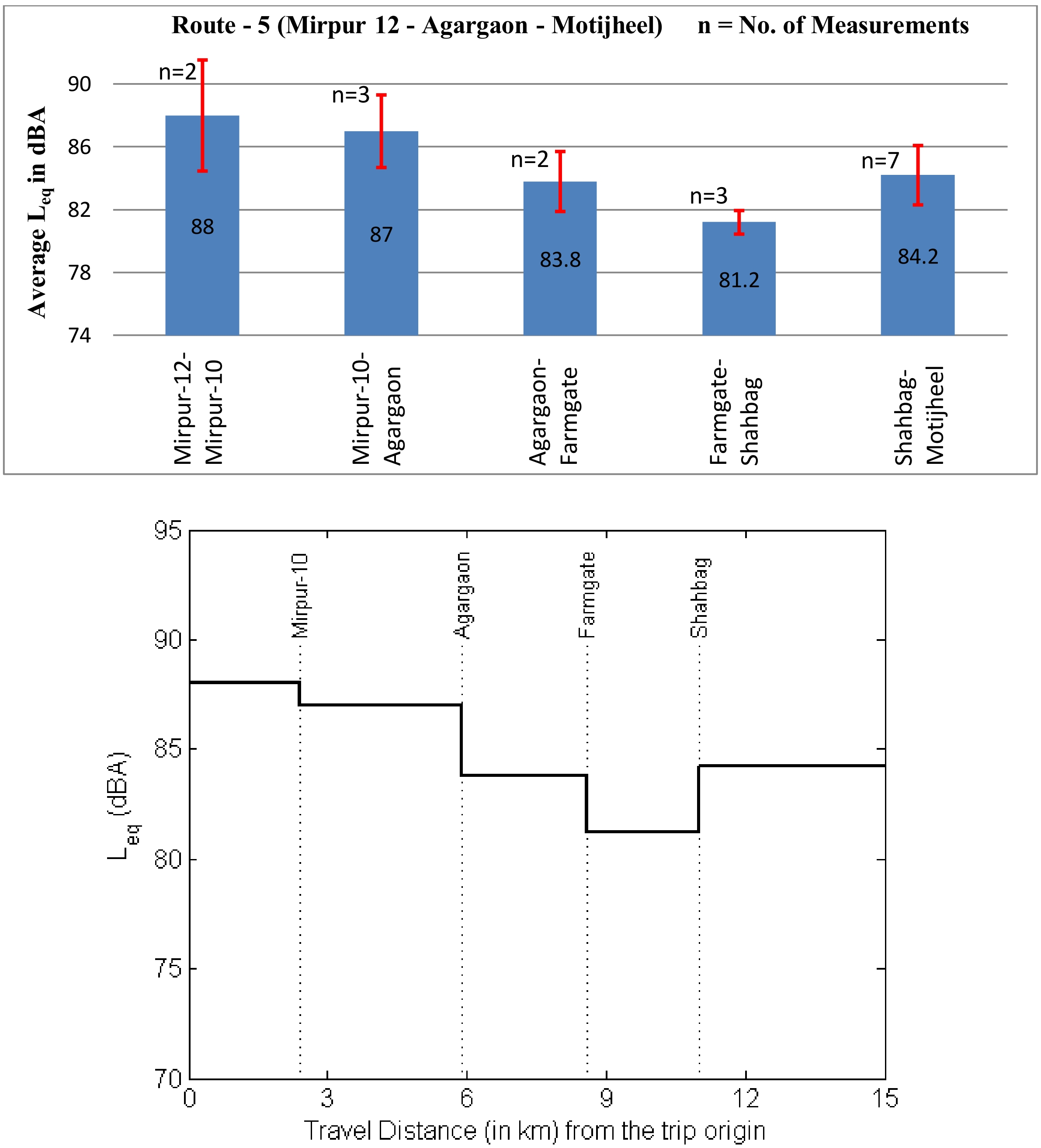
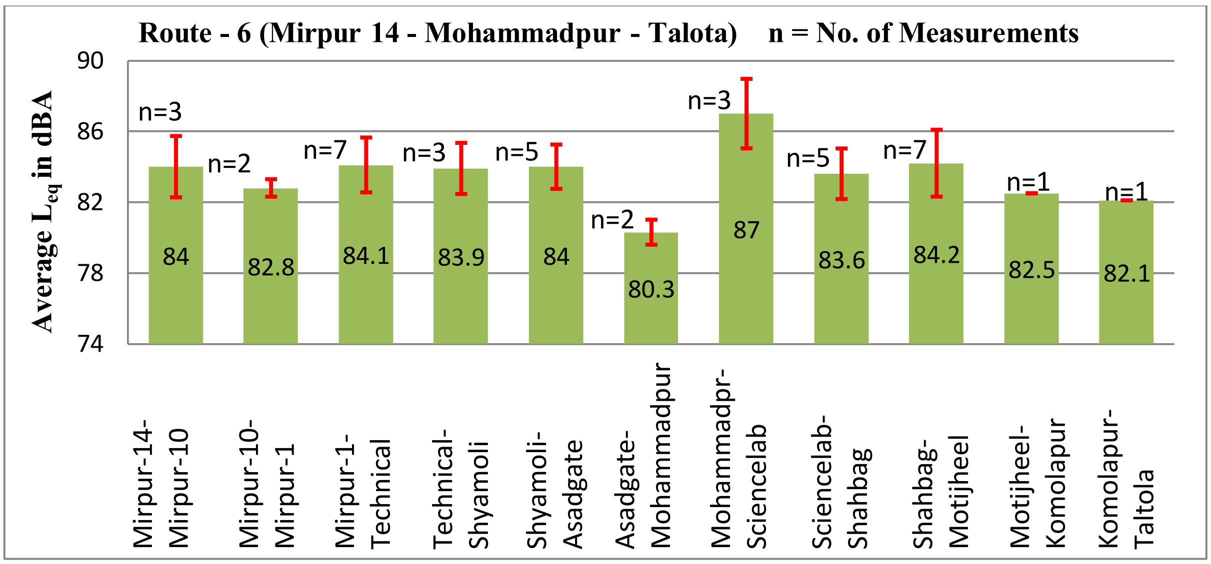


Figure 4.8: L_{eq} Bar diagram and Stair graph for Route -5

Figure 4.9 represents the bus interior noise level for Mirpur-14 to Taltola route. The second highest bus interior average equivalent continuous noise level (83.5 dBA) for entire length was experienced in this route due to large sized buses operate in this route. In this route, the highest equivalent continuous noise level (87 dBA) was found in the 3.4 km long Mohammadpur to Sciencelab route segment whereas the lowest equivalent continuous noise level (80.3 dBA) was found in the Asadgate to Mohammadpur route segment due to low traffic intensity.



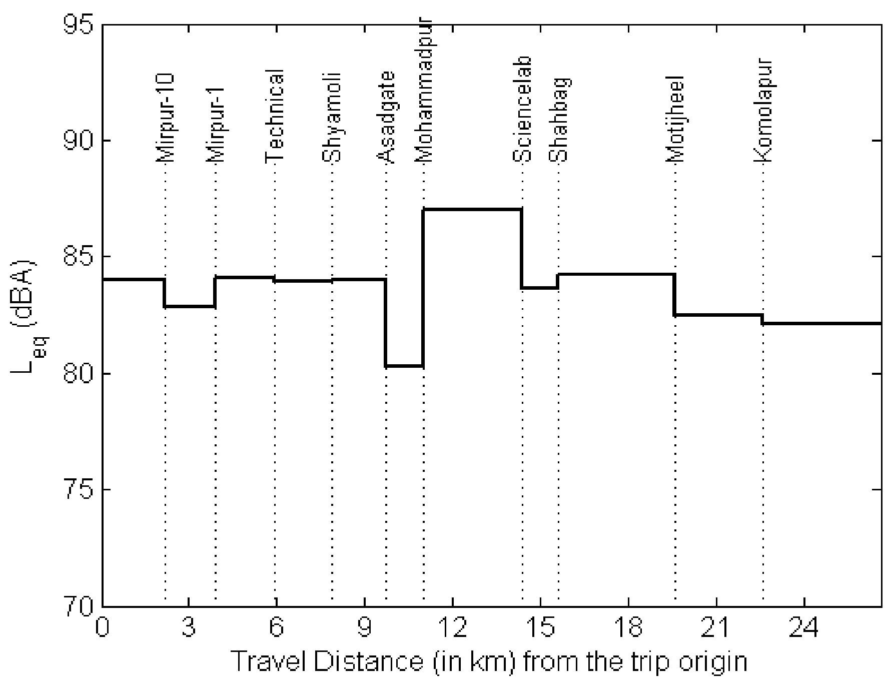
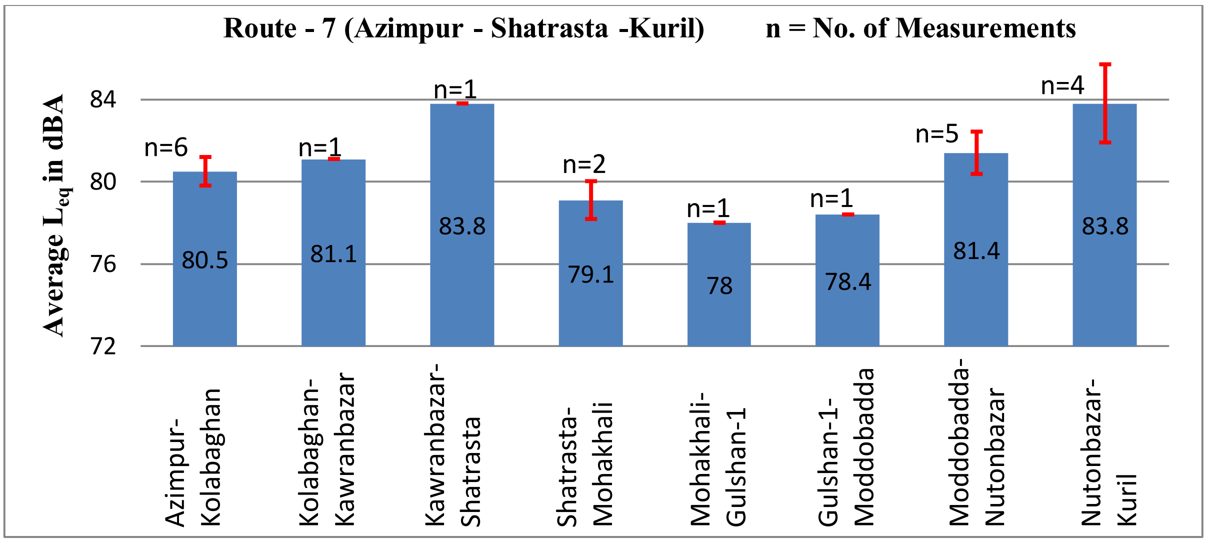


Figure 4.9: L_{eq} Bar diagram and Stair graph for Route -6

From the Figure 4.10, it can be seen that the highest equivalent continuous noise level (83.8 dBA) was experienced in Kawranbazar to Shatrasta and Nutonbazar to Kuril route segments. Traffic movement rate is significantly low in the 2.5 km long Mohakhali to Gulshan-1 route segment because this route segment is not part of the Dhaka city main bus route, so that the effect of outside traffic horn might have low. For this reason, the lowest equivalent continuous noise level (78 dBA) was experienced in this route segment.



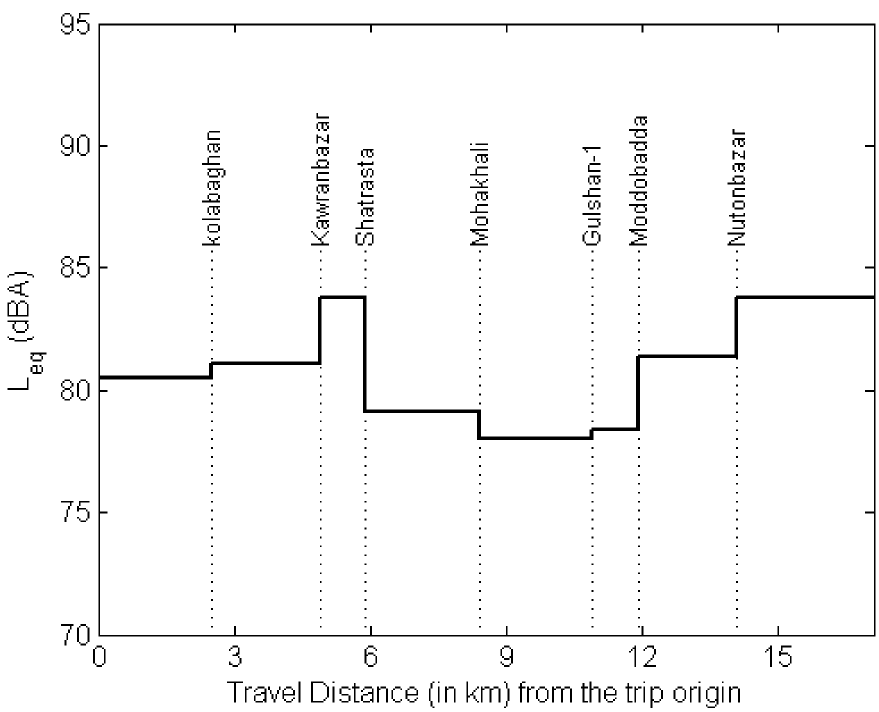


Figure 4.10: L_{eq} Bar diagram and Stair graph for Route -7

The relative bus interior equivalent continuous noise level for Sadarghat to Abdullapur route is shown by Figure 4.11. From this figure it can be seen that the lowest equivalent continuous noise level (77 dBA) was found in Kakrail to Moghbazar and Moghbazar to Shatrasta route segments. Besides, the lowest average bus interior equivalent continuous noise level (80.4 dBA) for entire length was experienced in this route. When buses were passing on the Moghbazar to Shatrasta route segment bus engines were stopped for long time due to traffic congestion. The intensity of traffic congestion is high in this route segment due to ongoing construction works of a Flyover in this route segment.

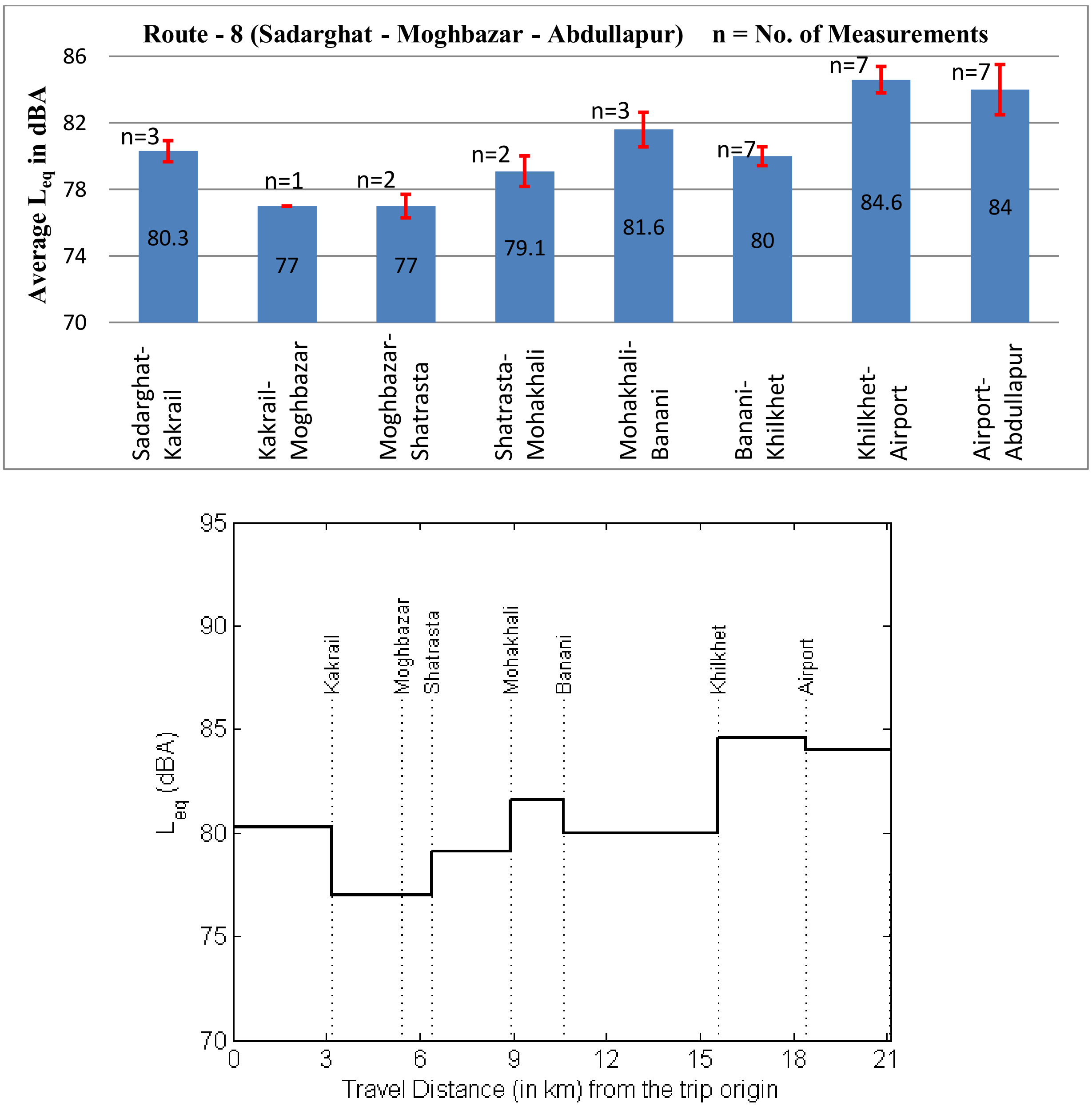
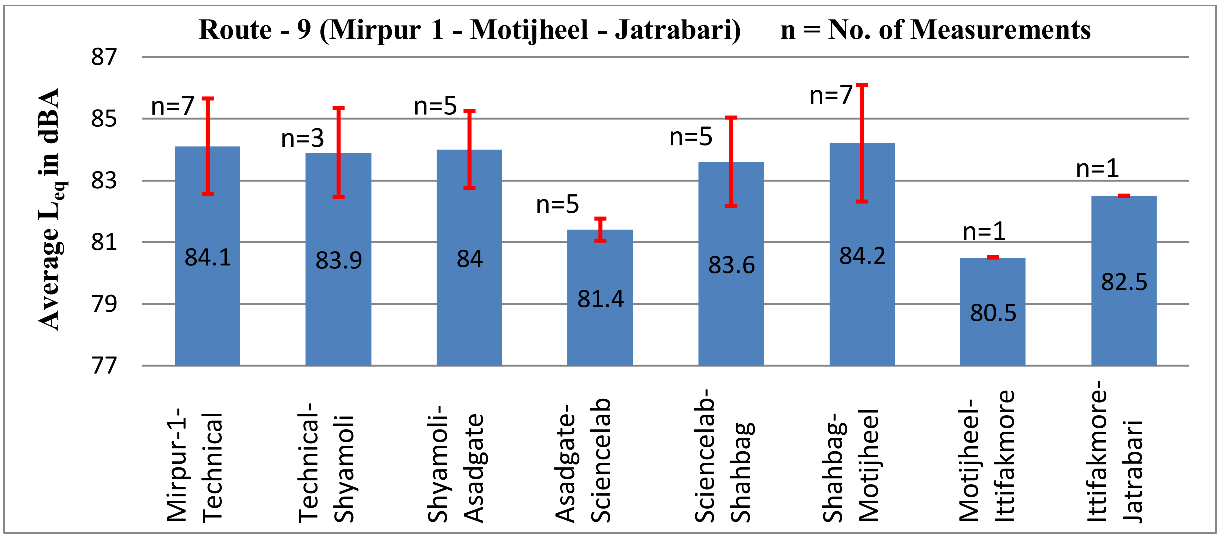


Figure 4.11: L_{eq} Bar diagram and Stair graph for Route -8

Figure 4.12 represents the relative bus interior equivalent continuous noise level for Mirpur-1 to Jatrabari route. The highest equivalent continuous noise level (84.2 dBA) was experienced in the 4 km long Shahabagh to Motijheel route segment because it is one of the busiest (mixed area i.e. commercial activities, traffic congestion and public gathering were high) route segment in the Dhaka city. The lowest equivalent continuous noise level (80.5 dBA) was found in the 2.1 km long Motijheel to Ittifaqmore route segment.



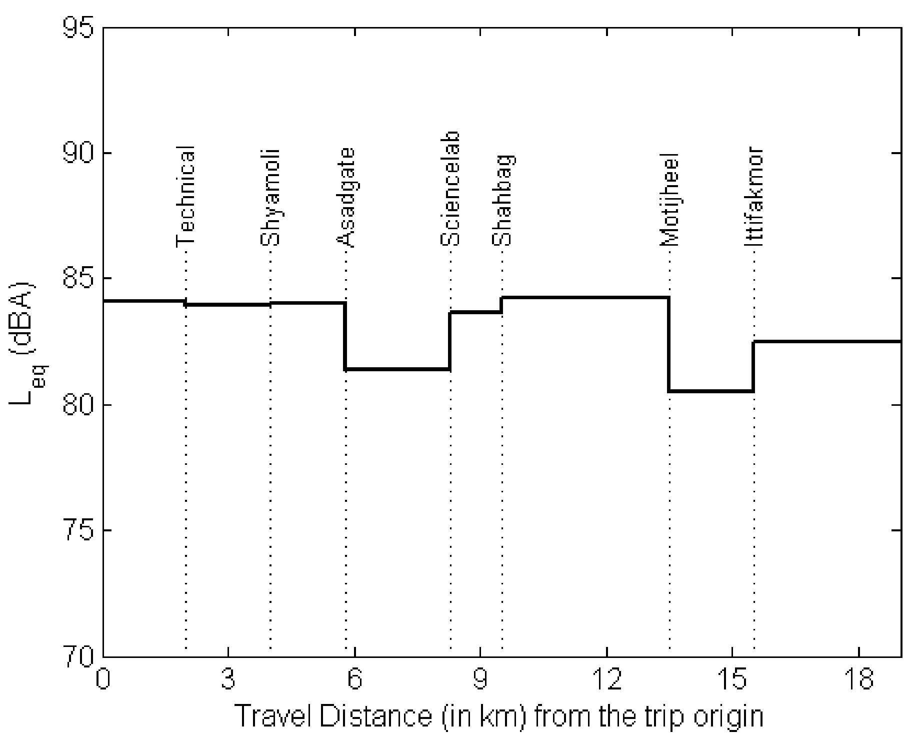


Figure 4.12: L_{eq} Bar diagram and Stair graph for Route -9

Figure 4.13 represents the interior noise level map of experienced average equivalent continuous noise level in distorted scale for bus transportation system of Dhaka city. From this map it can be seen that the 85 dBA average equivalent continuous noise level has been exceeding in Mirpur-12 to Mirpur-10, Mirpur-10 to Agargaon and Mohammadpur to Sciencelab route segments. The maximum average equivalent continuous noise level (88 dBA) was found in Mirpur-12 to Mirpur-10 route segment whereas the minimum average equivalent continuous noise level (77 dBA) was experienced in Kakrail to Shatrasta route segment.

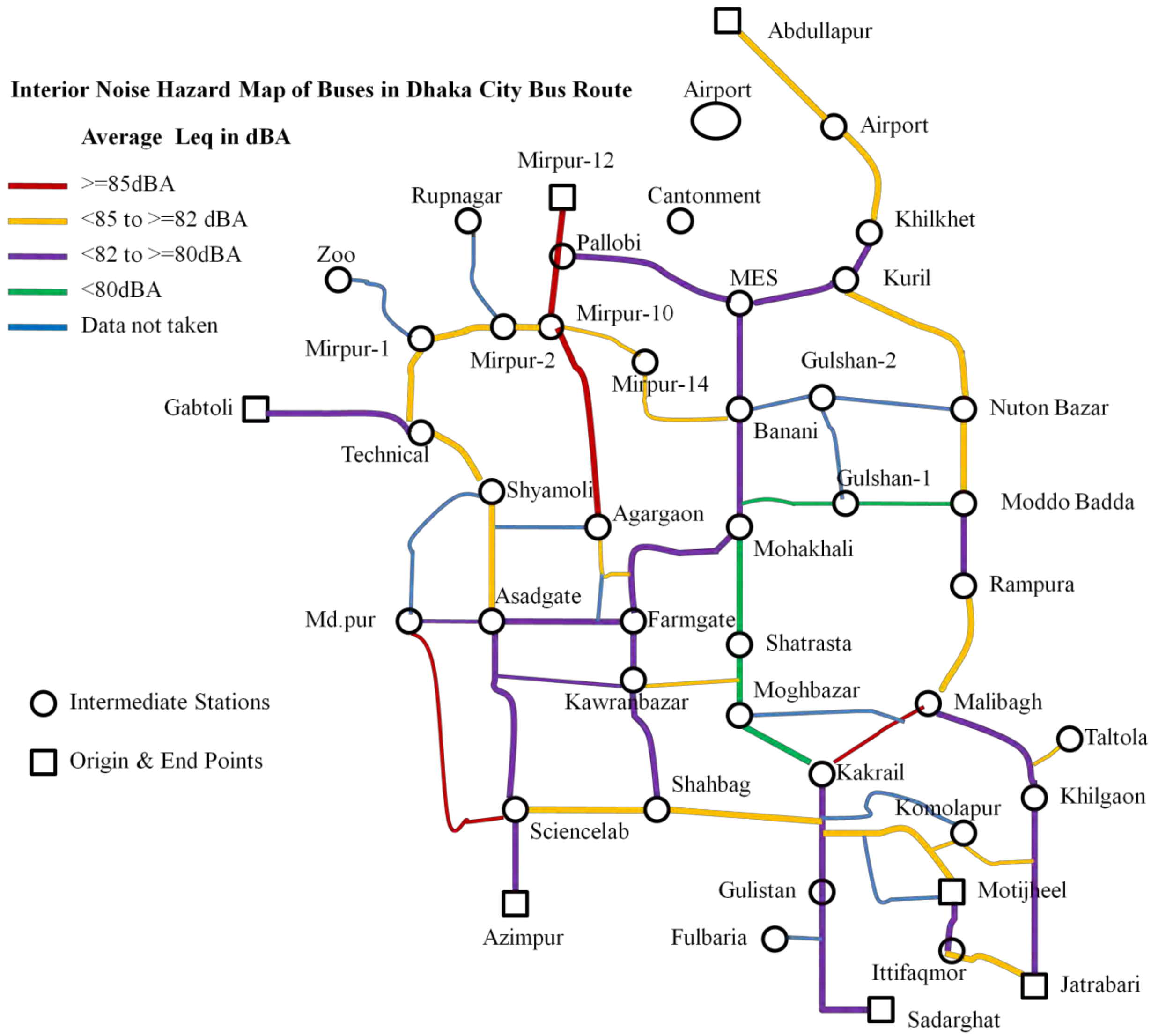


Figure 4.13: Interior Noise (Average L_{eq}) Map of Buses in Dhaka City Bus Route

The interior noise level map of the maximum experienced L_{eq} in distorted scale for bus transportation system of Dhaka city is represented by Figure 4.14. The highest maximum experienced equivalent continuous noise level (95.7 dBA) was found in Mirpur-10 to Agargaon route segment and the lowest maximum experienced equivalent continuous noise level (77 dBA) was found in Kakrail to Moghbazar route segment. From this map it can be seen that the maximum experienced L_{eq} was equaled or exceeded 85 dBA in significant number of route segments of Dhaka city bus routes.

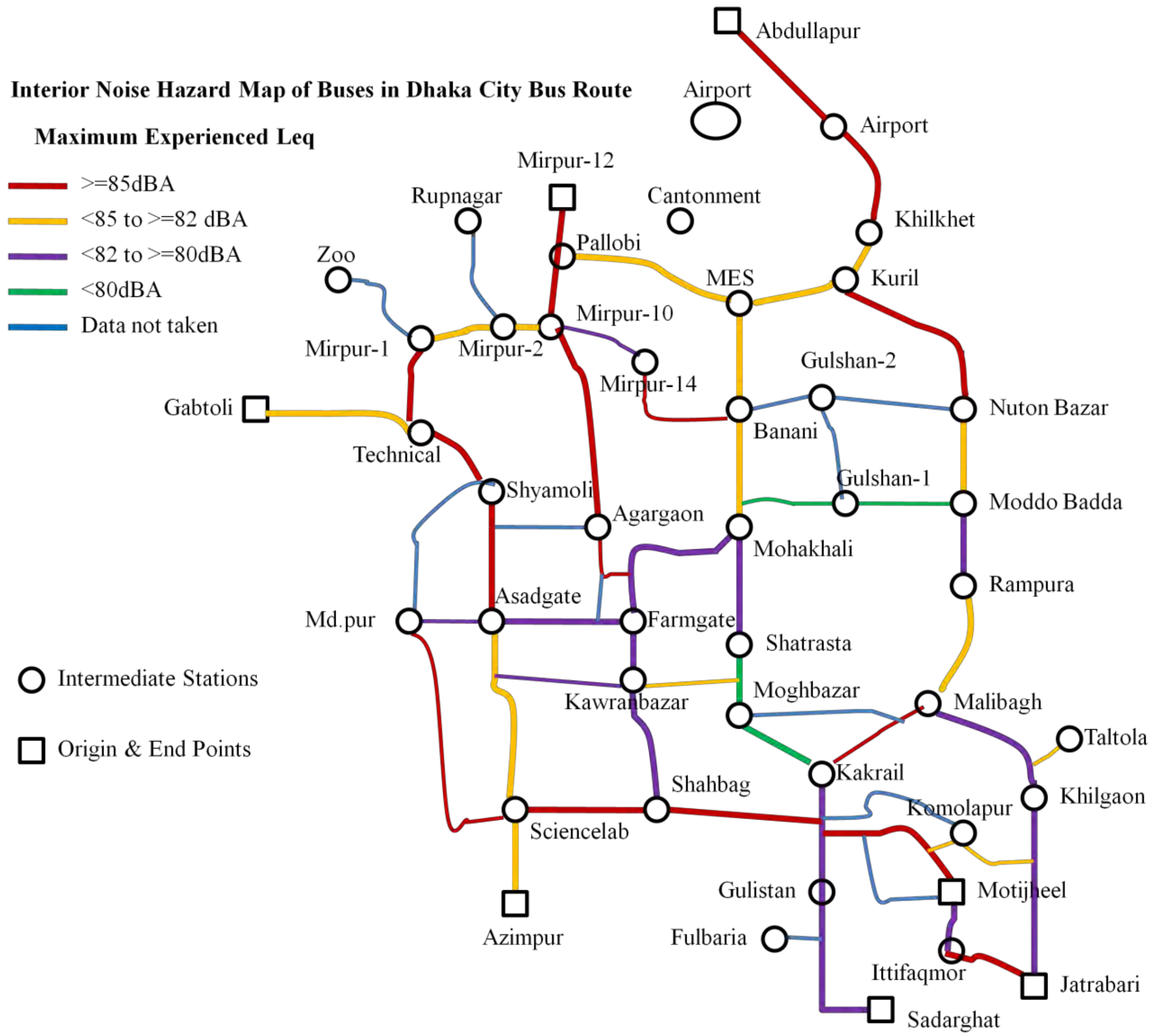


Figure 4.14: Interior Noise (Maximum Experienced L_{eq}) Map of Buses in Dhaka City Bus Route

Figure 4.15 represents interior noise level map of the minimum experienced L_{eq} in distorted scale for bus transportation system of Dhaka city. The highest minimum experienced equivalent continuous noise level (84.2 dBA) was experienced in Mohammadpur to Sciencelab route segment and the lowest minimum experienced equivalent continuous noise level (75 dBA) was found in Kakrail to Moghbazar route segment. From this map it can be seen that the most of the bus route segments having minimum experienced equivalent continuous noise level below 82 dBA.

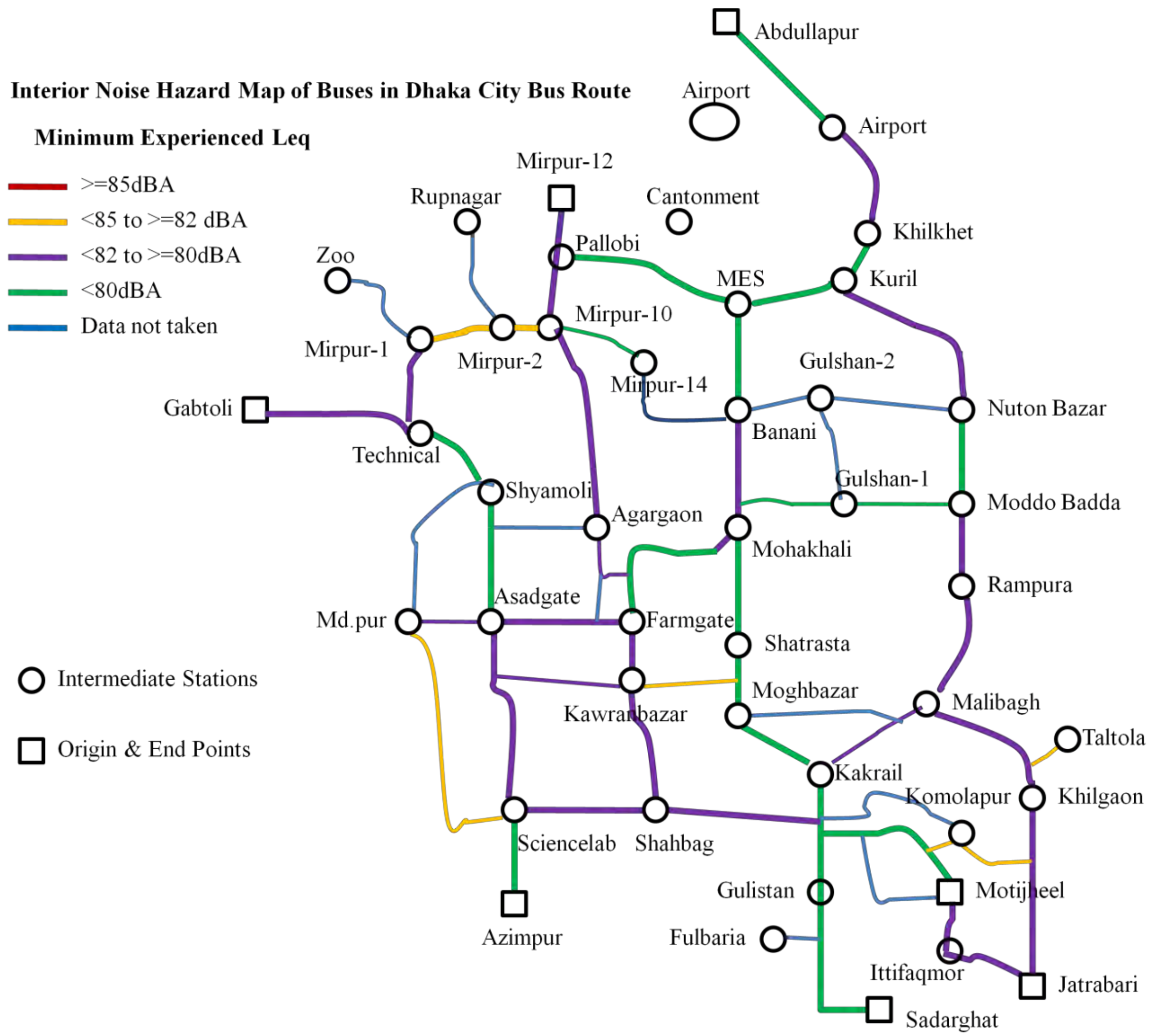


Figure 4.15: Interior Noise (Minimum Experienced L_{eq}) Map of Buses in Dhaka City Bus Route

4.4 IDENTIFIED HOTSPOTS OF NOISE POLLUTION IN DHAKA CITY BUS ROUTES

From interior noise map of buses, hotspots of noise pollution were identified in Dhaka city bus routes. According to NIOSH guideline, the permitted working shift length for 85 dBA and 84 dBA noise exposure level are 8 hours and 10 hours respectively. For that reason the route segments considered hotspots of noise pollution are those route segments that have average equivalent continuous noise level equal and above 85 dBA. 84 dBA noise level is extremely harmful to Dhaka city bus operators because of the average working shift length of Dhaka city bus operators is 14.4 hours. That's why the route segments those have equal and above 84 dBA average L_{eq} also listed with hotspots of noise pollution. Figure 4.16 presents the hotspots of noise pollution in Dhaka city bus route. From this figure it can be seen that the severely noise polluted route segment are Mirpur 12 to Mirpur 10, Mirpur 10 to Agargaon and Mohammadpur to Sciencelab. 85 dBA average equivalent continuous noise level was exceeded in these route segments.

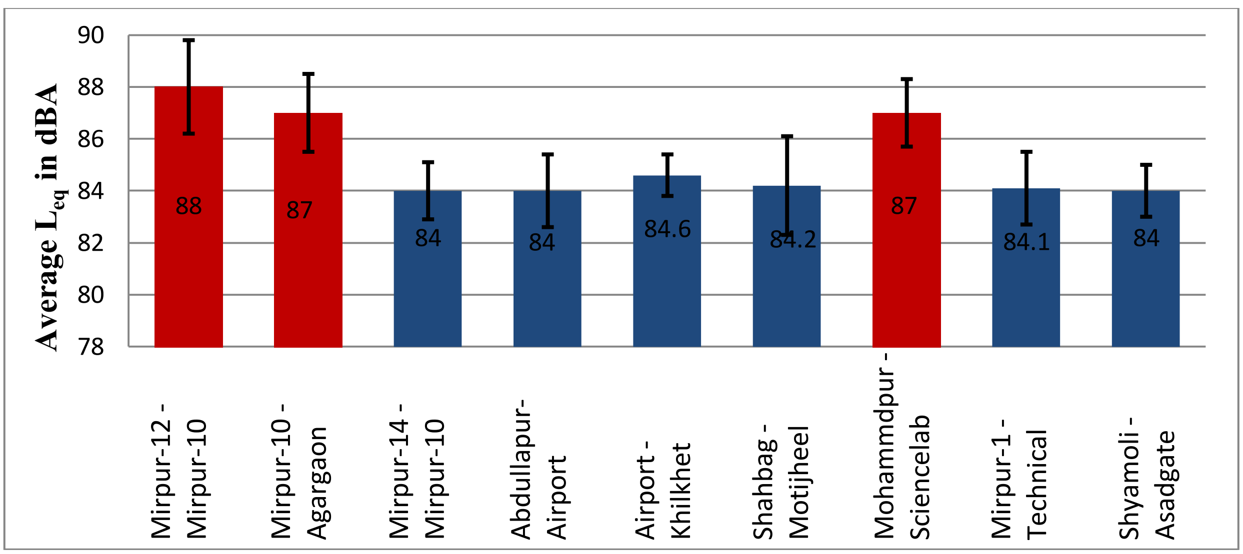


Figure 4.16: Hotspots of noise pollution in Dhaka city bus routes (L_{eq} >= 84 dBA)

Besides, equivalent continuous noise levels were calculated for specific route segments for every bus trip. The lowest equivalent continuous noise level (73 dBA) was experienced in the Mowchak to Moghbazar route segment. This phenomenon occurs because when buses were passing on this route segment bus engine was stopped for long time due to traffic congestion. The highest experienced equivalent continuous noise level (100 dBA) was found in the Mirpur-10 to Mirpur-11 route segment. In this study the route segments were considered highly noise polluted are those route segments that have maximum experienced equivalent continuous noise level equal and above 85 dBA. The highly noise polluted (maximum experienced L_{eq}) road segments are presented in Figure 4.17.

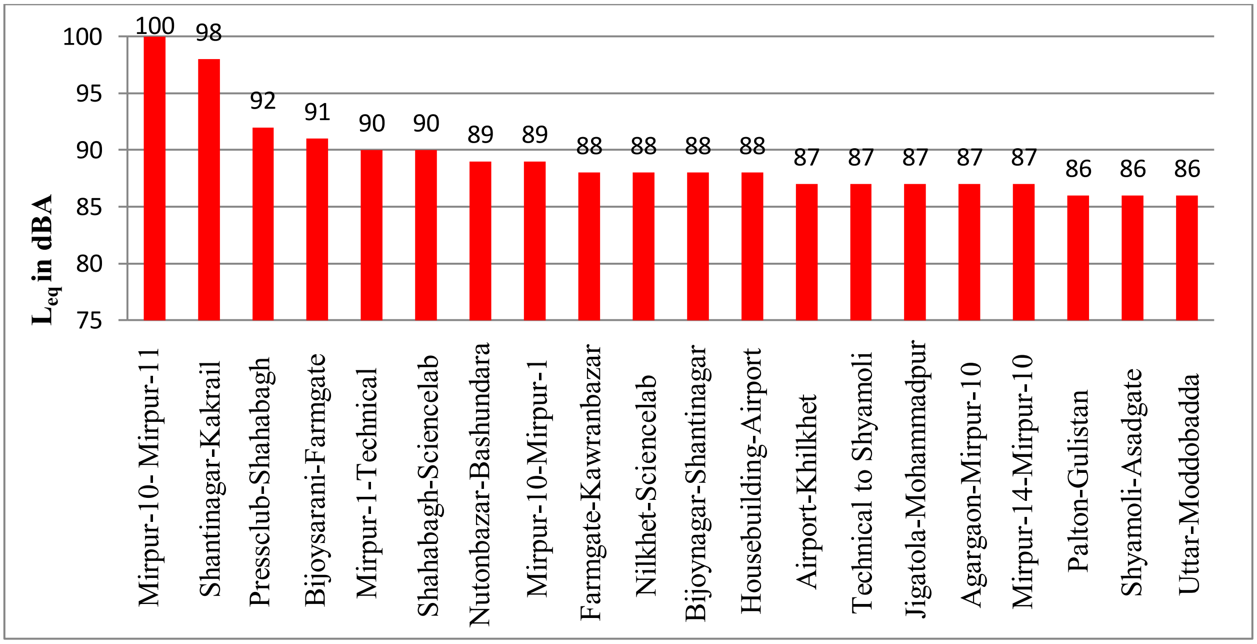


Figure 4.17: Severely noise-polluted route segments

4.5 COMPARISONS OF BUS TRIPS NOISE LEVEL WITH NIOSH GUIDELINES

Calculated noise exposure level and noise dose were compared with NIOSH guidelines to determine the severity of noise hazard level in bus transportation system of Dhaka city. An exposure to sound level 85 dBA for 8 hours corresponds to a 100% noise dose which is termed as an “acceptable” amount of noise according to the NIOSH guidelines. Equivalent continuous noise level (L_{eq}) can be calculated from the equation (1) and equation (2) that described earlier. Noise exposure level (L_{EX}) is closely related to the L_{eq} which actually measured. In fact, L_{EX} could be regarded as being the measured L_{eq} with a small correction. Noise dose can be calculated using the equation (3) and Permitted shift length for bus operators can be calculated using the equation (4) that described earlier in methodology chapter. From the Table 4.3 it can be seen that the shift length of 24 buses exceeded the permitted shift length as per NIOSH guidelines. For 5 buses the shift length did not exceed NIOSH guidelines which were Azmiriglori bus, Bikolpo poribahan, BRTC AC bus, Moitri Poribahan and Shuchona poribahan. Besides, nine buses among 29 buses exceeded Noise Dose as per NIOSH guidelines. According to NIOSH guideline the most severely noise polluted bus services were BRTC bus which operates on Mirpur-12 to Motijheel route, Dipon transport which operates on motijheel to Mohammadpur route and Konok Poribahan which operates on Abdullapur to Gabtoli route. Experienced Noise Exposure Levels (L_{EX}) in BRTC bus, Dipon Transport and Konok poribahan bus were 91.5 dBA, 92.9 dBA and 90.8 dBA respectively. For these noise exposure levels the permitted shift length according to NIOSH guidelines are 1.78 hours, 1.3 hours and 2.1 hours respectively but actual average shift length for these buses are 14.4 hours. This daily and prolonged exposure may lead to non-auditory pathological symptoms such as racing pulse, elevated blood pressure, dilated pupils, increased production of thyroid hormones and stomach and abdominal cramps (Portela, B. S. 2010). Findings of this research work had shown that level of noise exposure in bus transportation system in Dhaka city urban area is high enough to adversely affect the health and productivity of bus driver and helper as well as its residents.

Table 4.3: Comparisons of bus routes noise exposure level with NIOSH guidelines

Bus	L_{EX} (dBA)	ND (%)	Actual Average Shift Length (hr)/day	Permitted Shift Length (hr)/day (NIOSH)	Comments (guideline exceeded)*
3 no local bus	83.8	77	14.4	10.56	exceeded
7 no local bus	83.8	77	14.4	10.56	exceeded
Ashirbad	86.2	133	14.4	6	exceeded
Azmiri glori	79.8	31	14.4	26.6	not exceeded
Bangole Motors	83.5	72	14.4	11.3	exceeded
Bikolpo	80.9	40	14.4	20.67	not exceeded
BRTC	91.5	452	14.4	1.78	exceeded
BRTC AC	80.1	33	14.4	24.8	not exceeded
BRTC Double Decker	84.3	86	14.4	9.4	exceeded
Dipon Transport	92.9	624	14.4	1.3	exceeded
Dishari Poribahan	85	108	14.4	8	exceeded
Falgoan	89.4	279	14.4	6.3	exceeded
Jatrabari Poribahan	83.3	68	14.4	11.8	exceeded
Konok Poribahan	90.8	385	14.4	2.1	exceeded
Midway	86.1	130	14.4	6.2	exceeded
Moitri Poribahan	81.4	44	14.4	18.4	not exceeded
New Dhaka Link	83.1	65	14.4	12.4	exceeded
New Vision	85	100	14.4	8	exceeded
Nishorgo	86.1	130	14.4	6.2	exceeded

Bus	LEX (dBA)	ND (%)	Actual Average Shift Length (hr)/day	Permitted Shift Length (hr)/day (NIOSH)	Comments (guideline exceeded)*
Probati Bonosri	83.1	65	14.4	12.4	exceeded
Salsabil	86.3	137	14.4	6	exceeded
Shuprobat	84.2	84	14.4	9.5	exceeded
Shotabdi poribahan	91.3	432	14.4	1.87	exceeded
Shuchona poribahan	82.1	52	14.4	15.6	not exceeded
Transilba	84.2	84	14.4	9.5	exceeded
Turagh	83.7	75	14.4	10.8	exceeded
VIP	83.8	77	14.4	10.5	exceeded
Winner	83.5	72	14.4	11.3	exceeded
Cantonment mini service	84.3	86	14.4	9.4	exceeded

Footnote: *Guideline for noise exposure
For 8 hr working hour/day NIOSH limits 85 dBA LEX value and noise level of 100%.

4.6 EFFECT OF VELOCITY OF BUS ON INTERIOR NOISE LEVEL OF BUS

Based on previous evidence (Subramani et al, 2012) it is well known that the interior noise level of bus increase with increasing velocity of the bus. The scatter plots of average trip velocity versus average noise level are presented to determine the influence of velocity of bus on the interior level of noise. To establish the relationship between noise level and velocity, a trend between average trip velocity of buses and average noise levels was determined through the scatter plot shown in Figure 4.18. A regression between average trip velocity and L_{eq} shows positive correlation (R^2=0.04) which indicates that the interior noise level of the bus increase with increasing average trip velocity of the bus.

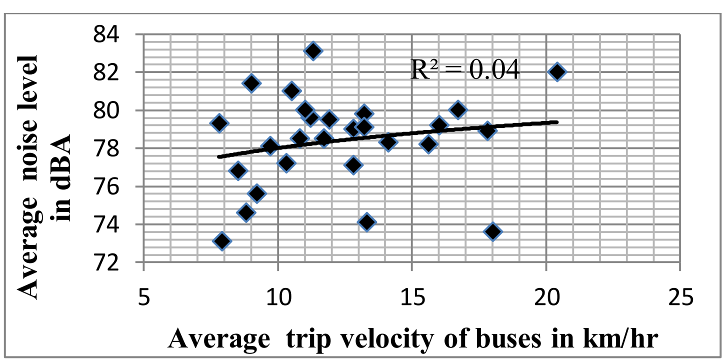


Figure 4.18: Scatter plots of average trip velocity and tripwise L_{eq} level for entire length of trips for 29 bus routes

To carry out detailed study on relationship between velocity and noise level, 28 different trends between segmentwise velocity of bus and segmentwise L_{eq} level were determined through the scatter plots for all the 28 bus trips which are presented in Figure 4.19, Figure 4.20 and 4.21.

19 bus trips among 28 bus trips showed positive correlation between segmentwise velocity and segmentwise equivalent continuous noise level for entire length of trip that verified the point that the bus interior noise level increase with increasing trip velocity of the bus which are presented in Figure 4.19. The strongest positive correlation was found for Ashirbad Poribahan whereas the weakest positive correlation was found for Shatabdi Poribahan. From field experience it was observed that when Ashirbad bus was began running from one station the velocity of bus gradually increased up to reach other station due to low traffic congestion. For this reason strong positive correlation was found between segmentwise velocity and segmentwise L_{eq} for Ashirbad Poribahan.

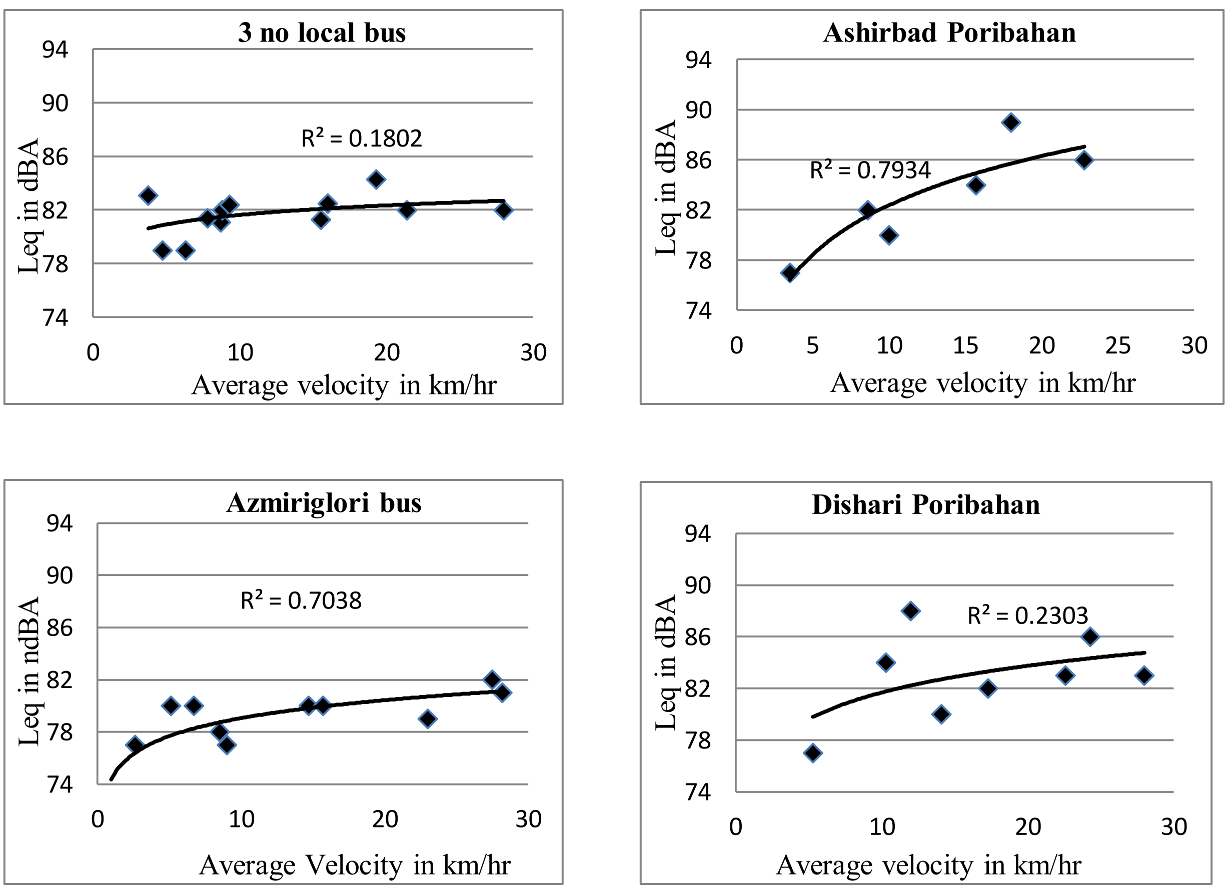


Figure 4.19: Scatter Plots of segmentwise L_{eq} versus segmentwise velocity for entire length of trips for 19 buses which showed positive correlation

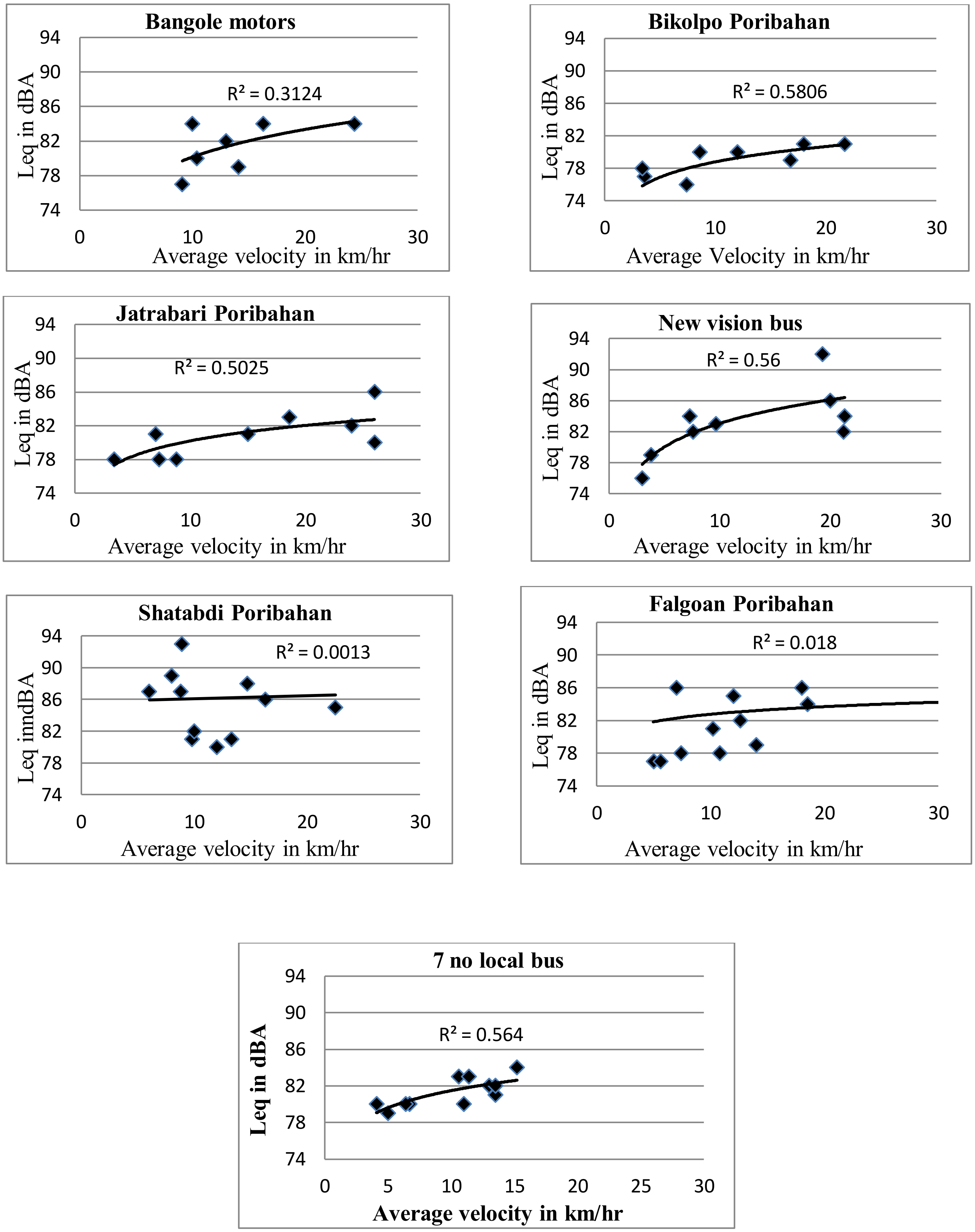


Figure 4.19: Scatter Plots of segmentwise L_{eq} versus segmentwise velocity for entire length of trips for 19 buses which showed positive correlation

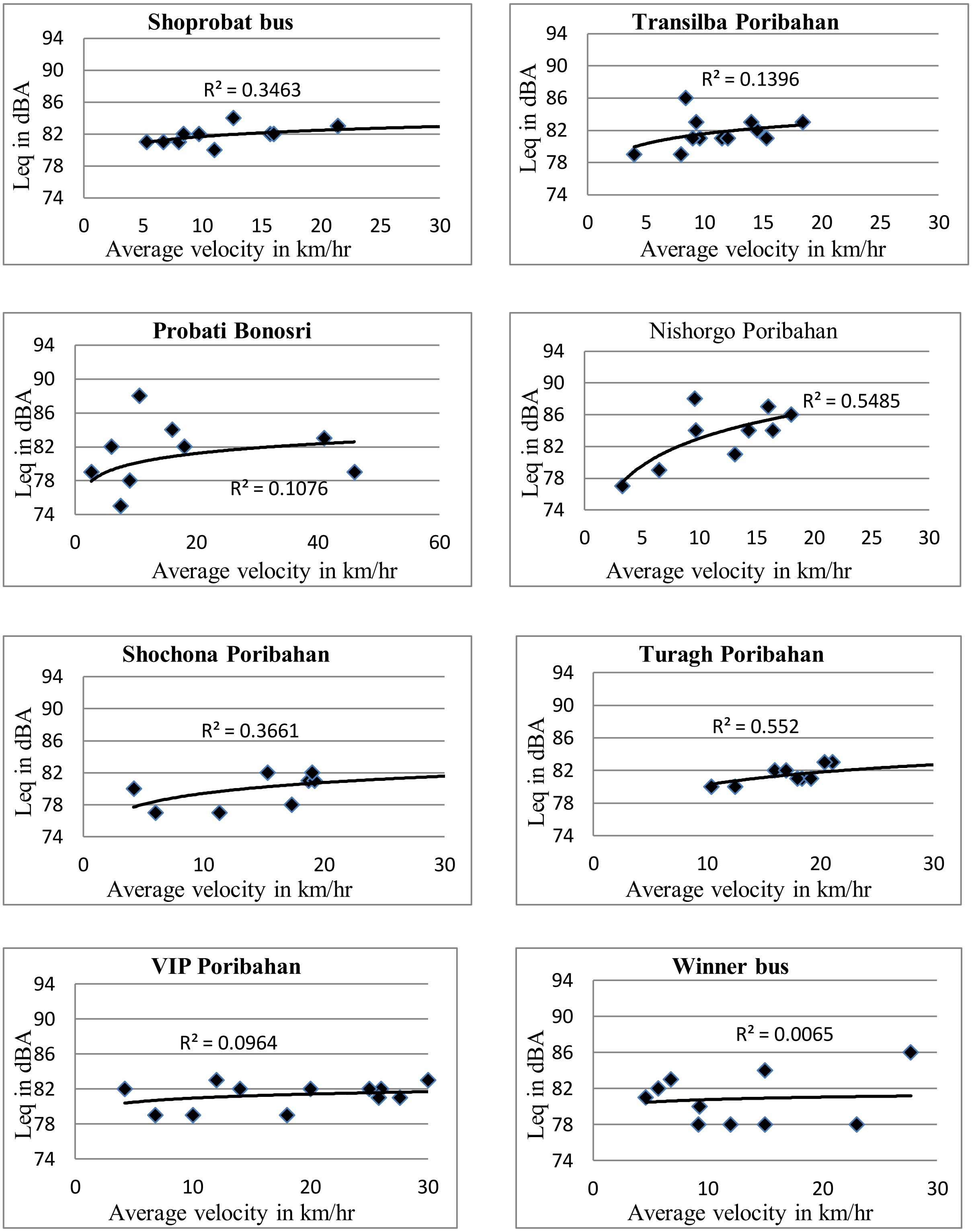


Figure 4.19: Scatter Plots of segmentwise L_{eq} versus segmentwise velocity for entire length of trips for 19 buses which showed positive correlation

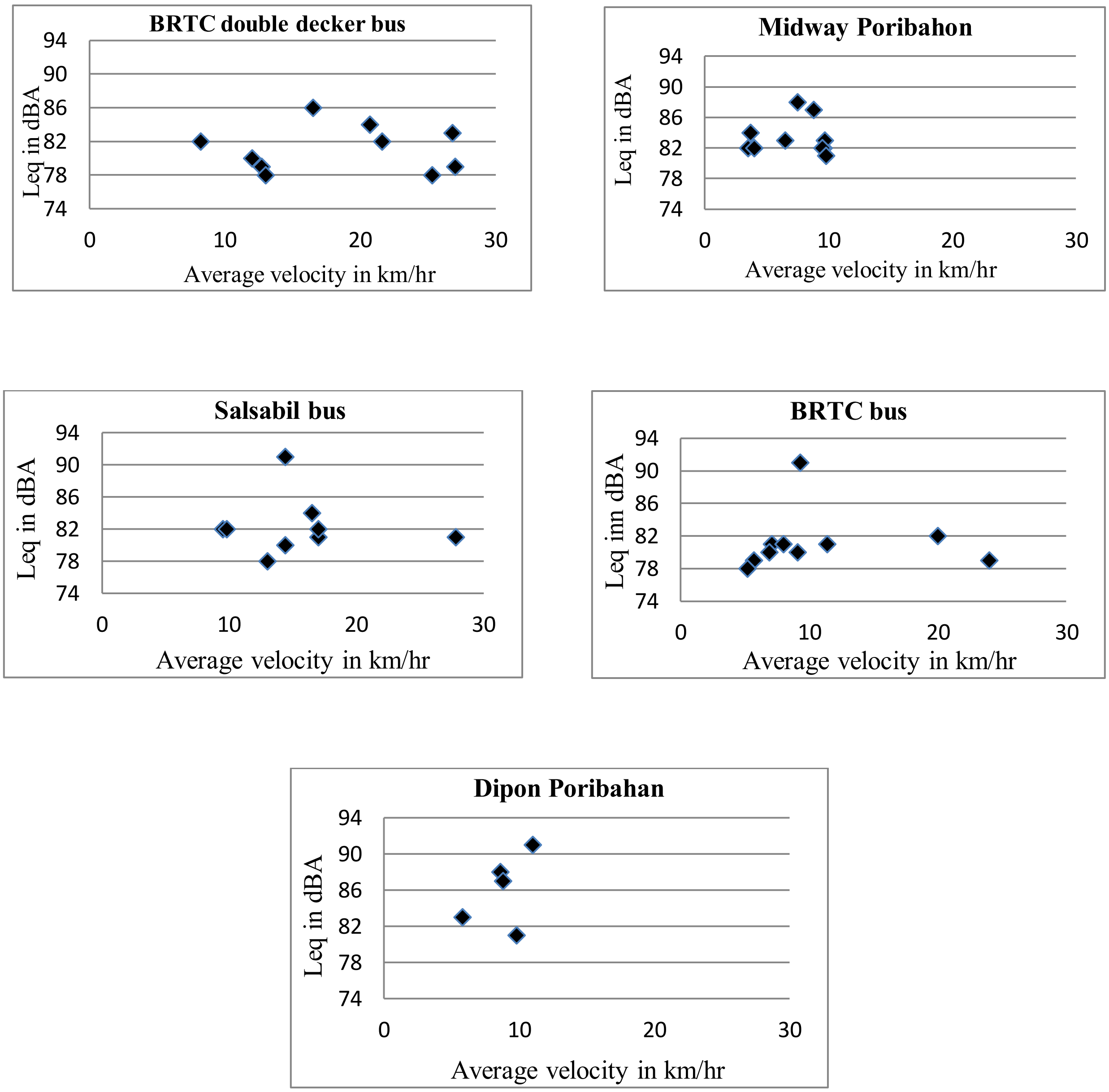


Figure 4.20: Scatter Plots of segmentwise L_{eq} versus segmentwise velocity for entire length of trips for 5 buses which showed insignificant (R^2=0) correlation

Besides, 5 bus trips among 28 bus trips showed insignificant (R^2=0.00) correlation between segmentwise trip velocity and segmentwise equivalent continuous noise level may be due to effect from outside noise was high to interior noise in these 5 buses. These 5 buses were Midway Poribahan, Dipon transport, Salsabil poribahan, BRTC double decker and BRTC bus that are presented in Figure 4.20.

On the other hand, we know that the interior noise level increases with increasing velocity of the buses in general but the opposite trend was experienced for BRTC AC bus, Konok Poribahan, Moitri Poribahan and New Dhaka link that are presented in Figure 4.21. Traffic congestions are a regular phenomenon in almost every road in Dhaka city. This traffic congestion is the root cause of noise pollution as most of the motor vehicles especially buses, mini-buses and trucks have hydraulic horns. From field experience it is speculated that these 4 buses faced severe traffic congestion during travel time. For that reason the trip velocity for these 4 buses were low but the drivers are trained to honk continuously till they get their ways clear. That is why opposite trend was found for these 4 buses.

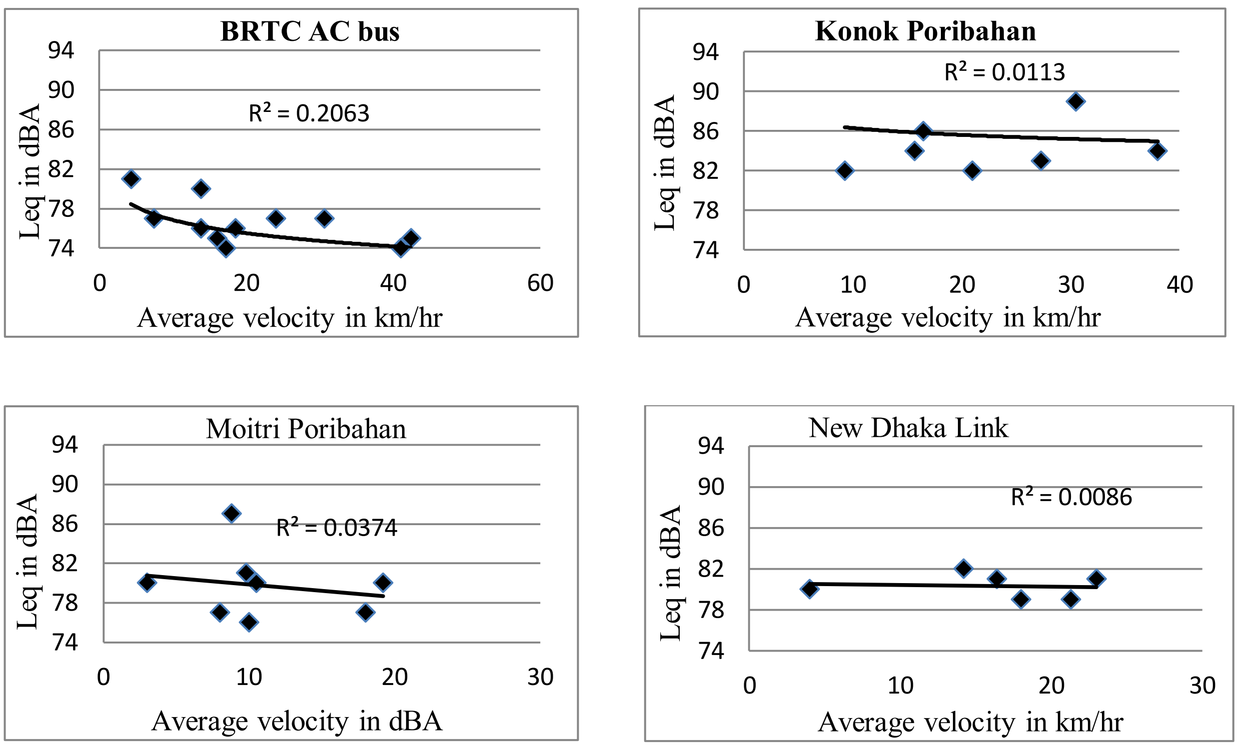


Figure 4.21: Scatter Plots of segment wise L_{eq} versus segment wise velocity for entire length of trips for 4 buses which showed negative correlation

4.7 EFFECT OF BUS SIZE ON NOISE LEVEL

There are different kinds of public and private buses plying within the Dhaka city and most of the buses can be classified into two categories, which are small sized buses that have around 35 seats and large sized buses that have around 55 seats. Figure 4.22 represents the relationship between bus interior equivalent continuous noise level for entire length of all the 29 bus trips and size of the corresponding buses. From this figure it can be seen that around 80 dBA equivalent continuous noise level was experienced in 24 buses and only 5 buses among 29 buses exceeded 85 dBA equivalent continuous noise level which are all larger in size.

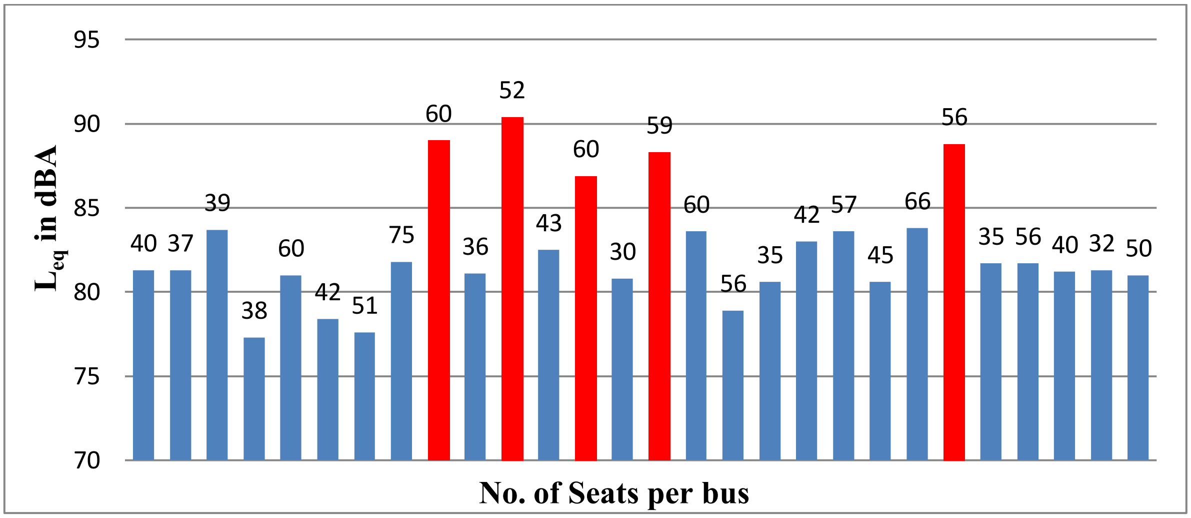


Figure 4.22: Relationship between bus size and L_{eq}

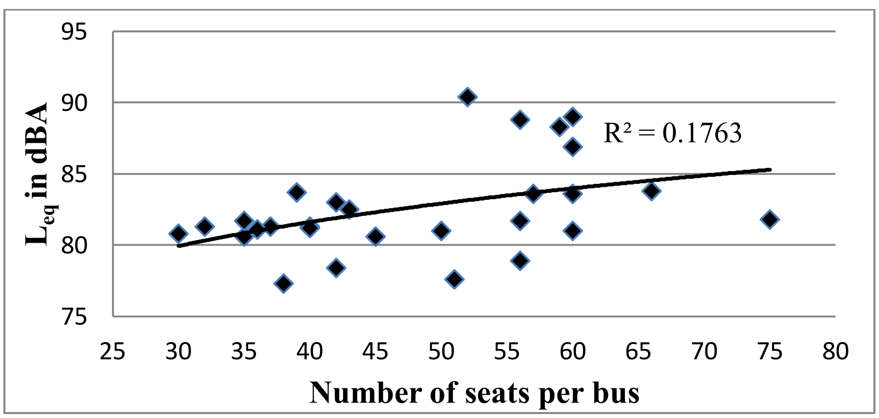


Figure 4.23: Noise level increase with bus size increase

To investigate the relationship between noise level and bus size, a trend between equivalent continuous noise level for entire length of all the 29 bus trips and size of the corresponding buses was determined through the scatter plot shown in Figure 4.23. A regression between bus size and L_{eq} shows positive correlation ($R^2 = 0.176$) which indicates that the interior noise level of bus increase with increasing bus size.

Besides, average L_{eq} bar diagrams were constructed for small sized and large sized buses that are presented in Figure 4.24. Average equivalent continuous noise level for entire length of all the 14 small sized bus trips was found to be 81 dBA whereas average equivalent continuous noise level for entire length of all the 15 large sized bus trips was experienced to be 83.7 dBA. Statistically the observed difference (83.7 – 81 = 2.7 dBA) between the average L_{eq} of small sized and large sized buses is not distinct (the p - value was found 0.03 by t-test) enough to say that the average experienced L_{eq} between small sized and large sized buses differ significantly. But in case of noise 2.7 dBA (difference between average noise level of small and large sized buses) more noise level significantly reduce the permitted working shift length of Dhaka city bus operators.

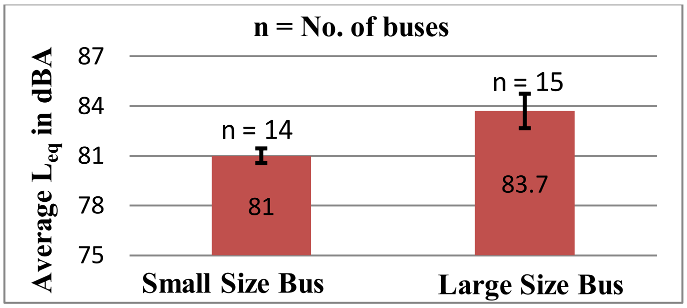


Figure 4.24: Experienced L_{eq} is higher in large sized buses compared to small sized buses

4.8 CORRELATION BETWEEN NUMBER OF INTERSECTION AND NOISE LEVEL

The severity of noise pollution mainly depends on the combination of noise exposure level and duration. For example 82dBA noise is not hazardous if exposure time is less than 16 hours but it will be harmful if it crossed 16 hours exposure time. It was found that the trip duration of a one way trip increases with increasing numbers of intersections on a one way trip. To examine the validity of this point a scatter diagram of number of intersections on a one way trip and time taken per kilometer during one way trip was plotted that is shown in Figure 4.25. From this figure it can be seen that the time taken per kilometer increases with no. of intersections in the corresponding trip. This indicates that the trips which have higher number of intersection may be subjected to longer noise exposure duration.

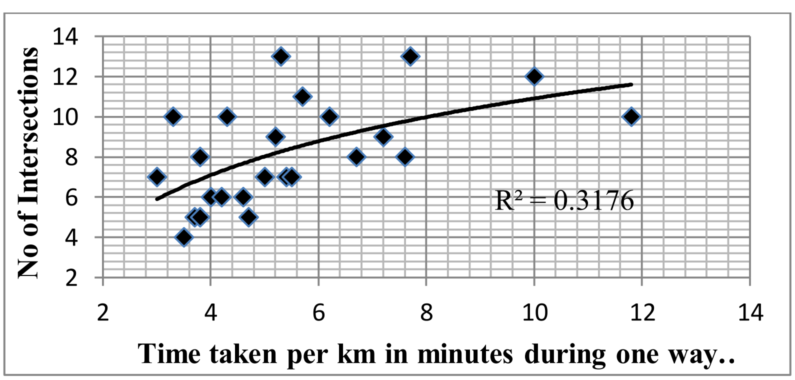


Figure 4.25: Correlation between noise exposure period and number of intersection

A scatter diagram of experienced average equivalent continuous noise level and total number of intersections in the corresponding bus route was plotted to establish the relationship between number of intersections and noise level as shown in Figure 4.26. As described earlier (Table 4.2) that, Dhaka city bus routes were classified into nine major routes to describe noise hazard level in Dhaka city bus routes. Average equivalent continuous noise levels were calculated for these major nine bus routes and the total number of intersections for each major bus route was counted. From Figure 4.26 it can be seen that a significant correlation was found between number of intersections and average equivalent continuous noise level. This indicates that the average equivalent continuous noise level for entire length of one way route increase with number of intersections in the corresponding route.

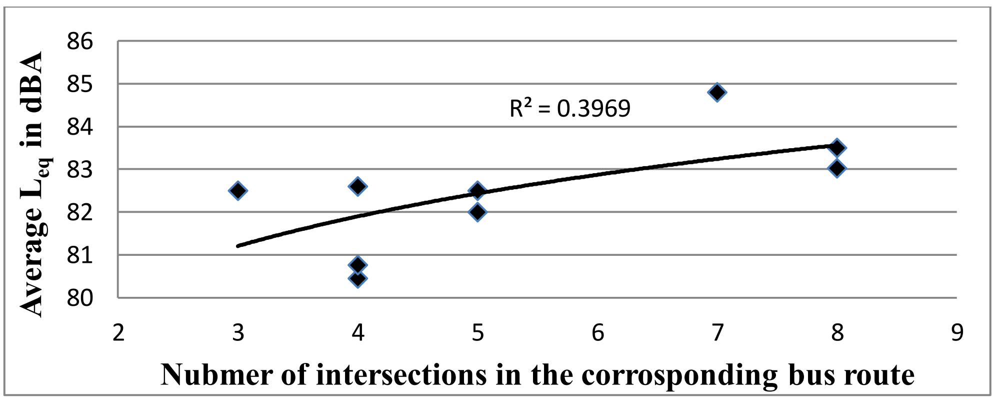


Figure 4.26: Noise level increase with increase number of intersections in the corresponding bus route

4.9 RELATIONSHIP WITH BUS AGE

The bus fleets operating in Dhaka city are mainly standard buses and minibuses. According to the strategic transport plan (STP 2005), it is estimated that there are around 7,100 buses in Dhaka. However, only 1,300 of them are plying of which less than 200 are of improved quality. The condition of the buses plying in Dhaka city is not good. This is because most of the buses in Dhaka city are reconditioned and the majority of bus fleet is very old and the maintenance is almost absent or very poor (Mahmud et al, 2012). It is well known that older engines produce more noise compared to new engines. To inspect this point a scatter diagram of equivalent continuous noise level versus age of bus was plotted and a significant correlation was found that is shown in Figure 4.27. The age of buses were determined by direct communication with bus driver and helper. This confirms the fact that older buses are responsible for increased noise levels in bus interior.

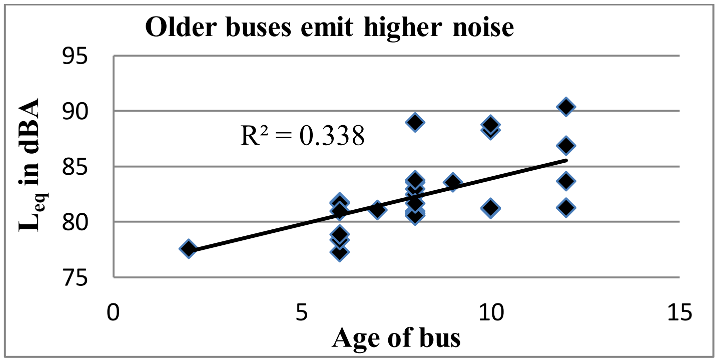


Figure 4.27: Correlation between noise level and age of buses

4.10 RELATIONSHIP WITH BUS MANUFACTURER

There are around 60 different bus services plying within Dhaka city. To carry out this study continuous noise level measurements were carried out in 29 different bus services. As mentioned earlier there are mainly two types of buses; which are small buses having around 35 seats per bus and large buses having approximately 65 seats per bus. It was found that manufacturers of most of the small buses are Hino and large buses are Tata. Besides, three types of BRTC bus were found whose manufacturers are DAWOO, Aedlus (China) and Ashok-Leyland. Among 29 buses 12 are Hino, 13 are Tata, one is DAWOO, one is Aedlus, one is Eicher and one is Asok-Leyland. According to many researchers, different vehicle manufacturer engine produce different levels of noise (Zannin et al, 2010). Variation of experienced equivalent continuous noise level due to variation of bus engine manufacturer is shown in Figure 4.28. From this Figure it can be seen that the experienced equivalent continuous noise levels in Hino buses (small size buses) are nearly similar on average having L_{eq} of 81.1 dBA with the standard deviation of 1.7 dBA. The highest experienced equivalent continuous noise level (90.4 dBA) was found in Dipon transport whose engine was manufactured by Tata (55 seats). The experienced L_{eq} in DAWOO and Ashok-Leyland bus were less than Aedlus (China) bus, although these three types of buses are larger in size.

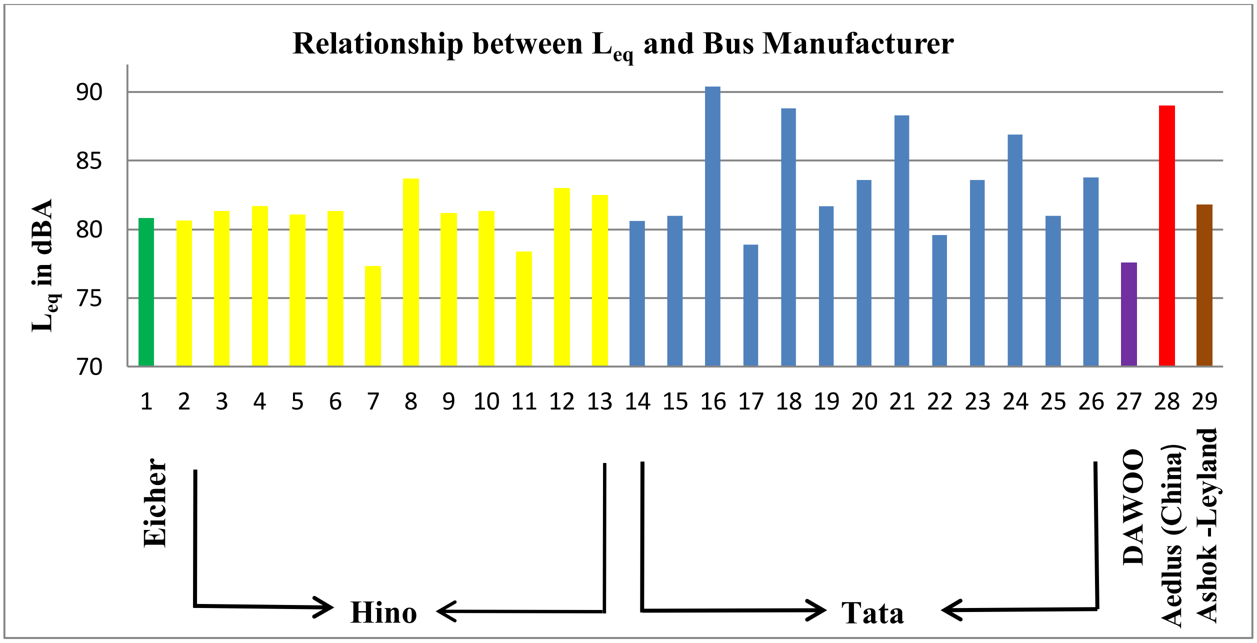


Figure 4.28: Relative bus interior L_{eq} (entire length of trip) for all the 29 Bus services

To examine the variation of bus interior noise level due to variation of bus engine manufacturer, a bar diagram of bus interior average L_{eq} for different bus manufacturer was constructed that is shown in Figure 4.29. 81.1 dBA average L_{eq} was found for 12 Hino buses and 83.7 dBA average L_{eq} was found for 15 Tata buses with the standard deviation of 3.6 dBA. Tata and Aedlus (China) buses are larger in size (65 seats per bus) but from Figure 4.29 it can be seen that they have some difference in experienced equivalent continuous noise level. Thus it can be said that the bus interior noise levels might be differ due to variation of bus engine manufacturer.

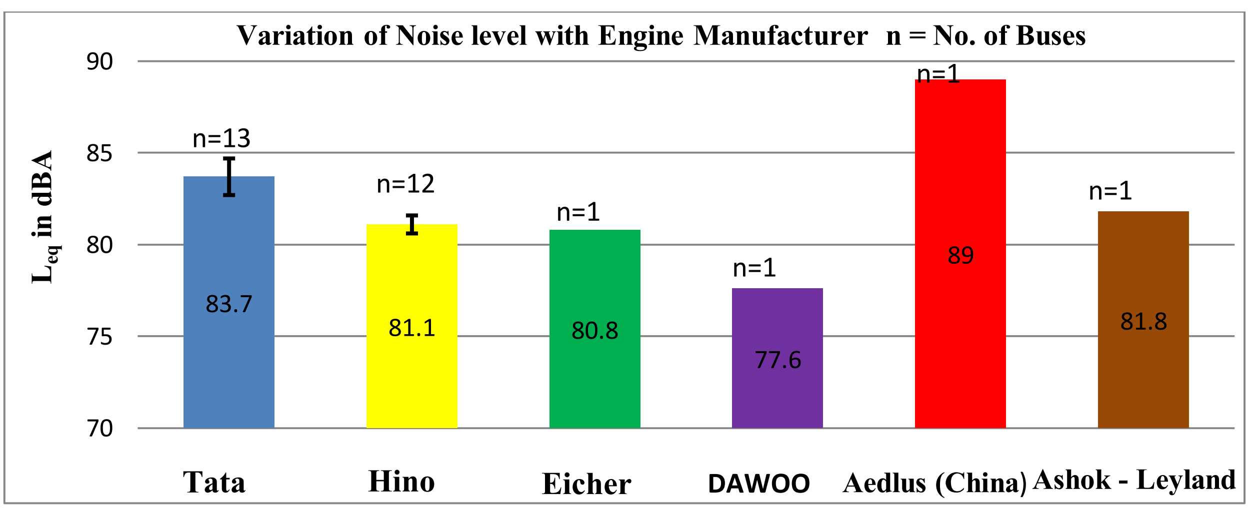


Figure 4.29: Variation of bus interior L_{eq} due to variation of bus Engine Manufacturer

4.11 THE EFFECTS OF NOISE FROM OUTSIDE SOURCES TO INSIDE NOISE LEVEL OF BUSES

Continuous noise level measurements were carried out in different kinds of buses and almost all buses were non AC which were directly open to outside environment. Noise level measurements were carried out only in one bus that was equipped with AC which is the BRTC AC bus that operates on Motijheel to Abdullapur route. It was found that the experienced bus interior equivalent continuous noise level in BRTC AC bus was relatively less than average experienced bus interior equivalent continuous noise level in all other buses that operated on the same route (shown in Figure 4.30). BRTC AC bus was isolated from outside environment except at specific stations (door open at specific stations to exit and enter passenger). For this reason noise from outside sources (traffic noise and other noises) do not affect the inside noise level in BRTC AC bus. Motijheel to Abdullapur route was divided into six route segments and from Figure 4.30 it can be seen that the average experienced bus interior equivalent continuous noise level in all buses was relatively high than BRTC AC bus on all six route segments. Thus from this phenomenon it can be said that the noise pollution from outside sources might contribute to variation in noise levels inside the buses.

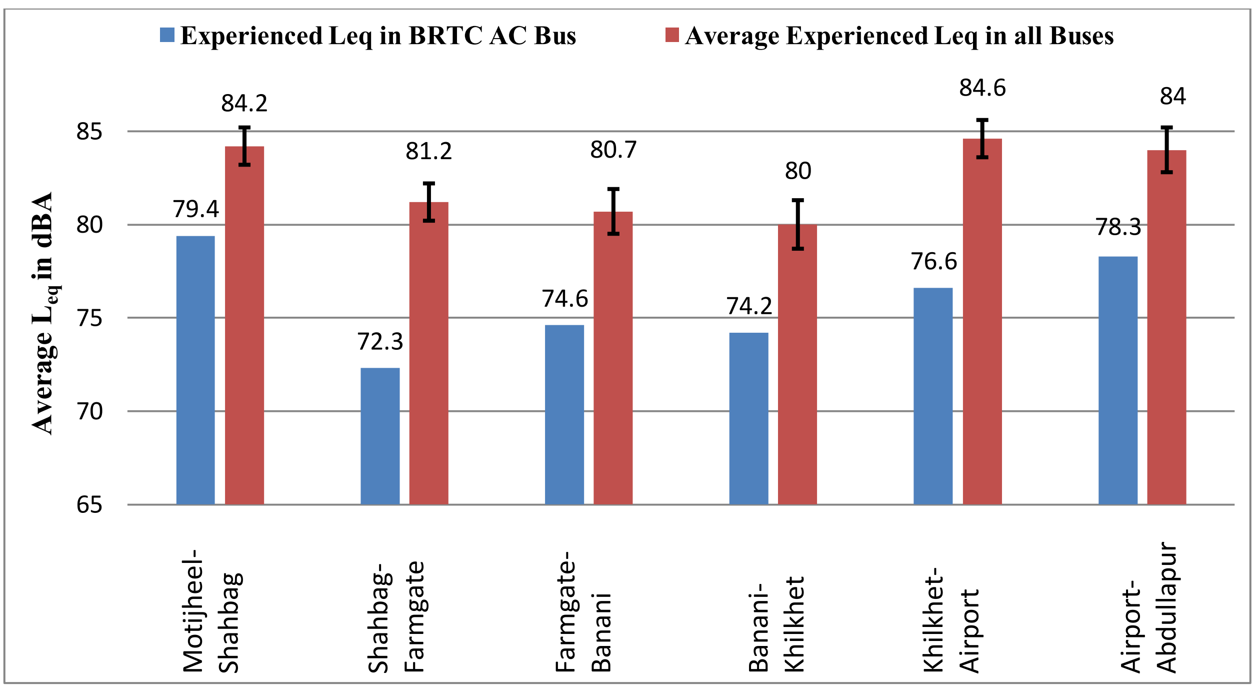


Figure 4.30: Relative bus interior Equivalent continuous noise level (route segment wise) in BRTC AC bus and other buses on Motijheel to Abdullapur route

4.12 EFFECT OF AVERAGE TRIP DURATION AND TRIP DISTANCE ON INTERIOR NOISE LEVEL OF BUSES

To examine whether the average trip duration and trip distance have any bearing on the average bus interior noise level experienced in a particular trip, a trend between average bus interior noise level with average trip duration and trip distance was determined through the scatter plots shown in Figure 4.31 and Figure 4.32 respectively. A linear regression between L_{eq} with average trip duration and trip distance show a weak negative correlation which indicates that the average trip duration and trip distance may not have any significant positive bearing on the average bus interior noise level experienced in a particular trip.

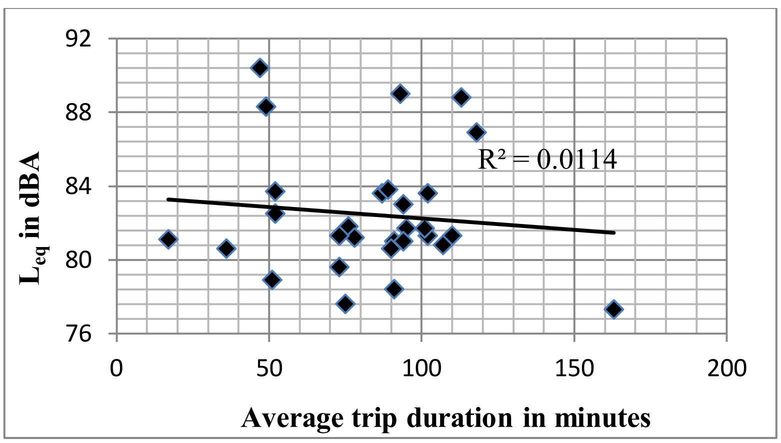


Figure 4.31: Relationship between L_{eq} and average trip duration

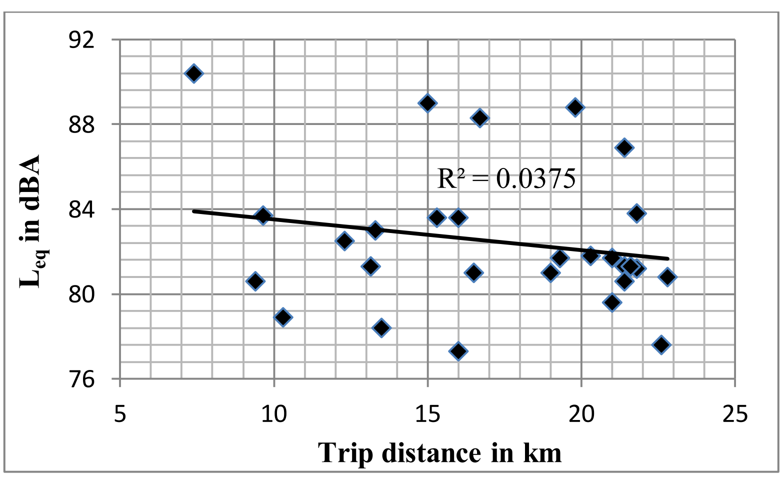


Figure 4.32: Relationship between L_{eq} and trip distance

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The major objectives of this study were to determine the internal noise environment of bus transportation system in Dhaka city and to determine the factors that influence noise levels inside urban buses. This chapter summarizes the major findings of this study. It also presents recommendation for future research on this relevant field.

5.2 SUMMARY CONCLUSIONS

- Cumulative noise distribution curves were constructed for all the 29 buses under the current study to determine the internal noise environment of buses in Dhaka city bus transportation system. Noise indices L_{90}, L_{50}, L_{10} are calculated for the 29 buses to characterize the internal noise environment.
  - The noise indices L_{90} varied between 65.8 dBA (Azmiriglori bus) to 77.3 dBA (Midway bus).
  - L_{50} ranged between a minimum of 72.9 dBA (BRTC AC bus) to a maximum of 82.2 dBA (Dipon transport and Konok Poribahan).
  - The maximum L_{10} (90 dBA) was experienced in Shatabdi poribahan whereas minimum (79 dBA) was experienced in BRTC AC bus.
  - The lowest minimum experienced noise level (L_{min}) was found in New vision bus which was 49.3 dBA whereas the highest maximum experienced noise level (L_{max}) was found in BRTC bus which was 111 dBA.
  - The highest average noise level L_{avg} (83.1 dBA) was experienced in Dipon transport that operates on Motijheel to mohammadpur route.

- Stair graphs of equivalent continuous noise level (L_{eq}) were portrayed for all the 29 bus trips to study the noise pollution levels in the bus interior along different road segments.
  - The highest L_{eq} (90.4 dBA) for entire length of all the 29 bus trips was found in Dipon transport bus and the lowest L_{eq} (77.3 dBA) for entire length was found in Azmiriglori bus.

- The highest segmentwise bus interior L_{eq} (100 dBA) was experienced at the 1.2 km-long Mirpur-10 to Mirpur-11 road segment in BRTC bus whereas the lowest segmentwise bus interior Leq (77.3 dBA) was found at the 1 km-long Shahabagh to Kawranbazar and 2.5 km-long Mohakali to Banani road segments in BRTC AC bus.

➢ The survey data of 29 bus services was consolidated into nine major routes to carry out comprehensive investigation on interior noise hazard level in buses along specific bus routes. A noise map was constructed for Dhaka city bus routes to visualize overall bus interior noise hazard scenario and to identify hotspots of noise pollution in Dhaka city bus routes.

- The maximum average equivalent continuous noise level (88 dBA) was found in Mirpur-12 to mirpur-10 route segment
- The minimum average equivalent continuous noise level (77 dBA) was found in Kakrail to Shatrasta route segment.

➢ Calculated noise exposure level and noise dose were compared with NIOSH guidelines to determine the severity of interior noise hazard level in bus transportation system of Dhaka city.

- The shift length of 24 buses exceeded the permitted shift length as per NIOSH guidelines whereas for 5 buses the shift length did not exceed NIOSH guidelines.
- Nine buses among 29 buses exceeded Noise Dose as per NIOSH guidelines.
- According to NIOSH guideline the most severely noise polluted bus services were BRTC bus, Dipon transport and Konok Poribahan.
- Experienced Noise Exposure Levels (L_{EX}) in BRTC bus, Dipon Transport and Konok poribahan bus were 91.5 dBA, 92.9 dBA and 90.8 dBA respectively. For these noise exposure levels the permitted shift length according to NIOSH guidelines are 1.78 hours, 1.3 hours and 2.1 hours respectively but actual average shift length for these buses are 14.4 hours.
- The lowest L_{EX} (79.8 dBA) and the lowest Noise Dose (31%) were found in Azmiriglori bus which operates on Sadarghat to Abdullapur route.

- The scatter plots of L_{eq} Vs average trip velocity, L_{eq} Vs No. of seats per bus, L_{eq} Vs No. of intersections in the corresponding route, L_{eq} Vs age of bus, L_{eq} Vs average trip duration and L_{eq} Vs trip distance were plotted to determine the influence of the parameter on the interior noise level of buses. The following conclusions were arrived from those plots:
    - Interior noise level of bus increase with increases velocity of the bus.
    - Interior noise levels of buses are higher in large sized buses compared to small sized buses.
    - Interior noise level of bus increases with increased number of intersections in corresponding bus routes.
    - Older buses produces more noise compared to new buses.
    - Average trip duration and trip distance do not have any significant positive bearing on the average bus interior noise level experienced in a particular trip.
    - The noise pollution from outside sources contributes significantly to variations in noise levels inside the buses
    - The bus interior noise levels differ significantly due to variation of bus engines.

5.3 RECOMMENDATION

The recommendations for future studies are listed below:

- In this study the occupational noise exposure was studied from the point of view of bus drivers and helpers only. Approximately 16 million people now live in the capital city where traffic congestions are a regular phenomenon in almost every road. It is necessary to assess noise exposure level of Dhaka city bus passengers. A survey can be carried out to determine passenger attitudes regarding noise hazard level in buses. In that case, monitoring noise exposure at different sections of the bus (front, rear and middle sections) can be important. Besides, noise induced hearing loss (NIHL) of bus driver and helper should be measured using medical diagnostic tools to determine the actual effect of noise pollution on Dhaka city bus driver and helper.

- It was found that the experienced bus interior equivalent continuous noise level in BRTC AC bus was significantly lower than average experienced bus interior equivalent continuous noise level in all other buses that operated on the same route because this AC bus was isolated from outside environment. To minimize interior noise exposure level the quality of Dhaka city bus fleet should be improved by designing a special bus fleet that can be isolated from outside environment. A thorough investigation can be carried out on this fact in future study.

- In Dhaka city most of the motor vehicles especially buses, mini-buses and trucks have hydraulic horns and the drivers are trained to honk continuously till they get their ways clear. The scenario of bus interior noise level in Dhaka city has got worse due to very old bus engines, weak physical condition of buses and poor maintenance of bus fleet. A rules and regulation can be formulated to control use of hydraulic horns, use of old bus engine and use of weak bus fleets. Working hour of bus driver and helper should be less than 10 hours per day to minimize noise exposure level.

- A comprehensive research work can be carried out on interior noise hazard of vehicles by monitoring noise levels in all available public transports (all kind of buses, CNG, Taxi and train) in Dhaka city.

- In this study exterior noise could not been segregated properly during interior noise level measurements in buses. To segregate exterior noise from interior noise level a controlled condition can be considered in future study.

- A campaign can be carried out to increase people awareness regarding noise pollution in bus transportation system; mass media like television, radio, newspapers may be helpful to a great extent for this purpose.

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APPENDIX A

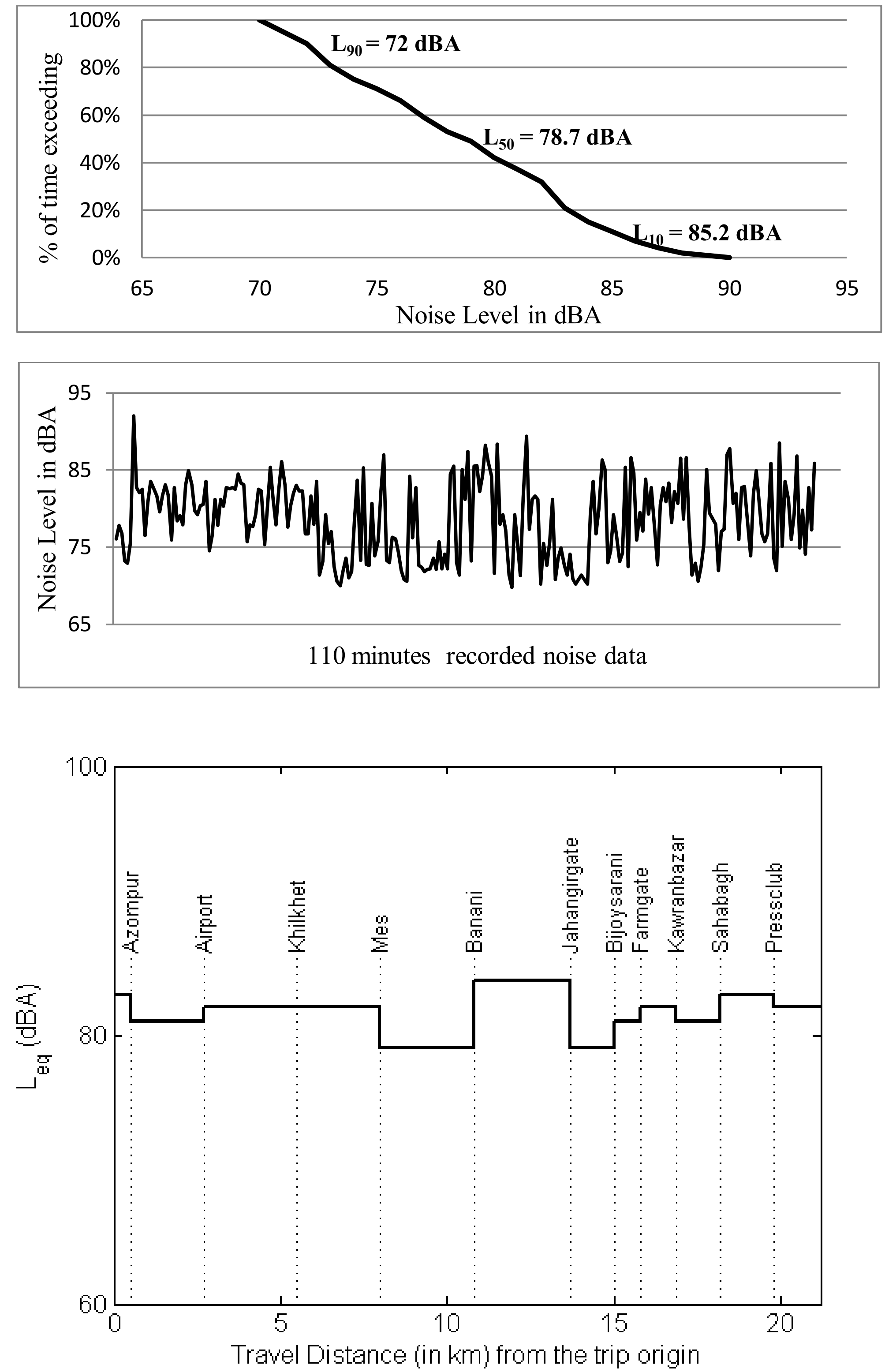


Figure A1: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for 3 no. local bus

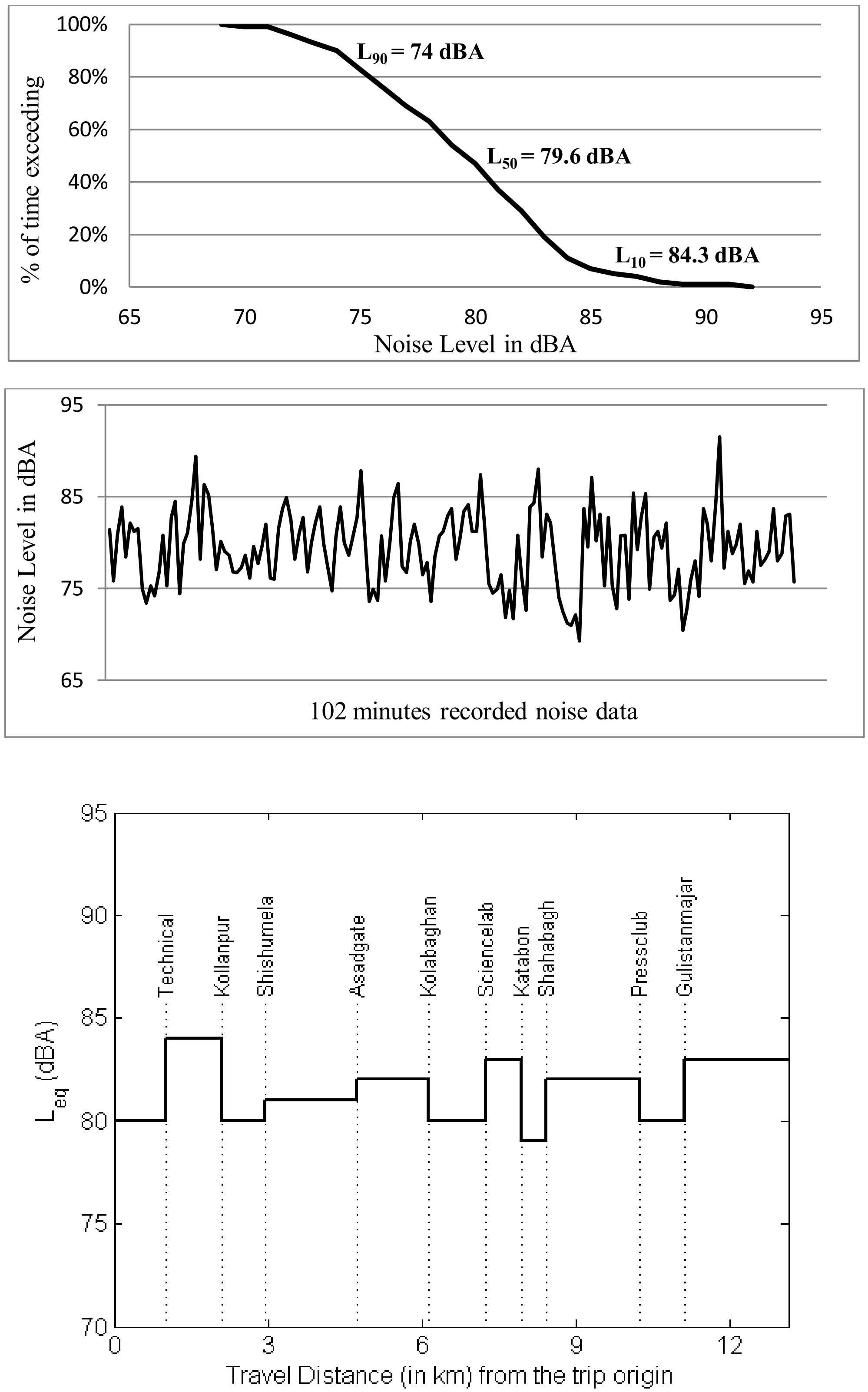


Figure A2: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for 7 no. local bus

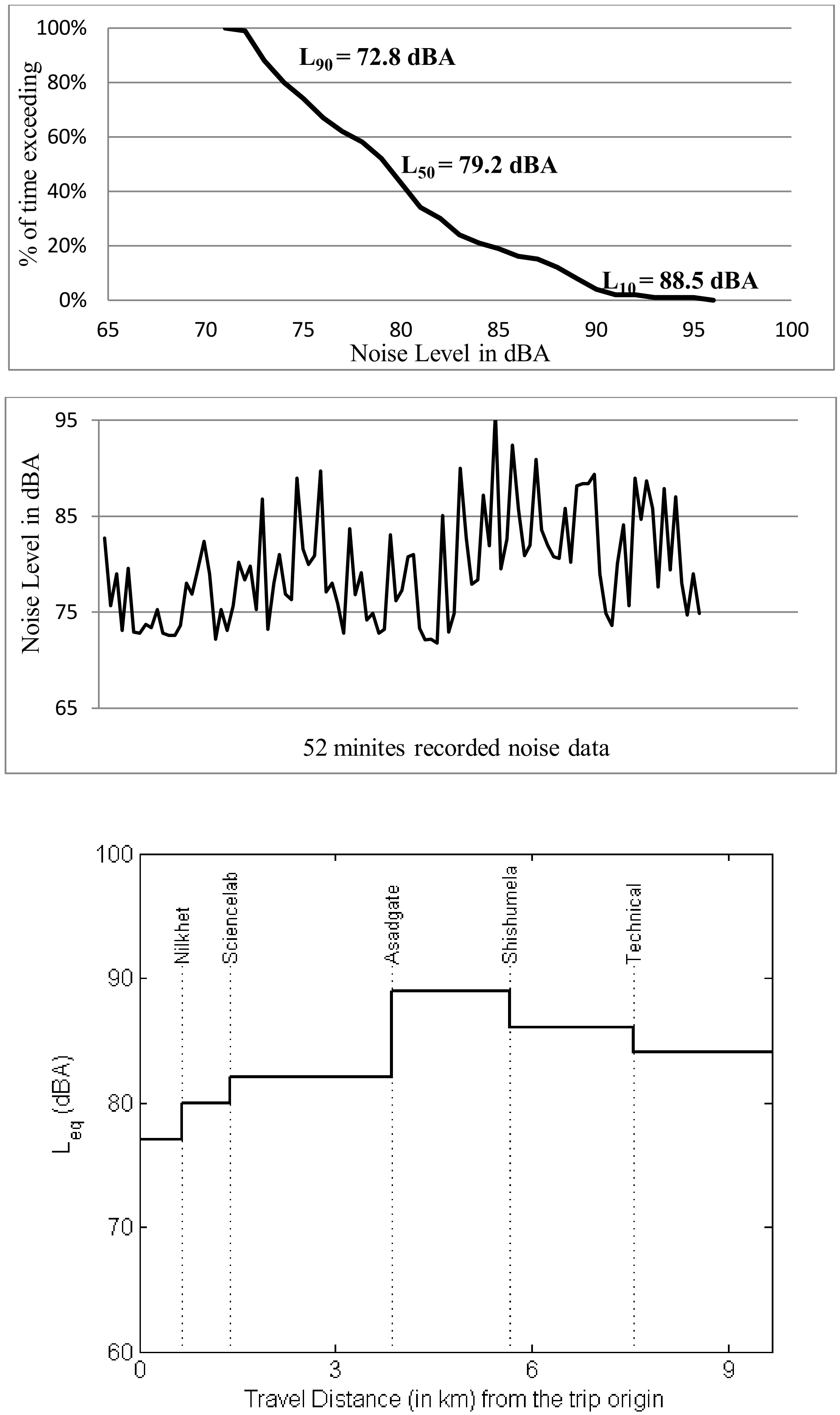
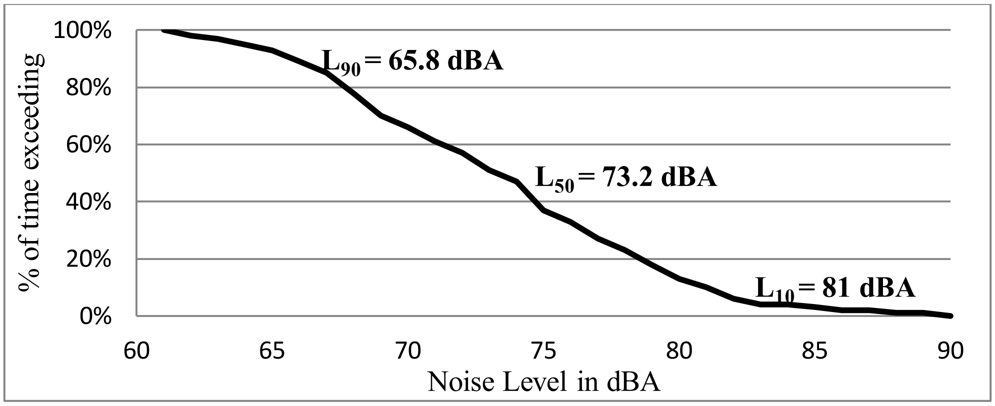
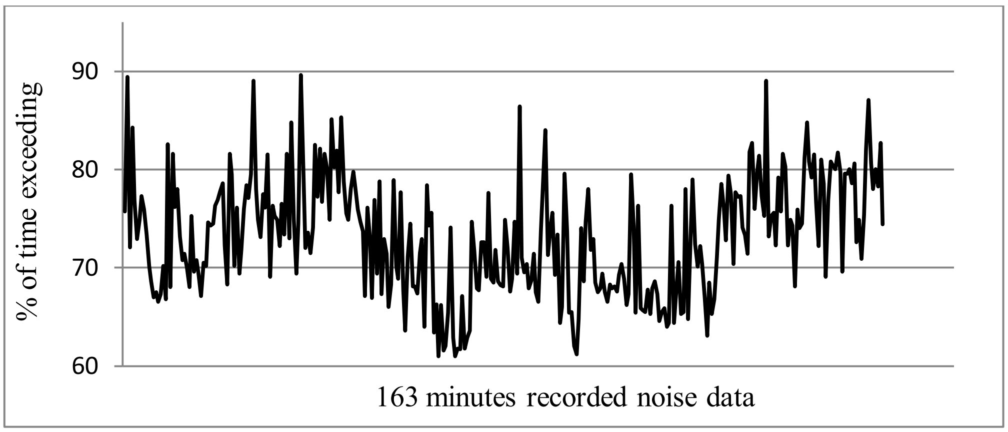


Figure A3: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Ashirbad Poribahan





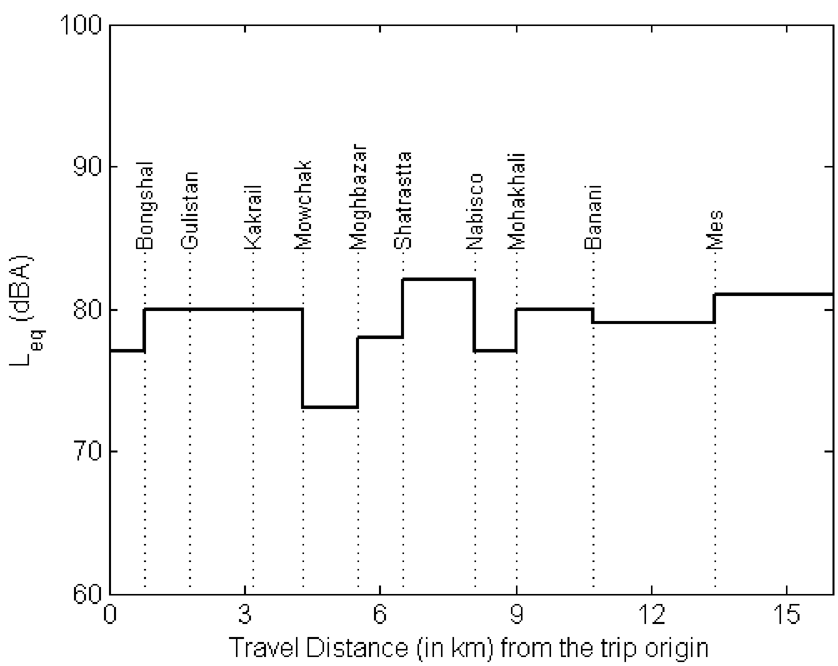


Figure A4: Cumulative Distribution (top) Noise profile (middle) and Stair graph (bottom) for Azmiriglori bus

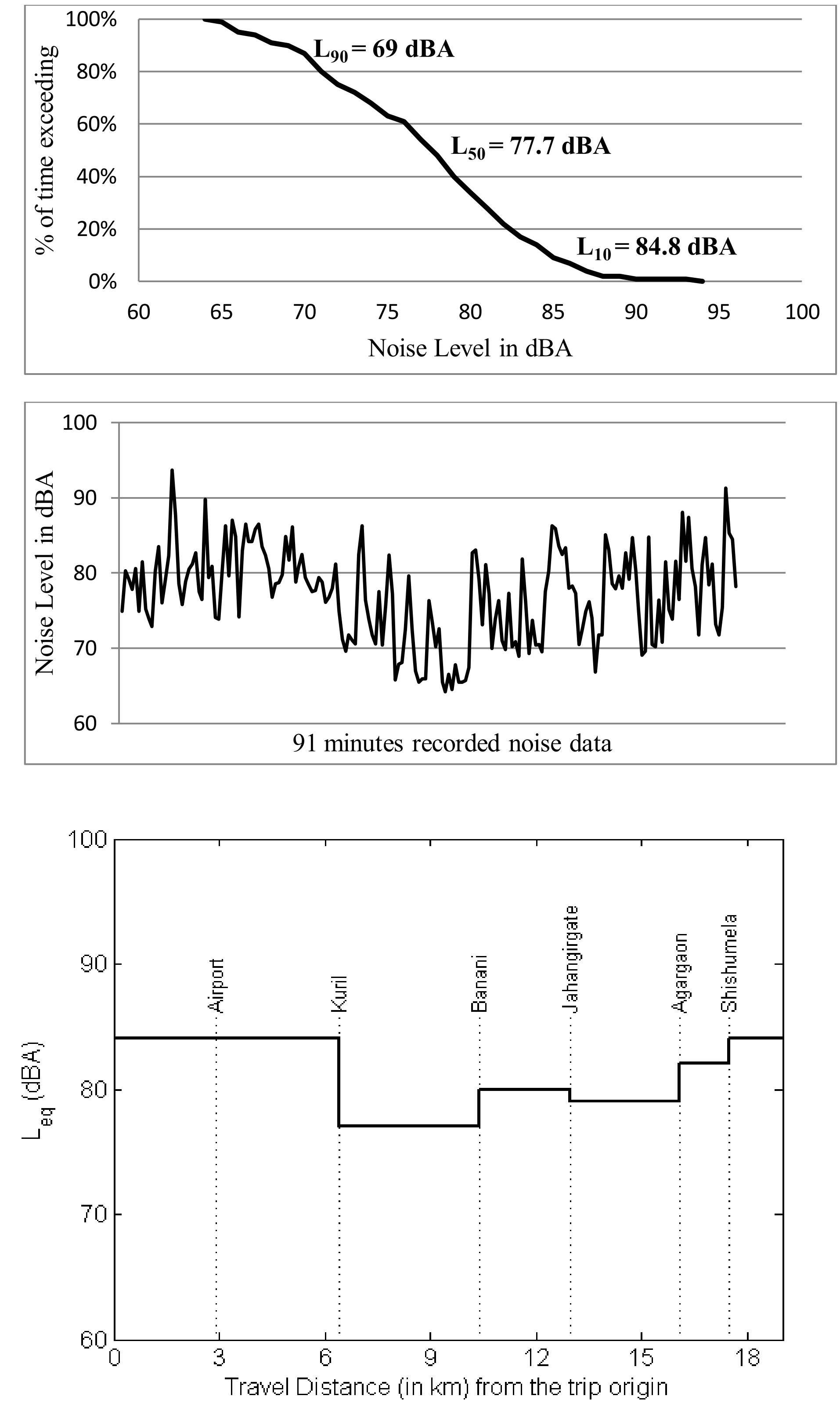
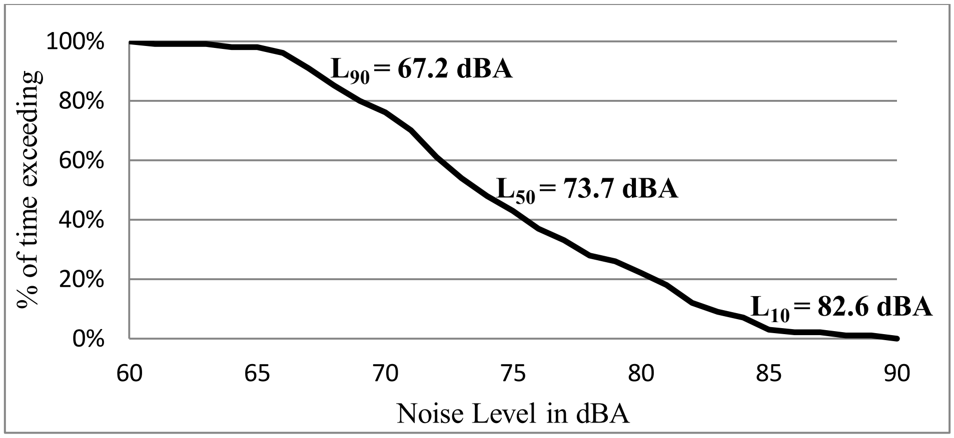
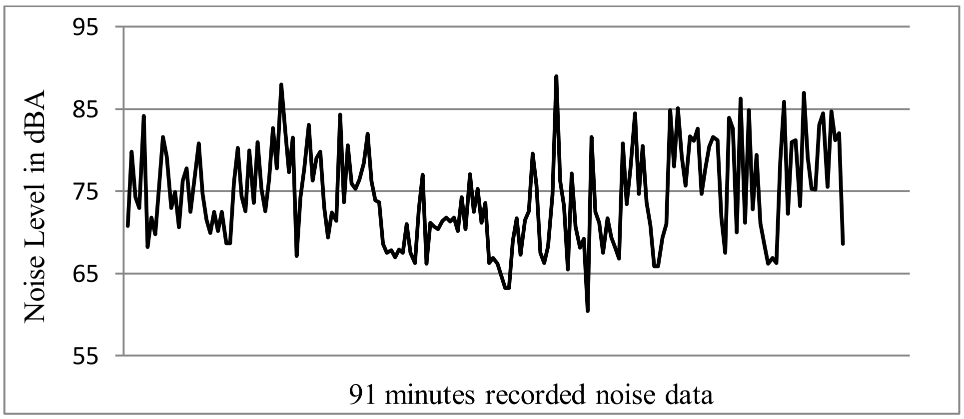


Figure A5: Cumulative Distribution (top) Noise profile (middle) and Stair graph (bottom) for Bangole Motors





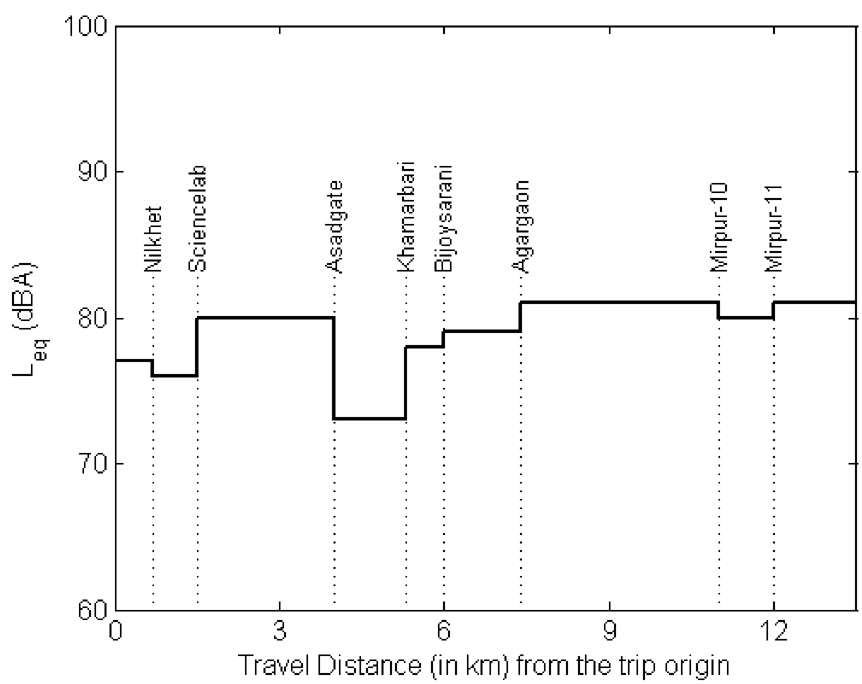


Figure A6: Cumulative Distribution (top) Noise profile (middle) and Stair graph (bottom) for Bikolpo Poribahan

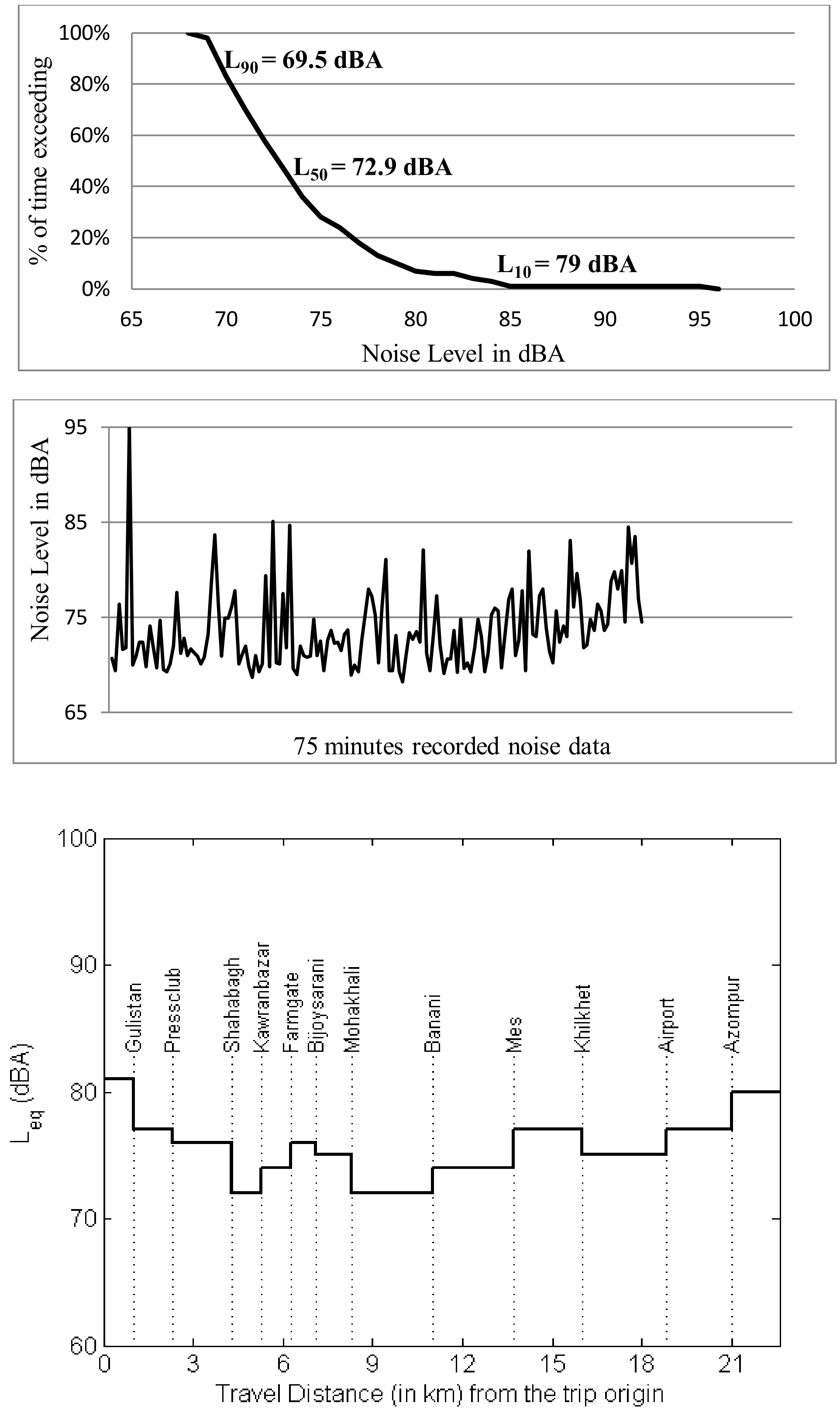


Figure A7: Cumulative Distribution (top), Noise Profile (middle) and Stair graph (bottom) for BRTC AC bus

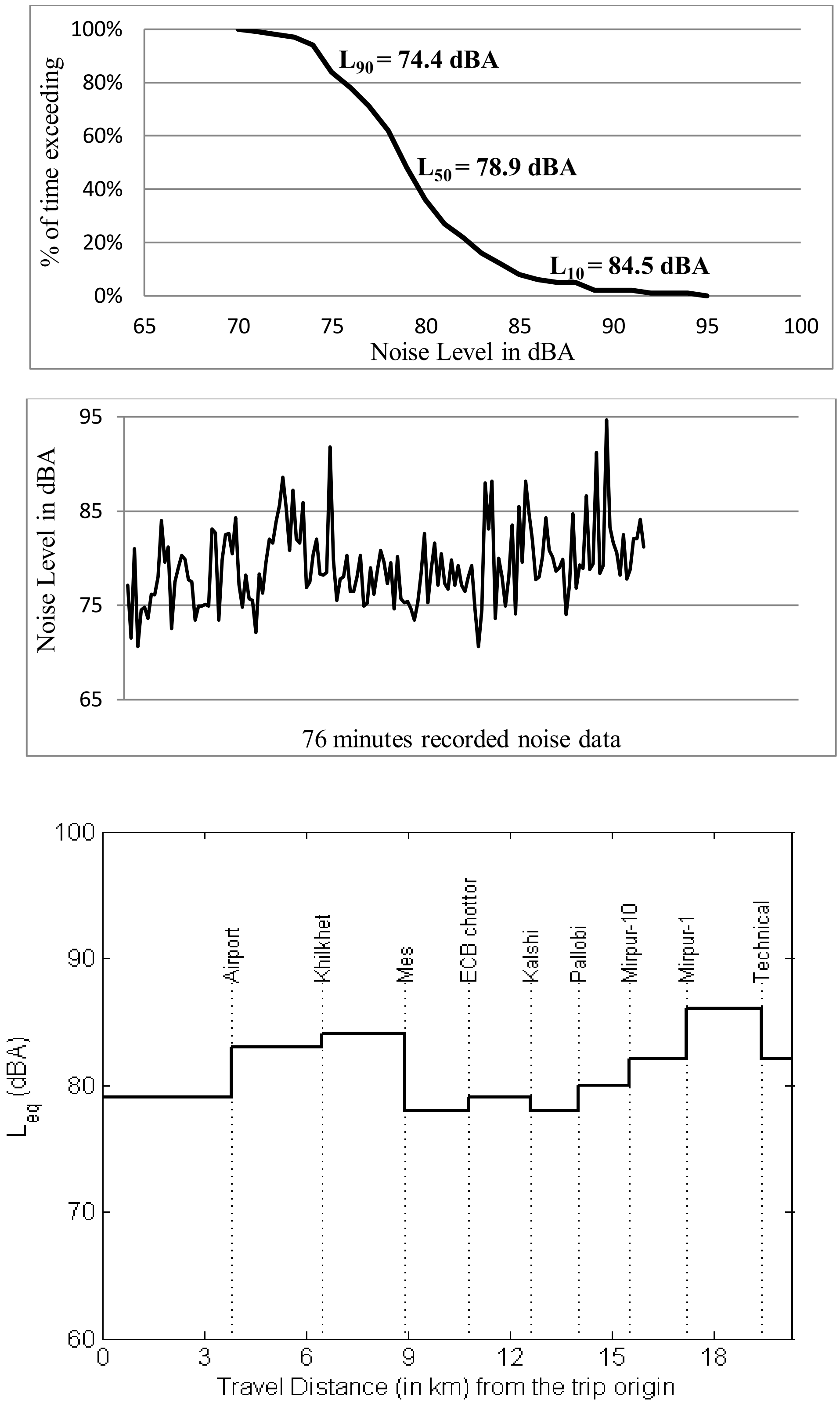


Figure A8: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for BRTC double Decker bus

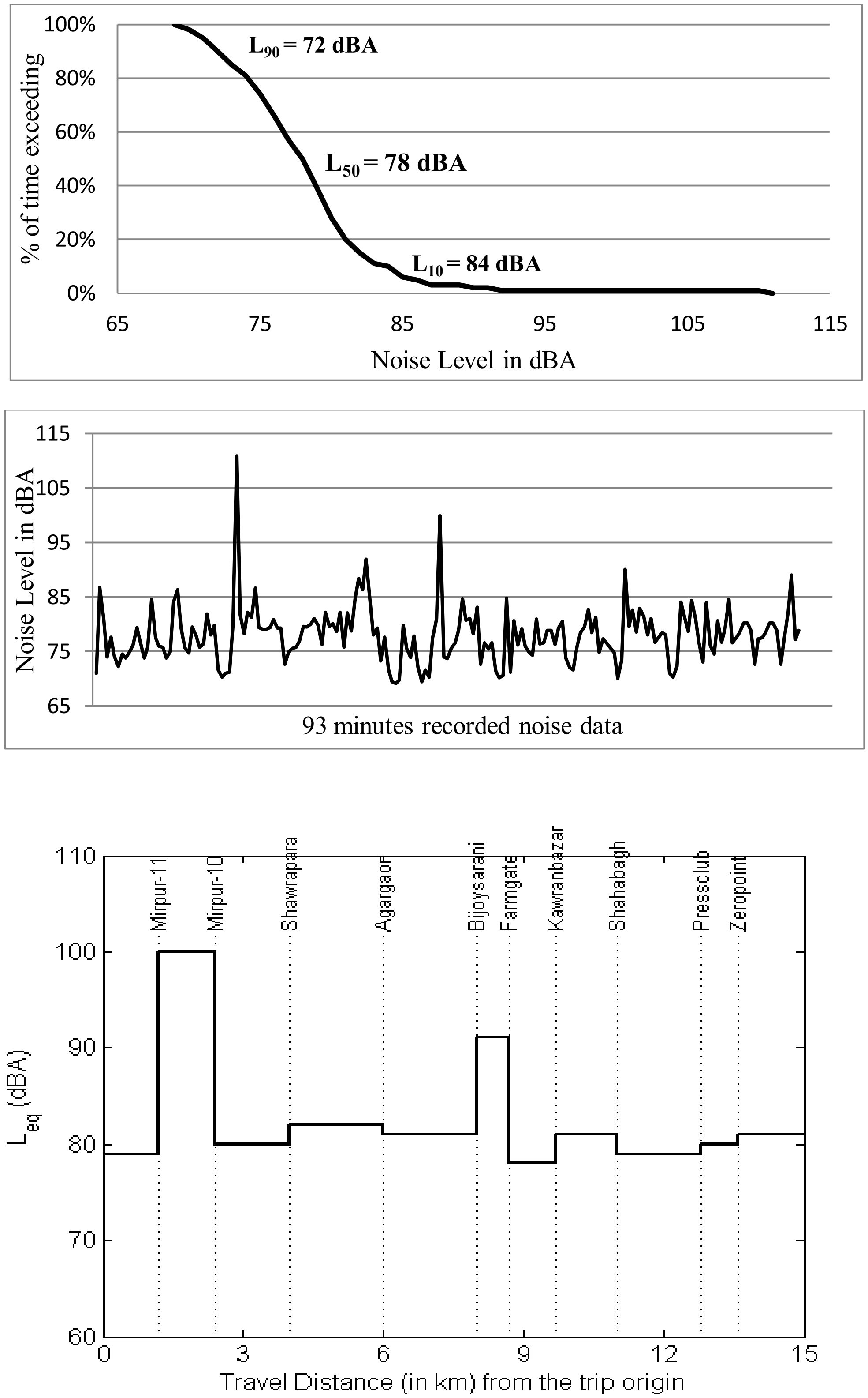
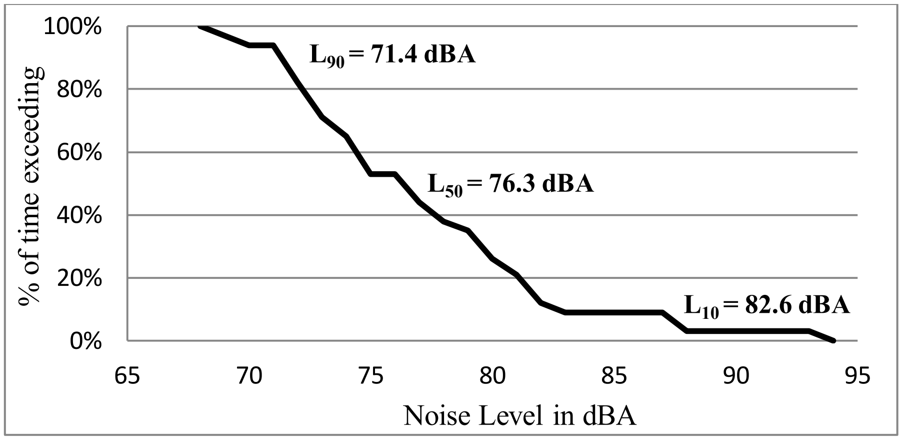


Figure A9: Cumulative Distribution (top), Noise Profile (middle) and Stair graph (bottom) for BRTC bus



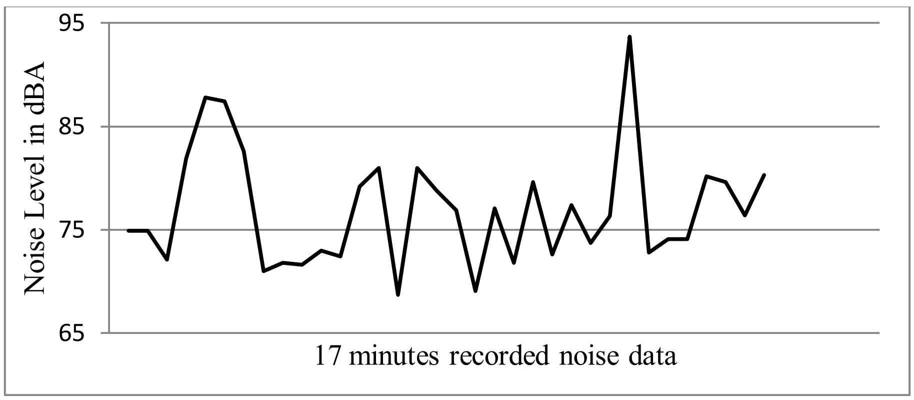
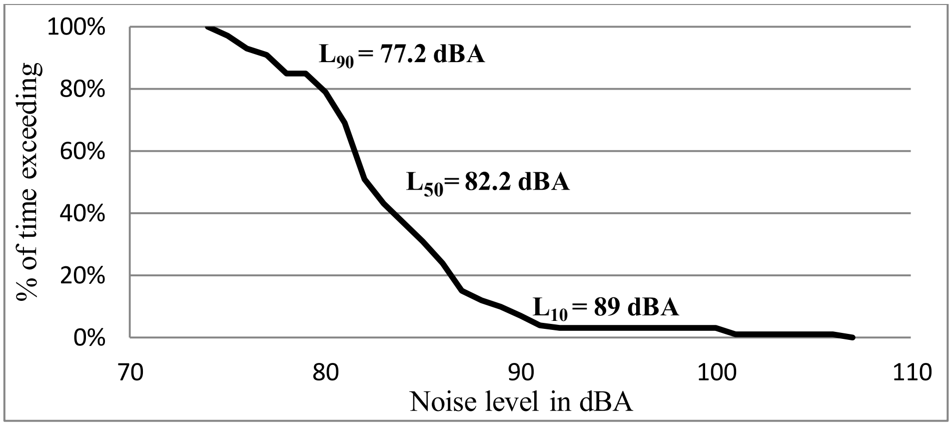
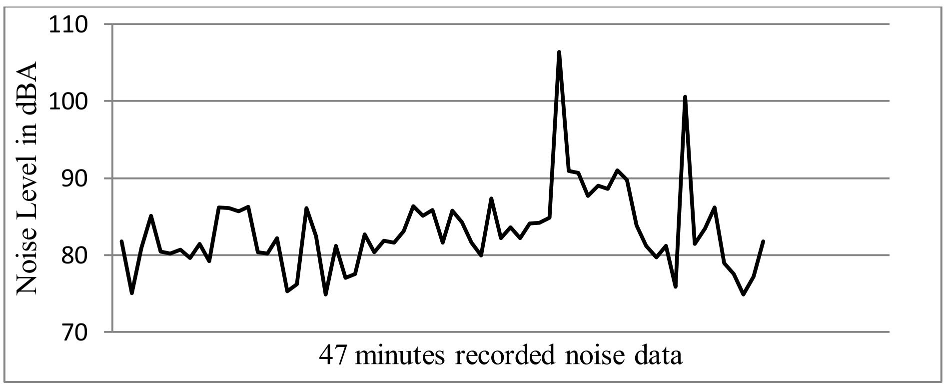


Figure A10: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Cantonment mini service





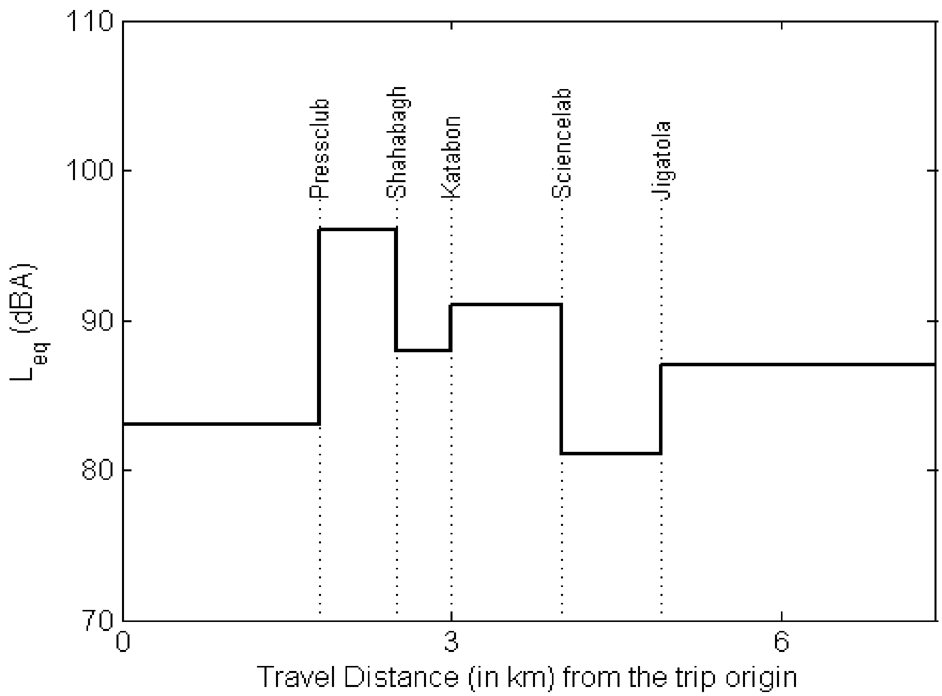


Figure A11: Cumulative Distribution (top) Noise Profile (middle) and Stair graph (bottom) for Dipon Transport

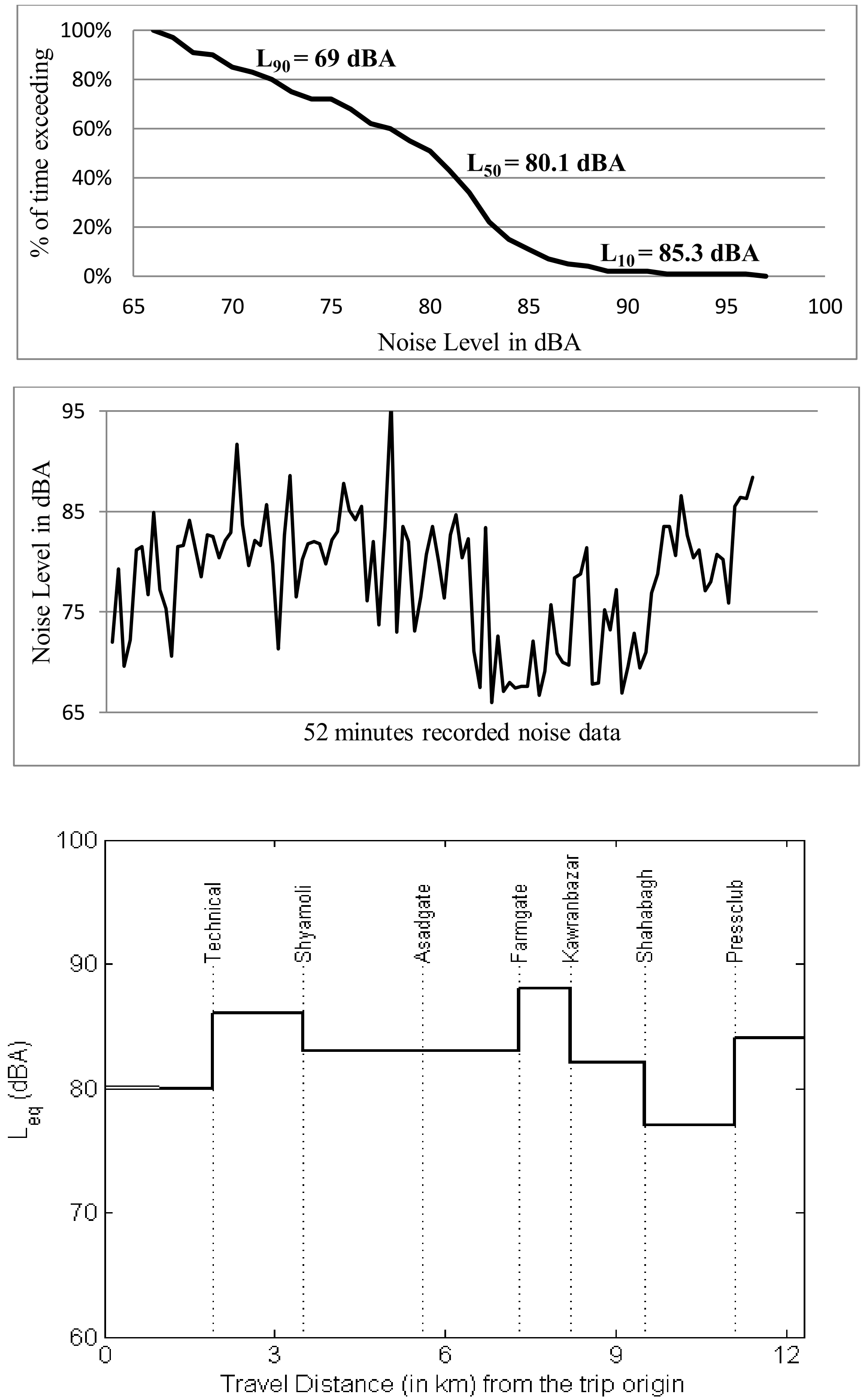


Figure A12: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Dishari Poribahan

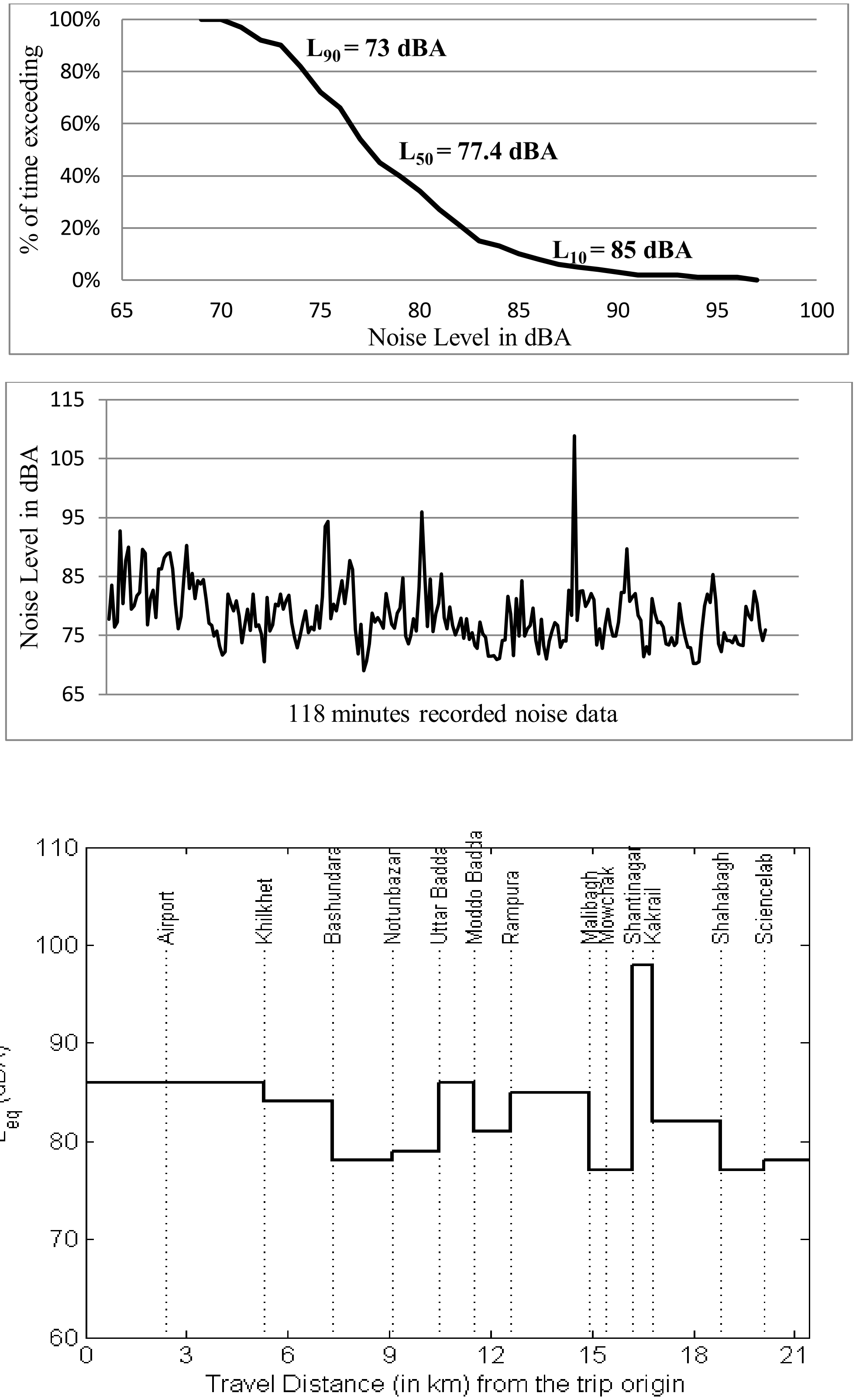


Figure A13: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Falgoan Poribahan

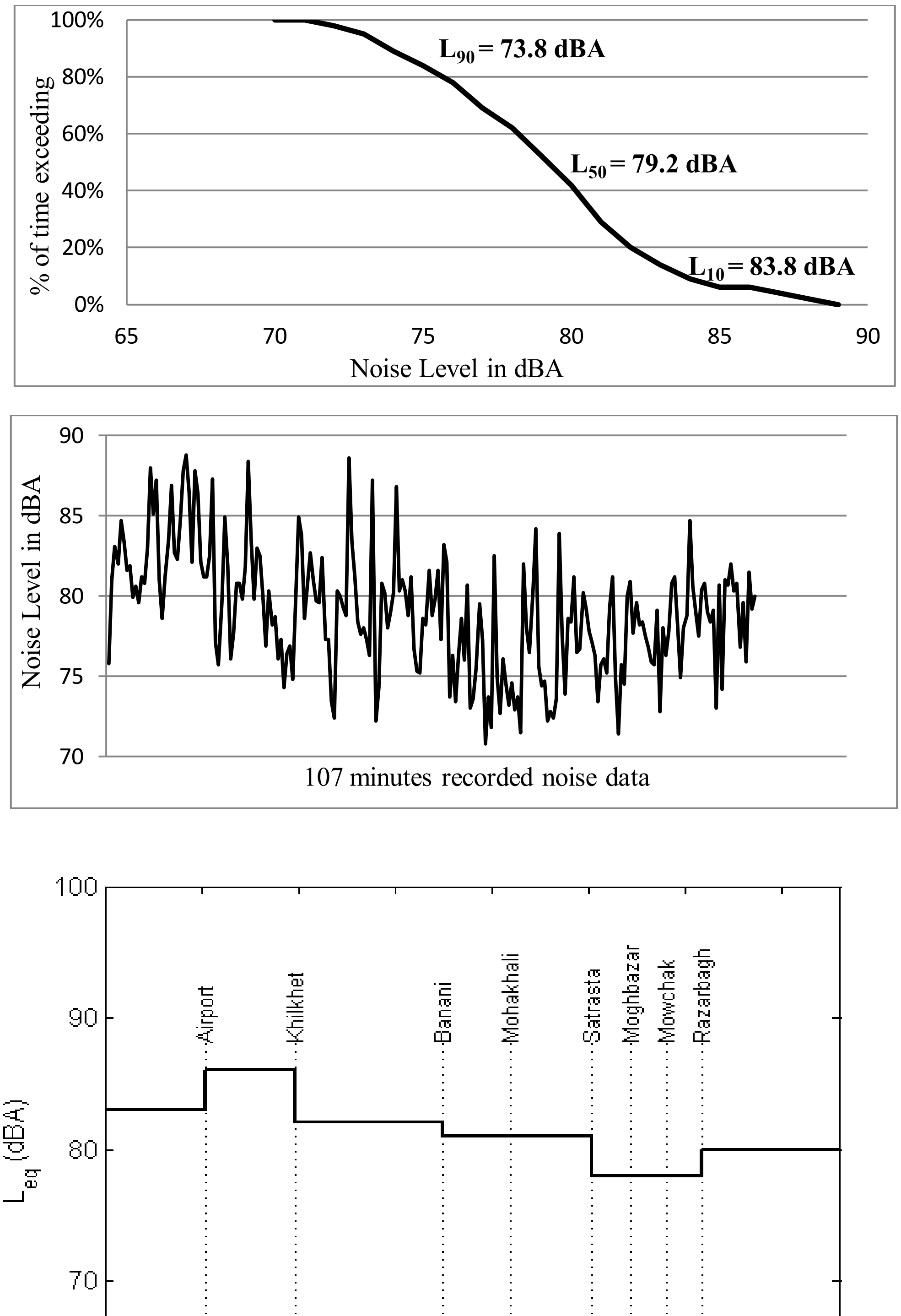


Figure A14: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Jatrabari Poribahan

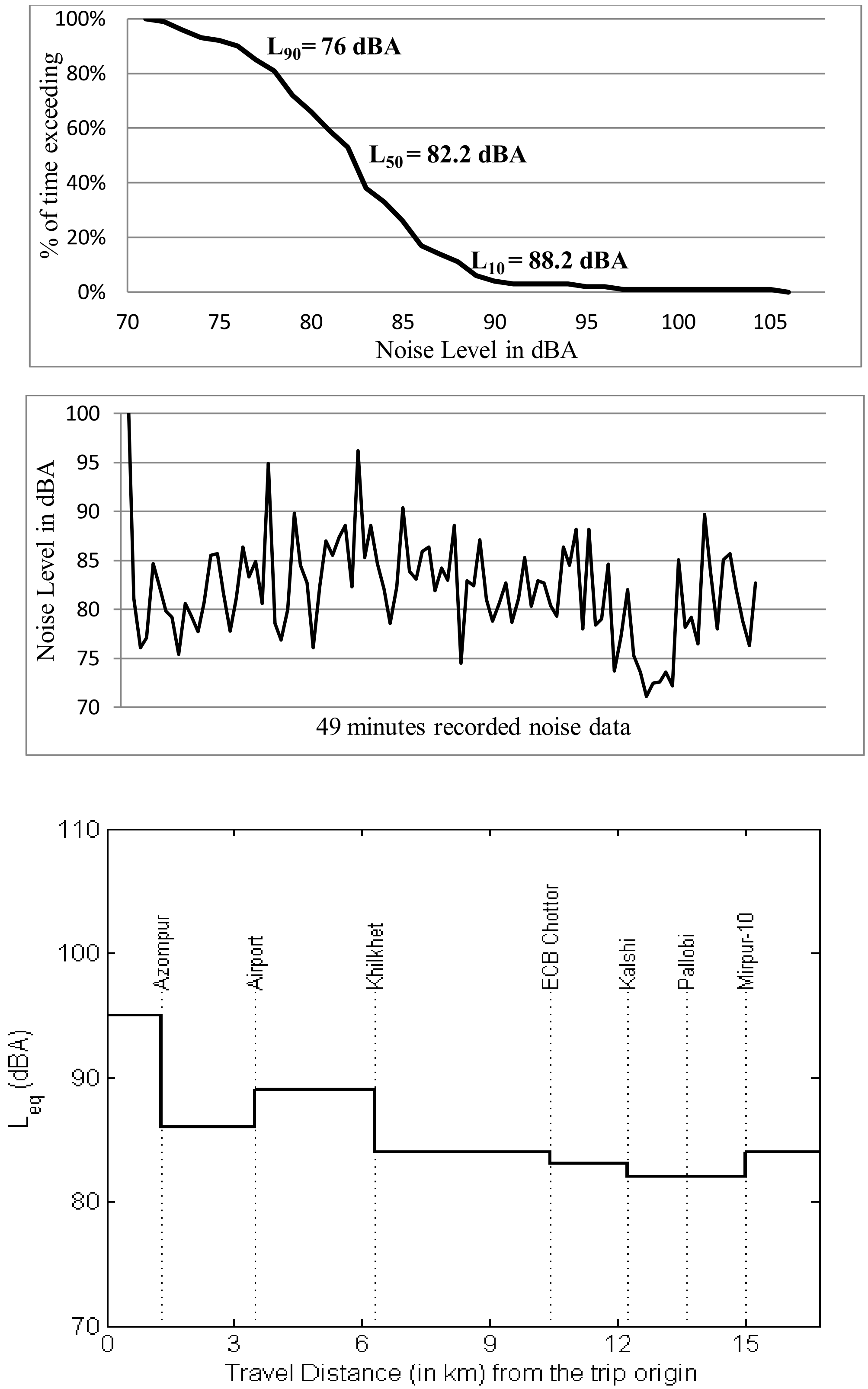


Figure A15: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Konok Poribahan

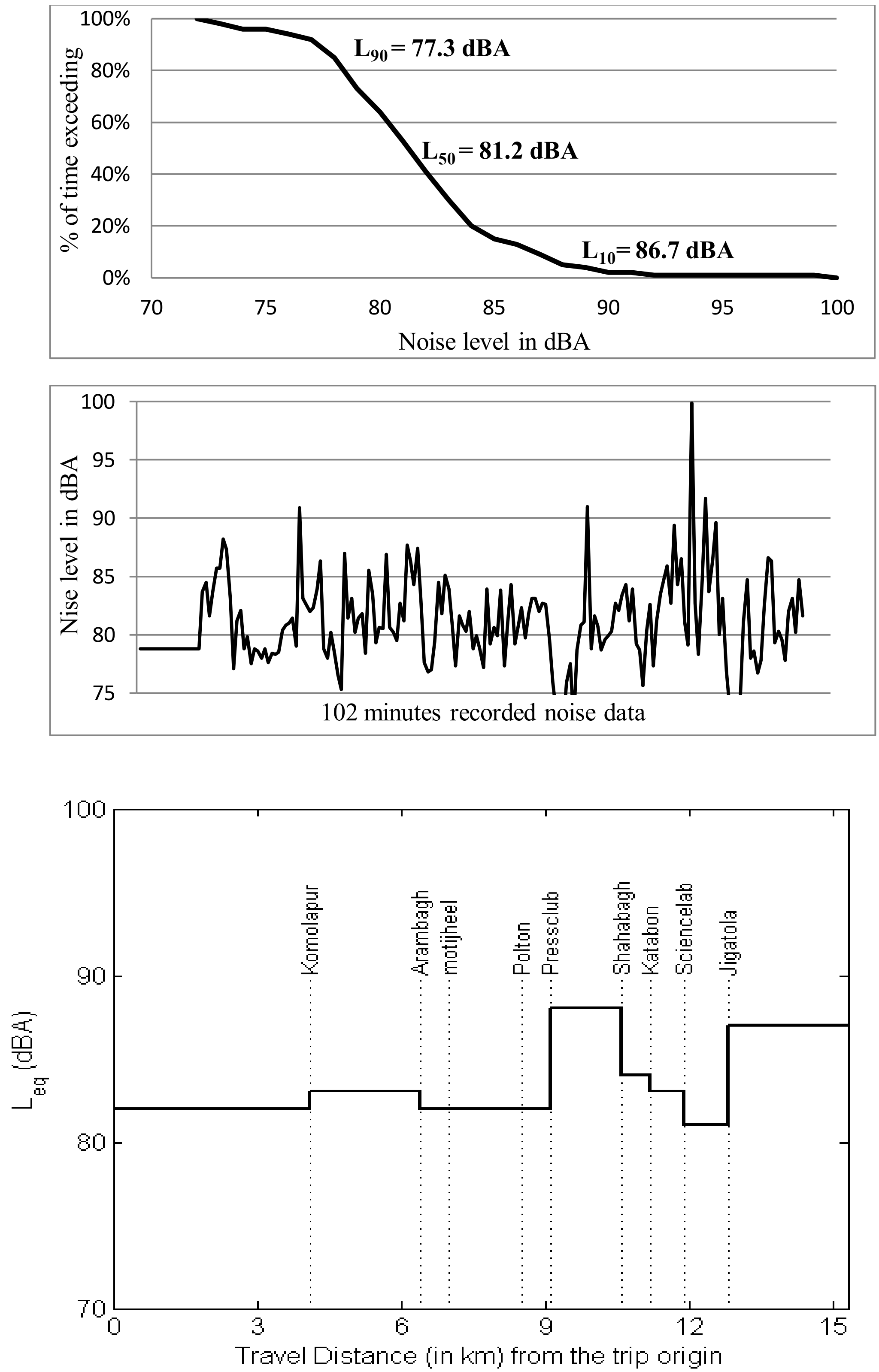
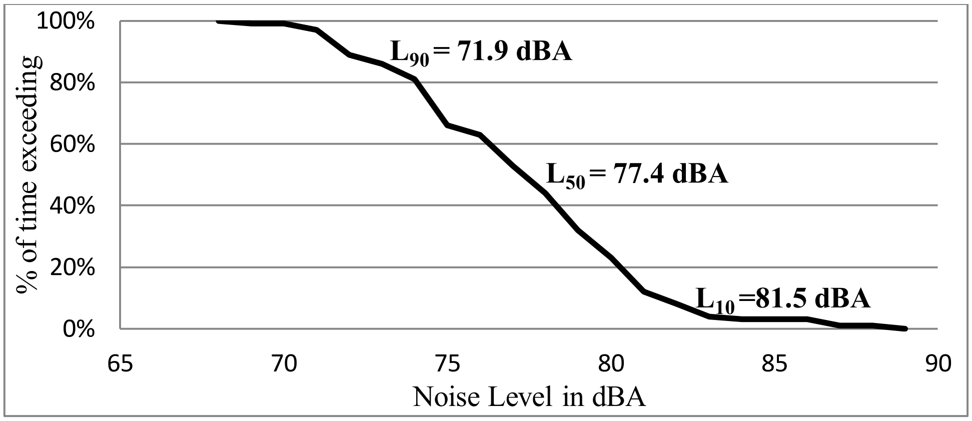
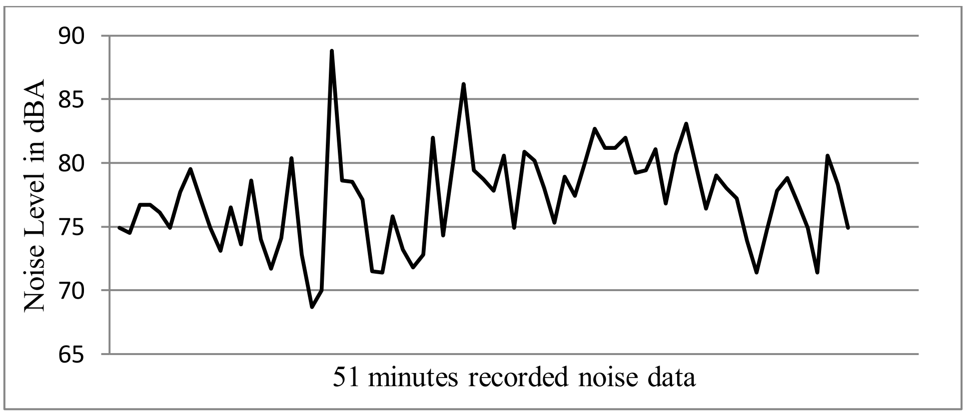


Figure A16: Cumulative Distribution (top), Noise Profile (middle) and Stair graph (bottom) for Midway Poribahan





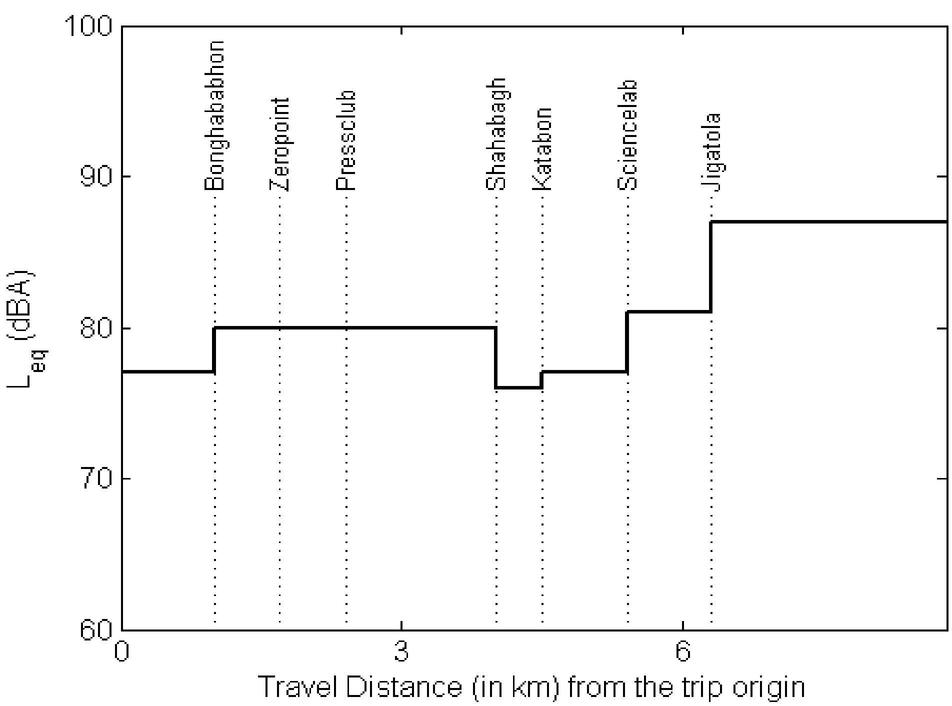
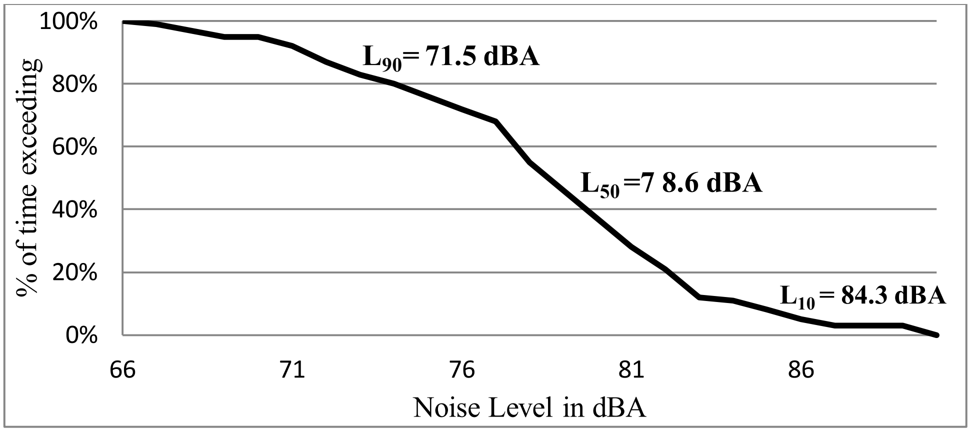
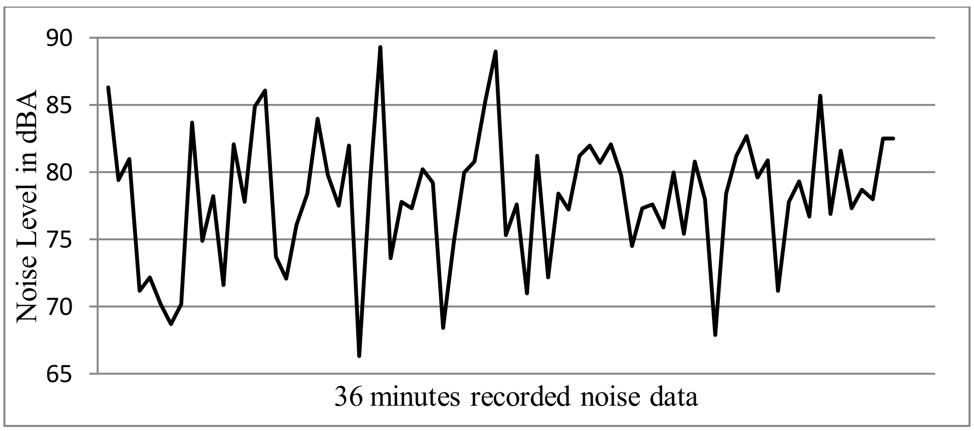


Figure A17: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Moitri Poribahan





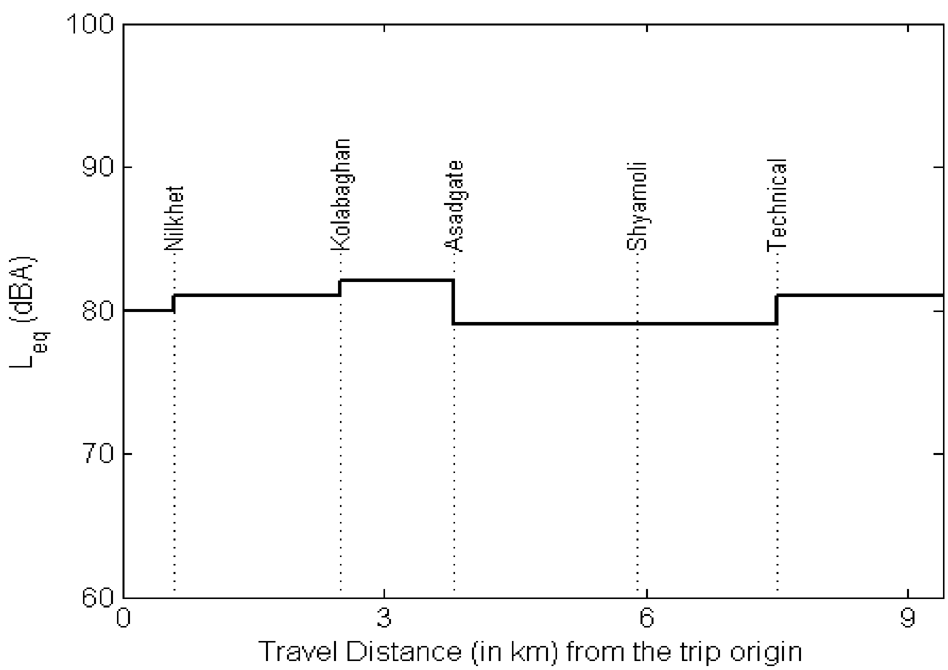
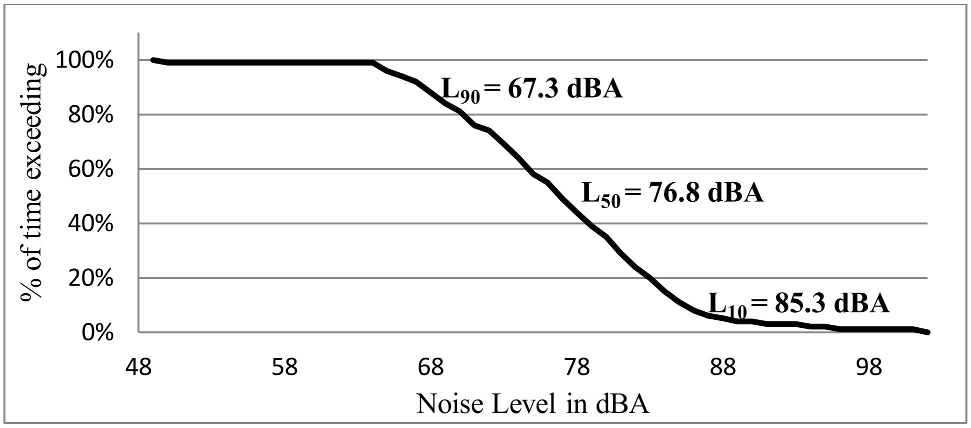
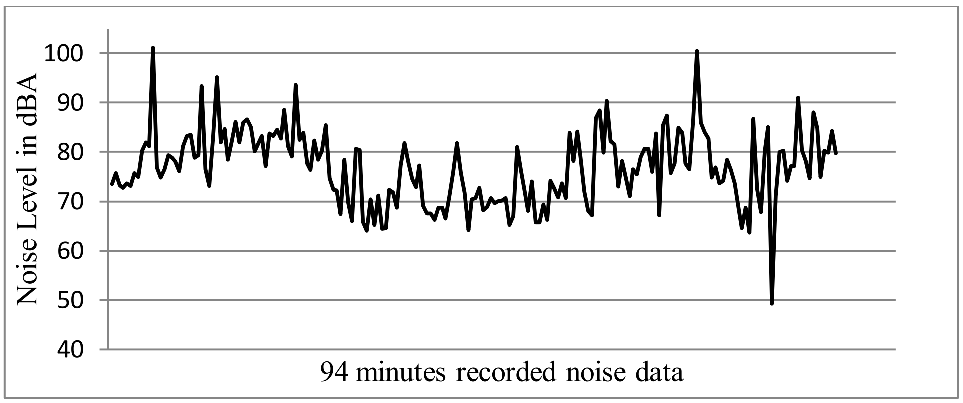


Figure A18: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for New Dhaka link Poribahan





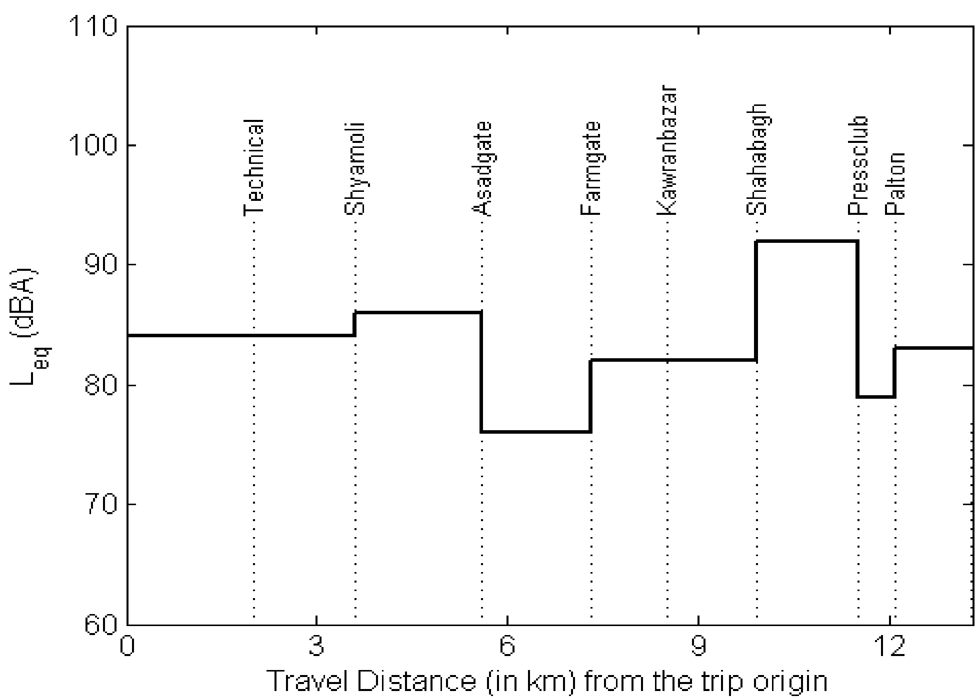


Figure A19: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for New Vision Poribahan

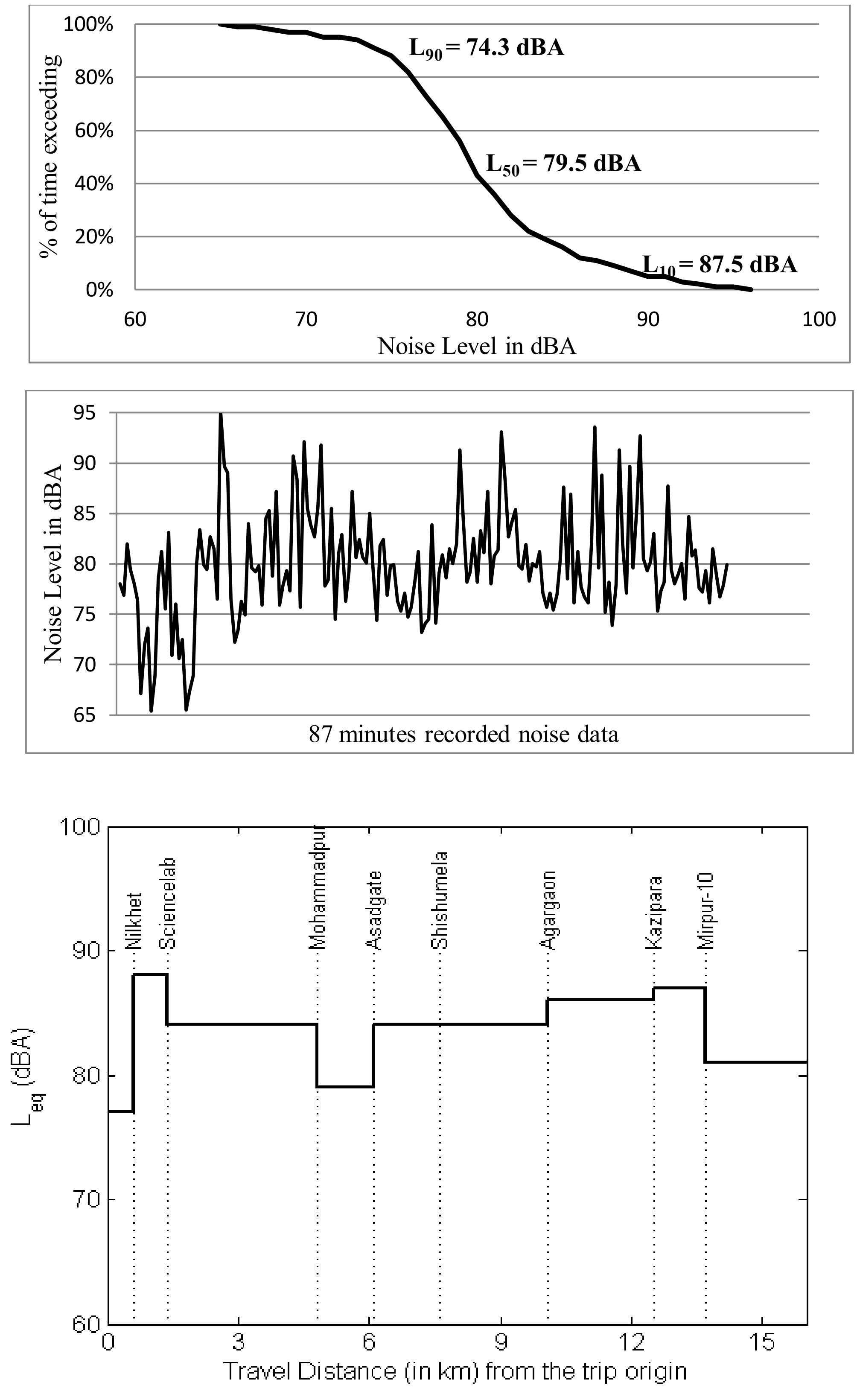


Figure A20: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Nishorgo Poribahan

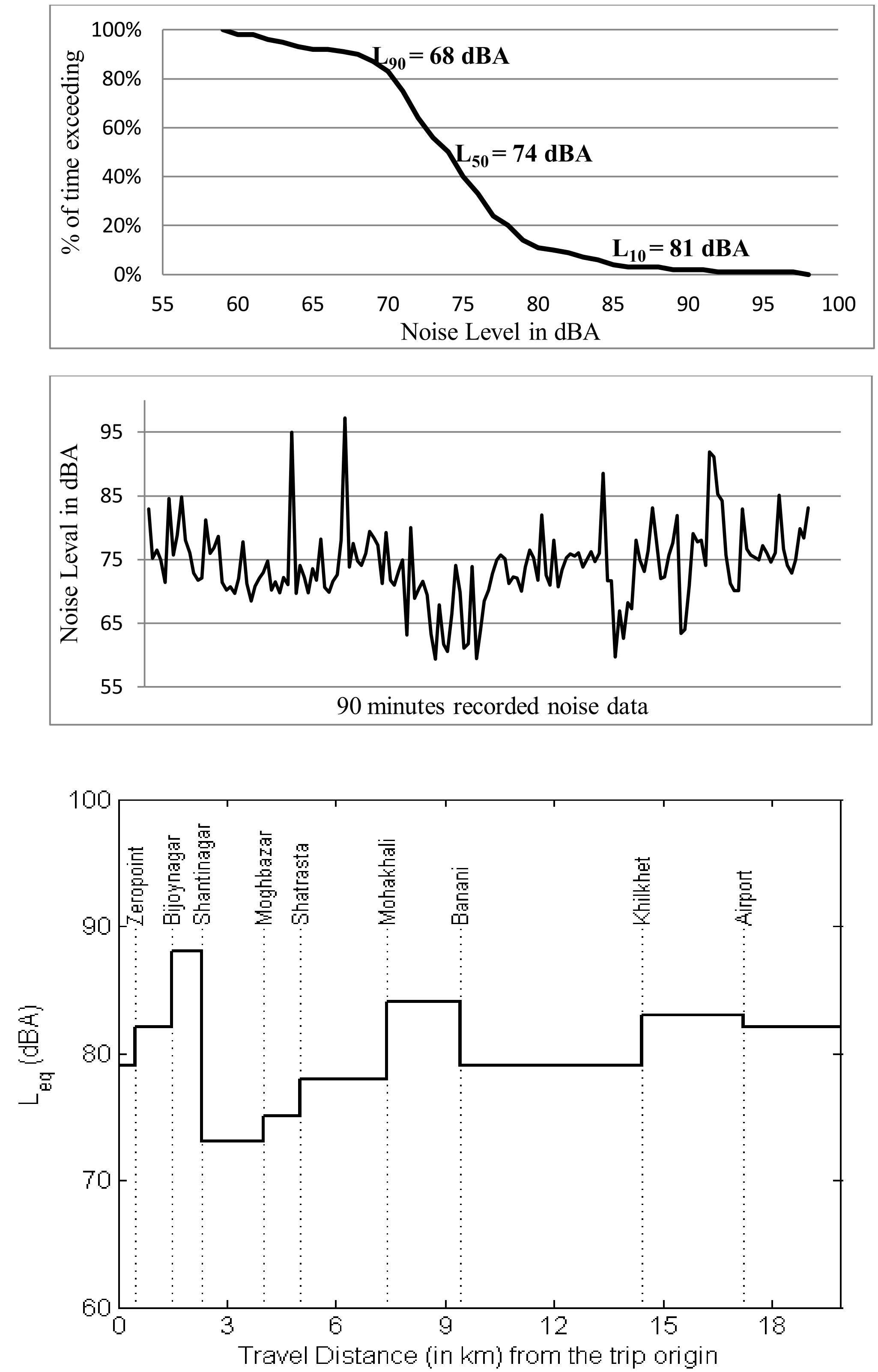
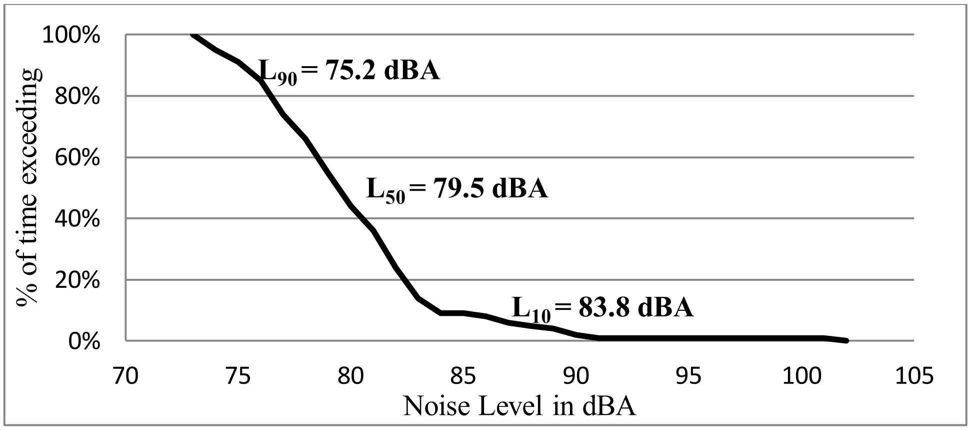
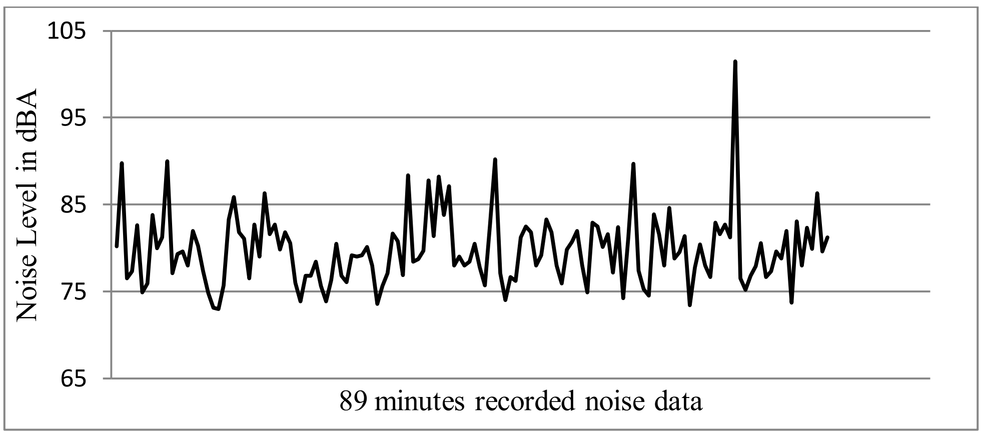


Figure A21: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Probati bonosri Poribahan





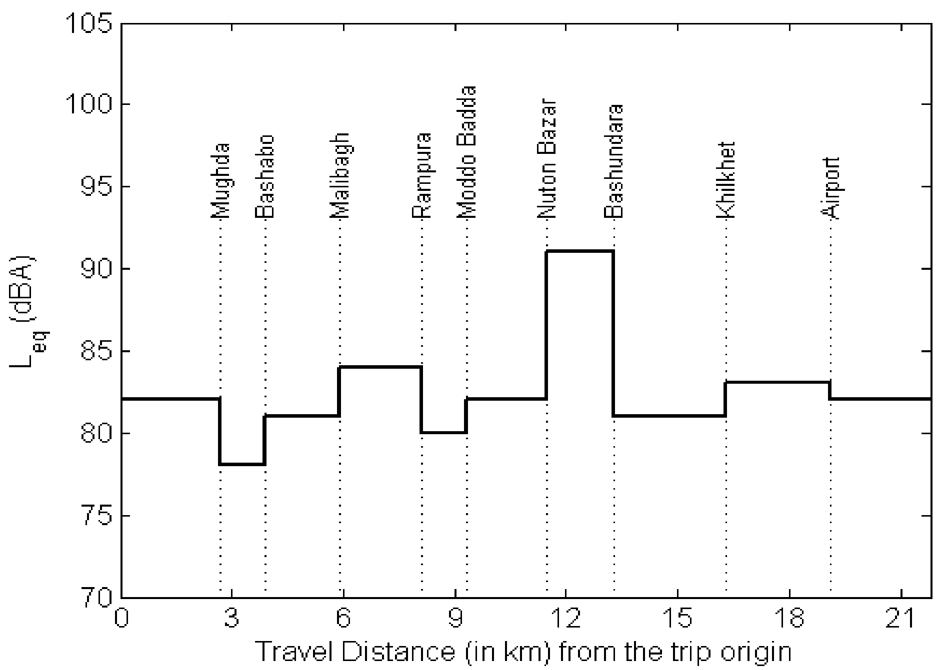
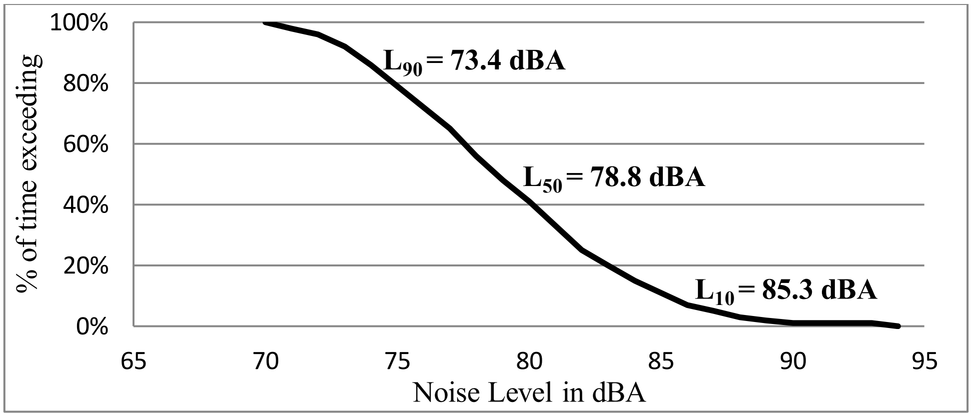
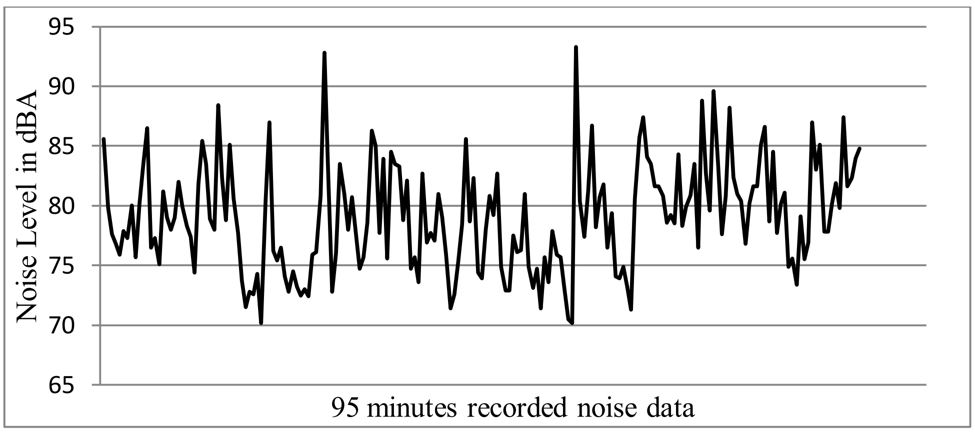


Figure A22: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Salsabil Poribahan





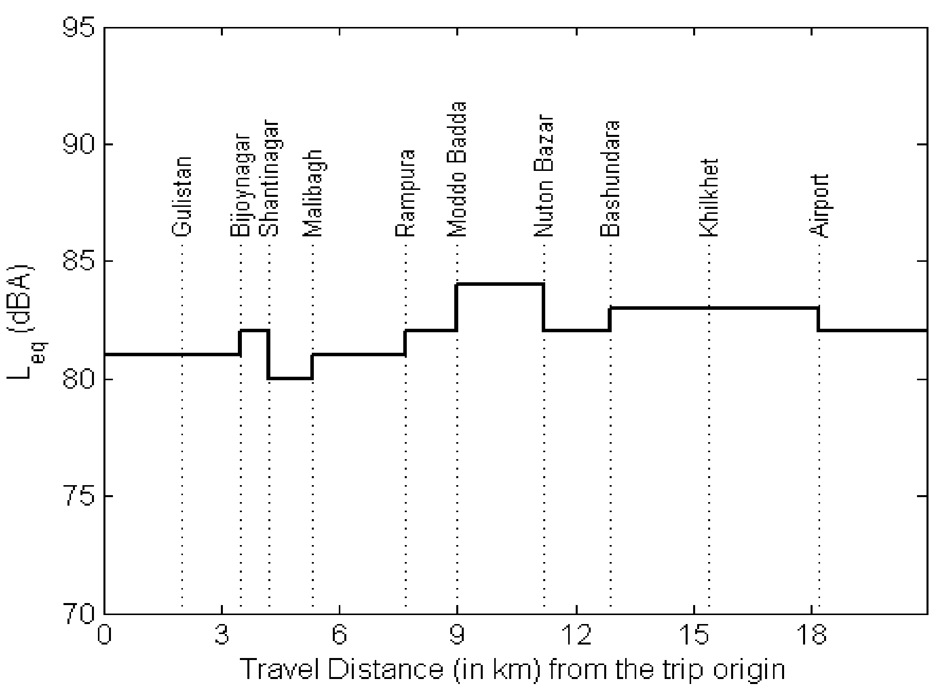


Figure A23: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Shuprobat Poribahan

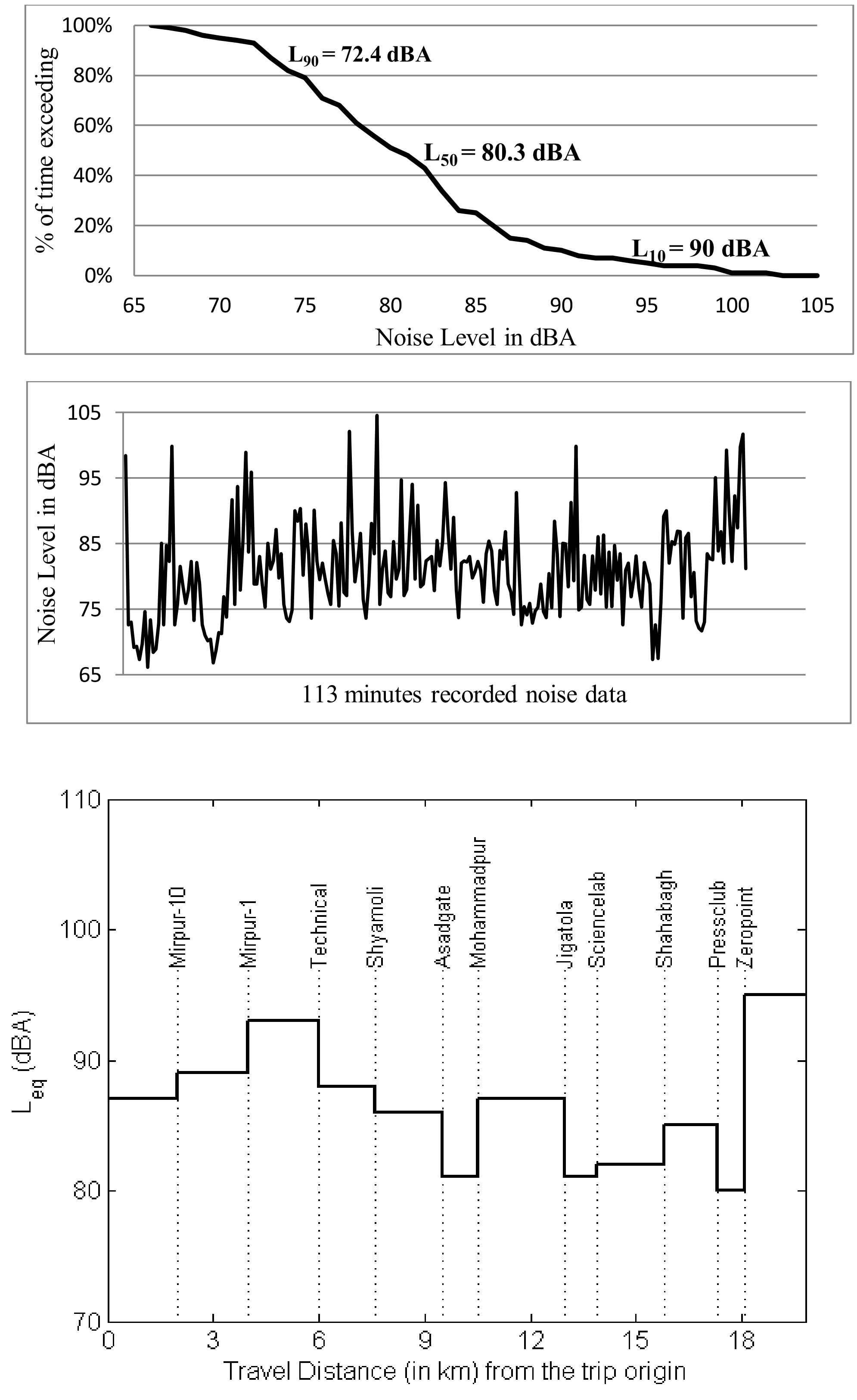


Figure A24: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Shatabdi Poribahan

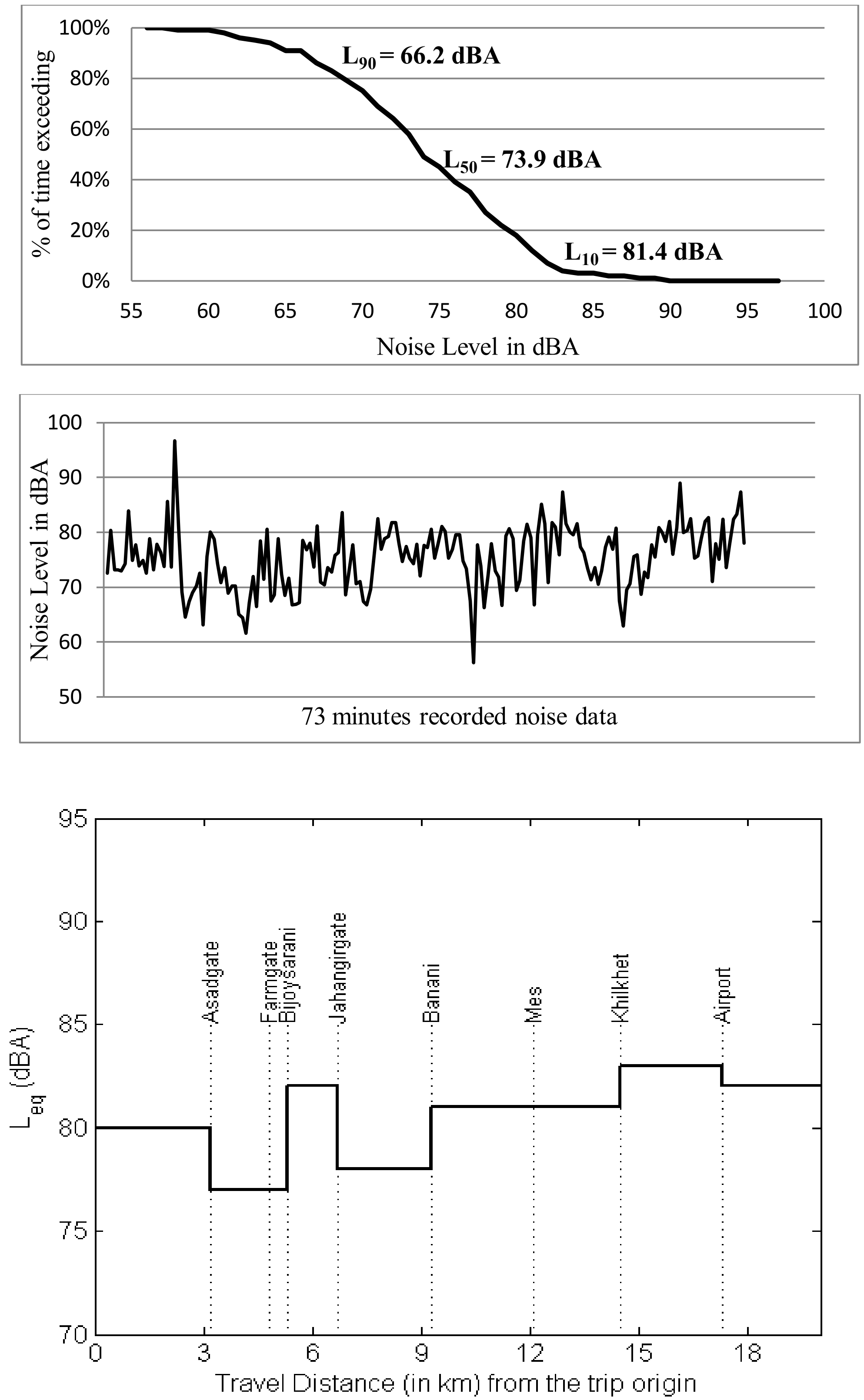
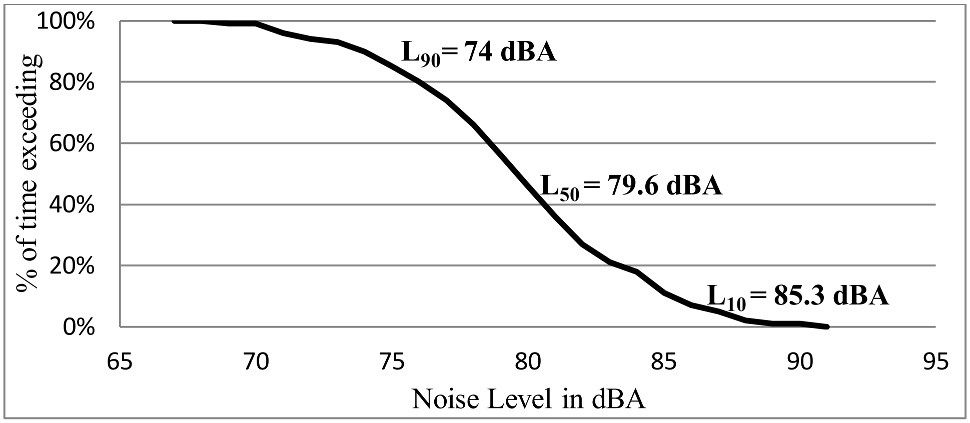
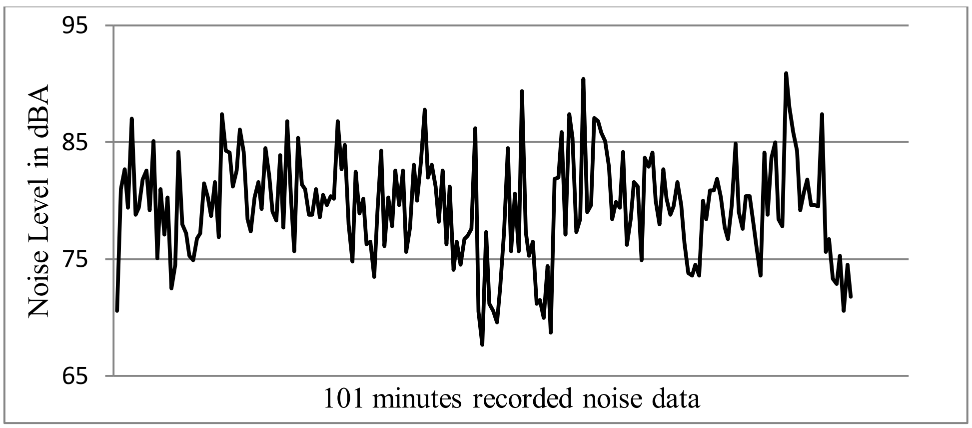


Figure A25: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Shuchona Poribahan





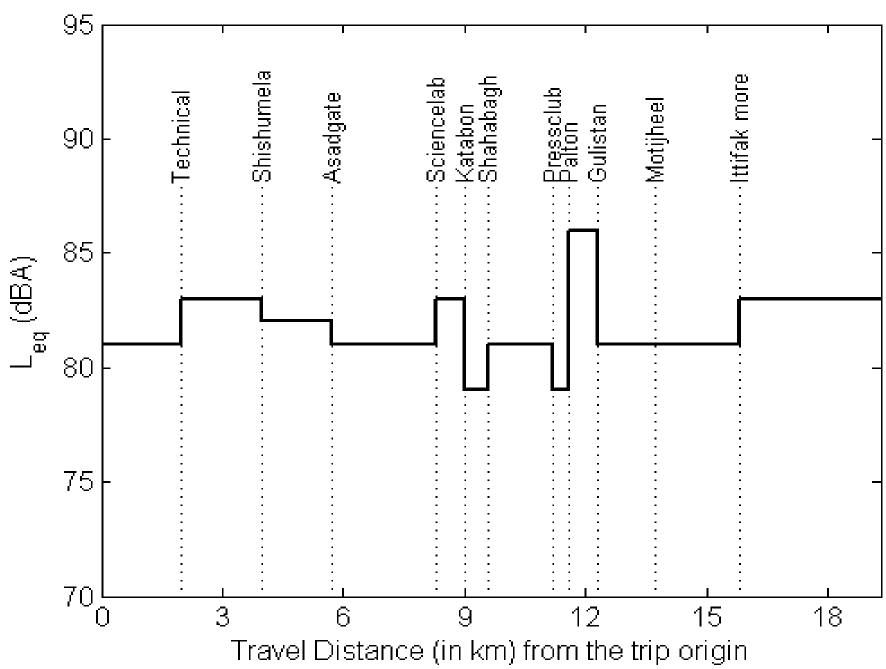


Figure A26: Cumulative Distribution (top), Noise profile (middle) and Stair graph (botton) for Transilba Poribahan

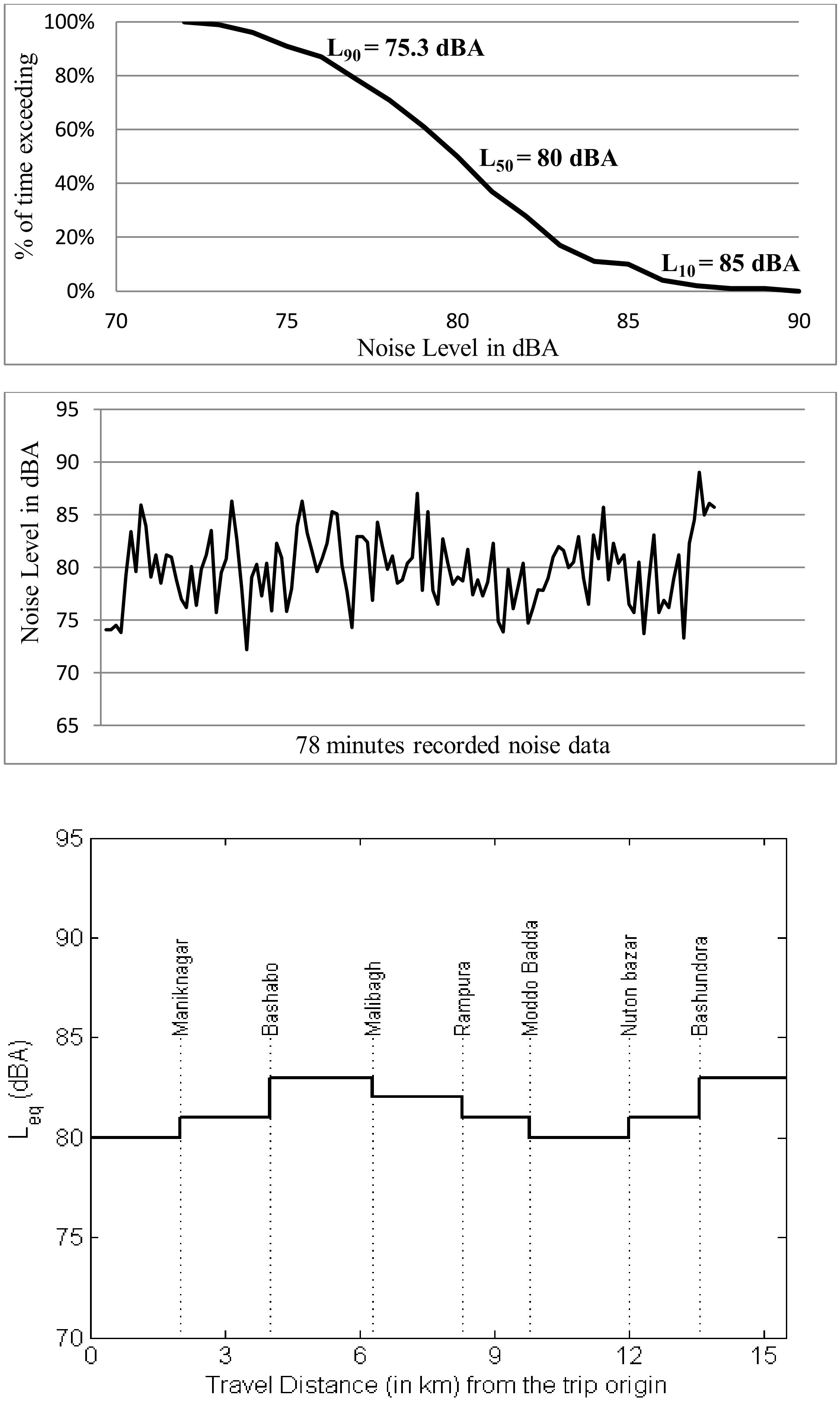
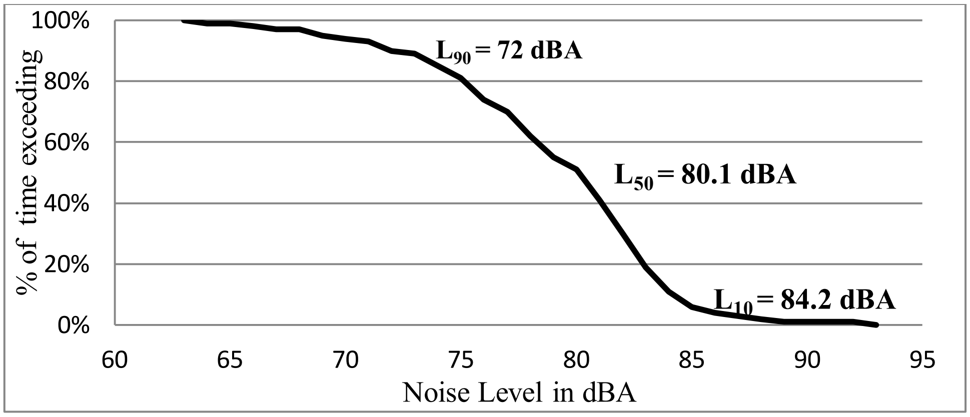
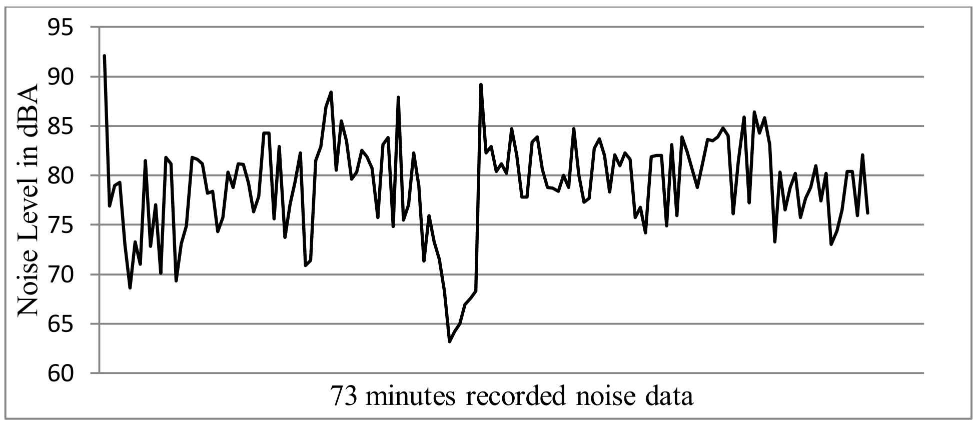


Figure A27: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Turagh Poribahan





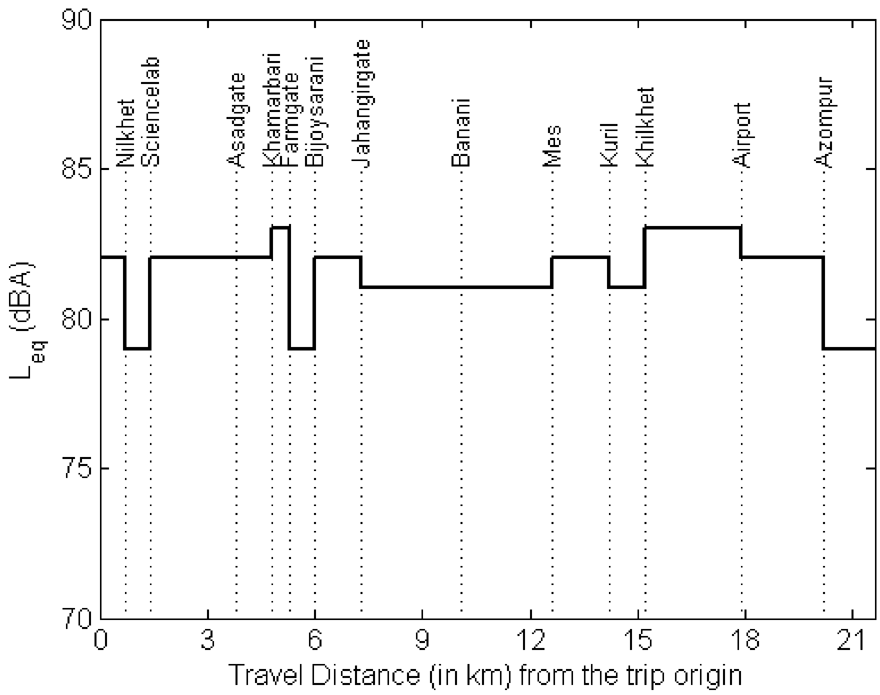


Figure A28: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for VIP Poribahan

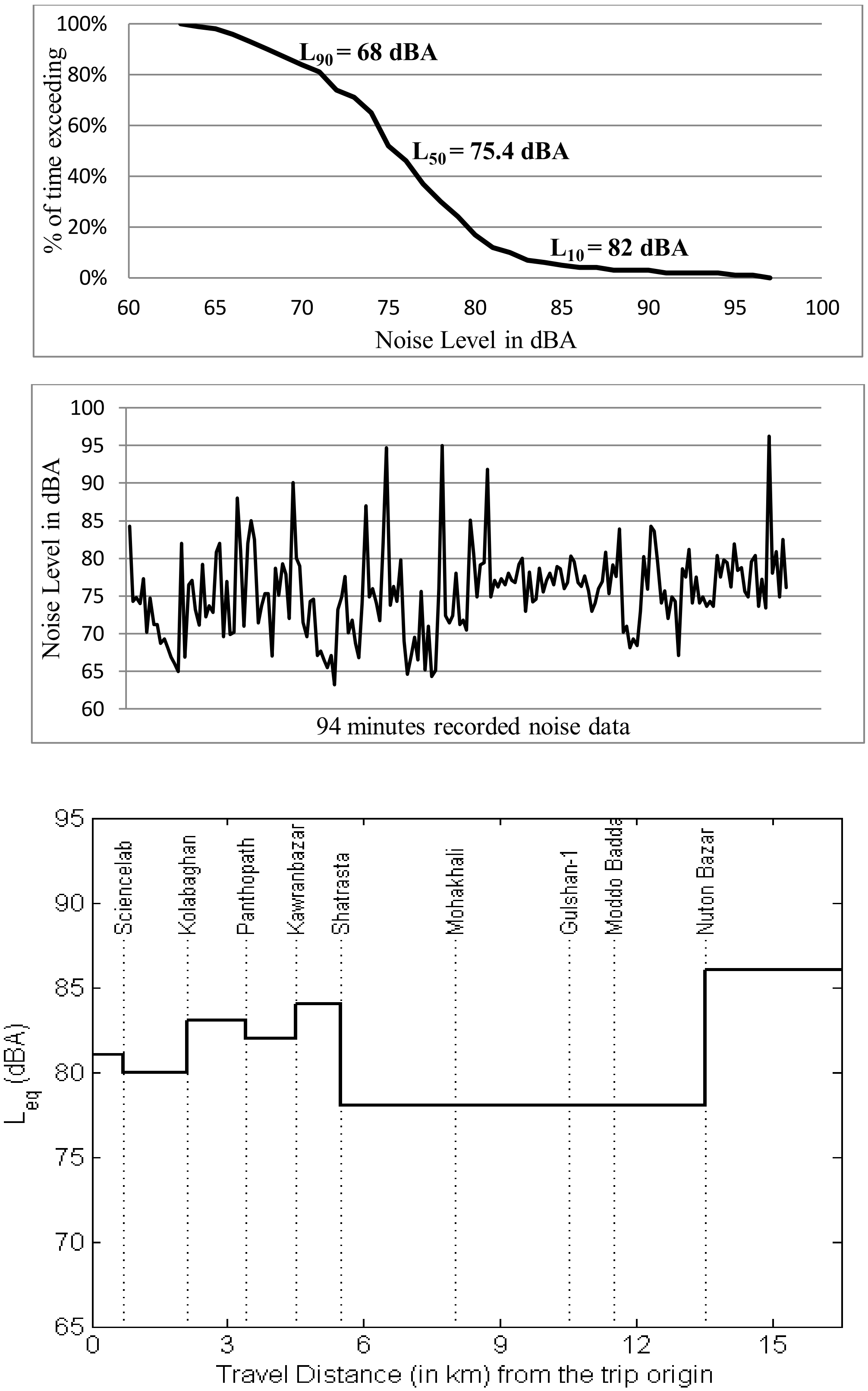


Figure A29: Cumulative Distribution (top), Noise profile (middle) and Stair graph (bottom) for Winner Poribahan

APPENDIX B

Table B1: Noise Level Meter Recorded Data

Bus Company	Bus Route	Record startingTime-Date	Minimum Noise level in dBA	Maximun Noise Level in dBA	Average Noise Level in dBA
3 no local bus	Abdullapur to Gulistan	10:23 Am-23.04.14	69.8	92	78.5
7 no local bus	Gabtoli to Sadarghat	11:47 Am-17.04.14	69.3	91.5	79.3
Ashirbad	Azimpur to Mirpur-1	10:23 Am-11.03.14	71.8	95.8	79.6
Azmiri glori	Sadarghat to Abdullapur	01:33 Am-17.04.14	61	89.6	73.1
Bangole Motors	Housebuilding to Kollanpur	09:52 Am-24.4.14	64.2	93.7	77.1
Bikolpo	Azimpur to Mirpur-12	11:56 Am-16.04.14	60.1	89	74.6
BRTC	Mirpur-12 to Motijheel	01:51 Pm-16.04.14	69	111	78.1
BRTC AC	Motijheel to Abdullapur	03:56 Pm-16.04.14	68.2	95.2	73.6
BRTC Double Decker	Abdullapur to Gabtoli	10:01 Am-17.04.14	70.6	94.7	79.2
Dipon Transport	Motijheel to Mohammadpur	01:10 Pm-11.03.14	74.9	106.4	83.1
Dishari Poribahan	Mirpur-1 to Gulistan	11:58 Am-24.04.14	66	96	78.3
Falgoan	Housebuilding to Azimpur	06:01 Pm-22.02.14	69	109	78.5
Jatrabari Poribahan	Housebuilding to Jatrabari	11:48 Am-09.04.14	70.8	88.8	79
Konok Poribahan	Abdullapur to Mirpur-1	09:30 Am-22.04.14	71.1	105.8	82
Midway	Taltola to Mohammadpur	05:24 Pm-10.03.14	72.2	99.9	81.4
Moitri Poribahan	Motijheel to Mohammadpur	02:05 Pm-26.04.14	68.7	88.8	77.2
New Dhaka Link	Azimpur to Mirpur-1	10:44 Am-26.04.14	66.3	89.3	78.2
New Vision	Mirpur-1 to Motijheel	11:24 Am-11.03.14	49.3	101.2	76.8
Nishorgo	Azimpur to Mirpur-14	12:07 Pm-19.04.14	65.4	95.2	79.9
Probati Bonosri	Gulistan to Abdullapur	01:39 Pm-24.04.14	59.4	97.2	74.1
Salsabil	Jatrabari to	12:42 Pm-	73	101.5	79.8

Bus Company	Bus Route	Record startingTime-Date	Minimum Noise level in dBA	Maximun Noise Level in dBA	Average Noise Level in dBA
	Abdullapur	22.04.14			
Shuprobat	Sadarghta to Abdullapur	05:49 Pm-23.04.14	70.2	93.3	79.1
Shotabdi poribahan	Mirpur-14 to Motijheel	12:02 Pm-26.04.14	66.1	104.6	80.9
Shuchona poribahan	Nilkhet to Abdullapur	05:38 Pm-09.03.14	56.2	96.7	75.3
Transilba	Mirpur-1 to Jatrabari	10:27 Am-22.04.14	67.7	90.9	79.5
Turagh	Jatrabari to Abdullapur	02:14 Pm-09.04.14	72.2	89	79.9
VIP	Azimpur to Abdullapur	11:35 Am-22.02.14	63	92	78.9
Winner	Nilkhet to Kuril	12:41 Pm-08.03.14	63	96	75.6
Cantonment mini service	Mirpur-14 to kakoli	02:07 Pm-19.04.14	68.7	93.7	76.9

Table B2: Data was collected by discussion with Driver & Helper (physical characteristics of the bus)

Bus Company	No. of bus	No of seat/bus	Bus age in years	Trips/ day	Maker	No of driver & Helper
3 no local bus	80	40	12	10	Hino	3
7 no local bus	70	37	12	10	Hino	3
Ashirbad	14	39	12	7	Hino	3
Azmiri glori	80	38	6	4	Hino	3
Bangole Motors	24	60	8	8	Tata	2
Bikolpo	160	42	6	10	Hino	2
BRTC	26	60	8	6	Chaina (Aedlus)	3
BRTC AC	28	51	2	6	DAEWOO	2
BRTC Double Decker	13	75	6	6	Asok-Leyland	4
Dipon Transport	30	52	12	8	Tata	3
Dishari Poribahan	48	43	8	8	Hino	2
Falgoan	46	60	12	6	Tata	4
Jatrabari Poribahan	20	30	8	3	Eicher	3
Konok Poribahan	17	59	10	10	Tata	2
Midway	18	60	8	6	Tata	3
Moitri Poribahan	35	56	6	12	Tata	3

Bus Company	No. of bus	No of seat/bus	Bus age in years	Trips/ day	Maker	No of driver & Helper
New Dhaka Link	17	35	8	12	Hino	2
New Vision	50	42	8	8	Hino	2
Nishorgo	18	57	9	7	Tata	3
Probati Bonosri	200	45	8	4	Tata	3
Salsabil	80	66	8	4	Tata	3
Shuprobat	300	35	8	8	Hino	2
Shotabdi poribahan	16	56	10	5	Tata	3
Shuchona poribahan	12	56	-		Tata	
Transilba	24	56	8	6	Tata	3
Turagh	500	40	10	6	Hino	2
VIP	75	32	10	6	Hino	3
Winner	42	50	6	4	Tata	3
Cantonment mini service	65	36	7	16	Hino	2

Table B3: Geometric features of the Routes

Bus Company	Geometric features of the Routes			
	Originate Point	End Point	No of Intersection	Route Length in km
3 no local bus	Abdullapur	Gulistan	9	21.4
7 no local bus	Gabtoli	Sadarghat	13	13.2
Ashirbad	Azimpur	Mirpur-1	7	9.7
Azmiri glori	Sadarghat	Abdullapur	12	21.5
Bangole Motors	Housebuilding	Kollanpur	5	19.4
Bikolpo	Azimpur	Mirpur-12	8	13.5
BRTC	Mirpur-12	Motijheel	10	15
BRTC AC	Motijheel	Abdullapur	10	22.6
BRTC Double Decker	Abdullapur	Gabtoli	8	20.3
Dipon Transport	Motijheel	Mohammadpur	6	8.8
Dishari Poribahan	Mirpur-1	Gulistan	10	12.3
Falgoan	Housebuilding	Azimpur	10	21.4
Jatrabari Poribahan	Housebuilding	Jatrabari	6	22.8
Konok Poribahan	Abdullapur	Mirpur-1	7	16.7
Midway	Taltola	Mohammadpur	8	15.3
Moitri Poribahan	Motijheel	Mohammadpur	8	8.8
New Dhaka Link	Azimpur	Mirpur-1	7	9.4
New Vision	Mirpur-1	Motijheel	9	13.3
Nishorgo	Azimpur	Mirpur-14	7	16
Probati Bonosri	Gulistan	Abdullapur	8	19.9
Salsabil	Jatrabari	Abdullapur	4	21.8
Shuprobat	Sadarghta	Abdullapur	5	20.9
Shotabdi poribahan	Mirpur-14	Motijheel	11	19.8
Shuchona poribahan	Nilkhet	Abdullapur	6	21

Bus Company	Geometric features of the Routes			
	Originate Point	End Point	No of Intersection	Route Length in km
Transilba	Mirpur-1	Jatrabari	13	20
Turagh	Jatrabari	Abdullapur	4	21.8
VIP	Azimpur	Abdullapur	6	21.6
Winner	Nilkhet	Kuril	7	16.5
Cantonment mini service	Mirpur-14	kakoli	2	2.6

Table B4: Trip characteristics data

Bus Company	Trip characteristics data						
	Trip Duration in minute	Max speed in km/hr	Moving overall velocity (km/hr)	Moving average velocity(km /hr)	Moving time in minute	Stopped time in minute	Trip Distance in km
3 no local bus	110	57.8	11.7	15.7	82	28	21.4
7 no local bus	102	51.6	7.8	13.2	60	42	13.2
Ashirbad	52	43.6	11.2	15.6	37	15	9.7
Azmiri glori	163	57.4	7.9	15.9	81	82	21.5
Bangole Motors	91	74	12.8	19.3	60	31	19.4
Bikolpo	91	42.8	8.8	13.4	60	31	13.5
BRTC	93	55.7	9.7	14.6	60	33	15
BRTC AC	75	82	18	22.8	58	17	22.6
BRTC Double Decker	76	35	16	19.7	62	14	20.3
Dipon Transport	47	40.4	11.3	15.1	35	12	8.8
Dishari Poribahan	52	48.3	14.1	20.5	36	16	12.3
Falgoan	118	68	10.8	14.6	88	30	21.4
Jatrabari Poribahan	107	69	12.8	15.9	86	21	22.8
Konok Poribahan	49	78.4	20.4	25.6	39	10	16.7
Midway	102	44.6	9	13.7	67	35	15.3
Moitri Poribahan	51	41.6	10.3	15.1	35	16	8.8
New Dhaka Link	36	48.7	15.6	19.5	29	7	9.4
New Vision	94	46.4	8.5	14.2	56	38	13.3
Nishorgo	87	44.5	11	13.9	69	18	16
Probati Bonosri	90	66.7	13.3	20	60	30	19.9
Salsabil	89	52.4	14.7	17.7	74	15	21.8
Shuprobat	95	47	13.2	17	74	21	20.9
Shotabdi poribahan	113	49.7	10.5	15.6	76	37	19.8

Bus Company	Trip characteristics data						
	Trip Duration in minute	**Max speed in km/hr**	**Moving overall velocity (km/hr)**	**Moving average velocity(km /hr)**	**Moving time in minute**	**Stopped time in minute**	**Trip Distance in km**
Shuchona poribahan	73	50	17.2	20.7	63	10	21
Transilba	101	43	11.9	14.5	83	18	20
Turagh	78	50	16.7	19.3	68	10	21.8
VIP	73	70	17.8	20.6	63	10	21.6
Winner	94	52	10.5	13.5	73	21	16.5
Cantonment mini service	17	36.6	9.2	14.4	11	6	2.6

Table B5: Equivalent Continuous Noise Level

1. 3 no local bus	L_{eq} in dBA	2. 7 no local bus	L_{eq} in dBA
Abdullapur to Gulistan	81.3 (overall)	Gabtoli to Sadarghat	81.3 (overall)
Selected Route segments	**Segmentwise**	**Slelected Route segments**	**Segmentwise**
Abdullapur-Azompur	83	Gabtoli-Technical	80
Azompur-Airport	81	Technical-Kollanpur	84
Airport-Khilkhet	82	Kollanpur-Shishumela	80
Khilkhet-Mes	82	Shishumela-Asadgate	81
Mes-Banani	79	Asadgate-Kolabaghan	82
Banani-Jahangirgate	84	Kolabaghan-Sciencelan	80
Jahangirgate-Bijoysarani	80	Sciencelab-katabon	83
Bijoysarani-Farmgate	81	Katabon-Shahabagh	79
Farmgate-Kawranbazar	82	Shahabagh-Pressclub	82
Kawranbazar-Sahabagh	82	Pressclub-Gulistanmajar	80
Sahabagh-Pressclub	82	Gulistanmajar-Sadarghat	83
Pressclub-Gulistan	82		

3. Ashirbad	L_{eq} in dBA	4. Azmiriglori	L_{eq} in dBA
Azimpur to Mirpur-1	**83.7 (overall)**	**Sadarghat to Khilkhet**	**77.3 (overall)**
Selected Route Segments	**Segmentwise**	**Slelected Route segments**	**Segmentwise**
Azimpur-nilkhet	77	Sadarghat-Bongshal	77
Nilkhet-Sciencelab	80	Bongshal-Gulistan	80
Sciencelab-Asadgate	82	Gulistan-Kakrail	80
Asadgate-Shishumela	89	Kakrail-Mowchak	80
Shishumela-Technical	86	Mowchak-Moghbazar	73
Tachnical-Mirpur-1	84	Moghbazar-Shatrasta	78
		Shatrasta-Nabisco	82
		Nabisco-Mohakhali	77
		Mohakhali-Banani	80
		Banani-Mes	79
		Mes-Khilkhet	81

5. Bangole Motors	L_{eq} in dBA	6. Bikolpo	L_{eq} in dBA
Housebuilding to Kollanpur	**81(overall)**	**Azimpur to Mirpur-12**	**78.4 (overall)**
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Housebuilding-Airport	84	Azimpur-Nilkhet	77
Airport-Kuril	84	Nilkhet-Sciencelab	76
Kuril-Banani	77	Sciencelab-Asadgate	80
Banani-Jahangirgat	80	Asadgate-Khamarbari	73
Jahangirgate-Agargaon	79	Khamarbari-Bijoysarani	78
Agargaon-Shishumela	82	Bijoysarani-Agargaon	79
Shishumela-Kollanpur	84	Agargaon-Mirpur-10	81
		Mirpur-10-Mirpur-11	80
		Mirpur-11-Mirpur-12	81

7. BRTC AC	L_{eq} in dBA	8. BRTC double decker	L_{eq} in dBA
Motijheel to Abdullapur	**77.6 (overall)**	**Abdullapur to Gabtoli**	**81.8 (overall)**
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Motijheel-Gulistan	81	Abdullapur-Airport	79
Gulistan-Pressclub	77	Airport-Khilkhet	83
Pressclub-Shahabagh	76	Khilkhet-Mes	84
Shahabagh-Kawranbazar	72	Mes-ECB chottor	78
Kawranbazar-Farmgate	74	ECB chottor-Kalshi	79
Farmgate-Bijoysarani	76	Kalshi-Pallobi	78
Bijoysarani-Mohakhali	75	Pallobi-Mirpur-10	80
Mohakhali-Banani	72	Mirpur-10-Mirpur-1	82
Banani-Mes	74	Mirpur-1-Technical	86
Mes-Khilkhet	77	Technical-Gabtoli	82
Khilkhet-Airport	75		
Airport-Azompur	77		
Azompur-Abdullapur	80		

9. BRTC	L_{eq} in dBA	10. Dipon Poribahan	L_{eq} in dBA
Mirpur-12 to Motijheel	89 (overall)	Motijheel to Mohammadpur	90.4 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Mirpur-12-Mirpur-11	79	Motijheel-Pressclub	83
Mirpur-11-Mirpur-10	100	Pressclub-Shahabagh	96
Mirpur-10-Sawrapara	80	Shahabagh-Katabon	88
Sawrapara-Agargaon	82	Katabon-Sciencelab	91
Agargaon-Bijoysarani	81	Sciencelab-Jigatola	81
Bijoysarani-Farmgate	91	Jigatola-Mohammadpur	87
Farmgate-Kawranbazar	78		
Kawranbazar-Shahabagh	81		
Shahabagh-Pressclub	79		
Pressclub-Zeropoint	80		
Zeropoint-Motijheel	81		

11. Dishari Poribahan	**L_{eq} in dBA**	**12. Falgoan**	**L_{eq} in dBA**
Mirpur-1 to Gulistan	82.5 (overall)	Housebuilding to Azimpur	86.9 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Mirpur-1-Technical	80	Housebuilding-Airport	86
Technical-Shyamoli	86	Airport-Khilkhet	86
Shyamoli-Asadgate	83	Khilkhet-Bashundara	84
Asadgate-Farmgate	83	Bashundara-Nutonbazar	78
Farmgate-Kawranbazar	88	Nutonbazar-Uttar badda	79
Kawranbazar-Shahabagh	82	Uttar badda-Moddo badda	86
Shahabagh-Pressclub	77	Moddo badda-Rampura	81
Pressclub-Gulistan	84	Rampura-Malibagh	85
		Malibagh-Mowchak	77
		Mowchak-Shantinagar	77
		Shantinagar-Kakrail	98
		Kakrail-Shahabagh	82
		Shahabagh-Sciencelab	77
		Sciencelab-Azimpur	78

13. Jatrabari Poribahan	**L_{eq} in dBA**	**14. Konok**	**L_{eq} in dBA**
Housebuilding to Jatrabari	80.8 (overall)	Abdullapur to Mirpur-1	88.3 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Housebuilding-Airport	83	Abdullapur-Azompur	95
Airport-Khilkhet	86	Azompur-Airport	86
Khilkhet-Banani	82	Airport-Khilkhet	89
Banani-Mohakhali	81	Khilkhet-ECB chottor	84
Mohakhali-Shatrasta	81	ECB chottor-Kalshi	83
Shatrasta-Moghbazar	78	Kalshi-Pallobi	82
Moghbazar-Mowchak	78	Pallobi-Mirpur-10	82
Mowchak-Razarbagh	78	Mirpur-10-Mirpur-1	84
Razarbagh-Jatrabari	80		

15. Midway	**L_{eq} in dBA**	**16. Moitri Poribahan**	**L_{eq} in dBA**
Taltola to Mohammadpur	83.6 (overall)	Motijheel to Mohammadpur	78.9 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Taltola-Komolapur	82	Motijheel-Bonghabhaban	77
Komolapur-Arambagh	83	Bonghabhaban-Zeropoint	80
Arambagh-Motijheel	82	Zeropoint-Pressclub	80
Motijheel-Palton	82	Pressclub-Shahabagh	80
Palton-Pressclub	82	Shahabagh-Katabon	76
Pressclub-Shahabagh	88	Katabon-Sciencelab	77
Shahabagh-Katabon	84	Sciencelab-Jigatola	81
Katabon-Sciencelab	83	Jigatola-Mohammadpur	87
Sciencelab-Jigatola	81		
Jigatola-Mohammadpur	87		

17. New Dhaka link	L_{eq} in dBA	18. New Vision	L_{eq} in dBA
Azimpur to Mirpur-1	80.6 (overall)	Mirpur-1 to Motijheel	83 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Azimpur-Nilkhet	80	Mirpur-1-Technical	84
Nilkhet-Kollabaghan	81	Technical-Shyamoli	84
Kollabaghan-Asadgate	82	Shyamoli-Asadgate	86
Asadgate-Shyamoli	79	Asadgate-Farmgate	76
Shyamoli-Technical	79	Farmgate-Kawranbazar	82
Technical-Mirpur-1	81	Kawranbazar-Shahabagh	82
		Shahabagh-Pressclub	92
		Pressclub-Palton	79
		Palton-motijheel	83

19. Nishorgo	L_{eq} in dBA	20. Probati Bonosri	L_{eq} in dBA
Azimpur to Mirpur-14	83.6 (overall)	Gulistan to Abdullapur	80.6 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Azimpur-Nilkhet	77	Gulistan-Zeropoint	79
Nilkhet-Sciencelab	88	Zeropoint-Bijoynagar	82
Sciencelab-Mohammadpur	84	Bijoynagar-Shantinagar	88
Mohammadpur-Asadgate	79	Shantinagar-Moghbazar	73
Asadgate-Shishumela	84	Moghbazar-Shatrasta	75
Shishumela-Agargaon	84	Shatrasta-Mohakhali	78
Agargaon-Kazipara	86	Mohakhali-Banani	84
Kazipara-Mirpur-10	87	Banani-Khilkhet	79
Mirpur-10-Mirpur-14	81	Khilkhet-Airport	83
		Airport-Abdullapur	82

21. Salsabil	L_{eq} in dBA	22. Shotabdi Poribahan	L_{eq} in dBA
Jatrabari to Abdullapur	83.8 (overall)	Mirpur-14 to Motijheel	88.8 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Jatrabari-Mughda	82	Mirpur-14- Mirpur-10	87
Mughda-Bashabo	78	Mirpur-10-mirpur-1	89
Bashabo-Malibagh	81	Mirpur-1-Technical	93
Malibagh-Rampura	84	Technical-Shyamoli	88
Rampura-Moddo badda	80	Shyamoli-Asadgate	86
Moddo badda-Nutonbazar	82	Asadgate-Mohammadpur	81
Nutonbazar-Bashundara	91	Mohammadpur-Jigatola	87
Bashundara-Khilkhet	81	Jigatola-Sciencelab	81
Khilkhet-Airport	83	Sciencelab-Shahabagh	82
Airport-Abdullapur	82	Shahabagh-Pressclub	85
		Pressclub-Zeropoint	80
		Zeropoint-Motijheel	95

23. Shoprobat	L_{eq} in dBA	24. Shochona	L_{eq} in dBA
Sadarghat to Abdullapur	81.7 (overall)	Nilkhet to Abdullapur	79.6 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Sadarghat-Gulistan	81	Nilkhet-Asadgate	80
Gulistan-Bijoynagar	81	Asadgate-Farmgate	77

Bijoynagar-Shantinagar	82	Farmgate-Bijoysarani	77
Shantinagar-Malibagh	80	Bijoysarani-Jahangirgate	82
Malibagh-Rampura	81	Jahangirgate-Banani	78
Rampura-Moddo badda	82	Bananai-Mes	81
Moddo badda-Nutonbazar	84	Mes-Khilkhet	81
Nutonbazar-Bashundara	82	Khilkhet-Airport	83
Bashundara-Khilkhet	83	Airport-Abdullapur	82
Khilkhet-Airport	83		
Airport-Abdullapur	82		

25. Transilba	**L_{eq} in dBA**	**26. Turagh Poribahan**	**L_{eq} in dBA**
Mirpur-1 to Jatrabari	81.7 (overall)	Jatrabari to Abdullapur	81.2 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Mirpur-1-Technical	81	Jatrabari-Maniknagar	80
Technical-Shishumela	83	Maniknagar-Bashabo	81
Shishumela-Asadgate	82	Bashabo-Malibagh	83
Asadgate-Sciencelab	81	Malibagh-Rampura	82
Sciencelab-katabon	83	Rampura-Moddo badda	81
Katabon-Shahabagh	79	Moddo badda-Nutonbazar	80
Shahabagh-Pressclub	81	Nutonbazar-Bashundara	81
Pressclub-Palton	79	Bashundara-Khilkhet	83
Palton-Gulistan	86	Khilkhet-Airport	83
Gulistan-Motijheel	81	Airport-Abdullapur	82
Motijheel-Ittifakmor	81		
Ittifakmor-Jatrabari	83		

27. VIP	**L_{eq} in dBA**	**28. Winner**	**L_{eq} in dBA**
Azimpur to Abdullapur	81.3 (overall)	Nilkhet to Kuril	81 (overall)
Selected Route Segments	**Segmentwise**	**Selected Route Segments**	**Segmentwise**
Azimpur-Nilkhet	82	Nilkhet-Sciencelab	81
Nilkhet-Sciencelab	79	Sciencelab-Kolabaghan	80
Sciencelab-Asadgate	82	Kolabaghan-Panthopath	83
Asadgate-Khamarbari	82	Panthopath-Kawranbazar	82
Khamarbari-Farmgate	83	Kawranbazar-Shatrasta	84
Farmgate-Bijoysarani	79	Shatrasta-Mohakhali	78
Bijoysarani-Jahangirgate	82	Mohakhali-Gulsion-1	78
Jahangirgate-Banani	81	Gulsion-1-Moddobadda	78
Banani-Mes	82	Moddobadda-Nutonbazar	78
Mes-kuril	81	Nutonbazar-Kuril	86
Kuril-Khikhet	83		
Khilkhet-Airport	82		
Airport-Abdullapur	79		
29. Cantonment mini service		**L_{eq} in dBA**	
Mirpur-14 to Kakoli		81.3 (overall)	
Selected Route Segments		**Segmentwise**	
Mirpur-14-Shadinota chottor		81.4	
Shadinota chottor-Shoinic club		78.3	
Shoinic club-Kakoli		83.6	

Table B6: Distance and velocity of bus for selected Route segments

1. 3 no local bus	Distance (km)	Velocity (km/hr)	2. 7 no local bus	Distance (km)	Velocity (km/hr)
Abdullapur to Gulistan	21.4	11.7	Gabtoli to Sadarghat	13.15	7.8
Selected Route segments	**Segmentwise**		**Slelected Route segments**	**Segmentwise**	
Abdullapur-Azompur	0.45	3.75	Gabtoli-Technical	1.0	6.7
Azompur-Airport	2.25	15.53	Technical-Kollanpur	1.1	15.2
Airport-Khilkhet	3.25	28	Kollanpur-Shishumela	0.75	6.4
Khilkhet-Mes	4.75	21.4	Shishumela-Asadgate	1.7	13.5
Mes-Banani	2.8	6.3	Asadgate-Kolabaghan	1.4	13
Banani-Jahangirgate	2.1	19.3	Kolabaghan-Sciencelan	1.1	11
Jahangirgate-Bijoysarani	1.3	4.73	Sciencelab-katabon	0.7	10.6
Bijoysarani-Farmgate	0.8	8.7	Katabon-Shahabagh	0.5	5
Farmgate-Kawranbazar	1.0	8.8	Shahabagh-Pressclub	1.6	13.5
Kawranbazar-Sahabagh	1.3	7.8	Pressclub-Gulistanmajar	0.9	4.1
Sahabagh-Pressclub	1.6	16	Gulistanmajar-Sadarghat	2.0	11.4
Pressclub-Gulistan	1.4	9.3			

3. Ashirbad	Distance (km)	Velocity (km/hr)	4. Azmiriglori	Distance (km)	Velocity (km/hr)
Azimpur to Mirpur-1	9.65	11.2	Sadarghat to Khilkhet	16	**7.9**
Selected Route Segments	**Segmentwise**		**Slelected Route segments**	**Segmentwise**	
Azimpur-nilkhet	0.65	3.5	Sadarghat-Bongshal	0.8	2.6
Nilkhet-Sciencelab	0.75	10	Bongshal-Gulistan	1.0	6.7
Sciencelab-Asadgate	2.5	8.6	Gulistan-Kakrail	1.4	5.1
Asadgate-Shishumela	1.8	18	Kakrail-Mowchak	1.1	14.7
Shishumela-Technical	1.0	22.8	Mowchak-Moghbazar	1.2	0.94
Tachnical-Mirpur-1	1.1	15.7	Moghbazar-Shatrasta	1.0	8.5
			Shatrasta-Nabisco	1.6	27.5
			Nabisco-Mohakhali	0.9	9.0
			Mohakhali-Banani	1.7	15.7
			Banani-Mes	2.7	23
			Mes-Khilkhet	2.6	28.2

5. Bangole Motors	Distance (km)	Velocity (km/hr)	6. Bikolpo	Distance (km)	Velocity (km/hr)
Housebuilding to Kollanpur	19	12.8	Azimpur to Mirpur-12	13.5	**8.8**
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Housebuilding-Airport	2.5	10	Azimpur-Nilkhet	0.7	3.6
Airport-Kuril	3.5	24.4	Nilkhet-Sciencelab	0.8	7.4
Kuril-Banani	4.0	9.1	Sciencelab-Asadgate	2.5	12
Banani-Jahangirgat	2.6	10.4	Asadgate-Khamarbari	1.3	3.6
Jahangirgate-Agargaon	3.1	14.1	Khamarbari-Bijoysarani	0.7	3.4

Agargaon-Shishumela	1.4	13	Bijoysarani-Agargaon	1.4	16.8
Shishumela-Kollanpur	1.5	16.3	Agargaon-Mirpur-10	3.6	21.7
			Mirpur-10-Mirpur-11	1.0	8.6
			Mirpur-11-Mirpur-12	1.5	18

7. BRTC AC	Distance (km)	Velocity (km/hr)	8. BRTC double decker	Distance (km)	Velocity (km/hr)
Motijheel to Abdullapur	22.6	18	Abdullapur to Gabtoli	20.3	16
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Motijheel-Gulistan	1.0	4.3	Abdullapur-Airport	3.8	12.7
Gulistan-Pressclub	1.3	7.4	Airport-Khilkhet	2.8	26.8
Pressclub-Shahabagh	2.0	18.5	Khilkhet-Mes	2.3	20.7
Shahabagh-Kawranbazar	1.0	17.2	Mes-ECB chottor	1.8	25.3
Kawranbazar-Farmgate	1.0	17.2	ECB chottor-Kalshi	1.8	27
Farmgate-Bijoysarani	0.8	13.8	Kalshi-Pallobi	1.4	13
Bijoysarani-Mohakhali	1.2	16	Pallobi-Mirpur-10	1.5	12
Mohakhali-Banani	2.7	13	Mirpur-10-Mirpur-1	1.7	8.2
Banani-Mes	2.7	41	Mirpur-1-Technical	2.2	16.5
Mes-Khilkhet	2.3	30.6	Technical-Gabtoli	0.9	21.6
Khilkhet-Airport	2.8	42.4			
Airport-Azompur	2.2	24			
Azompur-Abdullapur	0.6	13.8			

9. BRTC	Distance (km)	Velocity (km/hr)	10. Dipon Poribahan	Distance (km)	Velocity (km/hr)
Mirpur-12 to Motijheel	15	9.7	Motijheel to Mohammadpur	7.4	11.3
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Mirpur-12-Mirpur-11	1.2	5.7	Motijheel-Pressclub	1.8	5.8
Mirpur-11-Mirpur-10	1.2	10.3	Pressclub-Shahabagh	0.7	7
Mirpur-10-Sawrapara	1.6	9.1	Shahabagh-Katabon	0.5	8.6
Sawrapara-Agargaon	2.0	20	Katabon-Sciencelab	1.0	11
Agargaon-Bijoysarani	2.0	11.4	Sciencelab-Jigatola	0.9	9.8
Bijoysarani-Farmgate	0.7	9.3	Jigatola-Mohammadpur	2.5	8.8
Farmgate-Kawranbazar	1.0	5.2			
Kawranbazar-Shahabagh	1.3	7.1			
Shahabagh-Pressclub	1.8	24			
Pressclub-Zeropoint	0.8	6.9			
Zeropoint-Motijheel	1.4	8			

11. Dishari Poribahan	Distance (km)	Velocity (km/hr)	12. Falgoan	Distance (km)	Velocity (km/hr)
Mirpur-1 to Gulistan	12.3	14.1	Housebuilding to Azimpur	21.4	10.8
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Mirpur-1-Technical	1.9	14.1	Housebuilding-Airport	2.5	18
Technical-Shyamoli	1.6	24.3	Airport-Khilkhet	2.8	38.6
Shyamoli-Asadgate	2.1	28	Khilkhet-Bashundara	2.0	18.5
Asadgate-Farmgate	1.7	22.6	Bashundara-Nutonbazar	1.8	10.8
Farmgate-Kawranbazar	0.9	12	Nutonbazar-Uttar badda	1.4	14

Kawranbazar-Shahabagh	1.3	17.3	Uttar badda-Moddo badda	1.0	7.0
Shahabagh-Pressclub	1.6	5.3	Moddo badda-Rampura	1.1	10.2
Pressclub-Gulistan	1.2	10.3	Rampura-Malibagh	2.3	12
			Malibagh-Mowchak	0.5	5.0
			Mowchak-Shantinagar	0.8	4.2
			Shantinagar-Kakrail	0.6	6.0
			Kakrail-Shahabagh	2.0	12.6
			Shahabagh-Sciencelab	1.3	5.6
			Sciencelab-Azimpur	1.3	7.4

13. Jatrabari Poribahan	**Distance (km)**	**Velocity (km/hr)**	**14. Konok**	**Distance (km)**	**Velocity (km/hr)**
Housebuilding to Jatrabari	22.8	12.8	Abdullapur to Mirpur-1	16.7	20.4
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Housebuilding-Airport	2.5	18.6	Abdullapur-Azompur	1.3	13
Airport-Khilkhet	2.8	26	Azompur-Airport	2.2	16.5
Khilkhet-Banani	4.6	24	Airport-Khilkhet	2.8	30.5
Banani-Mohakhali	2.1	7.0	Khilkhet-ECB chottor	4.1	38
Mohakhali-Shatrasta	2.5	15	ECB chottor-Kalshi	1.8	27.3
Shatrasta-Moghbazar	1.2	3.4	Kalshi-Pallobi	1.4	21
Moghbazar-Mowchak	1.1	8.8	Pallobi-Mirpur-10	1.5	9.3
Mowchak-Razarbagh	1.1	7.3	Mirpur-10-Mirpur-1	1.7	15.7
Razarbagh-Jatrabari	4.3	26			

15. Midway	**Distance (km)**	**Velocity (km/hr)**	**16. Moitri Poribahan**	**Distance (km)**	**Velocity (km/hr)**
Taltola to Mohammadpur	15.3	9.0	Motijheel to Mohammadpur	10.3	8.5
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Taltola-Komolapur	4.1	9.6	Motijheel-Bonghabhaban	1.0	8.0
Komolapur-Arambagh	2.3	9.7	Bonghabhaban-Zeropoint	0.7	3.0
Arambagh-Motijheel	0.6	3.5	Zeropoint-Pressclub	0.7	10.5
Motijheel-Palton	1.5	9.5	Pressclub-Shahabagh	1.6	19.2
Palton-Pressclub	0.6	4.0	Shahabagh-Katabon	0.5	10
Pressclub-Shahabagh	1.5	7.5	Katabon-Sciencelab	0.9	18
Shahabagh-Katabon	0.6	3.7	Sciencelab-Jigatola	0.9	9.8
Katabon-Sciencelab	0.7	6.5	Jigatola-Mohammadpur	2.5	8.8
Sciencelab-Jigatola	0.9	9.8			
Jigatola-Mohammadpur	2.5	8.8			

17. New Dhaka link	**Distance (km)**	**Velocity (km/hr)**	**18. New Vision**	**Distance (km)**	**Velocity (km/hr)**
Azimpur to Mirpur-1	9.4	15.6	Mirpur-1 to Motijheel	13.3	8.5
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Azimpur-Nilkhet	0.6	4.0	Mirpur-1-Technical	2.0	7.3
Nilkhet-Kollabaghan	1.9	16.4	Technical-Shyamoli	1.6	21.3
Kollabaghan-Asadgate	1.3	14.2	Shyamoli-Asadgate	2.0	20
Asadgate-Shyamoli	2.1	18	Asadgate-Farmgate	1.7	3.0

Shyamoli-Technical	1.6	21.3	Farmgate-Kawranbazar	1.2	7.6
Technical-Mirpur-1	1.9	23	Kawranbazar-Shahabagh	1.4	21.2
			Shahabagh-Pressclub	1.6	19.3
			Pressclub-Palton	0,6	3.8
			Palton-motijheel	1.2	9.6

19. Nishorgo	**Distance (km)**	**Velocity (km/hr)**	**20. Probati Bonosri**	**Distance (km)**	**Velocity (km/hr)**
Azimpur to Mirpur-14	16	11	Gulistan to Abdullapur	21.4	13.3
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Azimpur-Nilkhet	0.6	3.3	Gulistan-Zeropoint	0.5	2.7
Nilkhet-Sciencelab	0.8	9.6	Zeropoint-Bijoynagar	1.0	6.0
Sciencelab-Mohammadpur	3.4	9.7	Bijoynagar-Shantinagar	0.8	10.6
Mohammadpur-Asadgate	1.3	6.5	Shantinagar-Moghbazar	1.7	5.8
Asadgate-Shishumela	1.5	16.4	Moghbazar-Shatrasta	2.4	7.5
Shishumela-Agargaon	2.5	14.3	Shatrasta-Mohakhali	2.0	9.0
Agargaon-Kazipara	2.4	18	Mohakhali-Banani	2.5	16
Kazipara-Mirpur-10	1.2	16	Banani-Khilkhet	4.5	46
Mirpur-10-Mirpur-14	2.3	13.1	Khilkhet-Airport	2.8	41
			Airport-Abdullapur	2.7	18

21. Salsabil	**Distance (km)**	**Velocity (km/hr)**	**22. Shotabdi Poribahan**	**Distance (km)**	**Velocity (km/hr)**
Jatrabari to Abdullapur	21.8	14.7	Mirpur-14 to Motijheel	19.8	13.2
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Jatrabari-Mughda	2.8	9.5	Mirpur-14- Mirpur-10	2.0	6.0
Mughda-Bashabo	1.2	13	Mirpur-10-mirpur-1	2.0	8.0
Bashabo-Malibagh	2.2	17	Mirpur-1-Technical	2.0	8.9
Malibagh-Rampura	2.0	16.5	Technical-Shyamoli	1.6	14.7
Rampura-Moddo badda	1.3	14.4	Shyamoli-Asadgate	1.9	16.3
Moddo badda-Nutonbazar	2.2	9.8	Asadgate-Mohammadpur	1.0	13.3
Nutonbazar-Bashundara	1.7	14.4	Mohammadpur-Jigatola	2.5	8.8
Bashundara-Khilkhet	2.8	27.8	Jigatola-Sciencelab	0.9	9.8
Khilkhet-Airport	2.8	42	Sciencelab-Shahabagh	1.9	10
Airport-Abdullapur	2.7	17	Shahabagh-Pressclub	1.5	22.5
			Pressclub-Zeropoint	0.8	12
			Zeropoint-Motijheel	1.7	17

23. Shoprobat	**Distance (km)**	**Velocity (km/hr)**	**24. Shochona**	**Distance (km)**	**Velocity (km/hr)**
Sadarghat to Abdullapur	21	10.5	Nilkhet to Abdullapur	21	17.2
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Sadarghat-Gulistan	2.0	8.0	Nilkhet-Asadgate	3.2	4.2
Gulistan-Bijoynagar	1.5	5.3	Asadgate-Farmgate	1.6	11.3
Bijoynagar-Shantinagar	0.7	8.4	Farmgate-Bijoysarani	0.5	6.0
Shantinagar-Malibagh	1.1	11	Bijoysarani-Jahangirgate	1.4	15.3
Malibagh-Rampura	2.4	6.7	Jahangirgate-Banani	1.6	17.3
Rampura-Moddo badda	1.3	9.7	Bananai-Mes	2.7	18.7

Moddo badda-Nutonbazar	2.2	12.6	Mes-Khilkhet	2.3	19.2
Nutonbazar-Bashundara	1.7	15.7	Khilkhet-Airport	2.8	45
Bashundara-Khilkhet	2.8	21.4	Airport-Abdullapur	2.7	19
Khilkhet-Airport	2.8	42			
Airport-Abdullapur	2.7	16			

25. Transilba	**Distance (km)**	**Velocity (km/hr)**	**26. Turagh Poribahan**	**Distance (km)**	**Velocity (km/hr)**
Mirpur-1 to Jatrabari	19.3	11.9	Jatrabari to Abdullapur	21.8	16.7
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Mirpur-1-Technical	2.0	9.6	Jatrabari-Maniknagar	2.0	10.4
Technical-Shishumela	2.0	18.4	Maniknagar-Bashabo	2.0	18.4
Shishumela-Asadgate	1.7	14.5	Bashabo-Malibagh	2.2	21.1
Asadgate-Sciencelab	2.6	11.5	Malibagh-Rampura	2.0	16
Sciencelab-katabon	0.7	9.3	Rampura-Moddo badda	1.3	18
Katabon-Shahabagh	0.6	8.0	Moddo badda-Nutonbazar	2.2	12.5
Shahabagh-Pressclub	1.6	12	Nutonbazar-Bashundara	1.7	19.2
Pressclub-Palton	0.4	4.0	Bashundara-Khilkhet	2.8	20.4
Palton-Gulistan	0.7	8.4	Khilkhet-Airport	2.8	45
Gulistan-Motijheel	1.4	15.3	Airport-Abdullapur	2.7	17
Motijheel-Ittifakmor	2.1	9.0			
Ittifakmor-Jatrabari	3.5	14			

27. VIP	**Distance (km)**	**Velocity (km/hr)**	**28. Winner**	**Distance (km)**	**Velocity (km/hr)**
Azimpur to Abdullapur	21.6	17.8	Nilkhet to Kuril	16.5	10.5
Selected Route Segments	**Segmentwise**		**Selected Route Segments**	**Segmentwise**	
Azimpur-Nilkhet	0.6	4.2	Nilkhet-Sciencelab	0.8	4.6
Nilkhet-Sciencelab	0.8	10	Sciencelab-Kolabaghan	1.3	9.3
Sciencelab-Asadgate	2.4	14	Kolabaghan-Panthopath	1.3	6.8
Asadgate-Khamarbari	1.0	20	Panthopath-Kawranbazar	1.1	5.7
Khamarbari-Farmgate	0.5	12	Kawranbazar-Shatrasta	1.0	15
Farmgate-Bijoysarani	0.7	6.8	Shatrasta-Mohakhali	2.5	23
Bijoysarani-Jahangirgate	1.3	26	Mohakhali-Gulsion-1	2.5	15
Jahangirgate-Banani	2.8	25.8	Gulsion-1-Moddobadda	1.0	9.2
Banani-Mes	2.7	25	Moddobadda-Nutonbazar	2.2	12
Mes-kuril	1.6	27.6	Nutonbazar-Kuril	3.0	27.7
Kuril-Khikhet	1.0	30			
Khilkhet-Airport	2.8	46.5			
Airport-Abdullapur	2.7	18			

29. Cantonment mini service	Distance (km)	Velocity(km/hr)	
Mirpur-14 to Kakoli	2.6	9.2	
Selected Route Segments	**Segmentwise**		
Mirpur-14-Shadinota chottor	1.0	9.6	
Shadinota chottor-Shoinic club	1.0	17.5	
Shoinic club-Kakoli	0.6	4.3	