Formulation of Surface Treatment Criteria of Adjacent Buildings to Reduce Noise Level at Selected Road Junctions in Dhaka City

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Nazia Afsoon

DEDICATION

To my parents,

Advocate Mr. Golam Mostafa Rabbani (Late)

Ms. Shireen Akhter.

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List of Abbreviations

ANOVA	: Analysis of variance
BRTA	: Bangladesh Road Transport Authority
BSMMU	: Bangabandhu Sheikh Mujib Medical University
DoE	: Department of Environment
EDT	: Early Decay Time
EIA	: Environmental Impact Assessment
NRC	: Noise Reduction Coefficient
OECD	: The Organisation for Economic Co-operation and Developmentô
RT	: Reverberation Time
SPL	: Sound Pressure Level
TL	: Transmission Loss
WHO	: World Health Organisation

Acknowledgement

First and foremost, I am grateful to my supervisor, Mr. Sheikh Muhammad Najmul Imam for giving me this wonderful opportunity to work on this topic. I am also grateful to him for showing me the ways to perform research on acoustical effects due to surface treatments in road junctions. I am thankful to him for his constant guidance and supervision, without which this work would never have met a completion.

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Abstract

Road noise is exceeding the standard limits in Dhaka city and has become detrimental to human wellbeing. This pollution is mostly caused by the growing number of vehicles, particularly the noise of horns they generate. A road junction is one of the busiest and noisiest places attracting many vehicles and commercial activities. As a result, road users, road side workers, hawkers, shoppers and adjacent building users are exposed to prolonged noise exposure at unacceptable levels, which is a threat to their health and productivity.

To reduce the noise level at road junctions in Dhaka city, there may be many options pertaining to traffic systems, noise control regulations, vehicle fitness and road conditions. This research tests the hypothesis, whether surface materials of adjacent buildings play a significant role to reduce external noise level, as an architectural approach to supplement other remedial options.

As a part of the methodology, a reconnaissance survey is conducted on thirty road junctions in Dhaka city to select three from those for detailed instrumental field survey. Based on field data, a typical road junction is chosen for parametric study using computer software for acoustic analysis, simulation and prediction for assessing effects of different building surface materials on the reduction of noise levels at road junctions. Results have gone through Analysis of Variances (ANOVA) for assessing significance of the findings and testing of the hypothesis.

The findings of this research postulate that, selection of appropriate building surface materials has a significant effect on noise reduction at road junctions; as for an example, a building surface of bricks with holes has better effect on noise reduction compared to that of smooth concrete.

As an outcome of this research work, propositions are made in the form of guidelines pertaining to building surface materials for architects, urban designers, engineers and allied bodies in building industry for improving noise conditions at road junctions. Suggestions for future research are also furnished to facilitate further remedial measures for noise problems at road junctions; towards a safe, healthy and liveable city.

Chapter One: Preamble

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Statement of the Problem

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Chapter One: Preamble

1.0 Introduction

Noise can be defined as the unwanted sound. It can also be explained mathematically as the auditory perception of the randomised-wave form. In another way, noise has been defined as the level which exceeds the acceptable amount and creates annoyance (Alam & Hoque, 2000).The word noise is derived from the Latin word ónauseaô meaning sickness. Noise is, however, among the most pervasive pollutant now-a-days (Saifuddin, Shahinuzzaman, Muhammad, & Quader, 2010). Everyday noises from road traffic, jet planes, construction equipment and manufacturing processes, to name a few, are the unwanted sounds in urban areas that are routinely broadcast into the air, and these have been called environmental noise.

In many metropolitan cities, road traffic noise has become the most severe environmental noise problem that affects a large number of residents. Being a vibrant city with dense population and intense economic activities, Dhaka is no exception. It is one of the biggest metropolitans and most polluted cities in the world. Along with the increasing degree of air and water pollution, noise pollution is also emerging as a threat to the inhabitants (Tanvir & Rahman, 2011).

During the 70s and early 80s, noise pollution was not a major concern for the dwellers of Dhaka city. With the increasing number of motorised vehicles in the city, the hazard of noise pollution has amplified (Alam, Rauf, & Ahmed, 2001). The immense road traffic noise problems are due to a combination of factors including the shortage of habitable land, a concentrated road transport network, a significant increase in population in the past 20 years, a huge housing demand and a lack of environmental concern in the past few decades. There are no simple answers to the road traffic noise problems.

1.1 Statement of the Problem

Noise has become a permanent part of manõs life in the present age of industrialization and urbanization. It seems that the traffic congestion is going to be a typical feature of urban life in Dhaka city and it is getting worse day by day. It is reported that the hearing ability of the inhabitants of the City has reduced during the last ten years (Ahmed, 1998). About five to seven percent of the patients admitted to the Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka are suffering from permanent deafness due to noise pollution (Ahmed, 1998). The ever-increasing number of private cars is evidently responsible for this situation (Ahmed, 1998). With 1,800 vehicles getting registered every month and road space in the city being limited; poor traffic management, absence of restrictions on use of private vehicles and non-traffic users' occupying the road space are causing traffic congestion in Dhaka (The Daily star, 2008). As a result, this is causing loss of fuel and productive time while Dhaka is losing its appeal. Hence, in present days city dwellers are compelled to face many kinds of harmful effects induced by noise.

Figure 1.1 The immense number of vehicles in Dhaka city (Photo credit: Demotix, 2010)

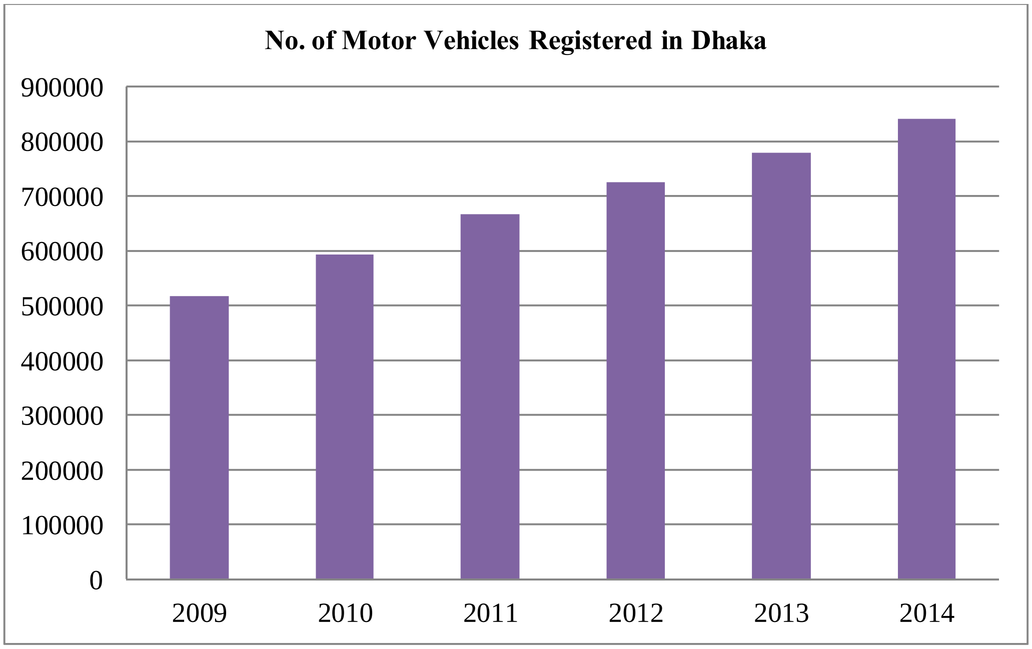


Figure 1.2 Number of Motor Vehicles Registered in Dhaka (Source: Bangladesh Road Transport Authority (BRTA), 2014)

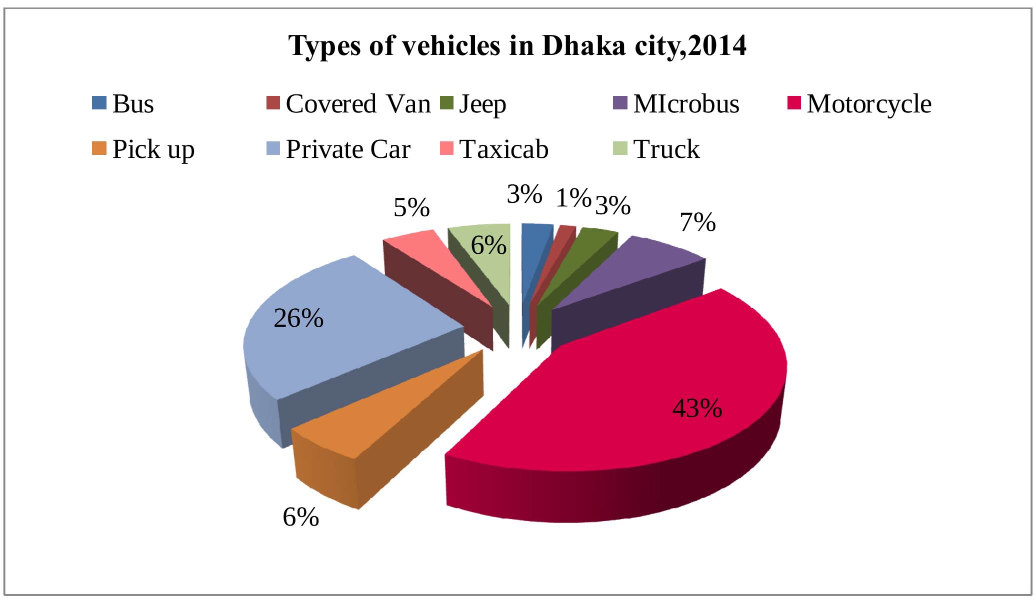


Figure1.3 Types of Motor Vehicles Registered in Dhaka City, 2014 (Source: Bangladesh Road Transport Authority (BRTA), 2014)

From Figure 1.2, it can be clearly stated that the number of motor vehicles, the main source of street noise in Dhaka, has been increased steadily from 51000 to 84000 for the last the six years (from 2009 to 2014). Focusing on the vehicle types in Dhaka city (year 2014), the Figure 1.3 also reveals that majority of the vehicles are Motorcycles (43%) and private cars (26%). Hence, these two figures indicate that the source of noise in the roads and junction points in Dhaka city are increasing where motorcycles and private cars are the major causes of noise.

1.2 Objective of the Research

The research focuses on observing and recording the existing noise level in the road junctions of Dhaka city. The main objective of this research is to study the effect of building surface materials on acoustical condition of the road junctions while selecting building surface materials of adjacent buildings to reduce noise level at road junctions in Dhaka City to help the architects, engineers and allied bodies.

1.3 Methodology

1.3.1 Research Strategy

Theoretically, a road junction is considered as an ‘open-roof room’ or ‘a room with a roof made of material with absorption coefficient 1.0 for all frequencies’. In that room, there are open doors and windows, which are similar to different road openings from junctions, having absorption coefficient 1.0 for all frequencies. Room walls are similar to surrounding building surfaces. Field surveys are conducted to collect data of existing condition of the selected road junctions considering the above postulations.

There are different types of noise containing different frequencies and amplitude at the road junctions. Noise levels are recorded in order to find the most prevalent amplitude and frequencies. With a simulation and prediction software, a 3D model of a road junction is created or imported from other relevant 3D modelling software (Figure 4.1). Acoustical properties of surface materials of surrounding objects (e.g. buildings, walls etc.), are assigned as per existing situation. Noise sources are placed at different positions and noise clip of average amplitude and frequency is assigned to those noise sources. Attenuated noise levels are derived as simulated and predicted by software at different positions of the road junctions. Thus, a noise-map of attenuated noise levels is generated. The research strategy can be described as Figure 1.4.

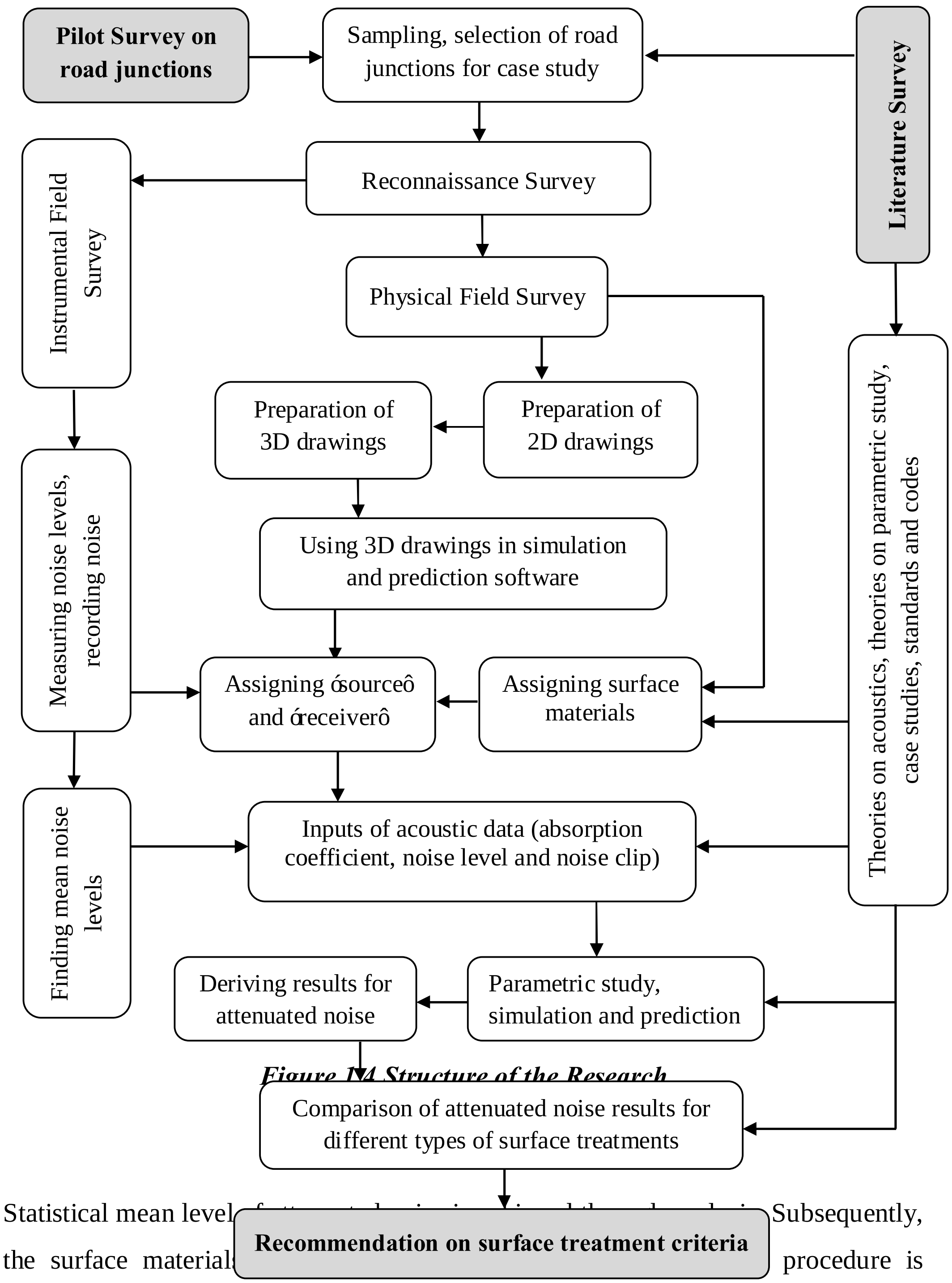


Figure 1.4 Structure of the Research

Statistical mean level[...] Subsequently, the surface material[...] procedure is repeated to get new results for attenuated noise levels. The objective is to identify there is any effect of surface materials on reduction of noise levels.

1.3.2 Literature survey

Literature survey on published data, research papers, books, standards and codes etc. are conducted to understand present situation of noise pollution at traffic junctions in Dhaka City, relevant standards and recommended solutions of noise problems.

1.3.3 Reconnaissance survey

Reconnaissance survey is undertaken prior to detailed field investigations to find out typical noise conditions of road junctions in Dhaka City as the objective is to observe and record the existing noise level and to study the effect of surface material on acoustical condition (Section 1.2).

1.3.4 Field Survey

Field surveys are carried out on sampled road junctions, to determine noise levels, types and patterns using a data logger type Sound Level Meter (Appendix 1.1). The physical attributes of a road junction, such as vegetation, topography, road surface finish, building surface materials, façade fenestration, voids etc. are noted and 3D digital models are prepared based on the field survey.

1.3.5 Parametric Study

As a supportive tool for checking the noise level of the selected road junctions, simulation software óODEONô, Version11.0 (Appendix 1.2) is used. The 3D models of the road junction are drawn in AutoCAD 2007. The models are imported to ODEON 11.0 and materials are assigned to the identified surfaces. The simulation is done changing various parameters or features of building facades on each of the selected road junctions.

1.3.6 Justification of Using the selected Software in Parametric Study

Possible methods for the research is explored and found that the option of parametric study in digital environment based on simulation and prediction techniques, using software óODEONô is most justified. Following is a summary of comparative analysis on pros and cons of different methods.

Method 1: Testing buildings modified in-situ. In this method, building surfaces are modified in life-size and in-situ for different design options and materials. After construction of each modification, acoustical measurements are done. Similarly, several options should be tested in-situ on a trial-and-error basis.

There are public and private buildings surrounding a road junction. It is difficult to get ownersô permission for such modifications and may have to pay high compensations for that. Several options of real-life and in-situ modifications and testing require huge cost, labour and time. Moreover, the result of any option remains uncertain till the construction is fully completed and acoustically tested. In the past, this method was used, while alternative methods (as stated in following sections) were not invented.

Method 2: Testing small-scale models in an anechoic chamber. Several small-scale models of road junctions and surrounding built forms are constructed in exactly the same designs and materials. These small-scale models are placed in an anechoic chamber and acoustically tested with pre-recorded and processed noise with high fidelity instruments.

There is no anechoic chamber in Bangladesh. Choosing this option means, firstly constructing an anechoic chamber. The whole process of designing, estimating, tendering (international) and constructing an anechoic chamber should take not less than three years! Besides, an anechoic chamber is a very costly installation. Making small scale models of case environment is also costly and time consuming.

Method 3: Testing in digital environment. Digital model of road junction and surrounding built forms are created and tested in digital environment applying simulation and prediction techniques.

With the advent of tremendous computational power and skill, digital environment is gradually taking place of all experiments in physical environment. Besides, this method of using software is reasonably cost-effective, requires much less labour and time compared to the preceding methods. This software can precisely simulate and predict expected acoustical result without laying a single brick for construction. Thus, it saves cost, labour and time from unwanted wastage, which is usually caused in a trial-and-error method. The auralization technique has matured to such a level, that the human ear can hardly tell whether it is a simulation or not (Rindel and Christensen, 2003).

The proposed computer software óODEONô has been validated in several researches by comparing its results with those measured in physical situations (Bork, 2002; Vries, 2001; Rindel, 2000; Bork, 2000; Vorlander, 1995; Lundeby 1995; Rindel, 2003). Many reputed research and professional bodies are using this software with confidence, satisfaction and cost-effectiveness. In short, this method is the state-of-the-art and the most viable and justified one for the research undertaken.

1.4 Limitation

It is understood that for noise level issues, implementation of noise rules, traffic regulations and similar non-architectural measures can play vital role. This study concentrates on how that can be improved through architectural approach. However, given the limited time and scope, this research concentrates on the effects of materials of building surface only.

This Chapter describes the overall objective of the work, methodology and scope of this research. The literature review related to the acoustical condition, noise pollution, building material usage and standards related to acoustics were briefly illustrated in óChapter Twoö. Details about road junctions, which involved the junction selection, physical condition study and acoustical conditions are elaborate in the óChapter Threeö. Chapter Four covers the process and results of simulation and prediction techniques by computer based acoustical tool óODEONô and establishes the fact that building surface materials can reduce noise level in the road junctions. The summary of the problems, noise conditions identified in the field survey, analysis and results is included in óChapter Fiveö. A guideline is also added for the architects, engineers and allied bodies in building industry to help improving the acoustical conditions of road junctions in context of Dhaka city.

References

Ahmed, K. (1998) *A study of noise pollution in Dhaka City.* Department of Environment (DoE), Bangladesh.

Alam, J.B., Hoque, M.M. and Ahmed, M.F. (2000) *Traffic induced noise pollution in Dhaka City*. Clean Air Initiative Bangladesh Environment. p.77-83.

Alam, Md., Rauf, A.F.M.A., and Ahmed, M.F., (2001) Traffic Induced Noise Pollution In Dhaka City. *The Institution of Engineers, Bangladesh*. CE 29 (1). p 55.

Bork, I. (2002) Simulation and Measurement of Auditorium Acoustics - the Round Robins on Room Acoustical Simulations, Proc. of the Institute of Acoustics, 24 (4).

Bork, I. (2000) A Comparison of Room Simulation Software, the 2nd Round Robins on Room Acoustical Simulations, *Acustica - acta acustica* 86, pp. 943-956.

Demotix. (2011) The home of World-Leading Photojournalism [Online] Available from: www.demotix.com/photo/562126/traffic-jams-dhaka-city. [Accessed: 18th November 2013].

BRTA. (2015) Bangladesh Road Transport Authority [Online] Available from: http://www.brta.gov.bd/index.php/statistics. [Accessed: 15th April 2014].

Lundeby, A. et al. (1995) Uncertainties of Measurement in Room Acoustics, *Acustica 81*, No. 4, pp. 344-355.

Mahmud, K.,Gopel, K., and Chowdhury, S.M.R. (2012) Possible Causes & Solutions of Traffic Jam and Their Impact on the Economy of Dhaka City. *Journal of Management and Sustainability*, Canadian Center of Science and Education. 2 (2). [Online] Available from: http://www.ccsenet.org/journal/index.php/jms/article/view/14879. [Accessed: 5th January 2014].

Rindell, J. H. (2000) The usage of computer modelling in room acoustics. *Journal of Vibroengineering*. 3 (4). pp 219-224.

Rindel, J. H. & Christensen, C. L. (2003) Room Acoustic Simulation and Auralization ï How Close Can We Get to the Real Room?, Keynote Lecture of WESPAC 8, The Eighth Western Pacific Acoustics Conference, Melbourne.

Rindel, J. H. (2000) The Use of Computer Modelling in Room Acoustics, *Journal of Vibroengineering*, No 3(4) /Index 41-72.

Roy, R., Rahman, M.A., and Uddin, M.J. (2006) ñNoise Induced Hearing Loss Assesment of the Road-noise Affected People of Dhaka cityò, Unpublished Undergraduate Thesis, Department of Environmental Sciences, Jahangirnagar University, Dhaka.

Saifuddin, K., Shahinuzzaman, Md., Muhammad, N. and Quader, M.A. (2010) ñPsychophysical Health in Relation to the Environmental Noise Perception in Younger Versus Older Groups of People in Dhaka Cityò, *Journal of Life and Earth Science*, 5 (81-84). p 81.

Staff Correspondent. (2008) Sound traffic management vital to make Dhaka liveable. The Daily Star. [Online] 12th October. Available from http://archive.thedailystar.net/newDesign/news-details.php?nid=58328. [Accessed: 22nd May 2009].

Tanvir, S. & Rahman, M.M. (2011) *Development of interrupted flow traffic noise prediction model for Dhaka City*. 4th Annual Paper Meet and 1st Civil Engineering Congress, Dhaka, Bangladesh. [Online] Iebconferences. Available from: http://www.iebconferences.info/371.pdf [Accessed: 10th January 2014].

Vorlander, M. (1995) International Round Robin on Room Acoustical Computer Simulation, Proc. of *15th International Congress on Acoustics*, Trondheim, Norway, pp. 577-580.

Vries, D. D. et al. (2001) Spatial Fluctuations in Measures for Spaciousness, *JASA* 110(2) Aug., pp. 947-954.

Chapter Two: Literature Review

Sound

Sources of Noise

Impacts of Noise

Road Junction

Building Materials in the Context of Dhaka City

Noise Problems in the Context of Dhaka City

Available Codes and Standards

Analysis of Variance (ANOVA)

Conclusion

Chapter Two: Literature Review

2.0 Sound

Sound can be defined as a wave motion in air or other elastic media (stimulus) or as that excitation of the hearing mechanism that results in the perception of sound (sensation) (Everest, 2001). These motions can be set up in a number of ways; however usually by some vibrating object, and are in the form of a longitudinal wave motion.

Noise is defined as unwanted sound. Sound has a range of different physical characteristics, but only becomes noise when it has an undesirable physiological or psychological effect on people (Rahman, Roy and Uddin, 2009).

Table 2.1 General Terms used in Acoustics (Source: Egan, 1972)

Term	Description
Absorption Coefficient	The fraction of the incident sound power that is absorbed by a material on a scale from 0 to 1.
Decibel (dB)	The measurement unit used in acoustics for expressing the logarithmic ratio of two sound pressures or powers. Typically used to describe the magnitude of sound with respect to a reference level equal to the threshold of human hearing.
Frequency	A descriptor for a periodic phenomenon. The frequency is equal to the number of times that the pressure wave repeats in a specified period of time. In the case of sound, frequency is measured in units of Hertz (Hz), which correspond to cycle per second.
Noise Criteria (NC) Curves	A set of spectral curves used to obtain a single number rating describing the ‶noisinessö of environments for a variety of uses. NC is typically used to rate the relative loudness of ventilation systems.
Noise Reduction Coefficient (NRC)	A single number index of sound absorbing efficiency. It is the arithmetic mean of a materialôs sound-absorption coefficients at 250, 500, 1,000 and 2,000 Hz octave frequency bands rounded to the nearest multiple of 0.05.
RT	Reverberation Time; time taken for a sound to decay by 60 dB, unit.

The EDT parameter (Early Decay Time) is the reverberation time, measured over the first 10 dB of the decay. This gives a more subjective evaluation of the reverberation time. As RT parameters, the EDT is computed for every octave band. It is expressed in ms.

2.1 Sources of Noise

All noise control problems involve three parts: the noise source, the recipient of the noise, and the ópathô between the two. This ópathô may be simple, such as the air between a machine and a man standing close to it; or it may be complicated, such as the varying air.

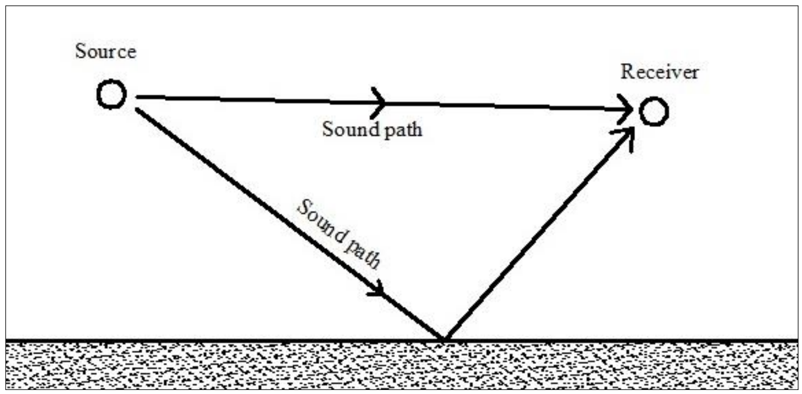


Figure 2.1 Three parts of sound propagation (After: Pennsylvania State University, 2009)

Although there are many sources of noise which include industries, construction works and indiscriminate use of loud speakers, motorised traffic is the principal source of noise in urban areas (Alam, Rauf, & Ahmed, 2001). Following are major contributors to noise pollution in the roads of Dhaka city:

- Engine and exhaust system of vehicles
- Use of loud and frequent horns of vehicles
- Noise created by vehicles plying on poor road surface
- Aerodynamic friction due to moving purposes
- Brake sequel of vehicles
- Loudspeakers used for different purposes
- Human voice

2.2 Impacts of Noise

Road traffic noise pollution has been recognised as a new threat to the inhabitants of cities. There are some studies carried out on road traffic noise pollution, which shows severe health problems both physical and psychological such as irritation, hypertension, heart problems, tiredness, headache and sore throat that also affects human performance and action (Daniel, 1998).

According to World Health Organisation (WHO), the highest acceptable noise level range is 60-65dB. Otherwise people constantly exposed to the higher noise level, interfere with speech and communication (Imam, Ahmed and Takahashi, 2009), decrease scholastic performance and develop annoyance. As a side effect of noise pollution, sound diffraction at road junction may create confusion and cause accidents (Debnath and Imam, 2013). Noise may also interfere with the social ends of an individual or group. A report on the social costs of land transport from óThe Organisation for Economic Co-operation and Developmentô (OECD) identified four categories of impact of transport noise (OECD, 1995). They are:

i. Productivity losses due to poor concentration, communication difficulties or fatigue due to insufficient rest
ii. Health care costs to rectify loss of sleep, hearing problems or stress
iii. Lowered property values
iv. Loss of psychological well-being

(Ayazl and Rahman, 2011)

Noise exposure can also lead to develop neurosis, irritability and excessive consumption of tranquilisers, increased incidence of admission in mental hospital. Chronic exposure of such noise level sometime causes permanent deafness (Roy, 2006).

Awareness about environmental noise and its effect has increased among people and there is a higher expectation for reduction of noise levels in urban areas.

2.3 Road Junction

Road junctions are important components of a transportation network. They are designed so that vehicular traffic can move in different directions in a systematic way. Roads are initially built to link locations of interest: towns, forts and geographic features. As a result, many such locations form the meeting point of such roads and they become the first road junctions.

Design and the classification of the junctions differ according to the road engineering principles and fundamental usage aims of the junctions. However, most common and basic classification of junctions is based on their grade separation. If a road junction has a grade separation, it is called an intersection. In this type of junction, roads cross each other directly. It is also called as ôinterchangesö; if roads pass above or below one another, preventing a single point of conflict and by utilising grade separation and slip roads. (Dogru, Van de Weghe, Ulugtekin, & De Maeyer, 2007)

The selected road junctions for survey are ôintersectionô as they directly cross each other which will be discussed in next chapter. Gulshan-2 (Figure 2.2), Dhanmondi 12A (Figure 2.3) and Shahid Minar Road (Figure 2.4) can be defined as 4-way junction. Here the crossing roads are perpendicular to each other. However, two roads may cross at a different angle in some cases.

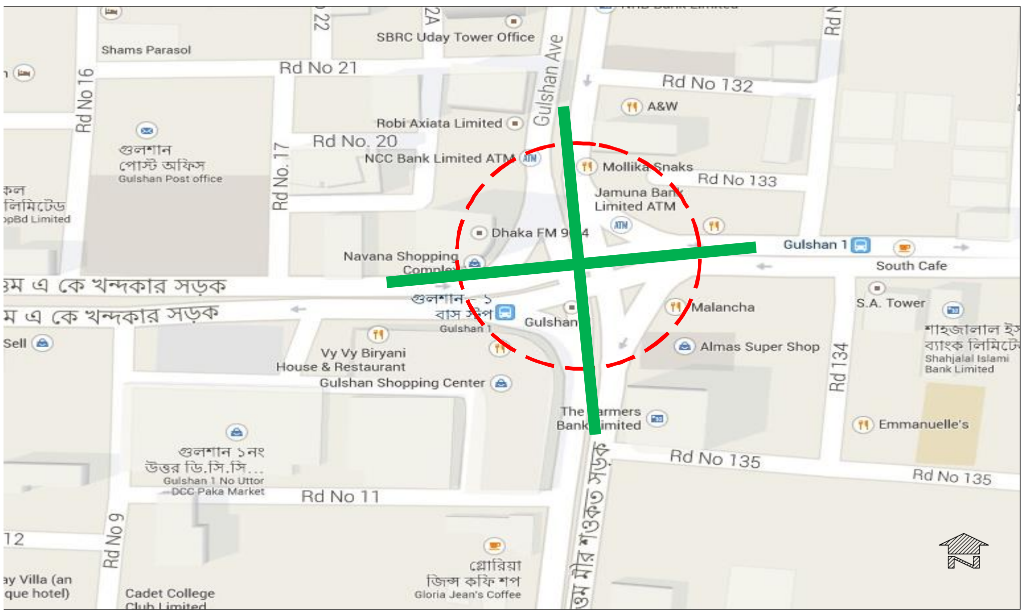


Figure 2.2 Gulshan-2 (Photo credit: Google map edited by the author)

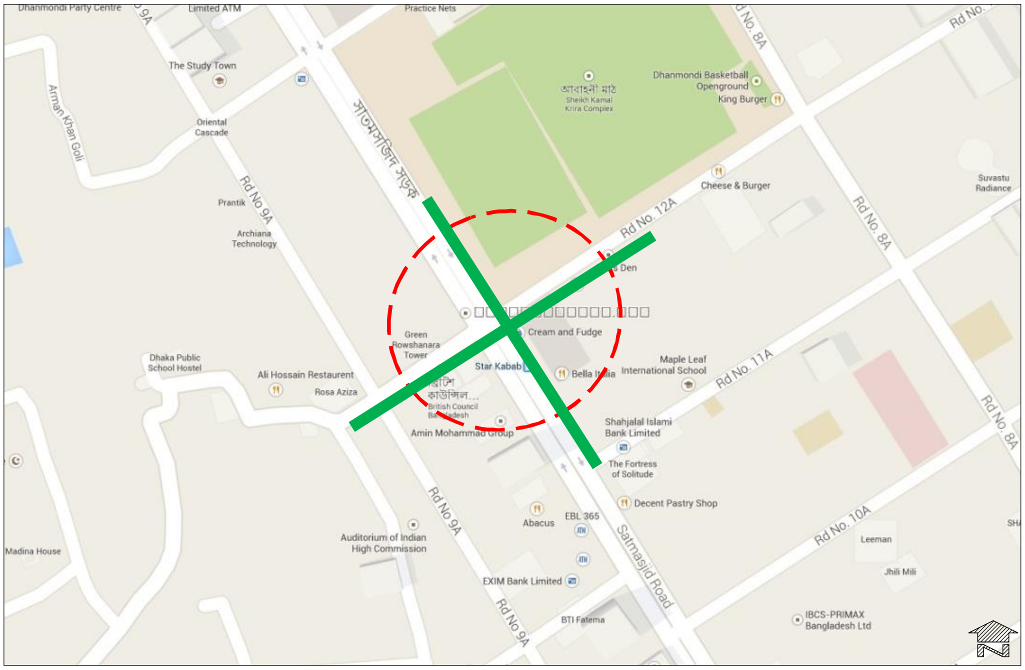


Figure 2.3 Dhanmondi 12A (Photo credit: Google map edited by the author)

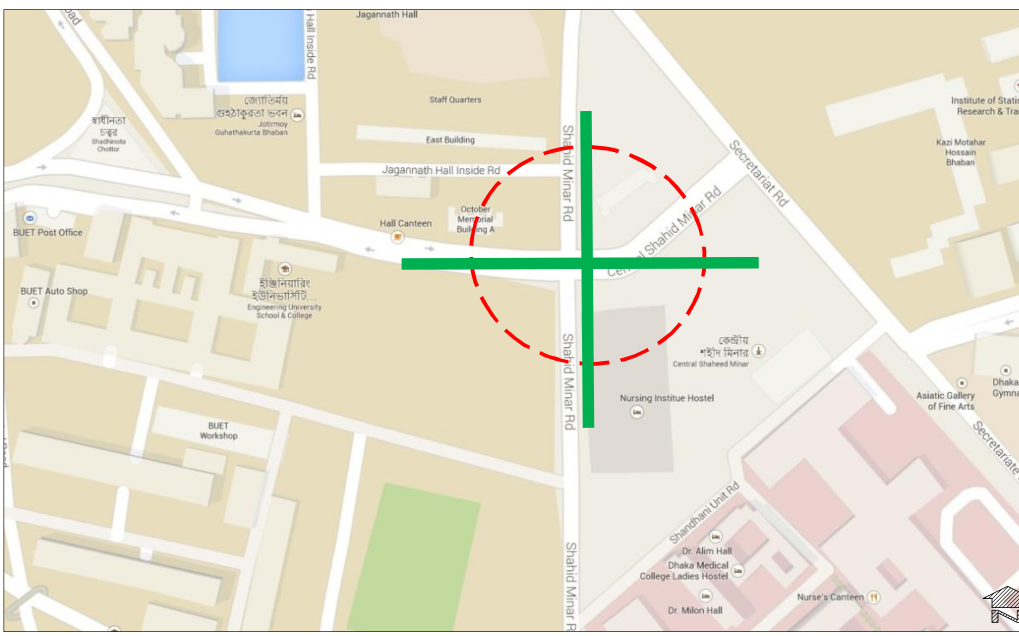


Figure 2.4 Shaheed Minar Road (Photo credit: Google map edited by the author)

2.4 Role of Building Material in Noise Reduction

The effectiveness of any material as a sound absorber can be expressed by its absorption coefficient, Ŭ (Egan, 1972). The sound absorption coefficient can be viewed as a percentage of sound being absorbed, where 1.00 is complete absorption

(100%) and 0.01 are minimal (1%). The sound absorption performance of a material is commonly published as a table of ósound absorption coefficientsô at octave band centre frequencies from 125 to 4kHz (Table 2.2).

Table 2.2 Sound Absorption of some common materials (Source: Egan, 1972)

Material	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07
Brick , painted	0.01	0.01	0.02	0.02	0.02	0.03
Concrete block, painted	0.10	0.05	0.06	0.07	0.09	0.08
Glass, Heavy plate	0.18	0.06	0.04	0.03	0.02	0.02
Glass, typical window	0.35	0.25	0.18	0.12	0.07	0.04
Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02
Plaster on Brick	0.01	0.02	0.02	0.03	0.04	0.05
Plaster on Concrete	0.12	0.09	0.07	0.05	0.05	0.04

Porous absorbers are the most commonly used materials for sound absorption. Panel absorbers, are typically non-rigid, non-porous materials, which are placed over an airspace that vibrates in a flexural mode in response to sound pressure exerted by adjacent air molecules (Vigran, 2008). Resonators typically tend to absorb sound in a narrow frequency range (Everest, 2001). It includes some perforated materials and the materials that have openings (holes and slots). Typically, perforated materials only absorb the mid-frequency range unless special care is taken in designing the facing to be as acoustically transparent as possible.

2.5 Building Materials in the Context of Dhaka City

Traditional urban forms in Mughal and colonial Dhaka were mostly based on indigenous materials and technologies. However, at present, new materials and technologies, mostly imported, are being used in response to changing cultural and aesthetics values which are also changing the cityscape. In some cases, fenestration, imitated from global cities, are imposed, and accepted (Sadria, 2009). Building material like brick, sand, cement, re-bar, etc are commonly used in the building construction of Dhaka city (Table 3.2, 3.4 and 3.6). Use of reflective glass, aluminium and stone claddings delineated most of our new buildings and also some old buildings through the renovation. However these materials are poor sound absorber while they may reflect sound in a great level.

2.6 Noise Problems in the Context of Dhaka City

According to a study conducted by WHO in 2002 at 45 locations of Dhaka city (Rabbani, & Sharif, 2005), most of the traffic points and many of the industrial, residential, commercial, silent and mixed areas are suffering from noises exceeding the standard limits for sound level in Bangladesh. An average sound level was measured after recording and observing the acoustic characteristics of the above area (Rabbani, & Sharif, 2005. p 55), was determined in all the above findings, which is represented in Table 2.3.

Table 2.3 Average noise level for different land use categories in Dhaka City in 1999 and 2002 (Source: WHO, 2002)

Location	Average Sound Level (dB) in Year		
	1999	**2002**	**Standard Limit for Sound Level in Bangladesh**
Silent Area	64.8	64.9	50
Residential Area	70.5	64.9	55
Mixed-use Area	84.3	81.6	60
Commercial Area	86.5	84.0	70
Industrial Area	85.6	83.0	75

Table 2.3 shows that sound level in different areas of Dhaka city is much higher than the accepted level. WHO found that noise level in Dhaka city varies from 64.8dB to 86.5dB, whereas the standard limit of those areas should be within 50 dB to 75 dB. Table 2.4 shows another study in 2005 where the measured average noise level is more elevated than the study conducted by WHO (Chakraborty, Khan, Samad and Amin, 2005).

Table 2.4 Level in Mixed Zone in Dhaka (Source: Chakraborty, Khan, Samad and Amin, 2005)

Name of Zones	Permissible level by Govt. of Bangladesh (dB)	Measured average noise level (dB)
Silent Zone	45	79
Residential Zone	50	72.33
Commercial Zone	70	90
Mixed Zone	60	91.6

Traffic personnel, Rickshaw pullers, open vehicle drivers, road side workers etc are exposed for long-term noise pollution which might cause severe mental and physical health problems (Rabbani & Sharif, 2005). According to a survey performed by Geography & Environment department of Jahangirnagar University on 100 people, it was found that all of them were invaded with diseases due to excessive exposure of noise pollution (Ayaz & Rahman, 2011). The diseases which attacked among those 100 people were as temporary hear loss = 12.31%, fatigue = 17.58%, insomnia =14.36%, irritability = 27.57%, hear diseases = 25.80%, others = 2.64% of those people (Ayaz & Rahman, 2011).

Especially for a city like Dhaka which has over the years grown into a mega city, the roadside pollution problem is severe and is reported to be serious and damaging to public health (Ayaz & Rahman, 2011).

2.7 Available Codes and Standards

To combat the hazards of noise pollution, standardisation and fixation of tolerance limits of noise pollution is essential. The Government has produced many policies for noise control to ensure a satisfactory noise environment which will help to safeguard the better quality of life for the public, and to protect people from excessive road noise.

ó*Environment Policy 1992*ô (Department of Environment & Local Government Engineering Department) has clause no 6.2.3, which says that the communities should be consulted in advance to reduce the degree of annoyances, created by noise.

No noise creating equipment should be used during night time. Workers operating equipment that generates noise should be equipped with noise protection gear. The workers should use earmuffs if the equipments generate more than 80 dBA noise continuously.

ó*Guidelines for the Use of the Environment Protection (Noise) Policy 2009*ô has the óclause 9ô that defines the objects of the Policy. The first objective is to establish the noise goals. If the noise exceeds the goal, then the authority can impose some requirements to address the noise issue. The policy addresses noise at the development stage to establish the related issue easily.

ó*The Environment Conservation Rules,* 1997ô and the Environmental Impact Assessment (EIA) have set some standards for different areas.

The acceptable noise levels for different zones are recommended by the Government of the Peopleøs Republic of Bangladesh are as shown in Table 2.5.

Table 2.5 Allowable upper limit of Outdoor Noise Levels (Source: Noise Pollution (Control) Rules 2006, the Government of the People's Republic of Bangladesh)

Sl. No	Category of zones	Upper Limit of Noise Level in dBA LAeq, T	
		Day time (06:00 AM - 09:00 PM)	Night time (09:00 PM - 06:00 AM)
01	Quiet Zone	50	40
02	Residential Zone	55	45
03	Mixed Use Zone	60	50
04	Commercial Zone	70	60
05	Industrial Zone	75	70

Notes:
1. The time from 6 AM to 9 PM is counted as daytime.
2. The time from 9 PM to 6 AM is counted as night time.
3. Area up to a radius of 100 meters around hospitals or educational institutions or special institutions/ establishments identified/to be identified by the Government is designated as Silent Zones where use of horns of vehicles or other audio signals, and loudspeakers are prohibited.

The standard noise values for different types of land use defined by EIA are shown in Table 2.6.

Table 2.6 Acceptable noise levels prescribed by EIA

Sl. No	Category of areas	Sound levels dB (A)	
		Day time	Night time
1	Institutional areas	50 or less	40 or less
2	Residential/Institutional area	50 or less	45 or less
3	Recreational areas	55 or less	45 or less
4	Residential/Commercial areas	60 or less	50 or less
5	Trade/Commercial/Residential areas	65 or less	55 or less
6	Industrial areas	70 or less	70 or less

2.7 Analysis of Variance (ANOVA)

Analysis of Variances is a test of hypothesis that is appropriate to compare means of a continuous variable in two or more independent comparison groups. The simultaneous comparison of several population means is called Analysis of Variance (ANOVA) (Lind, Marchal, and Wathen, 2009).

A hypothesis is a statement about a population parameter, which is developed for the purpose of testing. Subsequently, data are used to check the reasonableness of the statement. In statistical analysis, a hypothesis is stated; data are collected and used to test the assertion (Lind, Marchal, and Wathen, 2009).

Table 2.7 General Terms used in statistical analysis (Source: Lind, Marchal, and Wathen, 2009)

Term	**Description**
Null Hypothesis (H_o)	A statement about the value of a population parameter. It is designated as H_o, meaning there is no change.
Alternate Hypothesis (H_1)	A statement that is accepted if the sample data provide sufficient evidence that the null hypothesis is false. It is designated as H_1.
ε	Represents the population mean.
Level of significance	The probability of rejecting the null hypothesis when it is true. Traditionally 0.05 level is selected for research projects.
F distribution	óF distributionô is used to determine whether the means could be equal.
Sum of squares (SS)	The sum of the squared differences between each observation and the overall mean.
Mean squares (MS)	It is another expression for an estimate of the variance, which are computed by dividing sums of squares (SS) by degrees of freedom (df), row by row.
Degrees of Freedom (df)	The number of values in the final calculation of a statistic that are free to vary.
P-value	The probability of observing a sample value as, extreme as or more extreme than, the value observed, given that the null hypothesis is true. If p-value is smaller than the significance level, H_o is rejected.
F critical value	The dividing point between the region where the null hypothesis is rejected and the region where it is not rejected.

2.8 Conclusion

Dr. Alan Bell (WHO) has recently pointed out that noise is much more severe than an occupational hazard. It is one of the worst factors polluting the environment and creating health problem. Noise is a public nuisance and a danger to physical health (Shaha, S.K. 2000).

Moreover, in Bangladesh very little attention is paid to control noise and a poor number of research works has been done related to this field. Dhaka is the most vulnerable place for noise pollution in Bangladesh and should be focused first in case of the discussion of noise pollution. This chapter has tried to show the impact and significance of noise problem and control, with special reference to road junctions in Dhaka city.

References

Alam, Md., Rauf, A.F.M.A., and Ahmed, M.F., (2001) Traffic Induced Noise Pollution In Dhaka City. *The Institution of Engineers*, Bangladesh.CE 29 (1).p 55.

Ayaz, S. B. &Rahman, M.M. (2011) ñAssessment of Roadway Noise Level and Potential Mitigation Measuresò, DUET Journal, 1 (2). p 44.

Chakraborty, M.R., Khan, U.S., Samad, M.A, and Amin, M.N. (2005) Noise Level in Different Places of Dhaka Metropolitan City (DMC) and Noise-Induced Hearing Loss (NIHL) in Dhaka Dwellers. Bangladesh Medical Research Council Bulletin.

Daniel, G.N. (1998) Cause and Effects of Noise Pollution. Interdisciplinary Minor in Global Sustainability. *University of California*, Irvine.Student paper.

Debnath, K. B., Imam, S. M. N. (2013) Diffraction of Sound as a Side Effect of Noise Pollution at the Road Junctions of Dhaka city, Proceedings of 4th *International Conference on Environmental Aspects of Bangladesh (ICEAB)*, University of Kitakyushu, Japan, p 82-86, 24-26.

Dogru, A.O., Weghe,N.V., Ulugtekin, N.N. and Maeyer, D. (2007) Classification of road junctions based on multiple representations: adding value by introducing algorithmic and cartographic approaches. *XXIII International Cartographic Conference (ICC2007)*.Hosted by: The International Cartographic Association (ICA-ACI), Moscow, Russia.

Everest, F. A. (2001) *The Master Handbook of Acoustics*. 4th Ed. New York: McGraw-Hill

Imam, S. M. N. Ahmed, N. and Takahashi, D. (2009) Effects of Reverberation Time on Percentage Syllable Articulation for Bangla Language, *Journal of Asiatic Society of Bangladesh (Science)*, 35(1):37-48.

Lamancusa, J.S. (2009) *10.Outdoor Sound Propagation*. Noise Control. ME 458: Engineering Noise Control. State College.Pennsylvania State University.Availablefrom:

http://www.mne.psu.edu/lamancusa/me458/10_osp.pdf. [Accessed: 20th July 2014].

Lind, D.A., Marchal, W.G. and Wathen, S.A. (2009) *Statistical Techniques in Business & Economics*, Twelfth Edition, New York: Mcgraw-Hill/Irwin, p. 387.

Mahmud, K., Gope, K., and Chowdhury, S.M.R. (2012) Possible Causes & Solutions of Traffic Jam and Their Impact on the Economy of Dhaka City. *Journal of Management and Sustainability*. Canadian Center of Science and Education.

Rabbani, G. & Sharif, M.I. (2005) Dhaka City ï State of Environment (SOE) 2005. In collaboration United Nations Environment Programme Regional Resource Centre for Asia and the Pacific (UNEP RRC.AP) and Bangladesh Centre for Advanced Studies (BCAS),

Rahman, A.A., Roy, R., Uddin, M.J. and Nury, S.N. (Unknown) Noise Mapping of A Specific Area of Dhaka City: A State of the Art Strategy to Assess the Status of Road-Noise Pollution in Dhaka City. Unpublished draft study report.

Ravanbakhsh, M., Heipke, C., and Pakzad, K. (2007) Road junction extraction from high resolution aerial images. Stilla U et al (Eds). *PIA07 International Archives of Photogrammetry*, Remote Sensing and Spatial Information Sciences 36 (3/W49B), Munich, Germany.

Roy,R., Rahman, M.A., and Uddin, M.J. (2006) Noise Induced Hearing Loss Assessment of the Road-noise Affected People of Dhaka city. Undergraduate thesis.Department of Environmental Sciences, Jahangirnagar University.

Sadria, M. (2009) Homogenisation of Representations, Geneva: Aga Khan Award for Architecture.

Smyrnova, Y., Kang, J.,Cheal, C., Tijs, E., and Bree, H.E. (2010) Laboratory Test of Sound Absorption of Vegetation. *1st EAA-EuroRegio.Congress on Sound and Vibration*. Ljubljana, Slovenia.

Vigran, T.E. (2008) *Building Acoustics*. New York: Taylor & Francis.

WHO, (2002). *Noise Pollution of Dhaka City*, World Health Organization, Geneva.

Wilson, D.K., Andreas, E.L., and Weatherly, J.W. (2007) Characterization of uncertainty in outdoor sound propagation predictions. *Acoustical Society of America.*

Chapter Three: Field Survey

Objective of the Field Survey

Selection of the Road Junctions

Comparison with Standards

Survey and Observation

Analysis and Findings

Conclusion

References

Chapter Three: Field Survey

3.0 Objective of the Field Survey

Field survey is intended to portray the existing situation of noise pollution at different junctions in Dhaka city. The city is growing day by day along with the plying numbers of roads and vehicles (Alam, Rauf and Ahmed, 2001). It is neither possible in the given scope and objectives of this thesis, nor justified by the principle of statistics to take all the junctions for case study. The findings of acoustic situation described in the Chapter Two helped to determine the structure of the survey to identify some specific problems and to recognize improved acoustic condition on which the research can focus. The ultimate goal of field survey is to fulfil major part of the objectives (Section 1.2) of the survey considering existing acoustic condition.

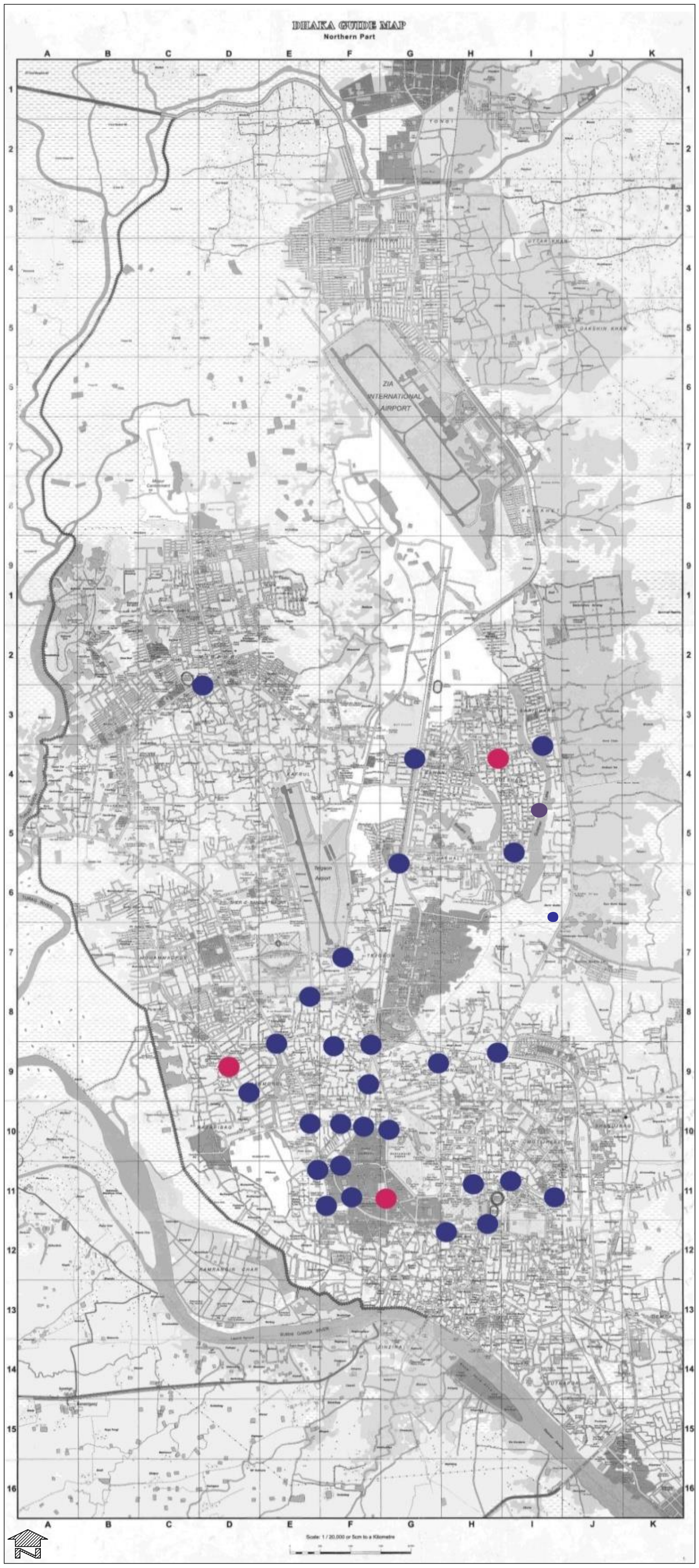
3.1 Selection of Road Junctions

A pilot survey on road junctions in different parts of Dhaka City was conducted to explore their different features. Table 3.1 lists these junctions undertaken for pilot survey. The author visited all these junctions to study their physical features. Findings from the pilot survey helped to identify the available types and their special features, which were used to select the cases for detailed study. The basis of selection is described in the following paragraphs.

Table 3.1 reveals that the widths of connecting roads at junctions vary from 9 m to 36.5 m. The road widths can be divided in three groups as, 9 ~ 18 m, 18 ~ 27 m and 27 ~ 36.5 m. Among those, three junctions are selected from three different areas so that each of those represents road widths from three groups. These junctions are at Road junctions 1 ï Gulshan 2, Road junction 2 - Dhanmondi 12A and Road junction 3 - Shahid Minar Road, which have 24.5~30.5 m, 9~36.5 m and 21~24.5 m wide connecting roads respectively. Traffic flow is also different in these three junctions due to the number of lanes, road widths, types and frequency of vehicle movements. Surface materials of adjacent buildings of selected road junctions also represent different types of materials available in buildings adjacent to road junctions in Dhaka city. In the Tables 3. 2, 3. 4 and 3.6, some existing features and context of the selected sample junctions have been illustrated.

Table 3.1 Road Junctions for Pilot Survey. Road junctions in bold face letters are selected for detailed case study.

Sl no	Name of the Junctions	Connecting Main Roads	Width of the Connecting Roads (m)			
			Road one	Road Two	Road Three	Road Four
1	Notun Bazar Bus Stand	Madani Avenue, Pragati Avenue	18	36.5	21	36.5
2	**Gulshan 2**	**Kamal Ataturk Avenue, Gulshan Avenue Madani Road**	**24.5**	**30.5**	**24.5**	**30.5**
3	Gulshan 1	BirUttamAkKhandakar Road, Gulshan Avenue, TejgaonGulshan Link Road	18	27.5	18	30.5
4	Kakolirmor	Kamal Ataturk Avenue, Dhaka Mymenshing Highway	24.5	36.5	9	36.5
5	Mohakhali	ShaheedTajuddin Ahmed Avenue, Dhaka Mymenshing Highway	36.5	36.5	36.5	18
6	BijoyShoroni Signal	BijoyShoroni, KaziNajrul Islam Avenue, BijoyShoroni-Tejgaon Link Road	49	30.5	18	30.5
7	Mirpur 10 No	Mirpur Road, Begum Rokeya Avenue	36.5	30.5	36.5	30.5
8	Manik Mia Avenue GolChottor	Manik Mia Avenue, Khamarbari Road, Indira Road	58	24.5	21	21
9	Kawran Bazar Signal	Panthopath, KaziNajrul Islam Avenue	30.5	42.5	21	33.5
10	Panthopath Signal	Panthopath, Green Road	36.5	18	39.5	21
11	Rasel Square	Mirpur Road, Dhanmondi 32, Panthopath	30.5	18	30.5	30.5
12	**Dhanmondi 12A**	**Shat Moshjid Road, Dhanmondi 12A**	**36.5**	**18**	**36.5**	**9**
13	Dhanmondi 9A	Shat Moshjid Road, Dhanmondi 9A	36.5	15	36.5	9
14	Science Lab Signal	Mirpur Road, New Elephent Road, Dhanmondi Road no1	30.5	24.5	30.5	15
15	Nilkhet Signal	Nilkhet Road, Katabon Road, ZahirRaihan Road	24.5	18	30.5	21
16	Azimpur Signal	Pilkhana Road, Azimpur Road	18	15	18	18
17	Bata Signal	New Elephent Road, Jahanara Imam Sharani, KamruzzamanSharani	27.5	18	21	18
18	Shahbag More	Shahbag Road, KaziNajrul Islam Avenue, MoulanaBhashani Road	18	36.5	27.5	130
19	Bangla Motor	Link Road, KaziNajrul Islam Avenue, New Eskaton Road	27.5	33.5	24.5	30.5
20	MaghBazar more	New Eskaton Road, ShaheedTajuddin Ahmed Avenue, Outer Circular Road	21	27.5	24.5	24.5
21	Malibag	DIT Road, AtishDiponkor Road	44	24.5	30.5	27.5
22	Polashi More	Pilkhana Road, ZahirRaihan Road	18	24.5	30.5	24.5
23	Chankharpul	ZahirRaihan Road, SuhrawardiUddan Road, Nazimuddin Road	21	12	24.5	9
24	Polton	Topkhana Road, S.S. Nazrul Islam Sharani	18	27.5	24.5	33.5
25	Doinik Bangla More	Topkhana Road, DIT Road, Motijheel Avenue	21	24.5	30.5	27.5
26	Motijhil Junction	Culvert Road, Toyenbee Circular Road	15	36.5	12	36.5
27	Katabon More	New Elephent Road, Shonargaon Road, Shahbag Road, Katabon Road	21	21	21	18
28	New Market Signal	New Market Pilkhana Road, Mirpur Road, Nilkhet Road, Azimpur Road	30.5	30.5	24.5	30.5
29	**ShahidMinar Road**	**Fuller Road, ShahidMinar Road**	**21**	**24.5**	**24.5**	**21**
30	Gulistan Junction	Phoenix Road, Bangabandhu Avenue, Gulistan Road	21	30.5	24.5	27.5



Legend

Road junctions for pilot survey

Selected road junctions for research

Figure 3.1 Map of Dhaka City, showing locations of road Junctions for Pilot Survey

3.1.1 Road Juncition 1 – Gulshan 2

In Table 3.2, it is shown that Gulshan 2 is a junction among Kamal Ataturk Avenue (24.5 m), Gulshan Avenue (30.5 m) and Madani Avenue (24.5 m). Building height varies from 3 storeys to 25 storeys which have different types of surface materials like glass, plaster on brick, steel, aluminium sheet and granite. The road surfaces of the sample junctions mainly contain Asphalt. However, grass and low shrubs are also observed on the road sides, road dividers and islands. At point 1, 2, 3, 4 (Figure 3.4) of the selected junction noise levels have been measured from 9 AM ï 6 PM and the average noise level was 75.49 dBA (Table 3.3). During the survey, traffic flow pattern was also observed. This observation reveals that the number of private cars was the highest in number (203 nos.) (Table 3.2).

Figure 3.2 Sound Level Meter installation at the Road Junction 1- Gulshan 2 (Photo credit: Ms. Bakhtour Mukarrama Aanika)

The data was collected at 1.5 meter above the roadside level. Any kind of noise barriers was avoided for measurements of noise levels.

Table 3.2 Physical features of the Road Junction 1 – Gulshan 2

Junction	Location	Building Material	Building Height	Vegetation	Road Width	Average No. of vehicle (per 5 minutes)
Gulshan 2 (Junction 1)	Junction among Kamal Ataturk Avenue, Gulshan Avenue, Madani Road	Glass, Plaster on Brick, Steel, Aluminium Sheet, Granite.	Minimum 3 Storey, Maximum 25 Storey	Grass, Shrubs	Minimum 24.5 m, Maximum 30.5 m	Private Car-203, Bus-13, Jeep-18, Microbus-13, Auto Rickshaw-12, Pick-up-9

Figure 3.3 Showing the Satellite image of Road Junction 1 - Gulshan 2 (Source: 'Google Earth')

Figure 3.4 Showing the aerial view of Road Junction 1- Gulshan 2 (Photo credit: Vimeo, 2014)

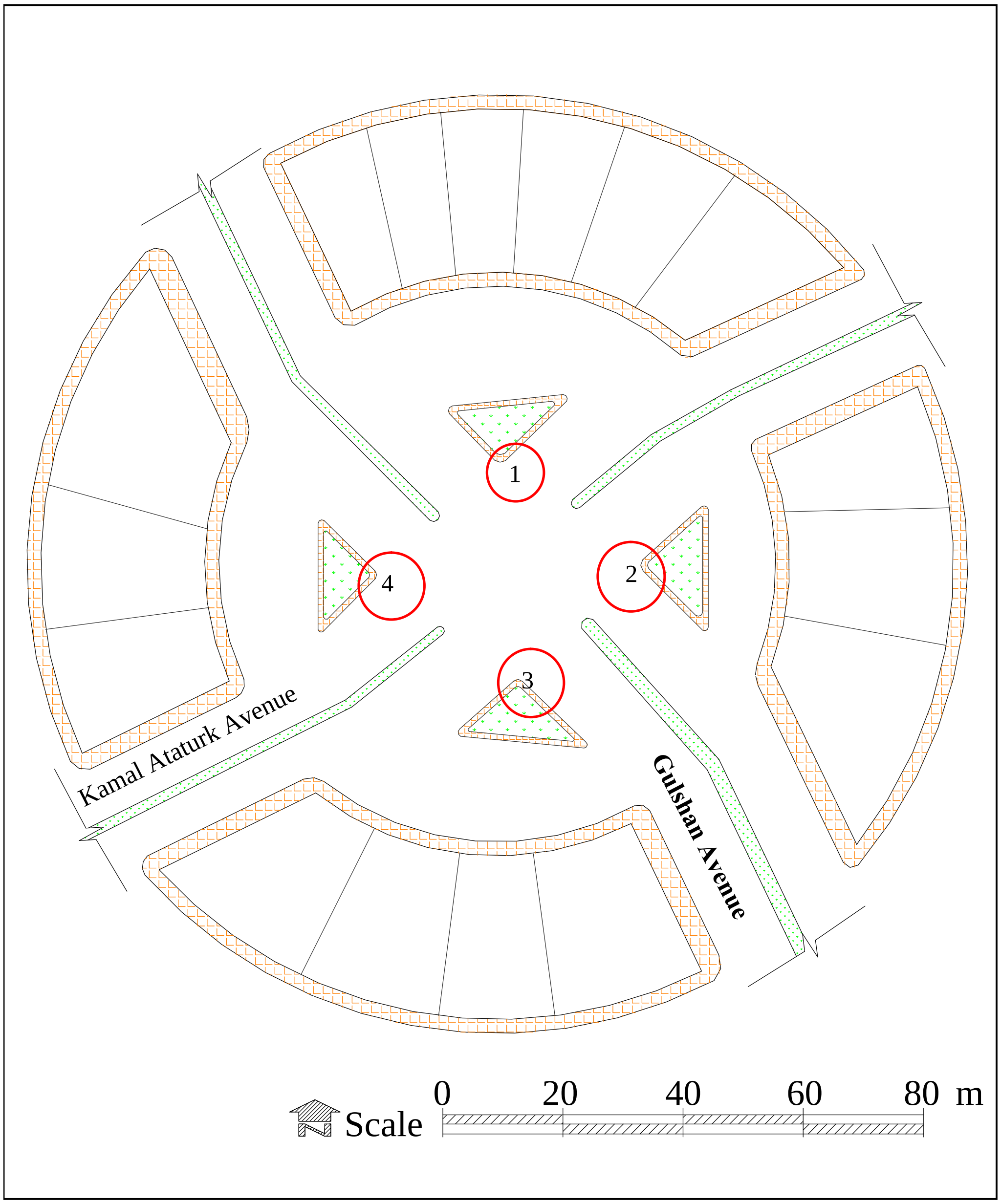


Figure 3.5 Plan of the Road Junction 1 – Gulshan 2

Figure 3.4 is showing the four locations, where noise level is recorded to find out the average noise level at road junction 1 ï Gulshan 2.

Table 3.3 shows that among the surveyed points, the Maximum Noise Level is 127.6 dBA and Minimum Noise Level is 60.9 dBA. Whereas, the Average Noise Level of the junction is 75.49 dBA.

Table 3.3 Noise Level at Different Points of the Road Junction 1 – Gulshan 2

Location	Maximum Noise Level (dBA)	Minimum Noise Level (dBA)	Average Noise Levels at different points (dBA)	Average Noise Level of the junction (dBA)
Point 1	125.7	62.5	76.26	**75.49**
Point 2	121.9	**60.9**	75.24	
Point 3	**127.6**	61.6	75.63	
Point 4	119.3	61.3	74.82	

Figure 3.5 is showing the data logged in position 1 (Figure 3.4). Figure 3.6 is showing a portion from the data , logged in junction 1as shown in Figure 3.5. It shows that the maximum sound level is more than 125 dBA (Table 3.3).

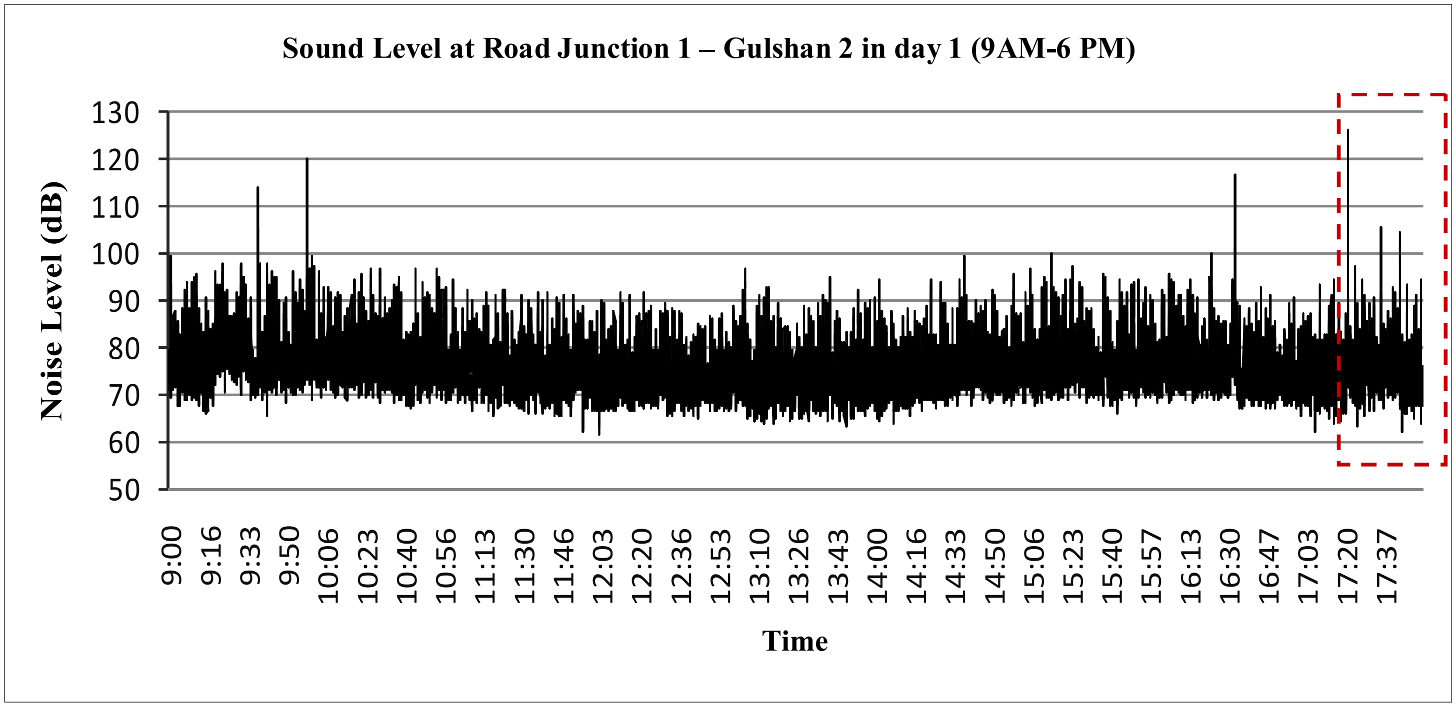


Figure 3.6 Chart showing the logged noise level at the Road Junction 1 – Gulshan 2 in day 1

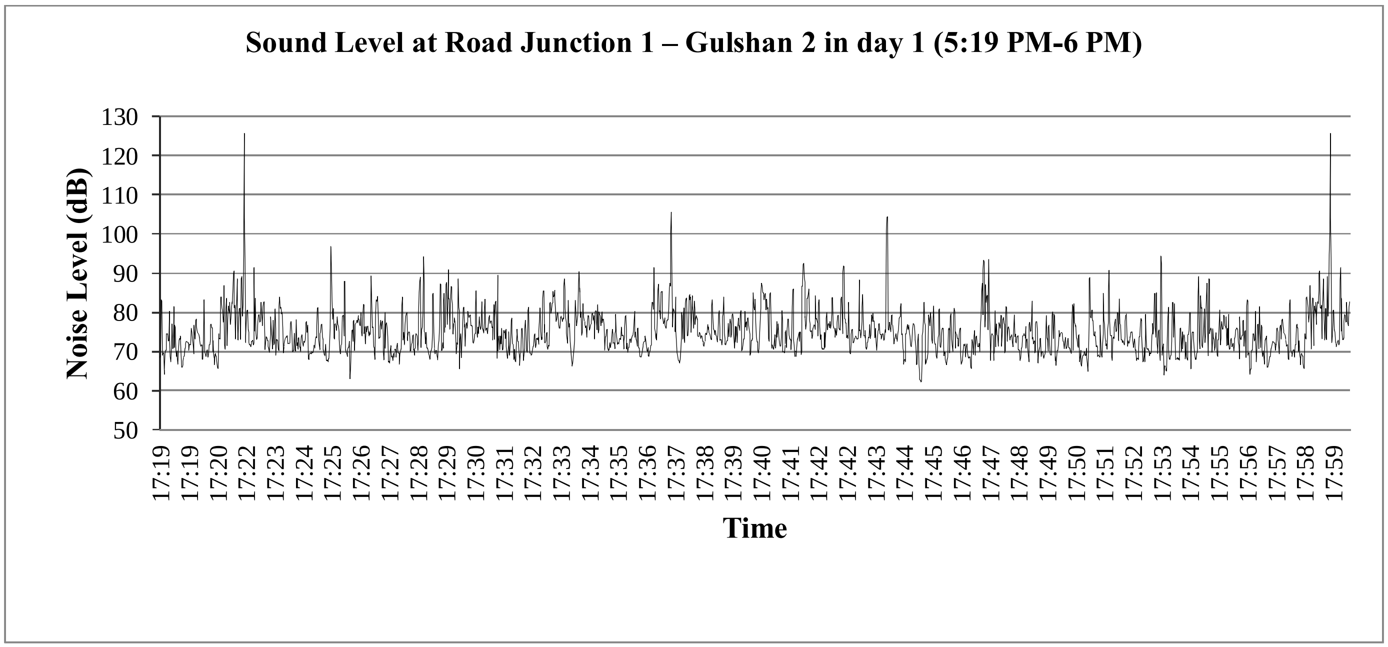
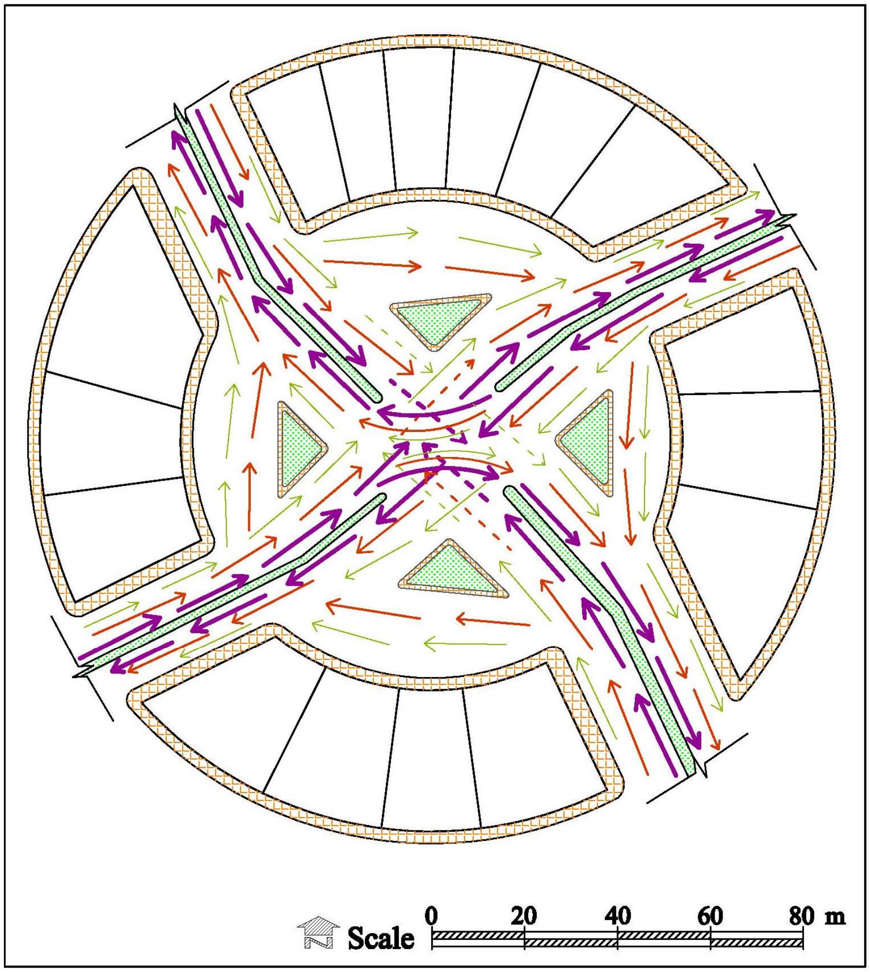


Figure 3.7 Highest levels of sound logged at Road Junction 1 – Gulshan 2 between 5:19 PM -6 PM in day1



Heavy Vehicle; Medium Vehicle; Light Vehicle

Figure 3.8 Traffic Flow at Road Junction 1 - Gulshan 2

3.1.2 Road junction 2 - Dhanmondi 12A

From Table 3.4, it can be found that road junction 2 - Dhanmondi12A is at between Shatmashjid Road (36.5 m) and Dhanmondi12A (18 m). Building height varies from 4 storeys to 6 storeys and the surface materials used are glass, plaster on brick and tiles. Asphalt is the surface material on roads. Trees like Krishnachura, Devdaru etc. are also notable in this junction. Noise level has been measured at point 1, 2, 3, 4 (Figure 3.9) from 9 AM ï 6 PM and the average noise level was 79.42 dBA. Table 3.4 shows that the number of private cars (153 nos.) was more than other heavy vehicles during the survey. However, the number of Rickshaw (194 nos.) was the highest in number.

Table 3.4 Physical features of Road Junction 2 - Dhamondi 12A

Junction	Location	Building Material	Building Height	Vegetation	Road Width	No. of vehicle (per 5 minutes)
Dhanmondi 12A (Junction 2)	Dhanmondi 12A, Shatmoshjid Road	Glass, Brick, Tiles, Metal Sheet.	Minimum 4Storey, Maximum 6 Storey	Grass, Tree.	Minimum 9 m, Maximum 36.5 m	Private Car-153 Bus-70, Microbus-7, CNG-34, Rikshaw-194 Motor cycle-26

Figure 3.9 Showing the Satellite image of Road Junction 2 - Dhanmondi 12A (Source: 'Google Earth')

Figure 3.10 Showing the aerial view of Road Junction 2 - Dhanmondi 12A (Photo credit: Self)

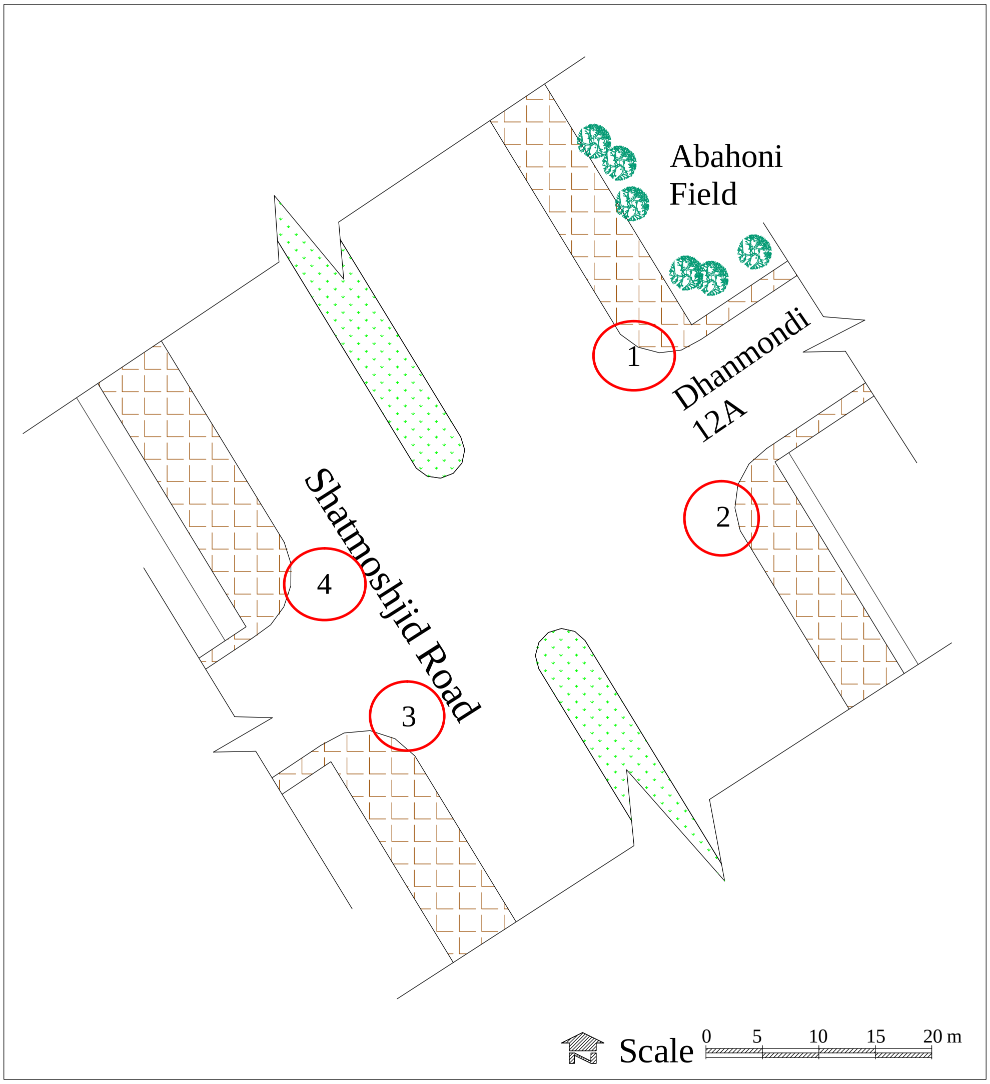


Figure 3.11 Plan of Road Junction 2 - Dhanmondi 12A

Figure 3.9 is showing the four locations, where noise level is recorded to find out the average noise level at road junction 2 ï Dhanmondi 12A.

Table 3.5 shows that among the surveyed points, the Maximum Noise Level is 124 dBA and Minimum Noise Level is 62.7 dBA. Whereas, the Average Noise Level of the junction is 79.42 dBA.

Table 3.5 Noise Level at Different Points of Road Junction 2 - Dhanmondi 12A

Location	Maximum Noise evel (dBA)	Minimum Noise Level (dBA)	Average Noise Levels at different points (dBA)	Average Noise Level of the junction (dBA)
Point 1	122.3	65.2	79.85	**79.42**
Point 2	**124**	64.1	79.88	
Point 3	103.5	**62.7**	78.49	
Point 4	108	66.5	79.49	

Figure 3.10 is showing the data logged in position 2 (Figure 3.9). Figure 3.11 is showing a portion from the data , logged in junction 2 as shown in Figure 3.10. It shows that the maximum sound level is 124dBA (Table 3.5).

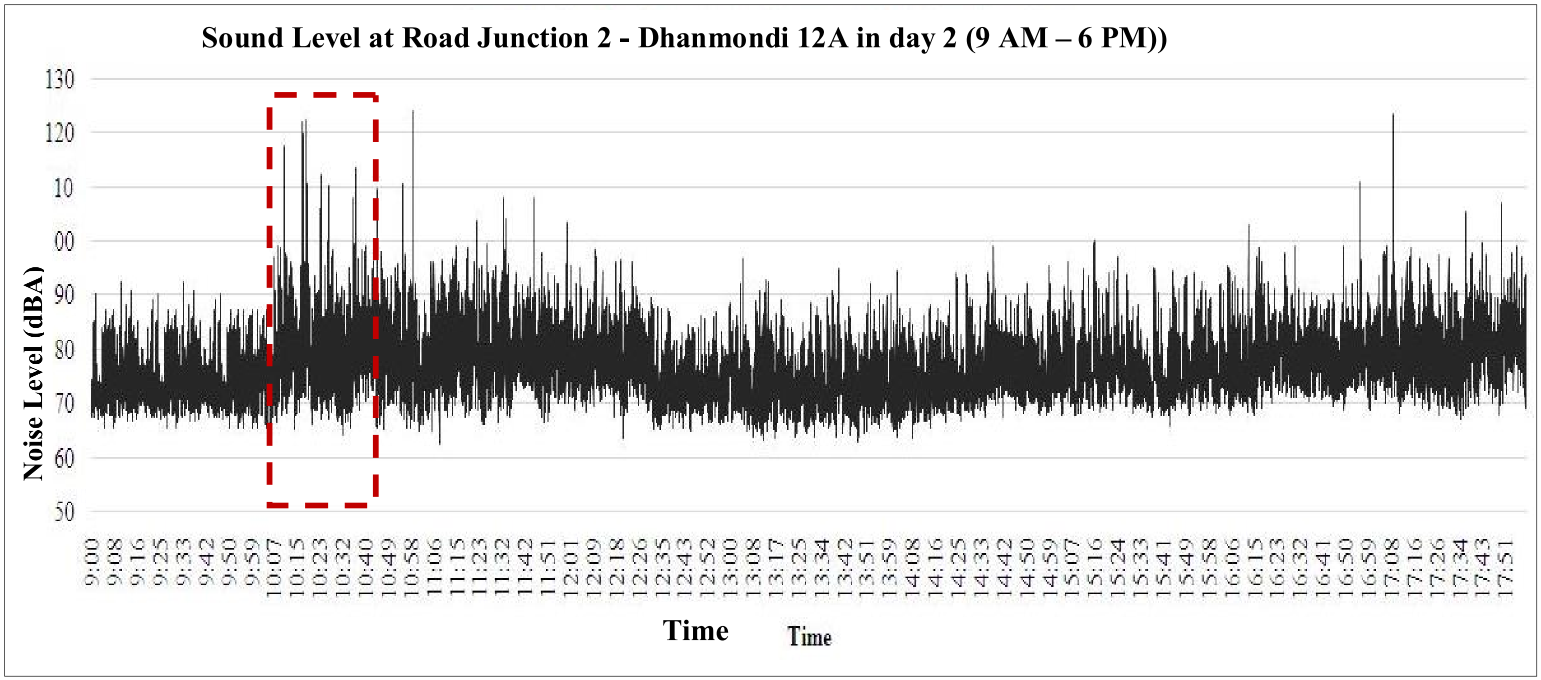


Figure 3.12 Chart showing the logged sound level at Road Junction 2 - Dhanmondi 12A in day 2

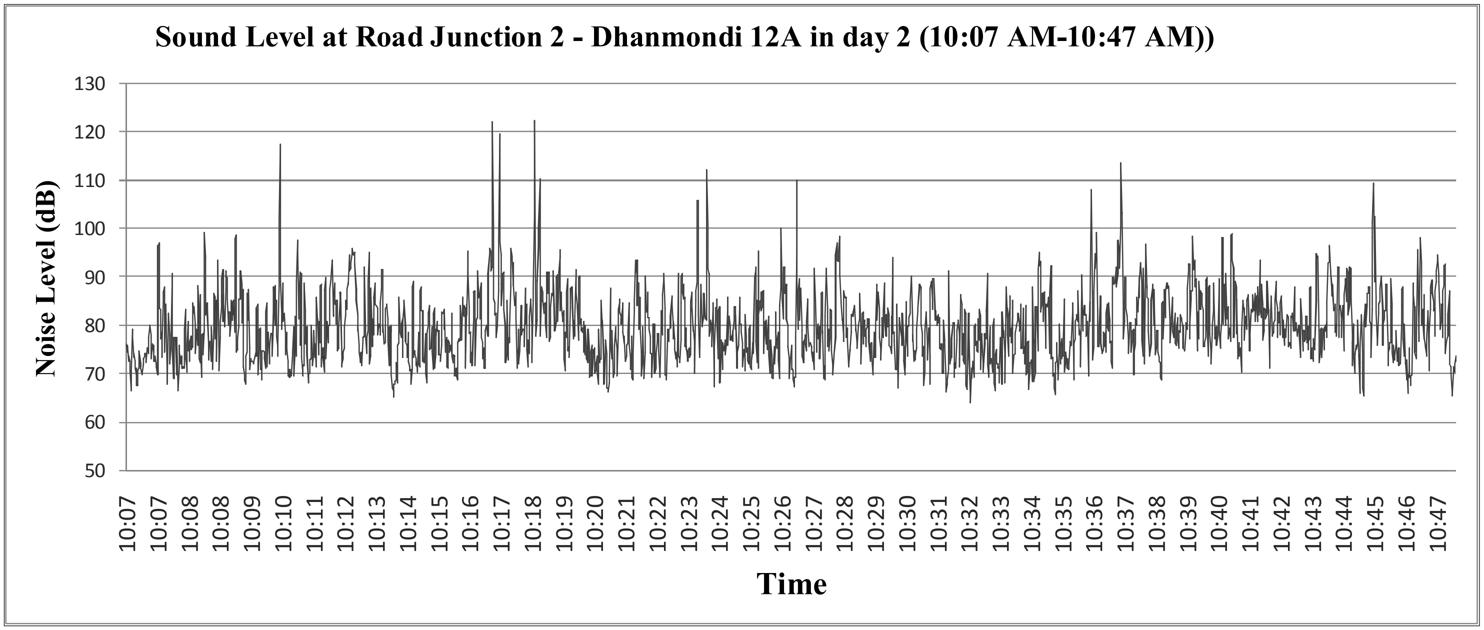
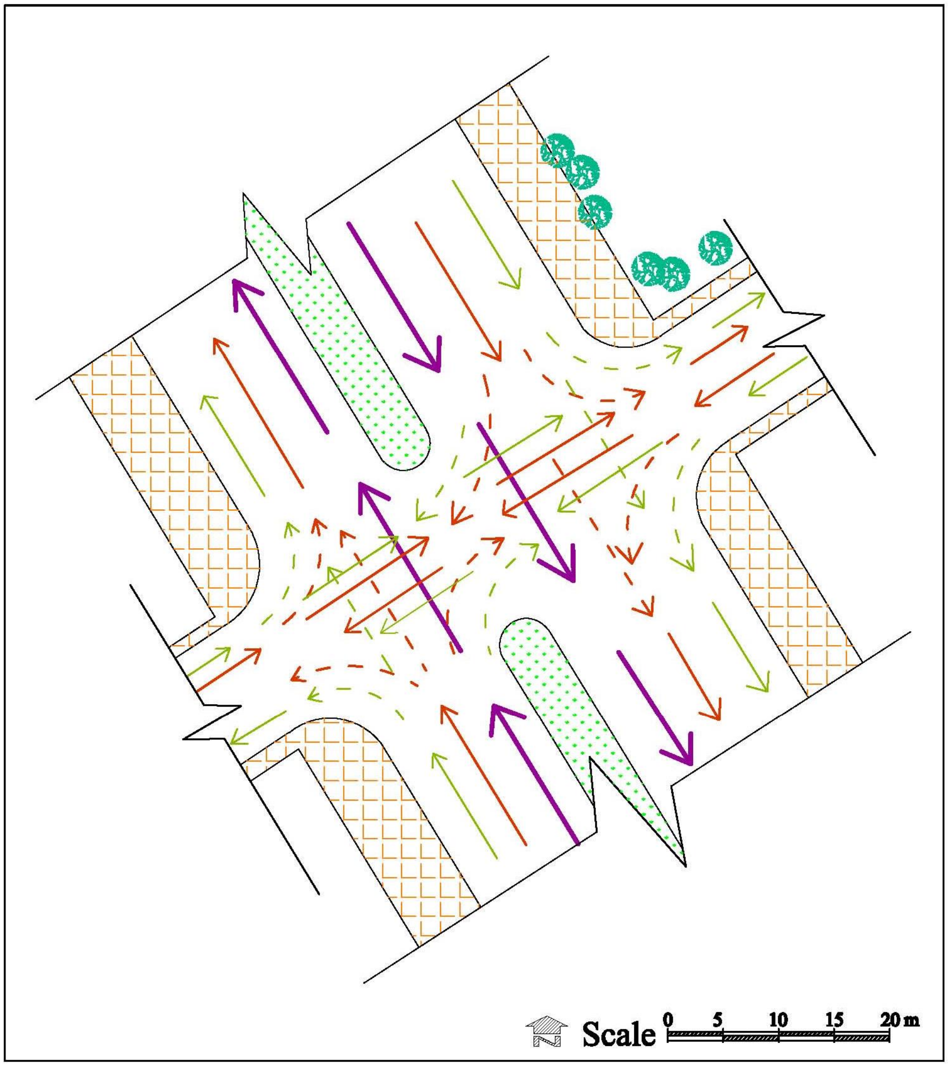


Figure 3.13 Highest levels of sound logged at Road Junction 2 - Dhanmondi 12A between 10:08 AM- 10:12 AM in day 2



Heavy Vehicle; Medium Vehicle; Light Vehicle

Figure 3.14 Traffic Flow at Road Junction 2 - Dhanmondi 12A

3.1.3 Road Junction 3 - Shahid Minar road

From Table 3.6, it can be found that road junction 3 - Shahid Minar Road is between Fuller Road (21 m) and Shahid Minar Road (24.5 m). The Buildings are of 5 storeys. Building materials like glass and plaster on brick is used on the surface. There are lots of trees in this junction as Krishnachura, Coconut tree, Rain Tree etc. These are acting as green barrier. Noise level has been measured at point 1, 2, 3, 4 (Figure 3.15) of this junction from 9 AM ï 6 PM and the average noise level was 73.14 dBA. Table 3.6 shows that, Rickshaws (134 nos.) were the highest in number, while private car (112 nos.) was the second highest during the survey.

Figure 3.15 Demonstration of Sound Level Meter installation at position 4 (Figure 3.15) and data logging by the thesis supervisor at road junction 3-Shahid Minar Road (Photo credit: Ms. Bakhtour Mukarrama Aanika)

Table 3.6 Physical Features of Shahid Minar Road

Junction	**Location**	**Building Material**	**Building Height**	**Vegetation**	**Road Width**	**No. of vehicle (per 5 minutes)**
Shahid Minar (Junction 3)	Fuller Road, ShahidMinar Road	Glass, Brick.	5 Storey	Grass, Tree.	Minimum 21 m, Maximum 24.5 m	Private Car-112, Bus-4, Microbus-6, CNG-18, Riksha-134, Motor cycle-16.

Figure 3.16 Showing the Satellite image of Road Junction 3 – Shahid Minar Road (Source: 'Google Earth')

Figure 3.17 Showing the aerial view of Road Junction 3 – Shahid Minar Road (Photo credit: Thesis Supervisor)

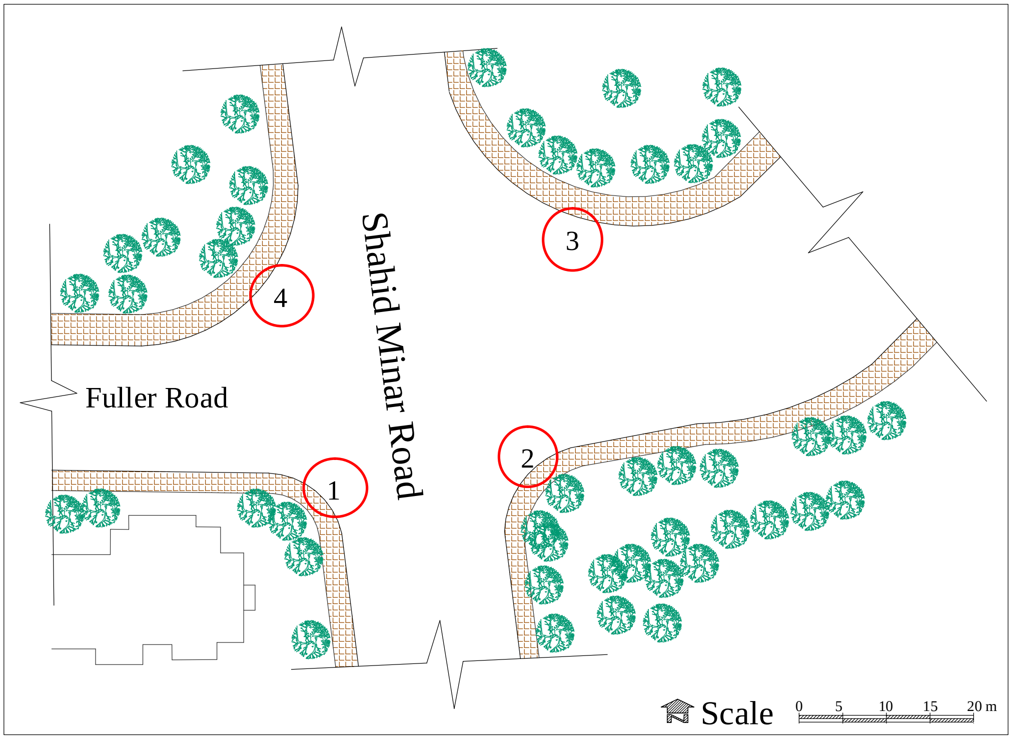


Figure 3.18 Plan of Road Junction 3 - Shahid Minar Road

Figure 3.15 is showing the four locations, where noise level is recorded to find out the average noise level at road junction 3 ï Shahid Minar Road.

Table 3.7 Noise Level at Different Points of the Road Junction 3 - Shahid Minar Road

Location	Maximum Noise Level (dBA)	Minimum Noise Level (dBA)	Average Noise Levels at different points (dBA)	Average Noise Level of the junction (dBA)
Point 1	**98.2**	58.9	75.35	**73.14**
Point 2	94.8	59.5	72.51	
Point 3	92.5	**58.2**	70.90	
Point 4	95	60	73.80	

Table 3.7 shows that among the surveyed points, the Maximum Noise Level is 98.2 dBA and Minimum Noise Level is 58.2dBA. Whereas, the Average Noise Level of the junction is 73.14 dBA.

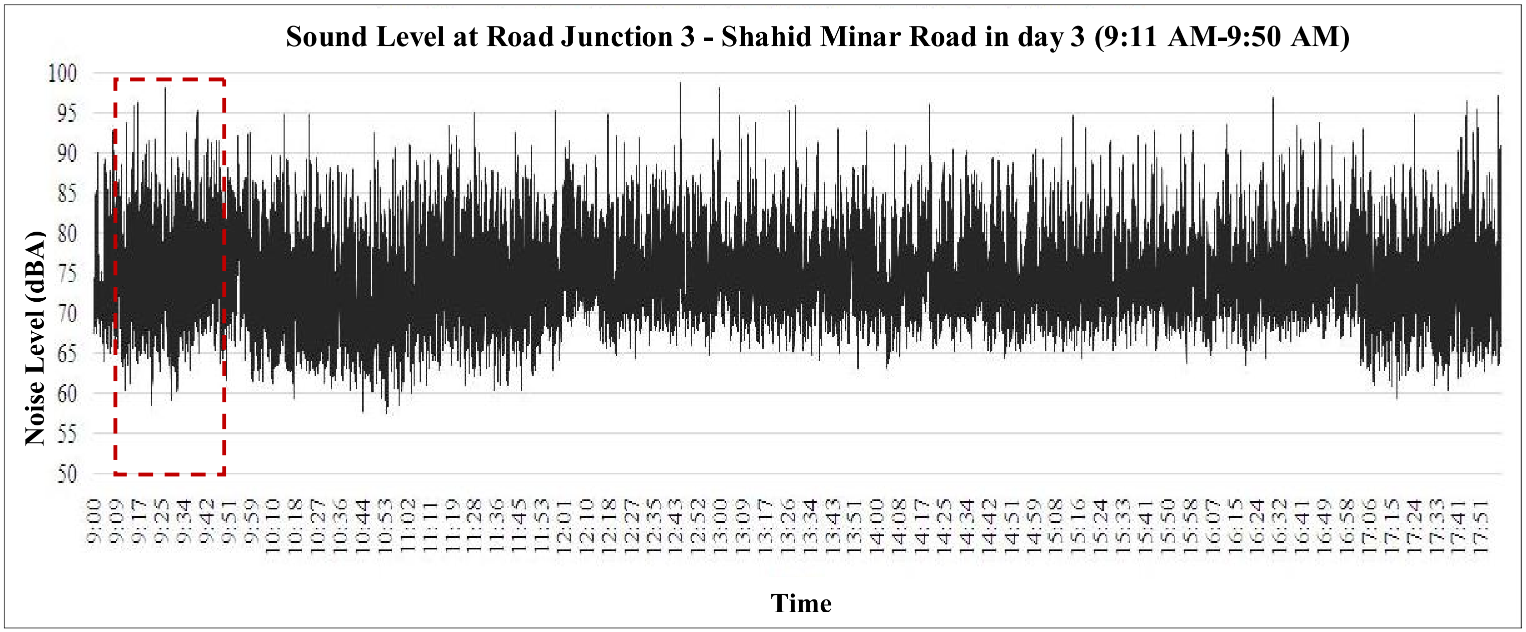


Figure 3.19 Chart showing the logged sound level at road junction 3 - Shahid Minar Road in day 3

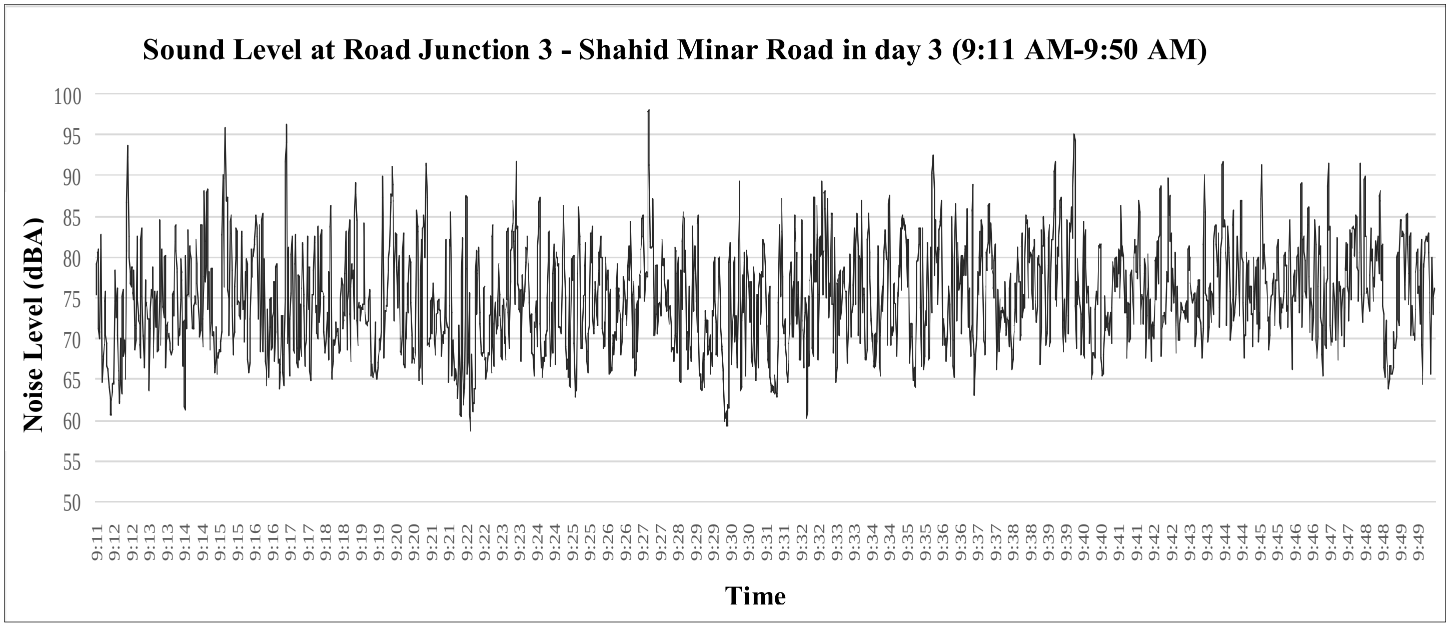
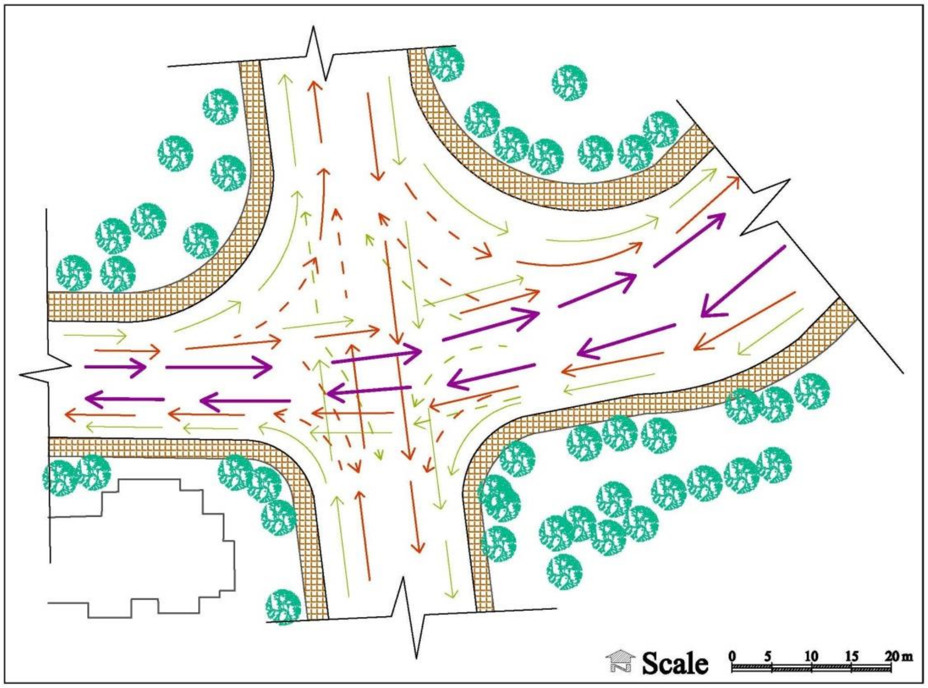


Figure 3.20 Highest levels of sound logged at road junction 3 – Shahid Minar road between 9:11 AM- 9:50 AM in day 3



Heavy Vehicle; Medium Vehicle; Light Vehicle.

Figure 3.21 Traffic Flow at Road Junction 3 - Shahid Minar Road

3.2 Comparison with Standard

One of the aims of these detailed investigations was to evaluate the existing acoustic conditions in these selected junctions. Table 3.8 gives comparison between the measured noise level in those junctions and the allowable upper limit of noise as recommended by Department of Environment (DoE).

Table 3.8 Comparison between measured sound level and standard

	Junction1 (Gulshan-2)	**Junction 2 (Dhanmondi 12A)**	**Junction 3 (ShahidMinar Road)**	**Standard (allowable upper limit)**
Average Noise Level (dBA)	**75.49**	**79.42**	**73.14**	**60**

The comparison shows that the noise level in the surveyed cases is much higher than the allowable limits. Hence, proper acoustic treatment is required to meet the expected noise level.

3.3 Survey and Observation

3.3.1 Physical features of selected junction for simulation

In this section, the physical features are observed and measured to identify the effect of noise pollution at the surveyed junctions. The effect of building surface materials, road width, green barrier, etc. on overall acoustic conditions is analysed with the help of simulation modelling as described in Chapter Four. Table 3.9 illustrates the important physical features of the sample junctions, some of which will be used in parametric study.

Plans and elevations of the surveyed road junctions are drawn using the software AutoCAD2007. Layers are created separately for different types of surface materials. From elevations, surface areas for different materials are measured and percentages (%) are calculated. As an example, plan and elevations of adjacent buildings at Road Junction 1 - Gulshan 2 is shown in Figure 3.22.

Table 3.9 shows that among these three junctions óGlassó (51%) is mostly used as adjacent building surface material in Gulshan-2 and 30% of the material is brick. Here 17% of surface material is metal sheet. In road junction 3 - Shaheed Minar Road only 5% of building surface material is glass and 95% is made of brick. No metal sheet or Granite is found in this junction. 36.5 m which is the maximum width and 9 m which is the minimum width, is found in road junction 2 - Dhanmondi 12A. In road junction 1 - Gulshan 2, 93% of the ground is used as road surface and the rest is used for vegetation (Figure 3.22). No vegetation is found on the road surface of road junction 3 - Shaheed Minar Road. Maximum noise level, which is 127.6dB, is found in road junction 1 ï Gulshan 2 junction whereas minimum noise level (58.2dB) is found in road junction 3 - Shaheed Minar Road.

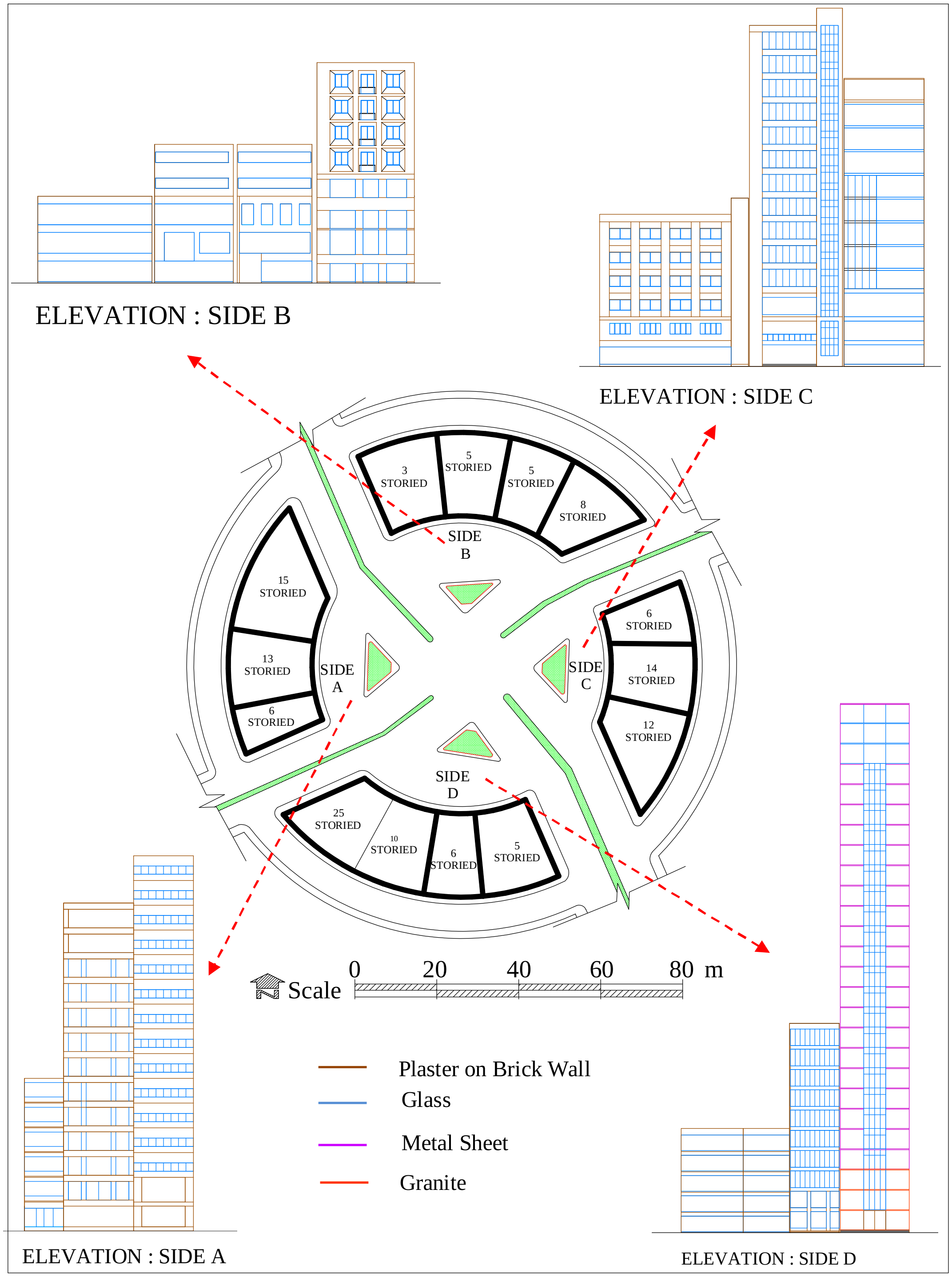


Figure 3.22 Plan and Elevations of Adjacent Buildings at Road Junction 1 - Gulshan 2

Table 3.9 Important physical features in the studied junctions

		Junction1 (Gulshan 2)	**Junction 2 (Dhanmondi12A)**	**Junction 3 (ShahidMinar Road)**
Building Surface Material	Glass (%)	51	45	5
	Brick (%)	30	24	95
	Aluminium Sheet (%)	17	13	0
	Open (%)	0	6	0
	Metal Sheet (%)	0	12	0
	Granite	2	0	0
Road Width	Minimum width (m)	24.5	9	21
	Maximum width (m)	30.5	36.5	24.5
Road Surface (%)		93	92	100
Vegetation (%)		7	8	0
Green Barrier (%)		0	0	42
Maximum Noise Level (dBA)		127.6	124	98.2
Minimum Noise Level (dBA)		60.9	62.7	58.2
Average Noise Level (dBA)		75.49	79.42	73.14

3.3.2 Surface materials used on the buildings

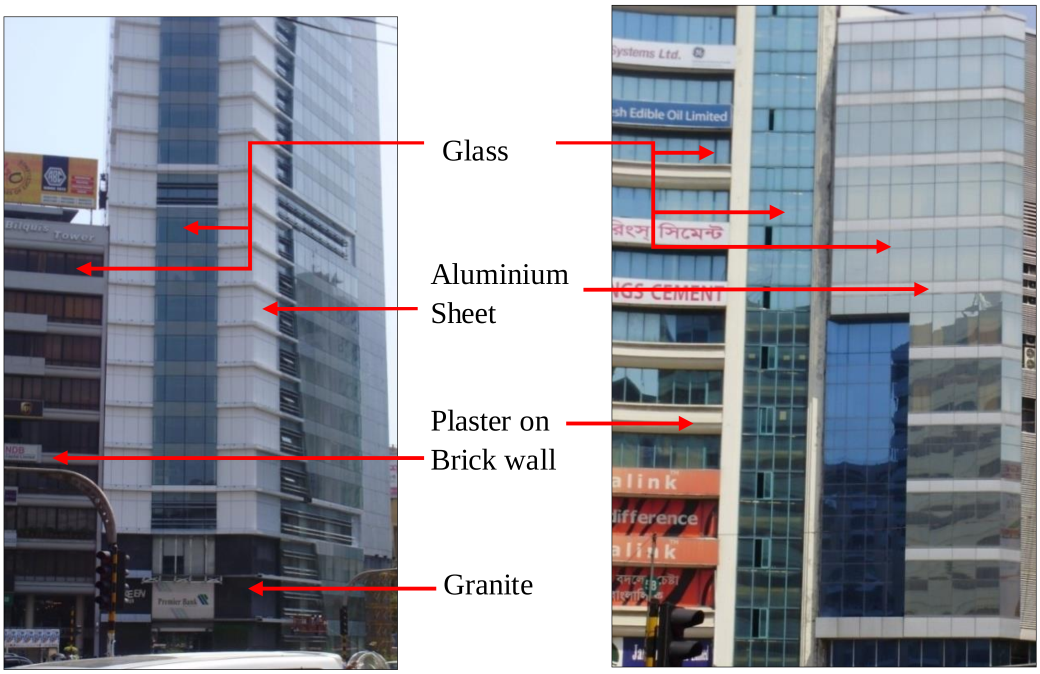


Figure 3.23 Different types of building materials used in Road Junction 1 – Gulshan – 2 (Photo credit: Self)

Various types of surface material are used on the adjacent building at Road Junction 1 ï Gulshan 2. Figure 3.23 illustrates that mostly glass is used on the front side of the buildings of this junction. Along with glass, Aluminium sheet is also used in vast scale. However, it is found that plaster on brick wall is used in less proportion. Relevant types of materials are also found in Road Junction 2 ï Dhanmondi 12A (Figure 3.24). Moreover, it is also found from the field survey that óTileô is used as surface material on some adjacent buildings of the junction. In the road junction 3 ï Shahid Minar Road (Figure 3.25) only two types of materials are found: glass and plaster on brick wall.

Figure 3.24 Different types of building materials used in Road Junction 2 - Dhanmondi 12A (Photo credit: Self)

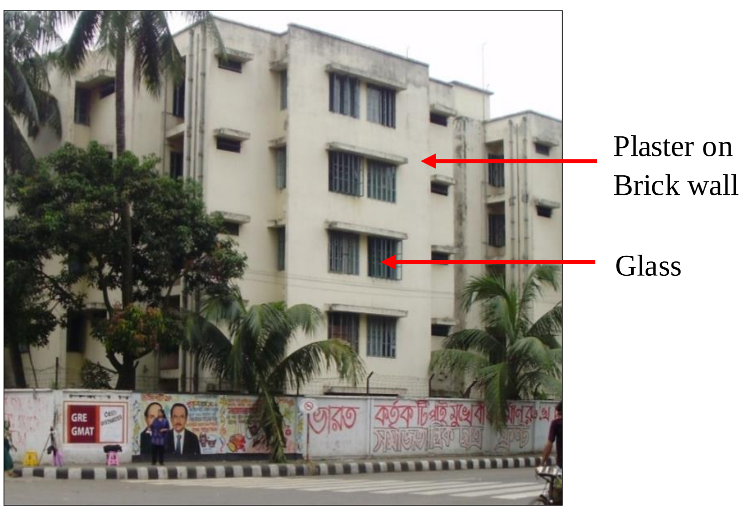


Figure 3.25 Different types of building materials used in Road Junction 3 - Shahid Minar Road (Photo credit: Self)

3.3.3 Vegetation in case study junctions

Figure 3.26 Vegetation in Road Junction 1– Gulshan 2 (Photo credit: Self)

In road junction 1 ï Gulshan 2, some grass and low shrubs are found (Figure 3.22). They are planted in the island separating the traffic flow. However, the amount of vegetation is very low with respect to the volume of the road junction 1 and it has insignificant effect on noise condition.

Figure 3.27 Vegetation in Road Junction 2 – Dhanmondi 12A (Photo credit: Self)

Some large trees like Krishnachura, Devdaru etc. are planted in road junction 2 ï Dhanmondi 12A, as seen in Figure 3.23. There is an open field in the North-East of the junction near position 1 (Figure 3.9).

Figure 3.28 Vegetation in Road Junction 3 – Shahid Minar Road (Photo credit: Self)

Road junction 3 ï Shahid Minar Road has more trees than road junction 1 and 2. Most of the trees at road junction 3 are Krishnachura, Coconut tree and Rain trees. These trees are working as green noise absorber.

3.4 Analysis and Findings

The coefficient of correlation between the main variables is considered to identify and measure the extent of any relationship or connection. óCorrelationô analysis among the main variables of the sample junctions is performed using *Microsoft Excel Data Analysis* tools. Here, the main independent variables are the various surface materials and the dependent variable is the sound level due to traffic volume

The correlation coefficient (a value between -1 and +1) tells how strongly two variables are related to each other. A correlation coefficient of +1 indicates a perfect positive correlation and -1 indicates a perfect negative correlation, whereas the coefficient near 0 indicates no correlation (Mian, M. A. and Miyan, M.A., 1971).

The value between 0.3 and 0.7 indicates moderate degree of correlation (Mian, M. A. And Miyan, M.A., 1971). While doing statistical data analysis to observe correlation among the variables of the studied junctions, moderate degree negative correlation is found among Average Noise Levels, Brick and Green noise absorber. Moderate degree positive correlations are also found among glass, aluminium sheet and other metal sheet.

Table 3.10 Correlation coefficients among noise levels, building surface material area and green surface area of road junctions

Correlation Coefficients	*Glass*	*Brick*	*Granite*	*Aluminium Sheet*	*Vacant surface on wall*	*Metal Sheet*	*Minimum width*	*Maximum width*	*Road Surface Area*	*Green Barrier*	*Diameter of the Junction*	*Volume of the junction space*	*Maximum Noise Level*	*Minimum Noise Level*	*Average Noise Level*
Glass	1.0														
Brick	-1.0	1.0													
Granite	0.6	-0.4	1.0												
Aluminium Sheet	1.0	-1.0	0.7	1.0											
Vacant surface on wall	0.4	-0.6	-0.5	0.3	1.0										
Metal Sheet	0.4	-0.6	-0.5	0.3	1.0	1.0									
Minimum width	-0.2	0.4	0.7	-0.1	-1.0	-1.0	1.0								
Maximum width	0.8	-0.9	0.0	0.7	0.9	0.9	-0.8	1.0							
Road Surface Area	-1.0	1.0	-0.4	-0.9	-0.6	-0.6	0.4	-0.9	1.0						
Green Barrier	-1.0	1.0	-0.5	-1.0	-0.5	-0.5	0.3	-0.9	1.0	1.0					
Diameter of the Junction	0.5	-0.3	1.0	0.6	-0.6	-0.6	0.8	-0.2	-0.3	-0.4	1.0				
Volume of the junction space	0.6	-0.4	1.0	0.7	-0.5	-0.5	0.7	0.0	-0.4	-0.5	1.0	1.0			
Maximum Noise Level	1.0	-0.9	0.7	1.0	0.2	0.2	0.0	0.7	-0.9	-0.9	0.6	0.7	1.0		
Minimum Noise Level	0.8	-0.9	-0.1	0.7	0.9	0.9	-0.8	1.0	-0.9	-0.8	-0.2	-0.1	0.6	1.0	
Average Noise Level	**0.7**	**-0.8**	-0.1	**0.6**	**0.9**	**0.9**	**-0.8**	1.0	**-0.9**	**-0.8**	**-0.3**	**-0.2**	0.5	1.0	1.0

Table 3.10 reveals that in the sample junctionçs correlation coefficient between average noise level and glass area is 0.7 which indicates that the increasing number of glass area will increase the overall sound level. Aluminium sheet (0.6) and metal sheet (0.9) also indicates the similar correlations. The correlation coefficient for maximum road width is 1, which shows that road width is strongly related to average noise level. Whereas correlation coefficients between average noise level and brick (-0.8), green noise barrier (-0.8) and minimum road width (-0.8) reveals that the increasing number of brick and green barrier will decrease the overall sound level. Moreover minimum road width has a moderate degree negative correlation. Results also indicate that surface materials with more sound absorbing quality will generate better noise attenuation at the road junctions.

3.5 Conclusion

The study shows that adjacent building surface materials and green barrier have effects on noise level at road junctions. The more absorbing quality of surface materials, the better will be the effect in noise attenuation. Basing on this observations and also on principles of acoustics, alternative surface materials can be used and analysed. This can be performed through parametric study in terms of simulation and prediction methods to assess if it has effect on improving noise conditions at road junctions.

Reference

Alam, Md., Rauf, A.F.M.A., and Ahmed, M.F., (2001) Traffic Induced Noise Pollution in Dhaka City. *The Institution of Engineers*, Bangladesh.CE 29 (1).p 55.

Mian, M. A. &Miyan, M. A. M. (1971) *An Introduction to Statistics*. 2nd Ed. Dhaka: The Universal Press.

Cochran, W.G., (1977) *Sampling Technique*. 3rd Ed. New York: John Wiley and Sons.

Vimeo. (2014) Available from: https://vimeo.com/67741376 [Accessed: 19th March 2014].

Chapter Four: Simulation and Parametric Study

Introduction

Simulation Tool

Sample Road Junction

Simulation Parameters and Evaluation Process

Comparison between Survey and Simulation Findings

Conclusion

Chapter Four: Simulation and Parametric Study

4.0 Introduction

In the field of architectural acoustics, many technological achievements regarding measurement and application techniques are notable. Among the advanced methods, computer aided simulation is widely used for the acoustical calculations of the buildings (Rindel, 2000). This parametric study method is also used for assessing and modifying the acoustical characteristics of a space during the design phase (Rindel, 2000). By using advanced simulation tools, the acoustical properties of road junction can be identified. Moreover, simulation modelling allows studying the effect of changes in any physical aspect while keeping other features constant in the road junction. The observation of simulated behaviour related to changing parameters allows the identification of elements, the reduction or introduction of surface materials to get the expected sound level in the concerned junction.

Basing on findings of field surveys on three road junctions, as presented in Chapter Three, finally one road junction, namely Road Junction 1 - Gulshan 2, is selected for simulation and parametric study. The justifications of selecting one particular road junction are given below:

- The Road Junction 1 - Gulshan 2 has similar features, in terms of surrounding building surface materials, noise patterns etc., to those in other two road junctions undergone field surveys. Thus, the results in simulation and parametric study on this junction should have qualitative similarity to assess if different types of building surface materials have any effect on reduction of noise levels in road junctions. However, the quantitative parameters, like prevailing noise levels, reduced noise levels due to surface treatments etc., are expected to differ due to variations in base conditions of other two road junctions. Since, this research focuses more to postulate if there is any effect of surface treatment criteria on noise reduction in road junctions rather than finding quantitative variations in different cases.
- In field studies on three road junctions, the observations were helpful to compare óbase conditionsô of different road junctions, considering the óroad junctionô as a variable. In parametric study, a comparison is done on different óbuilding surface materialsô to identify if those have varying effect on reduction of noise at a road junction, considering the óbuilding surface

materialô as a variable and the ôbase conditionô of the road junction as a constant. Thus, selection of a single road junction to compare the effect of building materials on noise reduction complies with the principles of comparability for assessing the postulation.

- Simulation and parametric study requires a huge amount of data processing along with time intensive operation of software to get dependable results. Increasing the number of sample cases, in the limited time frame of this research, may hinder the in-depth analysis and accuracy of results.

Based on the findings of these simulation and parametric studies, this chapter will suggest some proposals on use of surface materials on adjacent buildings to reduce noise levels at road junctions.

4.1 Simulation Tool:

The option of parametric study in digital environment based on simulation and prediction techniques, using software óODEONô (Version 11.10) is most justified (Chapter One, Section 1.3.6) as the software is acoustic computation based software. It is developed mainly for simulating the acoustical condition within buildings. Given the geometry and surface-properties, the acoustics can be predicted and illustrated. ODEON uses the óimage-source methodô combined with ray tracing for the simulation of acoustical incidences and formations for spaces (Odeon, 1996). The software is used to analyse and evaluate the acoustical properties of any kind of enclosed space as well as to assess with recommendations for optimum acoustical environments (Rindel, 2000).

4.2 Sample Road Junction

The road junction 1 - Gulshan 2 was taken as a sample road junction (Figure 4.1). The base conditions of the junction as well as detailed investigations on its acoustical performance were previously restated in Chapter Three. The reason behind choosing this particular junction is that different types of surface materials (Table 3.2) have been used in a large scale than the other two junctions and it contains more motorised vehicles. Moreover the amount of building surface material is higher (Table 3.9) where glass, which has less sound absorption coefficient, is mostly used on the exterior wall. From field survey, the highest sound level (Table 3.9) was also recorded in junction-1.

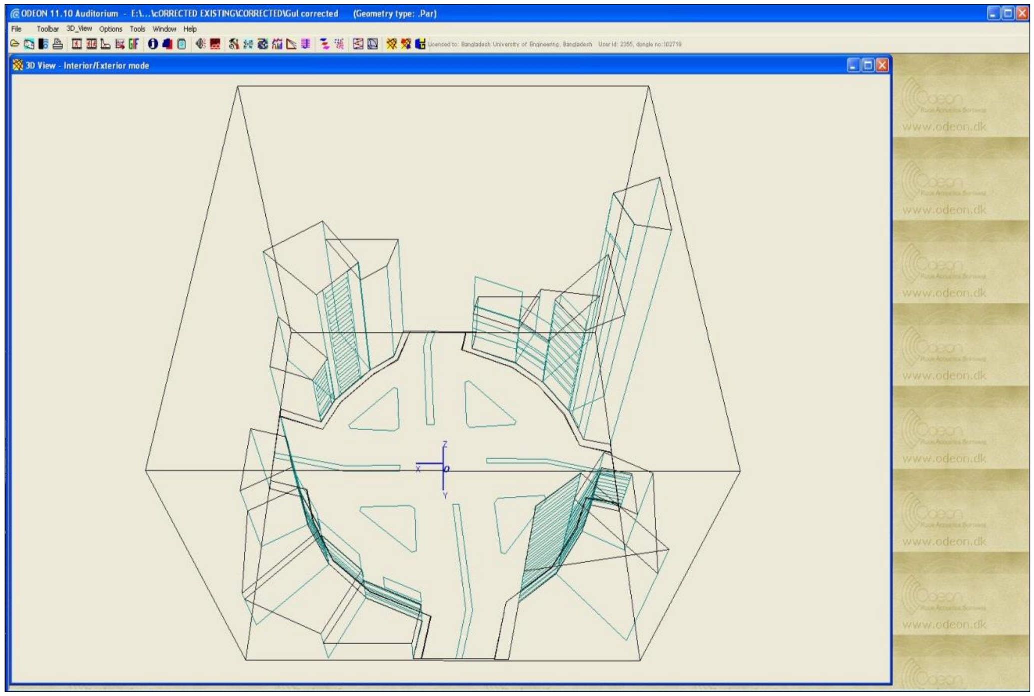


Figure 4.1 View of the model used for the simulation (Software: Odeon, Version 11.10 Auditorium)

4.3 Simulation Parameters and Evaluation Process

In order to accomplish the computer based simulations by ODEON software, the two dimensional (2D) plan of the road junction 1 - Gulshan 2 is initially drawn in AutoCAD 2007 and saved in óDWFô format. This file is imported into ó3D Studio Max8ô software for obtaining the three dimensional (3D) view of the selected junction (Figure 3.4) and exported as ó3DSô file. This ó3DSô file is imported to ODEON.

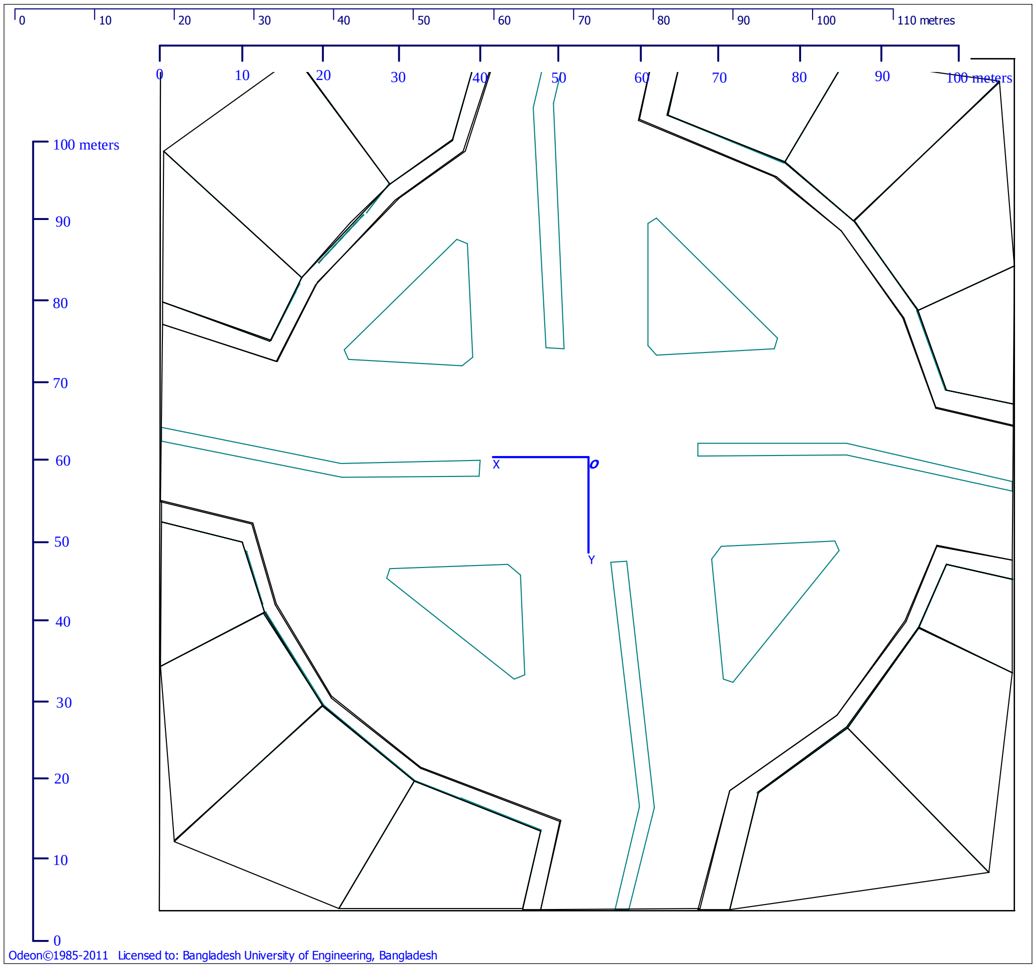


Figure 4.2 Top view of the 3D model used for the simulation (Software: Odeon)

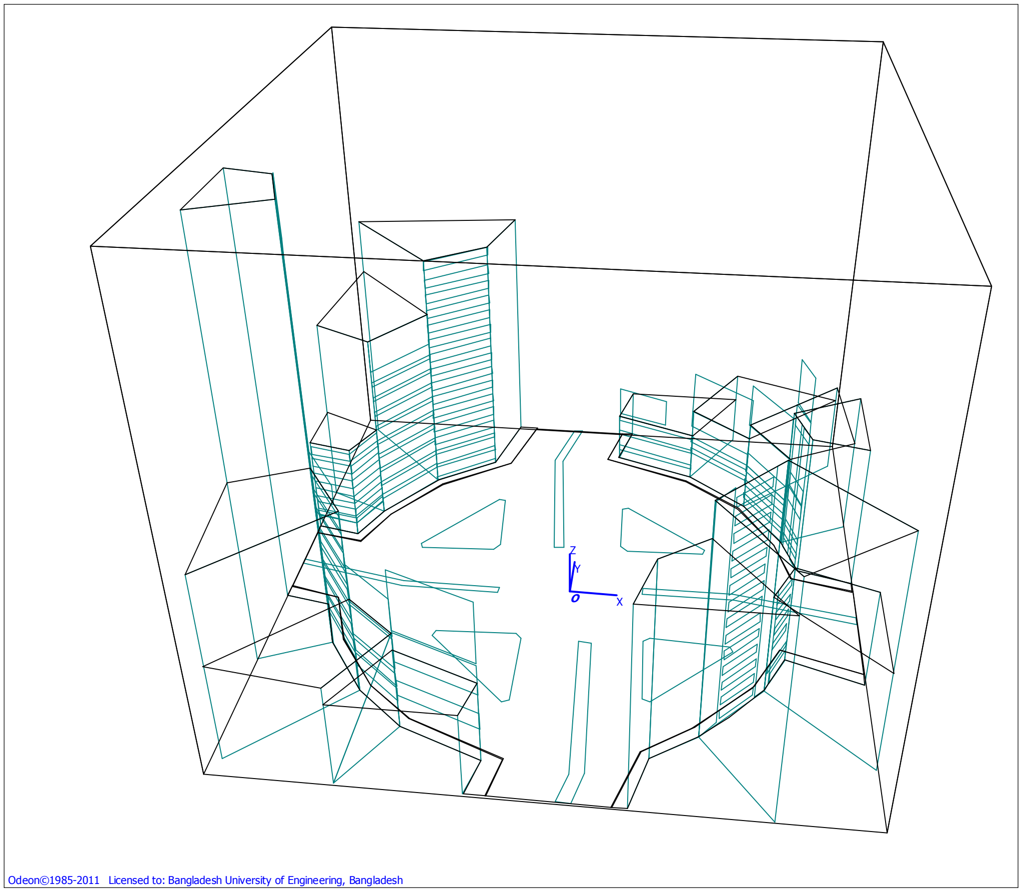


Figure 4.3 3D view of the model used for the simulation (Software: Odeon)

After the model was successfully imported (Figure 4.2 and Figure 4.3), the materials (Table 4.1) have been assigned to the identified surfaces (Figure 4.4) as found in the physical survey (Table 3.2) (Chapter Three). 100% absorbent material is assigned for the air surfaces around the junction.

Table 4.1 Absorption coefficient of various materials used in theRoad Junction 1 – Gulshan 2 (Source: field survey and Odeon 11.10 Auditorium)

Material	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Brick, unglazed	0.03	0.03	0.03	0.03	0.04	0.00	0.07	0.07
Painted plaster surface	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Linoleum	0.02	0.02	0.02	0.03	0.04	0.04	0.05	0.05

Material	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Granite	0.01	0.01	0.01	0.01	0.01	0.02	0.02	-
Grass	0.11	0.11	0.26	0.60	0.69	0.92	0.99	0.99
Glass, large panes of heavy plate glass	0.18	0.18	0.06	0.04	0.03	0.02	0.02	0.02
Asphalt	0.02	0.01	0.07	0.05	0.05	0.04	0.31	0.00

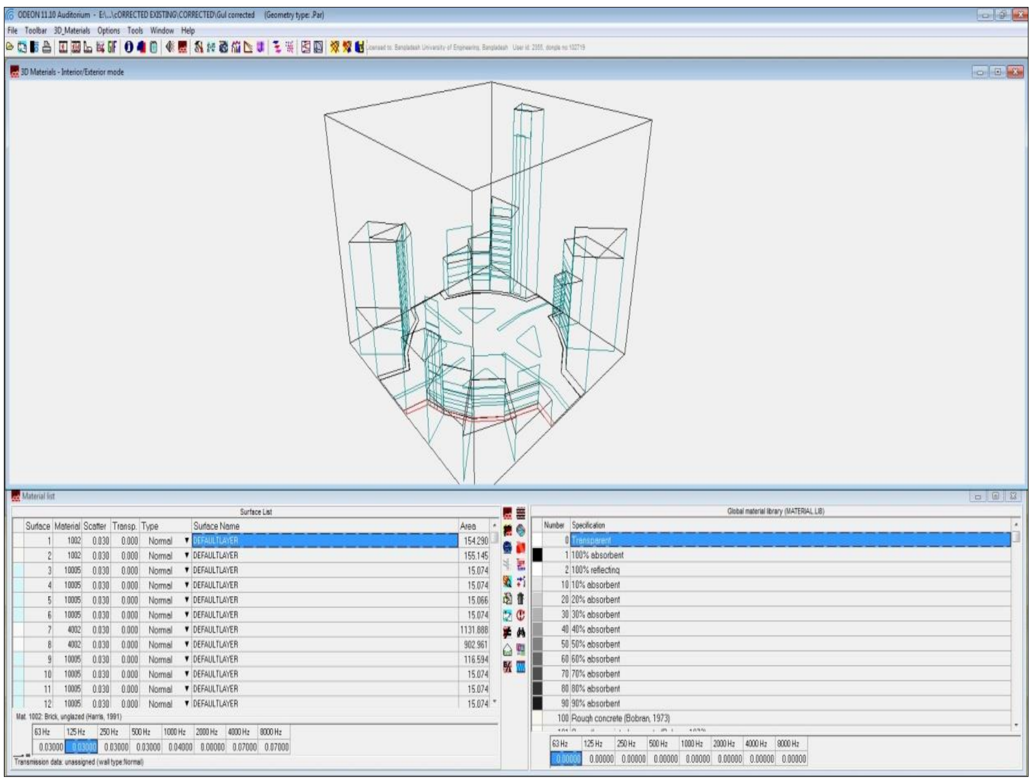
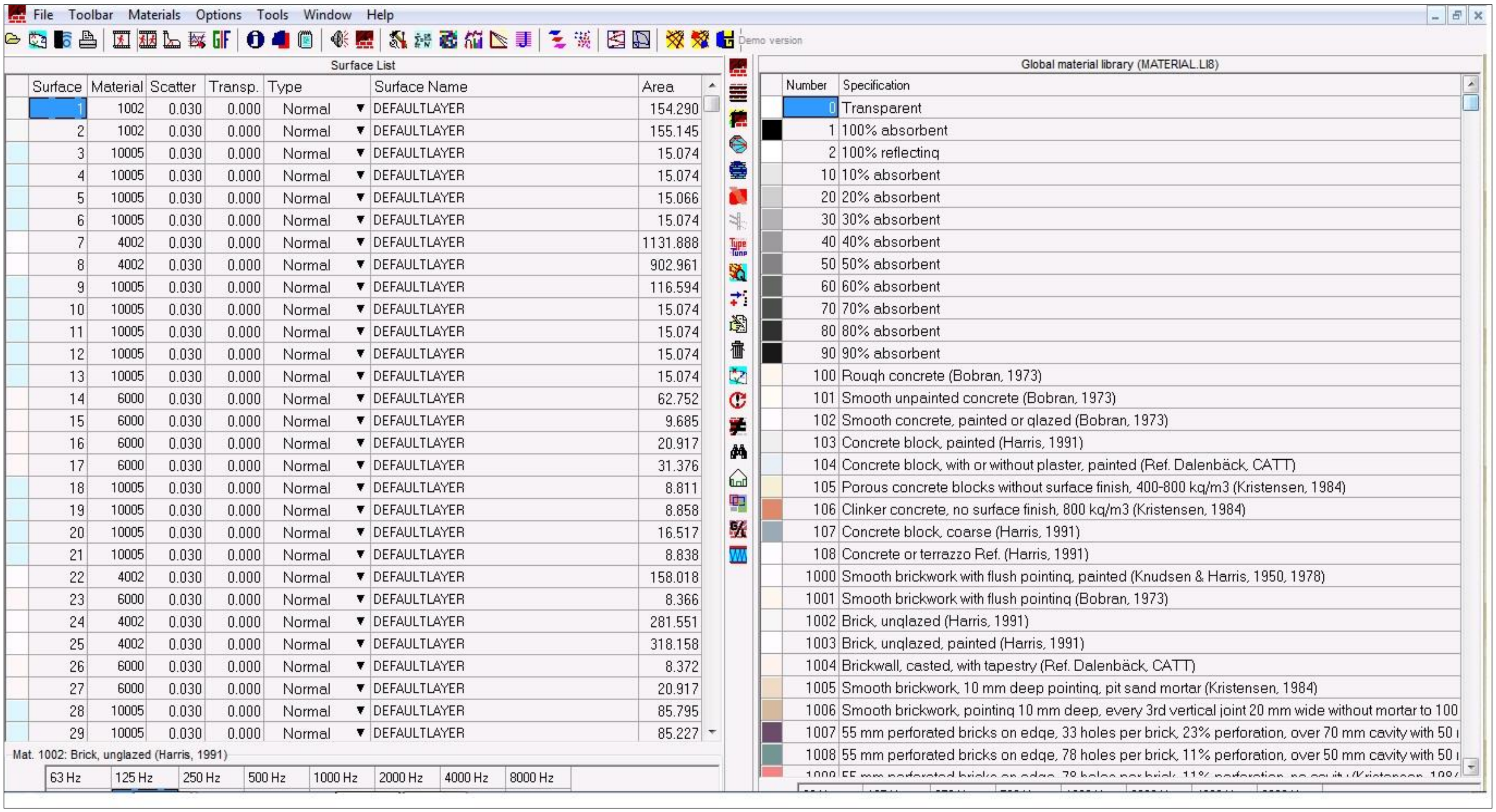


Figure 4.4 3D view of model with material list for existing condition (Software: Odeon)



Surface	Material	Scatter	Transp.	Type	Surface Name	Area
1	1002	0.030	0.000	Normal	DEFAULTLAYER	154.290
2	1002	0.030	0.000	Normal	DEFAULTLAYER	155.145
3	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
4	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
5	10005	0.030	0.000	Normal	DEFAULTLAYER	15.066
6	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
7	4002	0.030	0.000	Normal	DEFAULTLAYER	1131.888
8	4002	0.030	0.000	Normal	DEFAULTLAYER	902.961
9	10005	0.030	0.000	Normal	DEFAULTLAYER	116.594
10	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
11	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
12	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
13	10005	0.030	0.000	Normal	DEFAULTLAYER	15.074
14	6000	0.030	0.000	Normal	DEFAULTLAYER	62.752
15	6000	0.030	0.000	Normal	DEFAULTLAYER	9.685
16	6000	0.030	0.000	Normal	DEFAULTLAYER	20.917
17	6000	0.030	0.000	Normal	DEFAULTLAYER	31.376
18	10005	0.030	0.000	Normal	DEFAULTLAYER	8.811
19	10005	0.030	0.000	Normal	DEFAULTLAYER	8.858
20	10005	0.030	0.000	Normal	DEFAULTLAYER	16.517
21	10005	0.030	0.000	Normal	DEFAULTLAYER	8.838
22	4002	0.030	0.000	Normal	DEFAULTLAYER	158.018
23	6000	0.030	0.000	Normal	DEFAULTLAYER	8.366
24	4002	0.030	0.000	Normal	DEFAULTLAYER	281.551
25	4002	0.030	0.000	Normal	DEFAULTLAYER	318.158
26	6000	0.030	0.000	Normal	DEFAULTLAYER	8.372
27	6000	0.030	0.000	Normal	DEFAULTLAYER	20.917
28	10005	0.030	0.000	Normal	DEFAULTLAYER	85.795
29	10005	0.030	0.000	Normal	DEFAULTLAYER	85.227

Number	Specification
0	Transparent
1	100% absorbent
2	100% reflecting
10	10% absorbent
20	20% absorbent
30	30% absorbent
40	40% absorbent
50	50% absorbent
60	60% absorbent
70	70% absorbent
80	80% absorbent
90	90% absorbent
100	Rough concrete (Bobran, 1973)
101	Smooth unpainted concrete (Bobran, 1973)
102	Smooth concrete, painted or glazed (Bobran, 1973)
103	Concrete block, painted (Harris, 1991)
104	Concrete block, with or without plaster, painted (Ref. Dalenbäck, CATT)
105	Porous concrete blocks without surface finish, 400-800 kg/m3 (Kristensen, 1984)
106	Clinker concrete, no surface finish, 800 kg/m3 (Kristensen, 1984)
107	Concrete block, coarse (Harris, 1991)
108	Concrete or terrazzo Ref. (Harris, 1991)
1000	Smooth brickwork with flush pointing, painted (Knudsen & Harris, 1950, 1978)
1001	Smooth brickwork with flush pointing (Bobran, 1973)
1002	Brick, unglazed (Harris, 1991)
1003	Brick, unglazed, painted (Harris, 1991)
1004	Brickwall, casted, with tapestry (Ref. Dalenbäck, CATT)
1005	Smooth brickwork, 10 mm deep pointing, pit sand mortar (Kristensen, 1984)
1006	Smooth brickwork, pointing 10 mm deep, every 3rd vertical joint 20 mm wide without mortar to 100
1007	55 mm perforated bricks on edge, 33 holes per brick, 23% perforation, over 70 mm cavity with 50
1008	55 mm perforated bricks on edge, 78 holes per brick, 11% perforation, over 50 mm cavity with 50

Figure 4.5 Material list for existing condition (Software: Odeon)

As a next step, 20 nos. of sources were defined (Figure 4.6) according to the traffic flow and direction as it was found from the physical survey that around 20 nos. of cars pass through the junction in every 20 seconds. 2 receivers position were defined according to ôPosition 1ô and ôPosition 3ô in Figure 3.3. The position of the receiver-1 was defined as X:-10m; Y:-14m and Z: 1.5m while that for receiver- 2 was X: 12m; Y:16m and Z:1.5m. The receivers were identified at 1.5 meters of height. The source type and directivity pattern were also set accordingly.

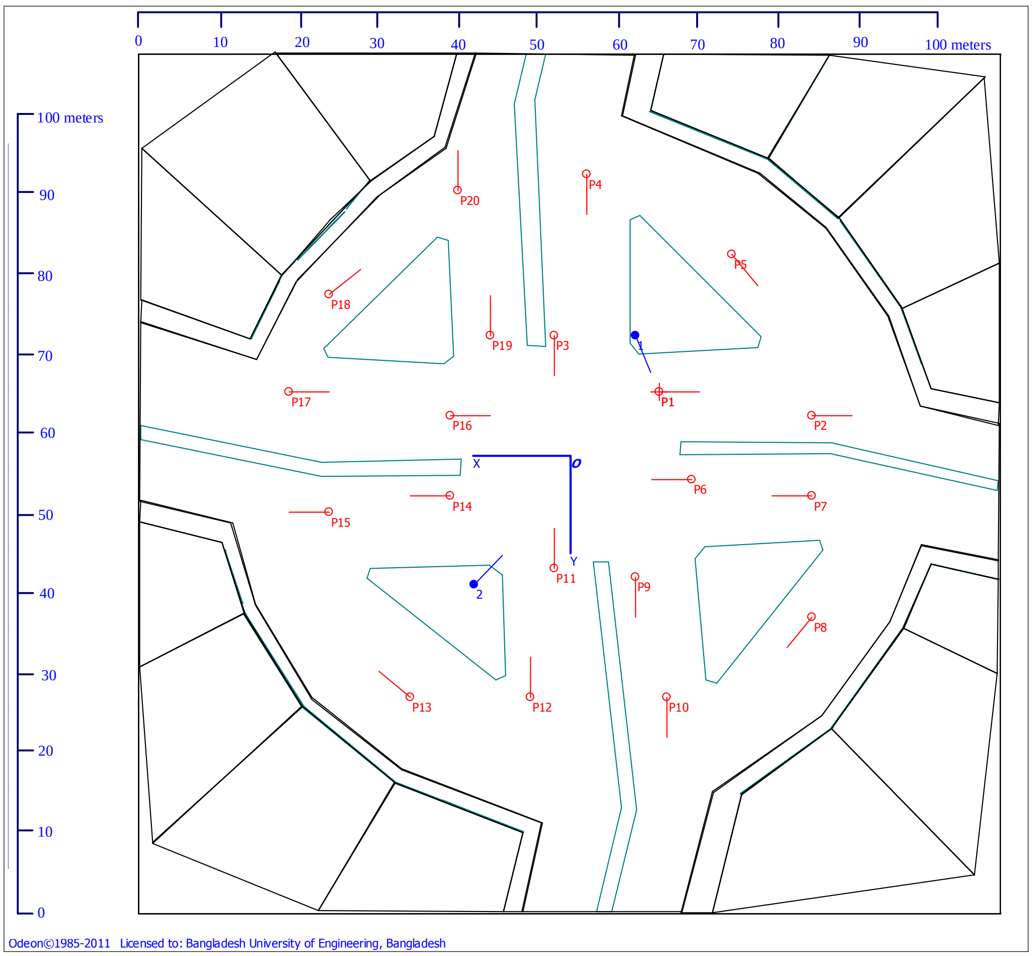


Figure 4.6 Position of sources and receiver in the model with existing condition (Software: Odeon)

Figure 4.7 is showing the reverberation time derived by the existing material properties used in junction 1. It shows that T-Sabine is the highest for 63 Hz and 125 Hz frequency. Reverberation times is 3.85 and 1 seconds accordingly. Same difference is found for Eyring and Arau-Punchades, 2.58 and 3.07 seconds for 3 Hz and 0.97 and 1.03 seconds for 8 KHz. Figure 4.8 shows that the air within the space, act as the main absorber for frequencies over 2 kHz. This figure also demonstrated that surrounding open area acts as a major absorber for all other frequencies.

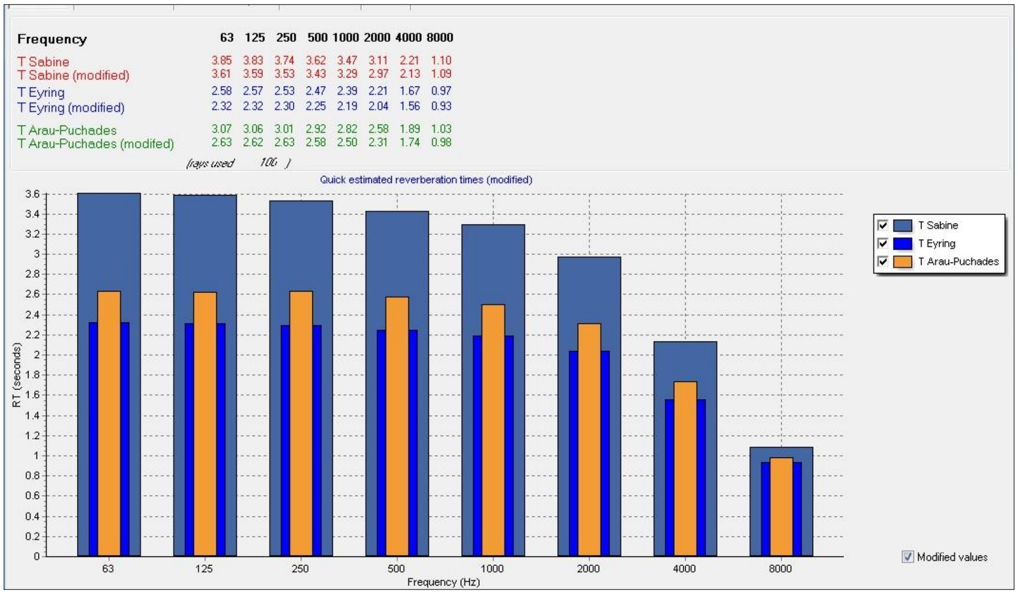


Figure 4.7 Estimated global reverberation times of Sabine, Eyring and Arau-Punchades derived by material properties (Software: Odeon)

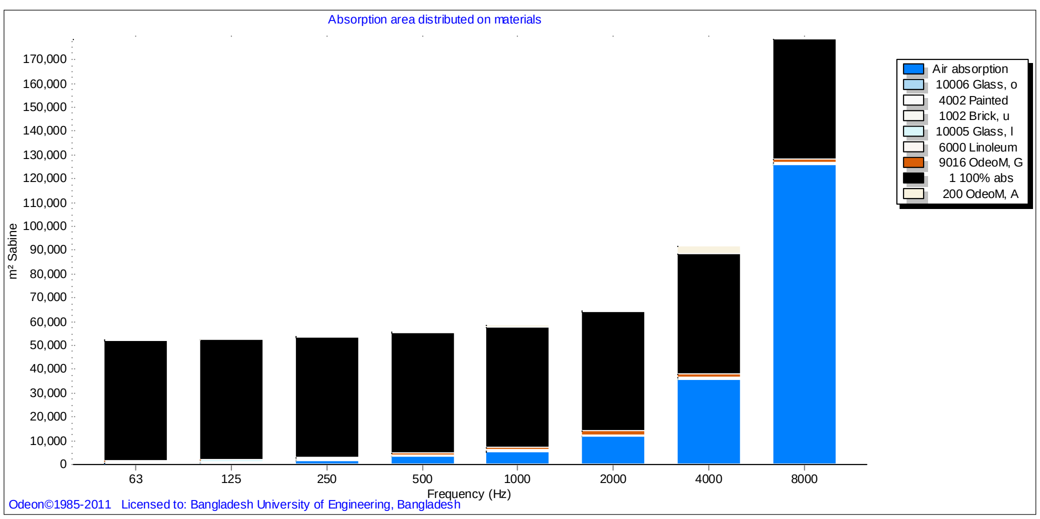


Figure 4.8 Bar chart showing the total absorption area of current materials assigned for the computer simulation (Software: Odeon)

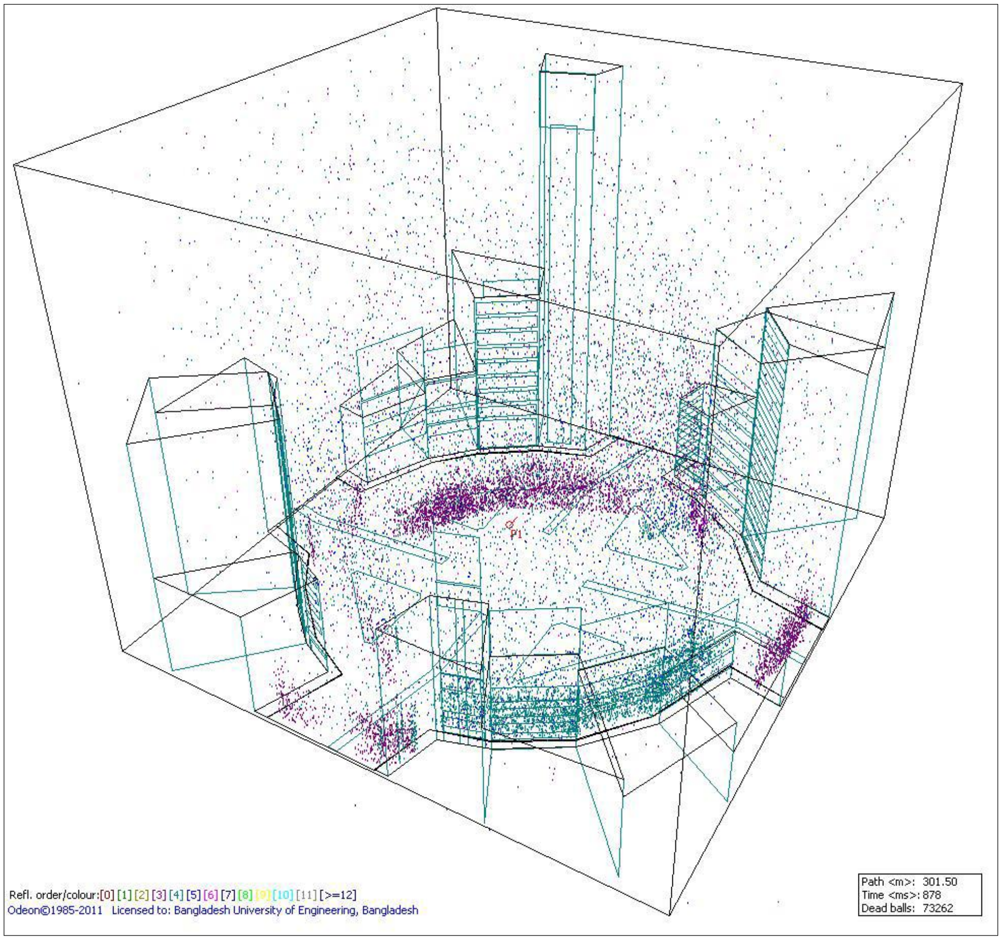


Figure 4.9 Billiard balls emitting from source1 and reflecting from the surfaces (Software: Odeon)

Figure 4.9 is showing that 1,00,000 billiard balls are emitting from source p1 and reflecting from the surfaces of the buildings to show the direction of sound propagation. According to Maekawa and Lord (1994; p-81), ñwhen floor and ceiling are highly absorptive but walls reflective, the reflected sounds in the vertical direction decay rapidly while the reflected sounds in the horizontal direction remain repeating reflections with slow decay, thus the decay curve bendsò. Figure 4.9 also shows that the billiard balls in the horizontal direction are repeating and slowly decaying.

Following the above procedure, computer simulation was only performed for the various materials, used on the existing building surfaces of junction-1 to limit the scope of this part of research, to identify the impact on the acoustical condition. Material types were previously identified during physical survey (Chapter Three). While considering overall acoustical condition, simulation study will be based on the change of building surface materials. This will help to discover the effect of material on this specified junction.

4.4 Comparison Between Survey and Simulation Findings

The decisions regarding acoustical condition of a road junction in this part of the research were partially based on the findings of the óOdeonô simulation program. Materials from the óMaterial Listô (Figure 4.5) is used for simulation. New material will be difficult to use as an anechoic chamber will be needed to record the absorption coefficient of that particular material. Three groups with three types of different surface materials are created to compare the simulation result. Comparative study between existing condition and modifying surface is mainly based on two key parameters which are the óEarly Decay Timeô (EDT) and óSound Pressure Levelô (SPL) values.

4.4.1 Early Decay Time (EDT)

Material Type-1

At first, materials found from the field survey is used for simulation and the distribution map for EDT is created (Figure 4.10).

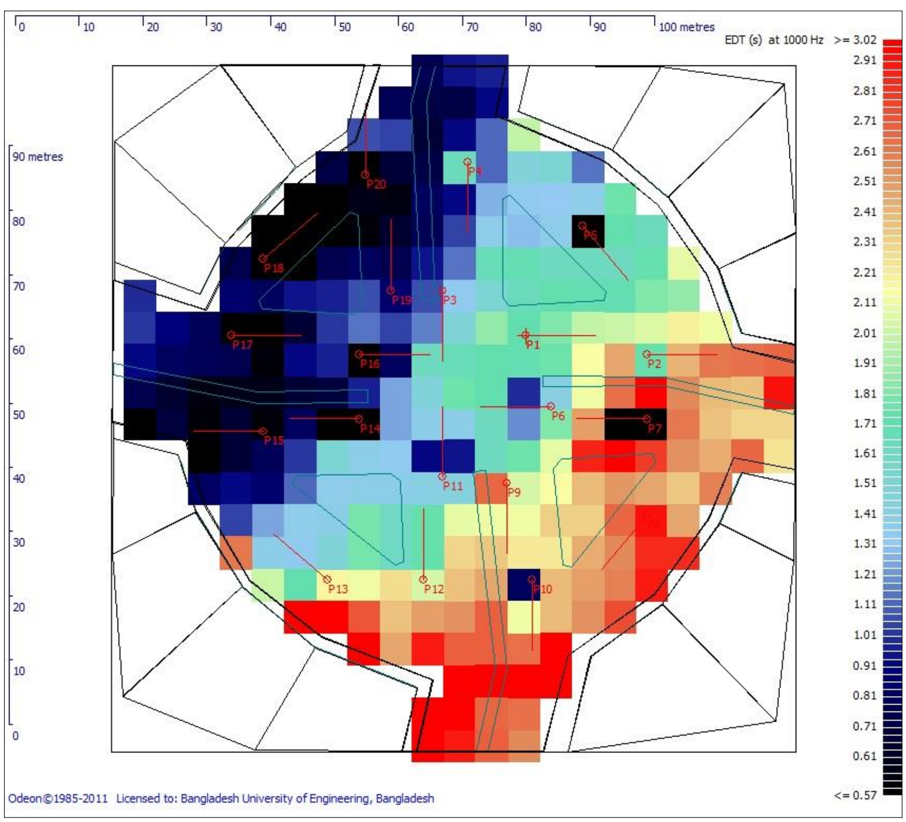


Figure 4.10 EDT distribution map for 1 kHz with existing condition (Software: Odeon)

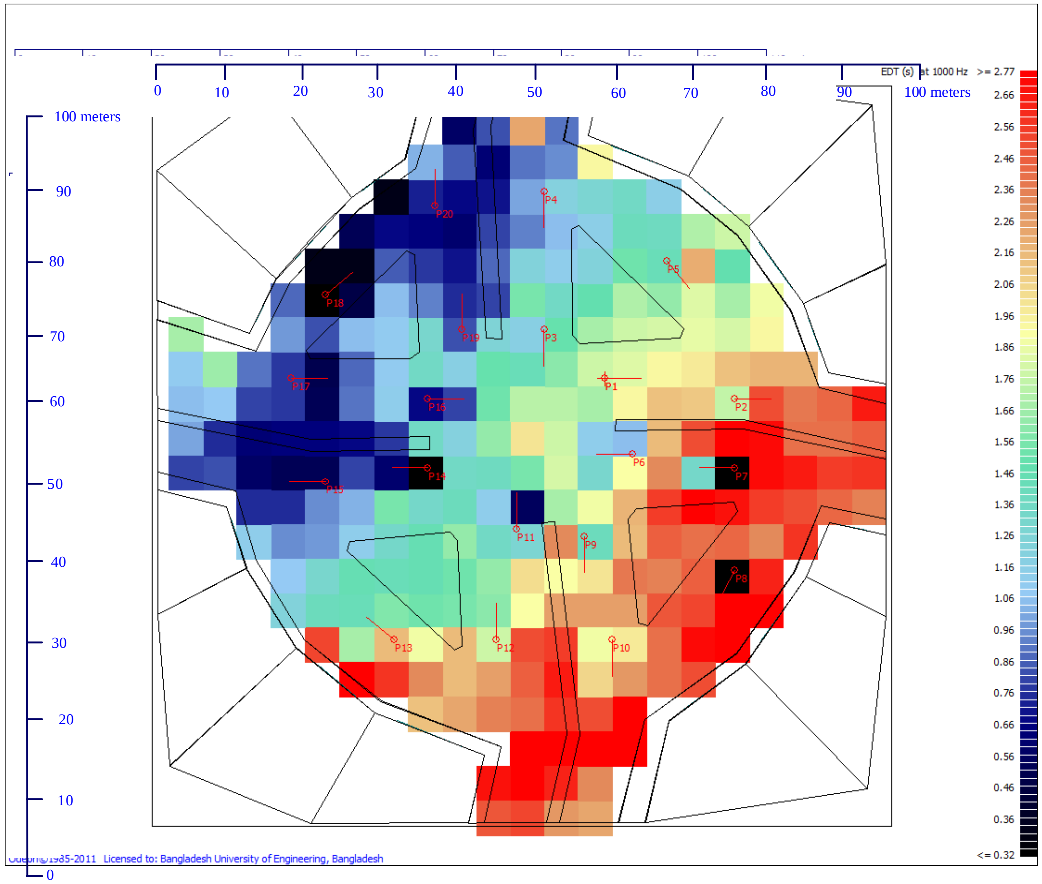


Figure 4.11 EDT distribution map for 1 kHz with smooth concrete, painted or glazed (Software: Odeon)

Material Type-2

Here some materials such as painted smooth concrete and large panes of heavy plate glass are selected from the material list of óODEONô which have lower absorption coefficient than the existing one. Figure 4.11 illustrates the EDT distribution map to observe the variation in the distribution.

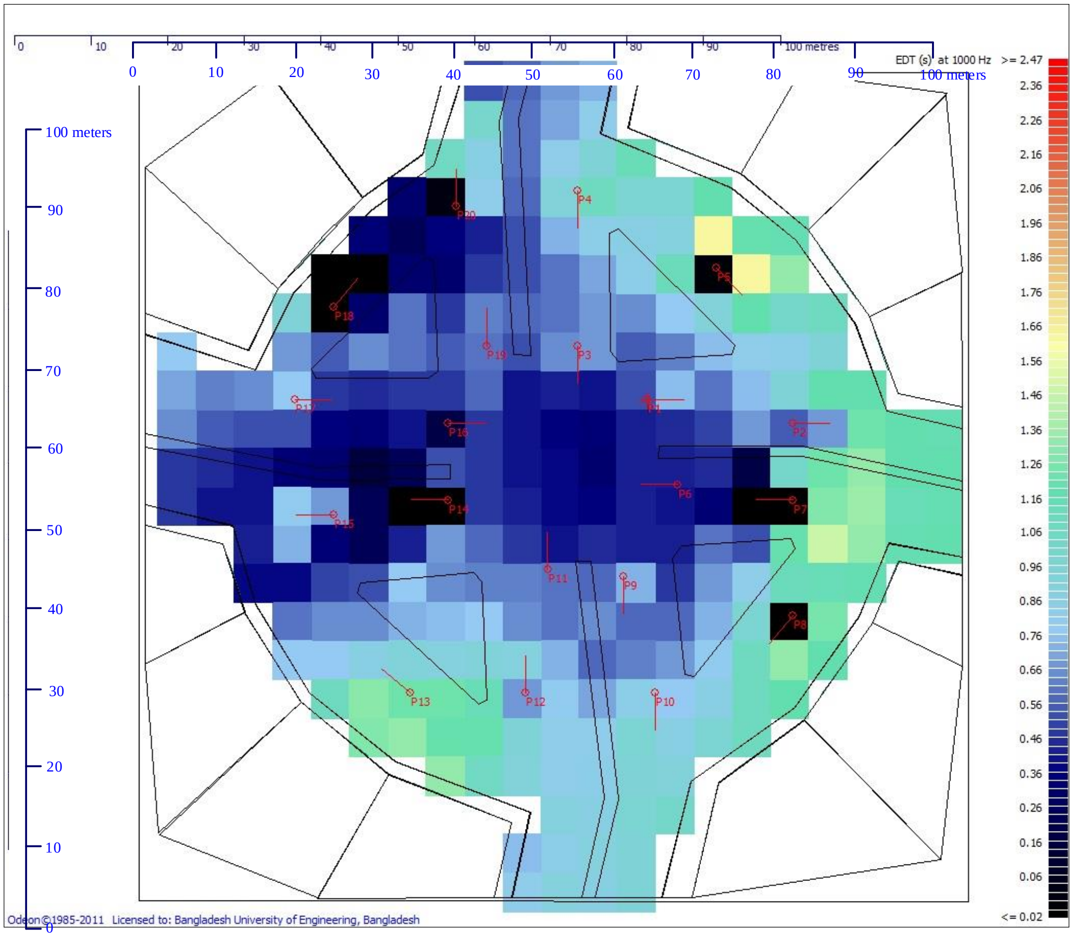


Figure 4.12 EDT distribution map for 1 kHz for bricks with 19 mm holes, 60 mm thick, directly on concrete wall (Software: Odeon)

Material Type-3

Materials such as bricks with 19 holes, 60 mm thick, directly on concrete wall (ODEON) with higher absorption coefficient and ordinary window glass (Figure 4.12) are used as surface material. EDT distribution map shows that EDT is decreased than the previous two conditions.

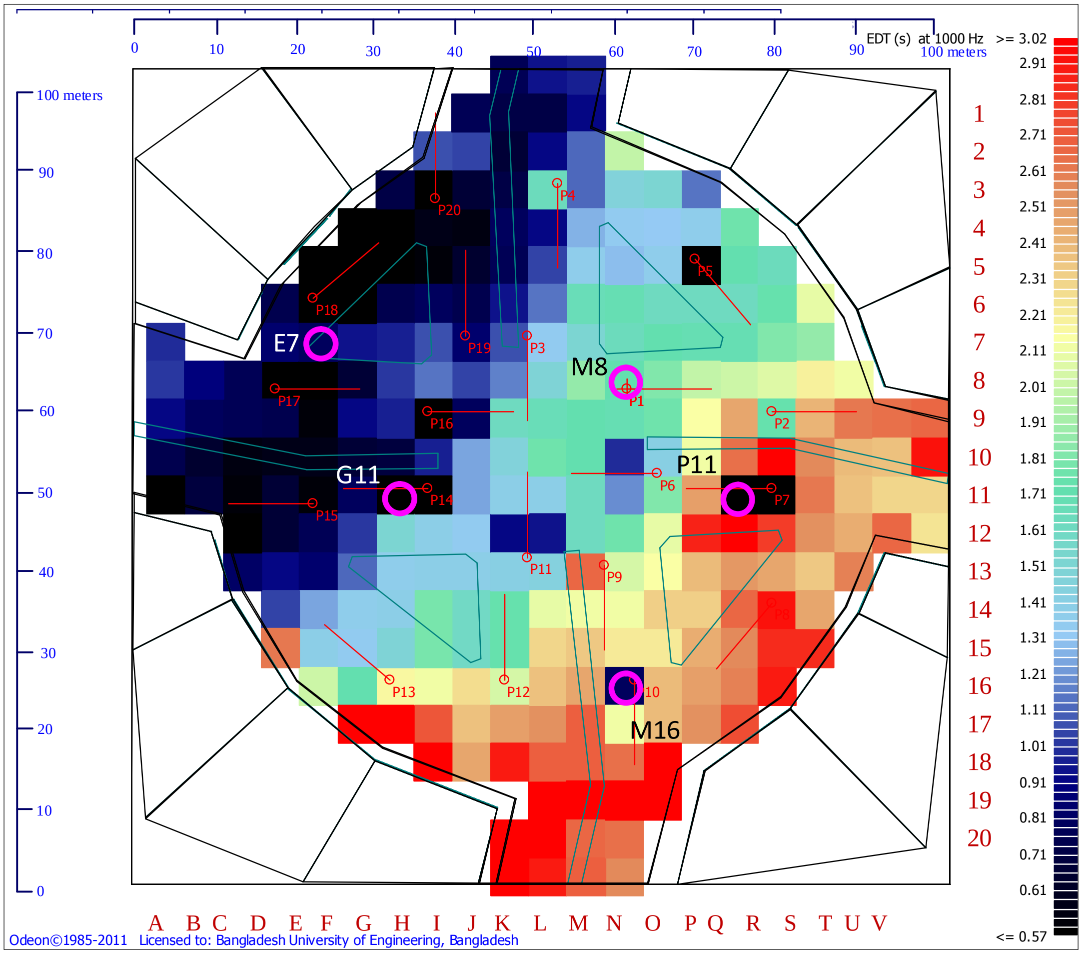


Figure 4.13 Map showing locations of the selected grid position for EDT in Road Junction 1 – Gulshan 2

Now in Figure 4.13, five grid points E7, M8, G11, P11 and M16 is marked. EDT is recorded from the above points for each material types (Material Type-1, 2 and 3) to get a more clear view among the variation of EDT.

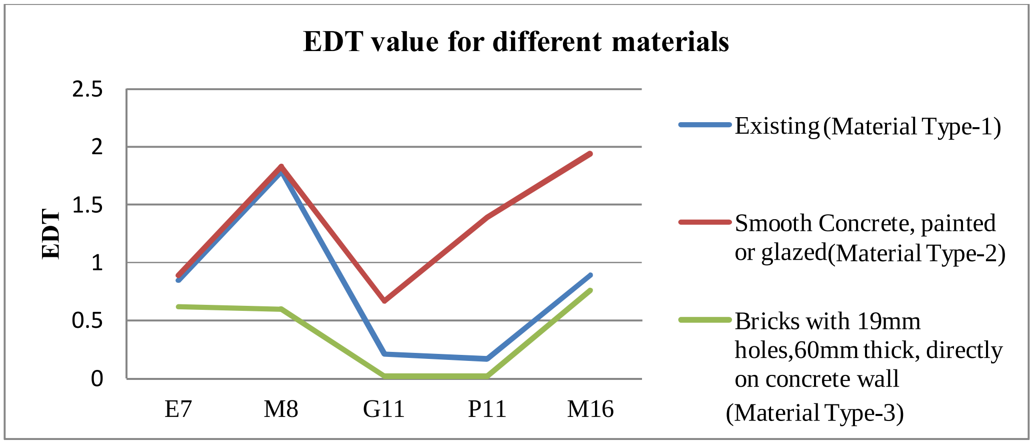


Figure 4.14 Graph showing the variation of EDT for different materials in Road Junction 1 – Gulshan 2

Figure 4.14 shows that the use of material (Material Type-2) with less absorption coefficient has higher EDT value, whereas use of material (Material Type-3) with high absorption coefficient can reduce the EDT value of junction-1.

Table 4.2 shows the selected data that are used in the analysis of variance. The data were collected from the selected grid points that are shown in Figure 4.13.

Table 4.2 EDT in different location in the Road Junction 1 – Gulshan 2

Position	Existing condition (second)	Smooth Concrete, Painted or glazed (Bobran, 1973)	Bricks with 19mm holes, 60mm thick, directly on concrete wall (second)
	Material Type 1	**Material Type 2**	**Material Type 3**
E7	0.85	0.89	0.62
M8	1.79	1.83	0.60
G11	0.21	0.67	0.02
P11	0.17	1.39	0.91
M16	0.87	1.94	0.63

óAnalysis of variance (ANOVA)ô(Chapter 2) is used to test differences among the EDT value, obtained from the simulation for material type1,2 and 3. óF distributionô is used to determine whether the means could be equal. At first, it is initially hypothesized that the use of different types of material on the surface of a building has no impact on the acoustical condition EDT of a road junction.

If the Null Hypothesis (H_0), is true then the mean of the EDT value for each material type (Table 4.2) will be equal. And the material will have no impact on the acoustical condition considering the EDT values.

Therefore, H_0: $\varepsilon_1 = \varepsilon_2 = \varepsilon_3$

However if the sample data can provide sufficient evidence to prove that null hypothesis is false then this hypothesis will be rejected and alternate Hypothesis (H_1) will be accepted, which will state that acoustical condition of a junction can be changed with the use of different materials.

Hence, if, F ÓCritical Value then null hypothesis will be rejected.

With the level of significance 0.05 for the research project, the following calculations are found with ANOVA.

Table 4.3 ANOVA-Analysis of variance for EDT

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Rows	2.62	4	0.65	5.26	0.02	3.84
Columns	2.11	2	1.06	**8.48**	0.01	**4.46**
Error	0.99	8	0.12			
Total	5.73	14				

The Table 4.3 shows that F, 8.48 ÓF critical value, 4.46.

Hence H_0 can be rejected and H_1 is acceptable. Thus it can be said that changing the facade material can certainly contribute to change the EDT in road junction 1 ï Gulshan 2.

4.4.2 Sound pressure level (SPL)

Material Type-1

The simulation can also predict the sound pressure level distribution in junction-1. Figure 4.15 derives the distribution map for SPL in junction-1 where materials found from the survey was used.

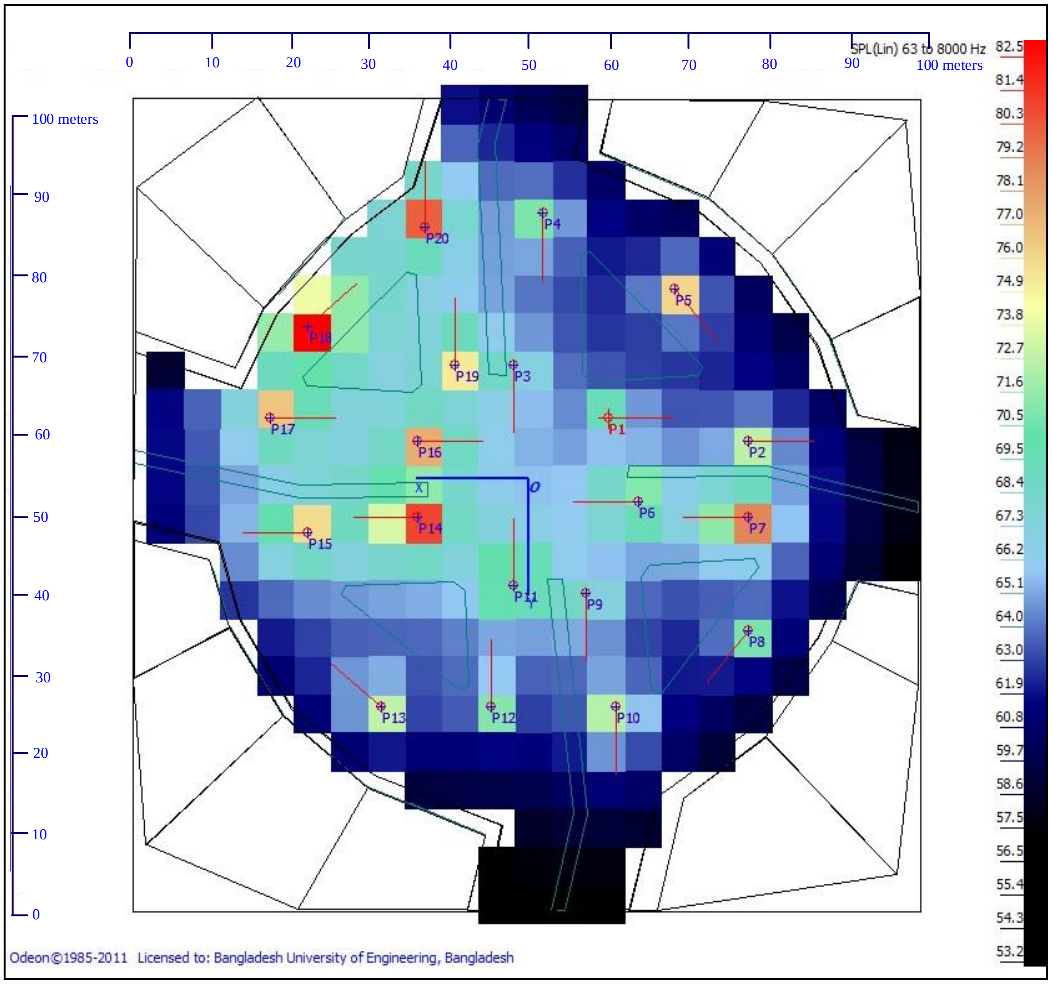


Figure 4.15 SPL distribution map for 8 kHz with existing condition (Software: Odeon)

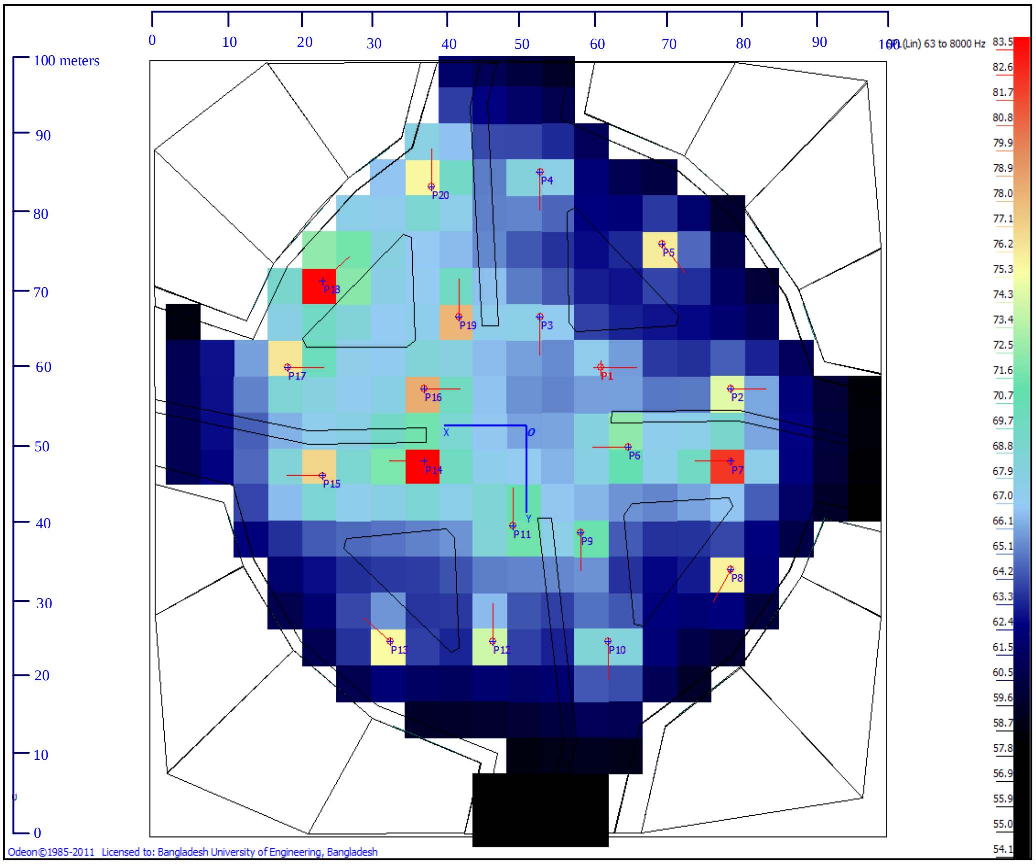


Figure 4.16 SPL distribution map for 8 kHz with smooth concrete, painted or glazed (Software: Odeon)

Material Type-2

Figure 4.16 shows the SPL distribution map for another case where painted smooth concrete and large panes of heavy plate glass with less absorption coefficient is used as surface material to observe the variation in the distribution.

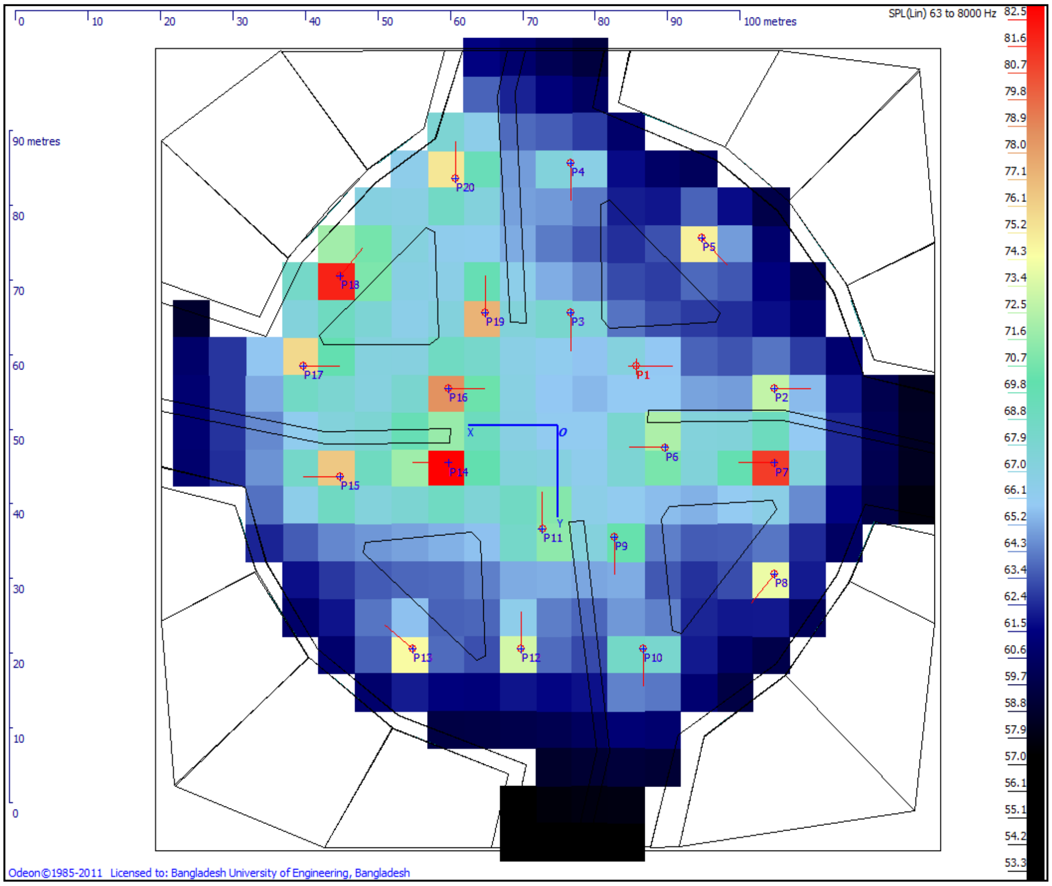


Figure 4.17 SPL distribution map for 8 kHz for bricks with 19mm holes, 60mm thick, directly on concrete wall (Software: Odeon)

Material Type-3

If bricks with 19 mm holes, 60 mm thick, directly on concrete wall and ordinary window glass with higher absorption coefficient (Figure 4.17) are used, SPL distribution map shows that SPL has decreased compared with the previous two conditions.

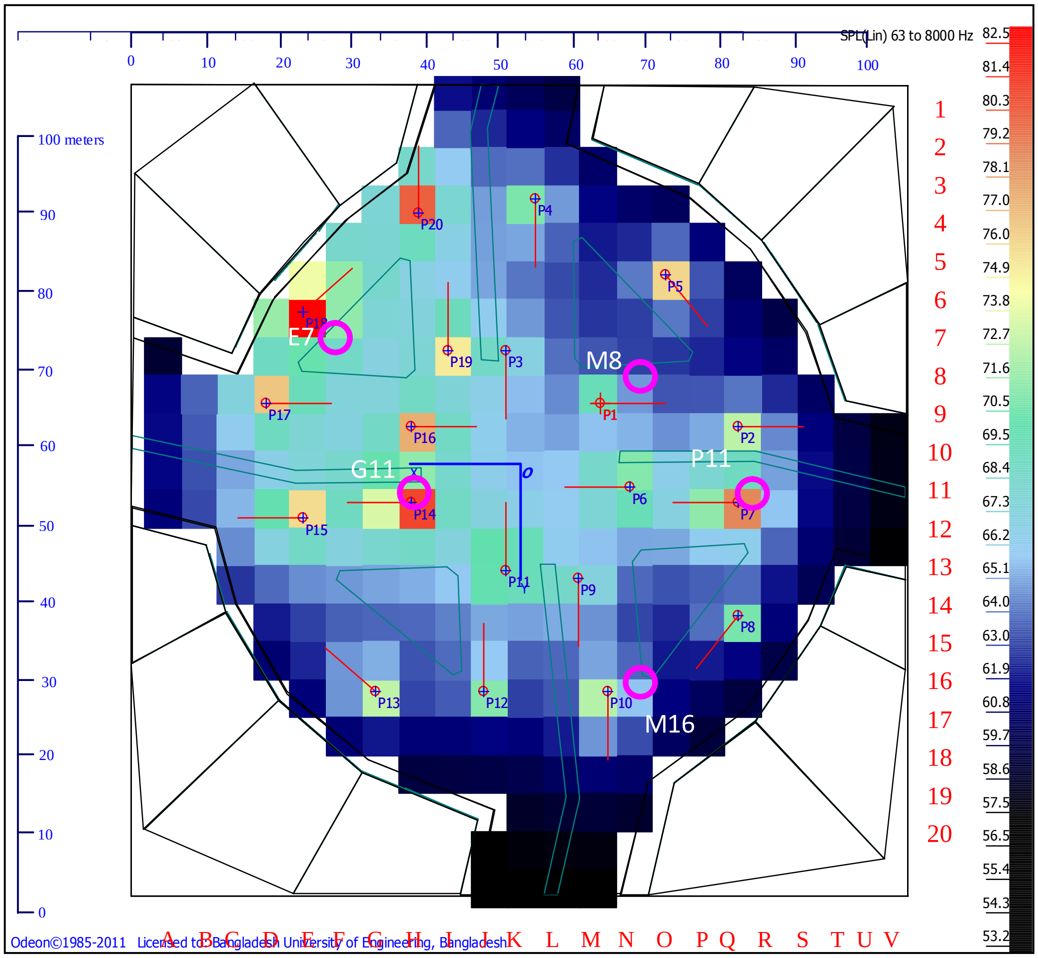


Figure 4.18 Map showing locations of selected grid position for SPL in Road Junction 1 – Gulshan 2

In Figure 4.18, five grid points E7, M8, G11, P11 and M16 is marked. SPL is recorded from the above points for each material types (Material Type-1, 2 and 3) to get a more clear view among the variation of SPL.

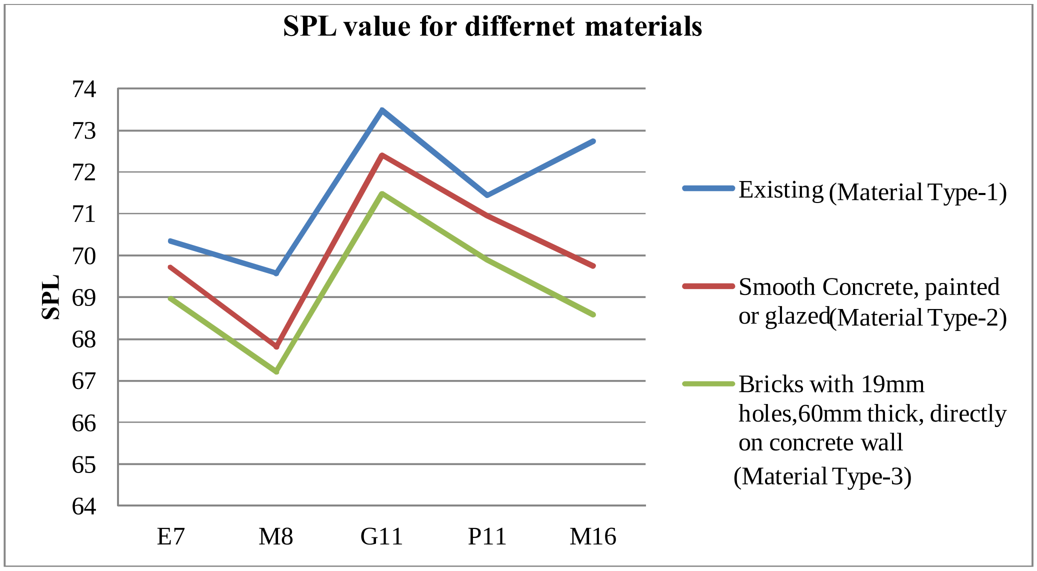


Figure 4.19 Graph showing the variation of SPL for different materials in Road Junction 1 – Gulshan 2

Figure 4.19 shows that the sound pressure level (SPL) is very high for the existing material (Material Type-1) in junction-1. Although use of different types of material (Material Type-2 and 3) can vary the SPL level.

Table 4.4 shows the selected data that are used in the analysis of variance. The data were collected from the selected grid points that are shown in Figure 4.18.

Table 4.4 SPL at different location of the junction-1

Position	Existing condition (second) (dBA)	Smooth Concrete, Painted or glazed (Bobran, 1973) (dBA)	Bricks with 19mm holes,60mm thick, directly on concrete wall (second) (dBA)
	Material Type 1	**Material Type 2**	**Material Type 3**
E7	70.35	69.71	68.97
M8	69.57	67.81	67.21
G11	73.49	72.41	71.48
P11	71.44	70.95	69.89
M16	72.74	69.75	68.59

óAnalysis of variance (ANOVA)ô can help again to find out the simultaneous comparison of the mean of the SPL, obtained from the simulation for material type1,2 and 3. Here similarly like previous section, the óF distributionô will be used to determine whether the means could be equal. Again it is initially hypothesized that the use of different types of material on the surface of a building has no impact on the acoustical condition SPL of a road junction.

If the Null Hypothesis (H_0), is true then the mean of the SPL value for each material type (Table 4.4) will be equal. And the material will have no impact on the acoustical condition focusing on SPL value.

Therefore, $H_0: \varepsilon_1 = \varepsilon_2 = \varepsilon_3$

However if the sample data can provide sufficient evidence to prove that null hypothesis is false then this hypothesis will be rejected and alternate Hypothesis (H_1) will be accepted, which will state that acoustical condition of a junction (SPL values) can be changed with the use of different materials.

Hence if, F ÓCritical Value then null hypothesis will be rejected.

With the level of significance 0.05 for the research project, the following calculations are found with ANOVA.

Table 4.5 ANOVA-Analysis of variance SPL

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Rows	30.38436	4	7.59609	15.36302	0.000799	3.837853
Columns	14.55401	2	7.277007	**14.71767**	0.002086	**4.45897**
Error	3.95552	8	0.49444			
Total	48.89389	14				

The Table 4.5 shows that F, 14.717 ÓF critical value, 4.458.

Hence H_0 can be rejected and H_1 can be accepted. Thus it can be said that changing the facade material can contribute to change the SPL in junction-1.

4.5 Conclusion

The results of simulation and parametric study reveal that the selection of appropriate surface materials of adjacent buildings may have mentionable effect on noise reduction at road junctions. Among sample surface materials used in the study, bricks with 19 mm holes and 60 mm thickness have highest effect compared to smooth concrete or other existing materials. This research only focuses on effect of building materials on acoustical condition of road junctions. Many other issues of a road junction (e.g., building form, junction size, width of the roads) may also have effects on noise scenario and simulation results. However, these issues are beyond the scope of this thesis. Impact of other parameters, like building form, junction size, width of the roads can be addressed in future researches.

Reference

Bork, I. (2002) *Simulation and Measurement of Auditorium Acoustics - the Round Robins on Room Acoustical Simulations*, Proc. of the Institute of Acoustics, 24 (4).

Bork, I. (2000) A Comparison of Room Simulation Software, the 2nd Round Robins on Room Acoustical Simulations, *Acustica - acta acustica* 86, pp. 943-956.

Dökmeci, P.N. (2009) Acoustical comfort evaluation in enclosed public spaces with a central atrium: a case study in food court of cepa shopping center, Ankara. Unpublished Master of fine art thesis.Department of interior architecture and environmental design and the institute of economics and social sciences.bİlkent university.

Lind, D.A., Marchal, W.G. and Wathen, S.A. (2009) *Statistical Techniques in Business & Economics*, Twelfth Edition, New York: Mcgraw-Hill/Irwin, p. 387.

Lundeby, A. et al. (1995) Uncertainties of Measurement in Room Acoustics, *Acustica 81*, No. 4, pp. 344-355.

Maekawa, Z. & Lord, P. (1994) *Environmental and architectural acoustics*. E&FN Spon: London.ofVibroengineering 3.4, pp 219-224.

Odeon. (1996) [Online] Available from: http://www.odeon.dk/content/acoustics-simulation-software. [Accessed: 23rd May 2013]

Rindell, J. H. (2000) The usage of computer modelling in room acoustics. *Journal of Vibroengineering*. 3 (4). pp 219-224.

Rindel, J. H. & Christensen, C. L. (2003) Room Acoustic Simulation and Auralization ï How Close Can We Get to the Real Room?, Keynote Lecture of WESPAC 8, The Eighth Western Pacific Acoustics Conference, Melbourne.

Rindel, J. H. (2000) The Use of Computer Modelling in Room Acoustics, *Journal of Vibroengineering*, No 3(4) /Index 41-72.

Vorlander, M. (1995) International Round Robin on Room Acoustical Computer Simulation, Proc. of *15th International Congress on Acoustics*, Trondheim, Norway, pp. 577-580.

Vries, D. D. et al. (2001) Spatial Fluctuations in Measures for Spaciousness, JASA 110(2) Aug., pp. 947-954.

Chapter Five: Recommendation and Conclusion

Introduction

Summary of Findings

Guidelines for the Architects, Engineers and Allied Bodies in Building Industry

Suggestion for Future Research

Conclusion

Chapter Five: Recommendation and Conclusion

5.0 Introduction

The noise conditions of road junctions in Dhaka city are studied in this research. Investigations are carried out to find if there is any impact of surface material of the adjacent buildings on reduction of noise. From collected field data, computer aided simulation and prediction techniques are used to check the effects of different surface materials of adjacent buildings on reduction of noise at road junctions. Chapter One of this dissertation describes the overall objective of the work, methodology and scope of this research. Through literature review, Chapter Two briefly illustrates the effects of noise on human being, noise pollution situation, standards of allowable noise levels and other issues related to road junctions in Dhaka city. Chapter Three elaborates details on road junctions in Dhaka City, which involved the junction selection, physical condition study and acoustical conditions. Chapter Four covers the process and results of simulation and prediction techniques by computer based acoustical tool óODEONô and establishes the fact that adjacent building surface materials have effect on the noise level at road junctions.

This concluding chapter presents the summary of findings, noise conditions identified in the field survey, analysis and results. A guideline is also added for the architects, engineers and allied bodies in building industry to help in improving the acoustical conditions of road junctions in context of Dhaka city. A brief discussion on scope of further research is also added.

5.1 Summary of Findings

Findings in this research are summarised in the following sections.

5.1.1 Findings from literature review

Literature Review (Chapter Two) reveals that, prevailing road traffic noise in Dhaka city has become a threat to the health of people. Constant exposure to the high noise levels can interfere in speech intelligibility, communication, physical and mental wellbeing. The sound levels at different road junctions and different zones in Dhaka city are much higher than the accepted level set by the Department of Environment (DoE), Bangladesh and other standards.

5.1.2 Findings from field study

Findings from Field Survey (Chapter Three) show that the road junctions have higher noise levels than those recommended by codes and standards. The highest level of noise is recorded in road junction 1- Gulshan 2, which contains more motorised vehicles than other surveyed junctions. Road junctions are surrounded by buildings with highly reflecting surface materials, like, glass, aluminium, metal sheet etc. The correlation analysis shows that there is a moderate degree of positive correlation among different surface materials of adjacent buildings with resultant noise levels at road junctions.

5.1.3 Findings from simulations and parametric study

Simulation and parametric study is carried out and results are shown in Chapter Four. The process was conducted on a selected road junction, namely Road Junction 1 - Gulshan 2, using the acoustic analysis, simulation and prediction software óODEONô to derive the effect of building surface materials on reduction of noise at road junctions. The results of this parametric study are delineated in Chapter Four. Experiments have been carried out on this road junction, involving existing material and by changing that with two other materials, namely smooth concrete and brick with 19 mm holes. Findings shown in Figure 4.13 of Chapter Four reveal that there is a significant difference in the acoustical conditions because of the change of surface materials. According to the Analysis of Variance (ANOVA) as shown in Table 4.3, it is found that F, 8.48 ÓF critical value, 4.46 for EDT. In case of SPL, Table 4.5 shows that F, 14.717 Ó F critical value, 4.458. Both results for EDT and SPL establish the fact that building surface materials can play positive role to reduce noise levels at road junctions.

5.2 Guidelines for Architects, Engineers and Allied Bodies in Building Industry

In order to improve the noise conditions at road junctions, following design guidelines can be helpful to the architects, engineers and allied bodies in building industry:

- Selection of surface materials should be given special importance for designing buildings adjacent to road junctions to facilitate reduction of noise at road junction.

- Some optimum quality of absorbing materials can be used on the surface of buildings adjacent to road junction to improve the acoustical condition, e.g., perforated brick.

In the Literature Review (Section 2.2, Chapter Two), it is shown that high noise levels have direct impact on human health and excessive noise may cause health hazards. This research reveals that building surface materials can, to some extent, reduce prevailing high noise levels at road junctions in Dhaka City. However, this option alone is not sufficient to reduce the noise level to the proposed standards. Along with this option, there should be other initiatives to ensure that the unacceptable level of noise is not generated from potential sources of noise. As sited in Literature Review (Chapter Two), different studies show that road noise can be reasonably controlled through strict adherence to traffic rules, implementation of noise control regulations, elimination noise sources, and most importantly, public awareness towards adverse effect of noise on human wellbeing (Mahmud, 2012).

5.2 Suggestion for Future Research

In Bangladesh, research on traffic noise pollution and its remedial measures are limited compared to other developed countries. Most of the research work on noise is limited to studies on existing conditions and comparison with standards. This research suggested some remedial measures by changing surface materials of adjacent buildings. Following are important aspects needed to be explored in future research to reduce noise level and improve the acoustical condition of a junction which were beyond the scope of this research:

- The effects of building geometry, form and placement of building components on noise condition at road junctions.
- The effect of setbacks, landscaping and vegetation on noise condition at road junctions.
- The effect of road surface treatment on noise condition at road junctions.

5.3 Conclusion

In this thesis, the existing noise levels of selected junctions in Dhaka city have been studied and found to be alarmingly beyond the allowable limit. Based on the computer aided parametric study, effects of surface materials of buildings on reduction of noise level have been checked and found to be significant. This thesis suggests some guidelines on use of building surface materials, which may be helpful to the architects, engineers and allied bodies in building industry for taking due initiatives for implementation, particularly at the design stage.

This study focused on the effects of building surface materials, as an architectural means to address the issue. Implementation of noise control rules, traffic regulations and similar options can contribute to the issue considerably. There is scope for further architectural study on effects of building setbacks, building geometry and articulation of building elements on noise reduction at road junctions. It is expected that this research will be used as a basis for further research to investigate other aspects and to propose remedial measures for noise problems at road junctions, ensuring a safe and healthy city.

References

Alam, J.B., Hoque, M.M. and Ahmed, M.F. (2000) Traffic induced noise pollution in Dhaka City. Clean Air Initiative Bangladesh Environment. p.77-83.

Ayaz, S. B. &Rahman, M.M. (2011) ñAssessment of Roadway Noise Level and Potential Mitigation Measuresò, DUET Journal, 1 (2).

Lamancusa, J.S. (2009) 10.*Outdoor Sound Propagation.* Noise Control. ME 458: Engineering Noise Control. State College.Pennsylvania State University.Availablefrom: http://www.mne.psu.edu/lamancusa/me458/10_osp.pdf. [Accessed: 20th July 2014].

Mahmud, K., Gope. K. & Chowdhury, S. M. R. (2012) Possible Causes & Solutions of Traffic Jam and Their Impact on the Economy of Dhaka City. Journal of Management and Sustainability. 2 (2). P. 112 ï 135.

Rabbani, G. & Sharif, M.I. (2005) Dhaka City ï State of Environment (SOE) 2005. In collaboration United Nations Environment Programme Regional Resource Centre for Asia and the Pacific (UNEP RRC.AP) and Bangladesh Centre for Advanced Studies (BCAS),

Bibliography

Bibliography

Ahmed, K. (1998) A study of noise pollution in Dhaka City. Department of Environment (DOE), Bangladesh.

Alam, J.B., Hoque, M.M. and Ahmed, M.F. (2000) Traffic induced noise pollution in Dhaka City. Clean Air Initiative Bangladesh Environment. p.77-83.

Alam, Md., Rauf, A.F.M.A., and Ahmed, M.F., (2001) Traffic Induced Noise Pollution In Dhaka City. The Institution of Engineers, Bangladesh. CE 29 (1). p 55.

Ayaz, S. B. &Rahman, M.M. (2011) ñAssessment of Roadway Noise Level and Potential Mitigation Measuresò, DUET Journal, 1 (2).

Bork, I. (2000) A Comparison of Room Simulation Software, the 2nd Round Robins on Room Acoustical Simulations, Acustica - acta acustica 86, pp. 943-956.

Bork, I. (2002) Simulation and Measurement of Auditorium Acoustics - the Round Robins on Room Acoustical Simulations, Proc. of the Institute of Acoustics, 24 (4).

BRTA. (2015) Bangladesh Road Transport Authority [Online] Available from: http://www.brta.gov.bd/index.php/statistics. [Accessed: 15th April 2014].

Budzynski, G. (1978) Theory of the Reflective Localization of Sound Sources. Archives of Acoustics.11 (1).Pp.13-24.

Chakraborty, M.R., Khan, U.S., Samad, M.A, and Amin, M.N. (2005) Noise Level in Different Places of Dhaka Metropolitan City (DMC) and Noise-Induced Hearing Loss (NIHL) in Dhaka Dwellers. Bangladesh Medical Research Council Bulletin.

Chandio, I.A., Brohi, Dr.K.M and Memon, M.A. (2010) Managing Road Traffic Noise Pollution, through Sustainable Planning Approach. International Journal of Chemical and Environmental Engineering. 1 (2).

Daniel, G.N. (1998) Cause and Effects of Noise Pollution. Interdisciplinary Minor in Global Sustainability.University of California, Irvine.Student paper.

Das, S. (2001) A Study on Noise Pollution in Roads in Sylhet City. B.Sc. Engineering Thesis.Department of Civil and Environmental Engineering.Shahjalal University of Science and Technology.Sylhet. Bangladesh.

Debnath, K. B., Imam, S. M. N. (2013)Diffraction of Sound as a Side Effect of Noise Pollution at the Road Junctions of Dhaka city, Proceedings of 4th International Conference on Environmental Aspects of Bangladesh (ICEAB), University of Kitakyushu, Japan, p 82-86, 24-26.

Demotix. (2011) The home of World-Leading Photojournalism [Online] Available from: www.demotix.com/photo/562126/traffic-jams-dhaka-city. [Accessed: 18th November 2013].

Dogru,A.O., Weghe,N.V., Ulugtekin, N.N. and Maeyer, D. (2007) Classification of road junctions based on multiple representations: adding value by introducing algorithmic and cartographic approaches. XXIII International Cartographic Conference.

Dökmeci, P.N. (2009) Acoustical comfort evaluation in enclosed public spaces with a central atrium: a case study in food court of cepa shopping center, Ankara. Unpublished Master of fine art thesis.Department of interior architecture and environmental design and the institute of economics and social sciences.bĽlkent university.

Everest, F. A. (2001) The Master Handbook of Acoustics. 4th Ed. New York: McGraw-Hill

Everest, F.A. (2001) The Master Handbook of Acoustics. 4th Ed. USA: The McGraw-Hill Companis, Inc.

Haq, M.A., Islam, M.M., Ali, M.S., Haque, M.F. and Akhand, M.R. (2012) Status of Noise Pollution in Mixed Areas of Dhaka City: a GIS Approach. J. Environ. Sci. & Natural Resources.5 (1).

Hayati, H. & Sayadi, M.H. (2012) Impact of tall buildings in environmental pollution. Environmental Skeptics and Critics 1 (1).

Hopkins, C. (2007) Sound Insulation. UK: Elsevier Linacre House.

Imam, S. M. N. Ahmed, N. and Takahashi, D. (2009) Effects of Reverberation Time on Percentage Syllable Articulation for Bangla Language, Journal of Asiatic Society of Bangladesh (Science), 35(1):37-48.

Kadiyali, L. R. (1997) Traffic Engineering and Transportation Planning. 6th Ed. India: Khanna Publishers.

Khan, K. S. (2005) Environmental Degradation due to Urbanization in Sylhet City. B. Sc. Engineering Thesis.Department of Civil and Environmental Engineering.Shahjalal University of Science and Technology.Sylhet. Bangladesh.

Kosten, C.W. (1960) The Mean Free Path in Room Acoustics. Acustica 10.pp245-250.

Lamancusa, J.S. (2009) 10.Outdoor Sound Propagation. Noise Control. ME 458: Engineering Noise Control. State College.Pennsylvania State University.Availablefrom: http://www.mne.psu.edu/lamancusa/me458/10_osp.pdf. [Accessed: 20th July 2014].

Long, M. (2006) Architectural Acoustics. USA: Elsevier Academic Press.

Lundeby, A. et al. (1995) Uncertainties of Measurement in Room Acoustics, Acustica 81, No. 4, pp. 344-355.

M¨oser, M. (2009) Engineering Acoustics An Introduction to Noise Control. 2nd Ed. Germany: Springer Dordrecht Heidelberg.

Maekawa, Z. & Lord, P. (1994) Environmental and architectural acoustics. E&FN Spon: London.ofVibroengineering 3.4, pp 219-224.

Mahmud, K., Gope, K., and Chowdhury, S.M.R. (2012) Possible Causes & Solutions of Traffic Jam and Their Impact on the Economy of Dhaka City. Journal of Management and Sustainability. Canadian Center of Science and Education.2 (2). [Online] Available from: http://www.ccsenet.org/journal/index.php/jms/article/view/14879. [Accessed: 5th January 2014].

Mian, M. A. &Miyan, M. A. M. (1971) An Introduction to Statistics. 2nd Ed. Dhaka: The Universal Press.

Nilsson, E. (1992) Decay process in rooms with non-diffuse sound fields. Report TVBA1004. Lund Institute of Technology. Depart. of Eng. Acoustics.

Odeon. (1996) [Online] Available from: http://www.odeon.dk/content/acoustics-simulation-software. [Accessed: 23rd May 2013]

OECD (Organization of Economic Cooperation and Development) (1995). Road side noise abatement. Road Transport Research, OECD, France.

Papacostas, C. S. &Prevedouros, P. D. (1993). Transportation Engineering and Planning.2nd Ed. USA: Prentice Hall Publishers.

Rabbani, G. & Sharif, M.I. (2005) Dhaka City ï State of Environment (SOE) 2005. UNEP in collaboration with BCAS & DOE.

Rahman, A.A., Roy, R., Uddin, M.J. and Nury, S.N. (Unknown) Noise Mapping of A Specific Area of Dhaka City: A State of the Art Strategy to Assess the Status of Road-Noise Pollution in Dhaka City. Unpublished draft study report.

Ravanbakhsh, M., Heipke, C. and Pakzad, K. (2007) Road junction extraction from high resolution aerial images. Stilla U et al (Eds). PIA07 International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 36 (3/W49B), Munich, Germany.

Rindel, J. H. (2000) The Use of Computer Modelling in Room Acoustics, Journal of Vibroengineering, No 3(4) /Index 41-72.

Rindell, J. H. (2000) The usage of computer modelling in room acoustics. Journal of Vibroengineering. 3 (4). pp 219-224.

Roy, R., Rahman, M.A., and Uddin, M.J. (2006) ñNoise Induced Hearing Loss Assesment of the Road-noise Affected People of Dhaka cityò, Unpublished Undergraduate Thesis, Department of Environmental Sciences, Jahangirnagar University, Dhaka.

Roy, R., Rahman, M.A., and Uddin, M.J. (2006) ñNoise Induced Hearing Loss Assesment of the Road-noise Affected People of Dhaka cityò, Unpublished Undergraduate Thesis, Department of Environmental Sciences, Jahangirnagar University, Dhaka.

Roy,R., Rahman, M.A., and Uddin, M.J. (2006) Noise Induced Hearing Loss Assessment of the Road-noise Affected People of Dhaka city. Undergraduate thesis.Department of Environmental Sciences, Jahangirnagar University.

Saifuddin, K., Shahinuzzaman, Md., Muhammad, N. and Quader, M.A. (2010) ñPsychophysical Health in Relation to the Environmental Noise Perception in Younger Versus Older Groups of People in Dhaka Cityò, Journal of Life and Earth Science, 5 (81-84). p 81.

Sen, P., Bhattacherjee, A., Das, A. and Das, D. (2014) Noise pollution assessment in greater agartala city: a case study. IJRET: International Journal of Research in Engineering and Technology. 3 (9) Available from: http://www.ijret.org/ . [Accessed: 12th February 2015]

Smyrnova, Y., Kang, J.,Cheal, C., Tijs, E. and Bree, H.E. (2010) Laboratory Test of Sound Absorption of Vegetation. 1st EAA-EuroRegio.Congress on Sound and Vibration. Ljubljana, Slovenia.

Staff Correspondent. (2008) Sound traffic management vital to make Dhaka liveable. The Daily Star. [Online] 12th October. Available from http://archive.thedailystar.net/newDesign/news-details.php?nid=58328. [Accessed: 22nd May 2009].

Tanvir, S. & Rahman, M.M. (2011) Development of interrupted flow traffic noise prediction model for Dhaka City. 4th Annual Paper Meet and 1st Civil Engineering Congress, Dhaka, Bangladesh. [Online] Iebconferences. Available from: http://www.iebconferences.info/371.pdf [Accessed: 10th January 2014].

Vigran, T.E. (2008) Building Acoustics. New York: Taylor & Francis.

Vorlander, M. (1995) International Round Robin on Room Acoustical Computer Simulation, Proc. of 15th International Congress on Acoustics, Trondheim, Norway, pp. 577-580.

Vries, D. D. et al. (2001) Spatial Fluctuations in Measures for Spaciousness, JASA 110(2) Aug., pp. 947-954.

WHO, (2002). *Noise Pollution of Dhaka City*, World Health Organization, Geneva.

Wilson,D.K., Andreas, E.L., and Weatherly, J.W. (2007) Characterization of uncertainty in outdoor sound propagation predictions. Acoustical Society of America.

Appendix 1

Specifications and Details

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Appendix 1.1: Lutron SL-4023SD Sound Level Meter

Features:

- Main functions are designed to meet IEC 61672 class 2.
- A & C weighting networks comply with standards.
- 0.5" standard microphone head.
- Time weighting (Fast & Slow) dynamic characteristic modes.
- Build External calibration VR.
- Auto range & Manual range selection.
- Available for external calibration adjustment.
- Condenser microphone for high accuracy & long-term stability.
- Memory function to store the Max. & Min. value.
- Hold and Peak Hold functions.
- Real time SD memory card Datalogger, it Built-in Clock and Calendar, real time data recorder, sampling time set from 1 second to 3600 seconds.
- Manual datalogger is available (set the sampling time to 0 second), during execute the manual datalogger function, it can set the different position (location) No. (Position 1 to position 99).
- Innovation and easy operation, computer is not need to setup extra software, after execute datalogger, just take away the SD card from the meter and plug in the SD card into the computer, it can down load the all the measured value with the time information (year/month/date/ hour/minute/second) to the Excel directly, then user can make the further data or graphic analysis by themselves.
- SD card capacity: 1 GB to 16 GB.
- LCD with green light backlight, easy reading.
- Can default auto power off or manual power off.
- Data hold, record max. and min. reading.
- Microcomputer circuit, high accuracy.
- Power by UM3/AA (1.5 V) x 6 batteries or DC 9V adapter.

Specifications:

Circuit	Custom one-chip of microprocessor LSI circuit.
Display	LCD size : 52 mm x 38 mm LCD with green backlight (ON/OFF).
Measurement Range	30 - 130 dB.
Resolution	0.1 dB
Function	dB (A & C frequency weighting) Time weighting (Fast, Slow) Peak hold, Data hold Record (Max., Min.)
Accuracy (23 ± 5)	Characteristics of " A " frequency

	weighting network meet IEC 61672 class 2 Under 94 dB input signal, the accuracy are: 31.5Hz ± 3.5 dB 63 Hz ± 2.5 dB 125 Hz ± 2.0 dB 250 Hz ± 1.9 dB 500 Hz ± 1.9 dB 1K Hz ± 1.4 dB 2K Hz ± 2.6 dB 4K Hz ± 3.6 dB 8K Hz ± 5.6 dB *Remark:* *The above spec. are tested under the environment RF Field Strength less than 3 V/M & frequency less than 30 MHz only.*
Frequency Weighting Network	Characteristics of A & C. A weighting: The characteristic is simulated as "Human Ear Listing" response. Typical, if making the environmental sound level measurement, always select to A weighting. C weighting: The characteristic is near the "FLAT" response. Typical, it is suitable for checking the noise of machinery (Q.C. check) & knowing the sound pressure level of the tested equipment.
Data hold	To freeze the measurement value.
Peak hold	To keep the peak (max.) measurement value
Time weighting (Fast & Slow)	Fast - t= 200 ms * "Fast" range is simulated the human ear response time weighting. Slow - t = 500 ms * "Slow" range is easy to get the average values of vibration sound level.
Range selector	Auto range: 30 to 130 dB. Manual range : 3 range, 30 to 80 dB, 50 to 100 dB, 80 to 130 dB, 50 dB on each step, with over & under range indicating.
Frequency	31.5 to 8,000 Hz
Microphone type	Electric condenser microphone.
Microphone size	Out size, 12.7 mm DIA. (1/2 inch).
Calibration VR	Build in external calibration VR, easy to

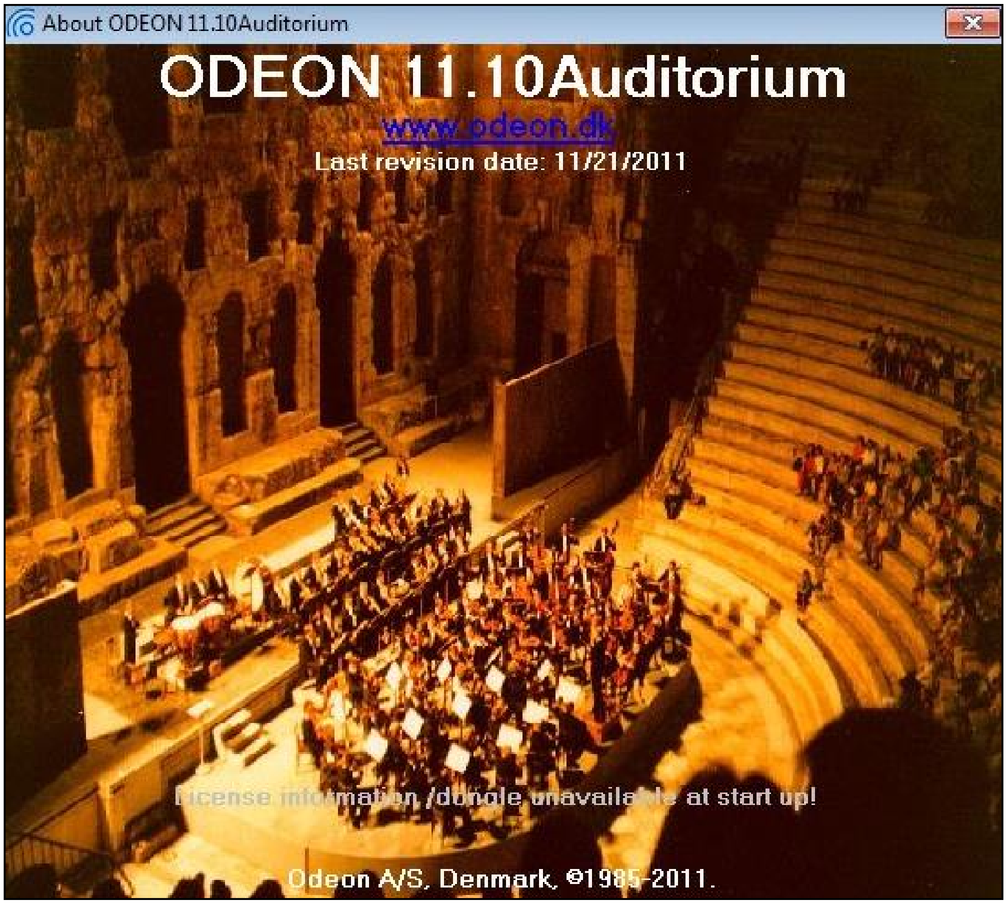
	calibrate on 94 dB level by screw driver. Calibrated via external SOUND CALIBRATOR (SC-941, optional).
Calibrator	B & K (Bruel&kjaer), MULTIFUCTION ACOUSTIC CALIBRATOR 4226.
Dataloger Sampling Time Setting Range	Auto: 1 second to 3600 seconds @ Sampling time can set to 1 second, but memory data may loss.
	Manual: Push the data logger button once will save data one time. @ Set the sampling time to 0 second. @ Manual mode, can also select the 1 to 99 position (Location) no.
Memory Card	SD memory card. 1 GB to 16 GB.
Advanced setting	* Set clock time (Year/Month/Date, Hour/Minute/ Second) * Decimal point of SD card setting * Auto power OFF management * Set beep Sound ON/OFF * Set sampling time * SD memory card Format
Over Indication	Show " - - - - ".
Data Hold	Freeze the display reading.
Memory Recall	Maximum & Minimum value.
Sampling Time of Display	Approx. 1 second.
Data output	RS 232/USB PC computer interface. * *Connect the optional RS232 cable UPCB-02 will get the RS232 plug.* * *Connect the optional USB cable USB-01 will get the USB plug.*
AC output	AC 0.5 Vrms corresponding to each range step. Output impedance: 600 ohm.
Power off	Auto shut off saves battery life or manual off by push button.
Operating Temperature	0 to 50 .
Operating Humidity	Less than 85% R.H.
Power Supply	* Alkaline or heavy duty DC 1.5 V battery (UM3, AA) x 6 PCs, or equivalent. * DC 9V adapter input. (AC/DC power adapter is optional).
Power Current	Normal operation (w/o SD card save data and LCD Backlight is OFF) : Approx. DC 8.5 mA.
	When SD card save the data but and LCD Backlight is OFF): Approx. DC 30 mA.
	If LCD backlight on, the power consumption will increase approx. 14 mA.
Weight	489 g/1.08 LB.
Dimension	245 x 68 x 45 mm. (9.6 x 2.7x 1.9 inch).

Accessories Included	Instruction manual....................... 1 PC
Optional Accessories	* Sound calibrator (94 dB), SC-941. * Sound calibrator (94/114 dB), SC-942. * Sound wind shield ball, SB-01 * SD Card (1 GB) * SD Card (2 GB) * USB cable, USB-01. * RS232 cable, UPCB-02. * Data Acquisition software, SW-U801-WIN. * AC to DC 9V adapter. * Soft carrying case, CA-05A. * Hard carrying case, CA-06.

Appendix 2

Details about Simulation Software: ODEON

Appendix 2 : Details about Simulation Software: ODEON



Acoustics Simulation Software:

- State of the art auralisation
- ODEON algorithms for reliable results
- Ease and flexibility in room modelling
- Optimized for high calculation speed
- Equipped with an impulse response measuring system

ODEON software is developed for simulating the interior acoustics of buildings. Given the geometry and surface-properties, the acoustics can be predicted, illustrated and listened to. Sound reinforcement is easily integrated in the acoustic predictions. ODEON uses the image-source method combined with ray tracing.

Standards Supported:

- ISO 3382 series ï Performance places, ordinary rooms, open-plan offices.
- ISO 14257 ï Workplaces.
- IEC 60268-16 ï Speech Transmission Index.

Calculation Algorithms:

Hybrid reflection method: A combination between the image source method, raytracing and ray radiosity. **Early reflections** are defined by image sources and ray-radiosity. **Late reflections** are defined by a special ray-tracing/radiosity method. The **transition order** (by default 2) decides at which reflection order the reflections go from early to late reflection method.

The reflection based scattering coefficient s, ensures that scattering depends on surface roughness defined by a surface scattering, frequency, size of surface and distance between surface and source/receiver. **Vector based scattering:** Includes vector based scattering in the ray-tracing algorithm. If s = 0 the ray is reflected in the specular direction, if s = 1 it is reflected in a random direction and in between the ray is reflected as a resulting vector of a specular vector, weighted 1-s and a random vector, weighted s. **Oblique Lambert scattering:** in raytracing a number of secondary sources are placed at the reflection point if visible to the source and receiver, distributing the reflections with an oblique lambert, which can include specular as well as scattered energy. Read more about the Odeon algorithms in a paper, from Forum Acousticum 2005 by Claus Lynge Christensen, Jens HolgerRindel.

Measurement System:

Since version 12, ODEON is equipped with a powerful measuring system that provides high quality impulse responses with the least possible effort by the user.

Sweep generator: Impulse responses are recorded using upward linear or exponential sweep signals. A sound file in .WAV format is produced from a measurement.

Impulse response processing: The impulse response obtained with the sweep generator (or an external recording; such as a gunshot, a balloon burst or clapping) can be processed for derivation of the ISO room acoustic parameters. The impulse response is Octave-band filtered and truncated automatically at the noise floor.

Measurements vs Simulations: Once the Impulse response has been loaded in ODEON and the acoustic parameters have been calculated, they can be imported to the multi-point response of a room model, for a direct comparison between simulations and measurements.

Hardware needed: A sound card, which is mentioned on the Computer System Requirements, a loudspeaker (preferable omni-directional) and a microphone for capturing impulse responses, when using the ODEON sweep generator. Amplification is needed for both the loudspeaker and the microphone.

Modelling Tools:

Odeon editor: Text editor supporting parametric modelling.

Import Facility: Import of DXF (Drawing Exchange Format) and 3DS format files from CAD software such as: AutoCAD®, Microstation®, 3DS max, IntelliCAD®, Google-Skechup and Rhino.

Geometry verification: Automatic check for warped and overlapping surfaces, with problematic surfaces. Automatically displayed in 3D. 3D raytracing finding holes in geometry with lost rays, 3D view for visual check.

Patch Tools: Missing surfaces in geometry can be created using the integrated3DView.

Extrusion Modeller Drawing tools for fast modelling of geometries such as industrial work rooms and offices.

Surface input properties:

Absorption coefficient: User defined sound absorption for each type of surface in 1 octave bands (63 - 8000 Hz) as a value between 0 and 1.

Scattering coefficient: User defined scattering from the shape or texture, roughness of a surface. scattering s is a value between 0 and 1.

Transparency: User defined transparency of a surface as a value between 0 and 1.

Sound reduction index For simulating sound transmission a user defined sound reduction index R, in 1/3 octave-bands (50-10.000 Hz) can be specified. Can be imported directly from the Insul software or Excel.

Source input properties:

Point sources: Directivity patterns created from within Odeon in the .s08 format.

Natural directivity pattern, such as a singer or a trumpet. Typically used for auralisation purpose.

Loudspeakers, supported by the **C**ommon**L**oudspeaker **F**ormat: .CF1 and .CF2, available from the CLFgroup homepage.

Generic directivity pattern, such as semi- or omni- directional sources, defined by mathematical expression. Typically used for calculating room acoustical parametres.

line sources. E.g. used for simulation of trains or roads.

surface sources. Used for large sound generators, like machinery, where the sound radiation cannot be located from a point source anymore.

Results:

Quick Estimate: Fast estimate of reverberation time, and effect from different absorbing materials, based on diffuse field assumptions (Sabine, Eyring, and Arau-Purchades).

Global Estimate: Estimate of reverberation time taking room shape, position of absorbing materials and sources into account.

Single point response: Detailed results of acoustical parameters and auralisation option for a selected receiver.

Multi point response: Acoustical parameters for a specified number of receivers.

Grid Maps: Map of room-acoustical parameters and statistics for the grid receivers.

Grid Maps of Direct Sound: Fast displayed grid map of direct sound to check the loudspeaker coverage before the room acoustical parameters are calculated.

Reflector Coverage: 1st and 2nd order reflector coverage.

Ray-Tracing: Dynamic display of raytracing from selected source.

3D billiard: Interactive display for 107isualization of wavefronts to demonstrate scattering, flutter echoes, focusing and coupling effects.

Auralisation:

Input: Anechoic or semi-anechoic sound file in .wav format. Mono, stereo as well as multichannel recordings can be handled in the following input file formats: 16 bit PCM, 24 bit PCM, 32 bit PCM (32 bit float 16 bit aligned!), 32 bit IEEE float, 8 bit PCM, Extensible, 16 bit PCM, Extensible, 24 bit PCM, Extensible, 32 bit PCM, Extensible, 32 bit IEEE float, Extensible or 8 bit PCM.

Mixer: Multiple sources and multiple signals can be included in one simulation.

Processing: Convolution of sound files with BRIRs (Binaural Room Impulse Responses), BFormat impulse responses and/or Surround impulse responses. All types of impulse responses are filtered using full filtering in nine-octave bands. For the binaural filtering a set of HRTFs (Head Related Transfer Functions) is applied for each reflection.

Output: Binaural (2-channel) .wav file optimised for headphone playback. 1st and 2nd order BFormat files (Ambisonics) output is an option for the advanced user.

N-channel surround-sound for standard systems such as 4.1, 5.1, 6.1 and 7.1 as defined by sound card/loudspeaker system and specified in the setup by user.

SuperStereo special made for standard stereo loudspeaker setup as specified in the setup by user.

The output files can be generated in following formats:16 bit PCM, 24 bit PCM, 32 bit PCM (32 bit float 16 bit aligned!), 32 bit IEEE float, 8 bit PCM, Extensible, 16 bit PCM, Extensible, 24 bit PCM, Extensible, 32 bit PCM, Extensible, 32 bit IEEE float, Extensible or 8 bit PCM.

Sound Card Minimum Requirements: Stereo, Duplex, 16 bits, 44100Hz sampling. Printout, Graphs and Export:

Graphs and tables can be exported via clipboard or file in several formats. (.wmf, .emf., .bmp., .gif., .jpg, .pcx, .png), or printed. Results, including **parameters, reflection data, curves, etc.**, can be exported in ASCII (text) format for further processing in other programs.

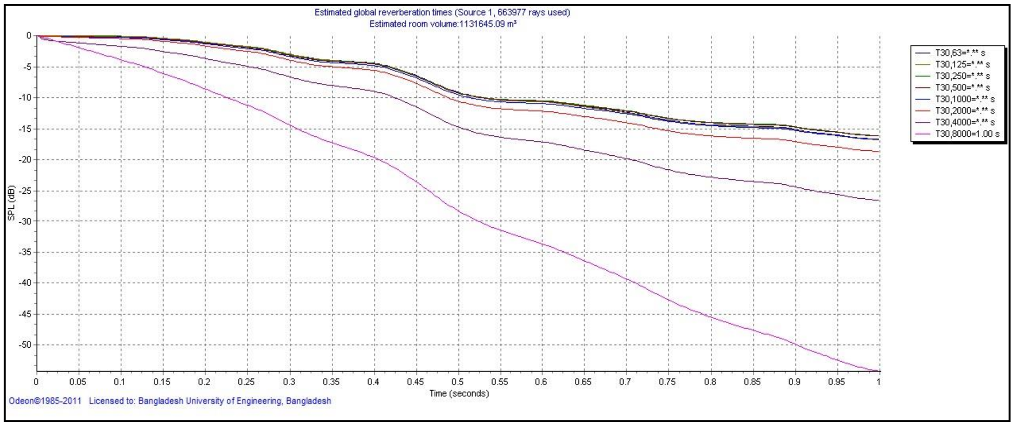
Exports **animations in GIF format** from any of the displays in the program, single-shot as well as sequence-shooting are available. An editing tool for animations is included.

Appendix 3

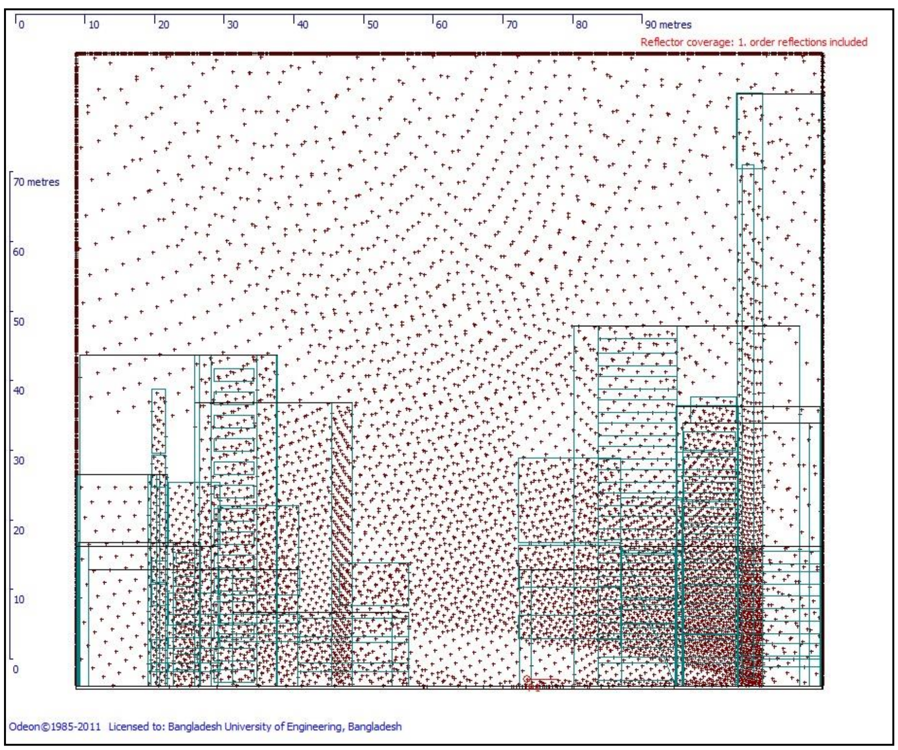
ODEON Data and Results

Appendix 3 : ODEON Data and Results

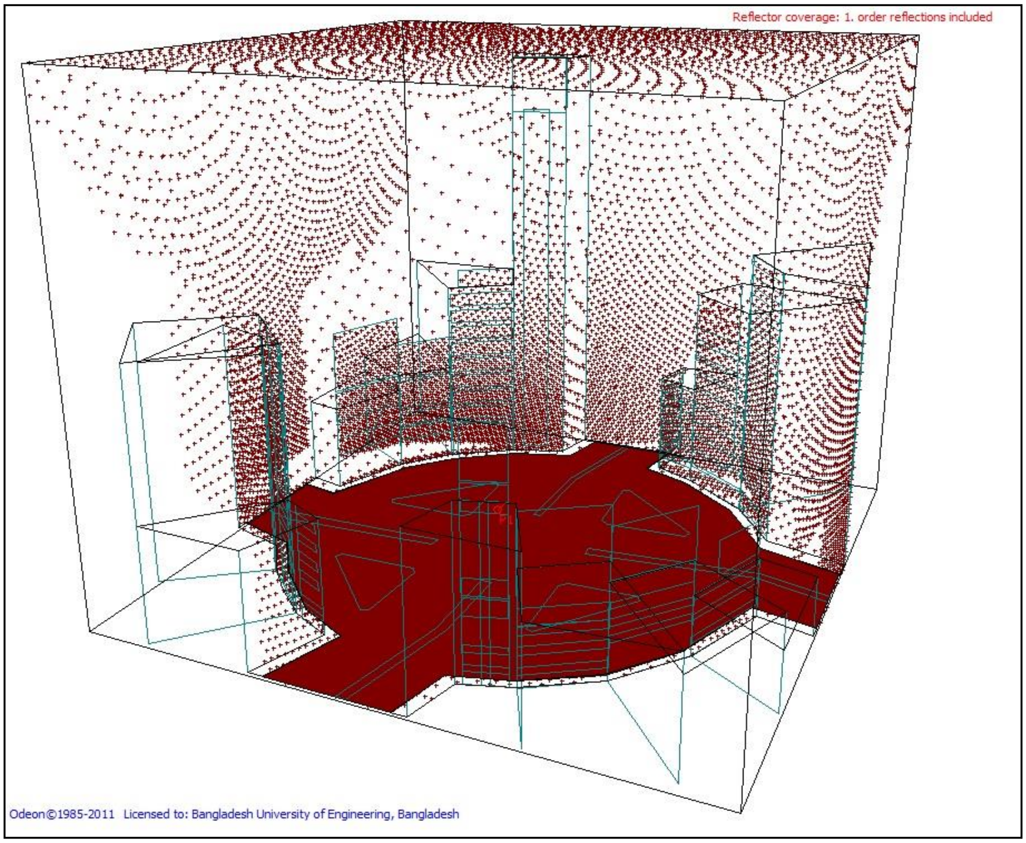
Material Type 1: Road Junction 1 – Gulshan 2 with existing Condition



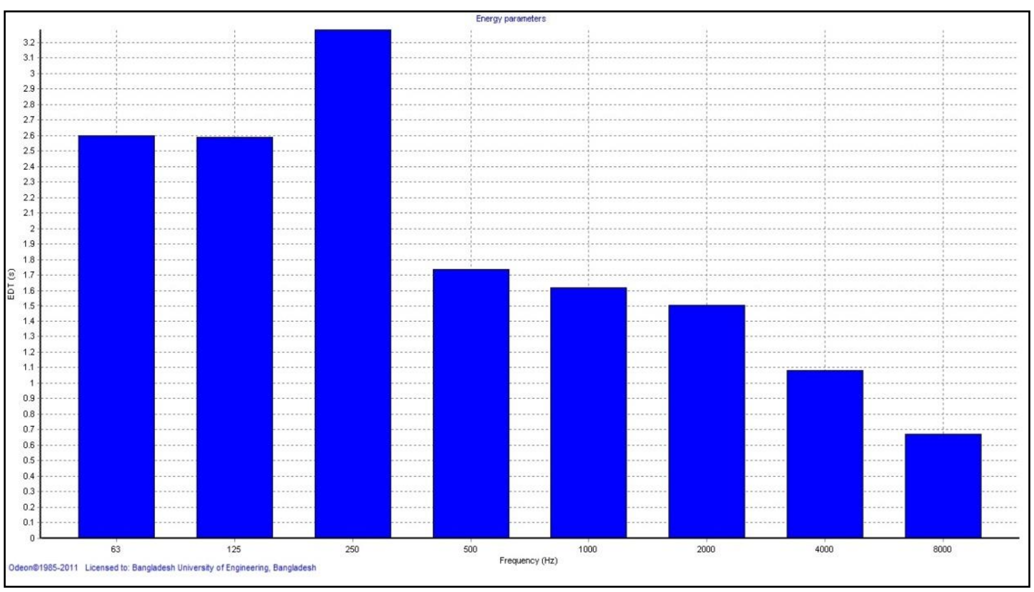
Estimated Global reverberation Time



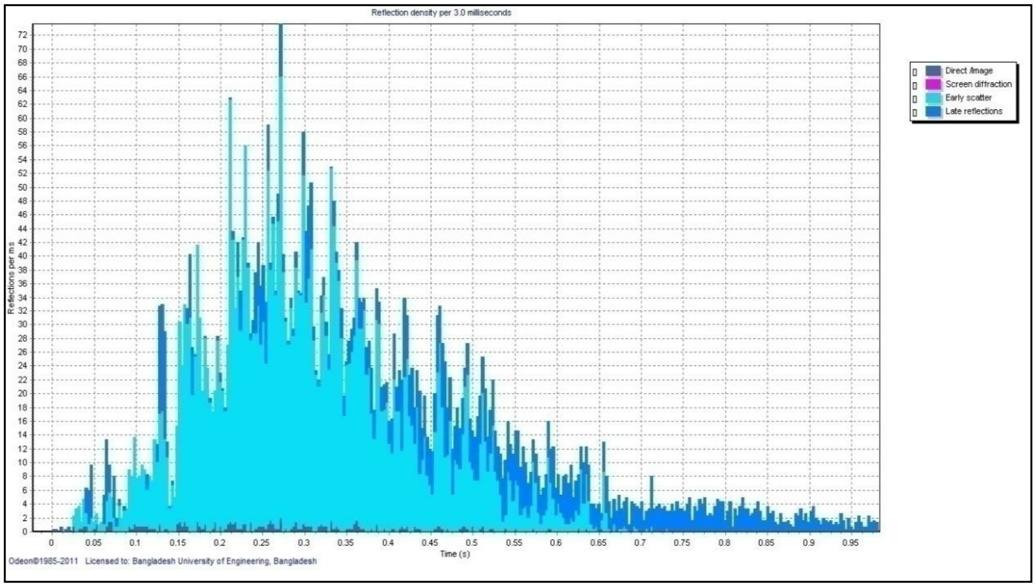
Reflector Coverage (Side View)



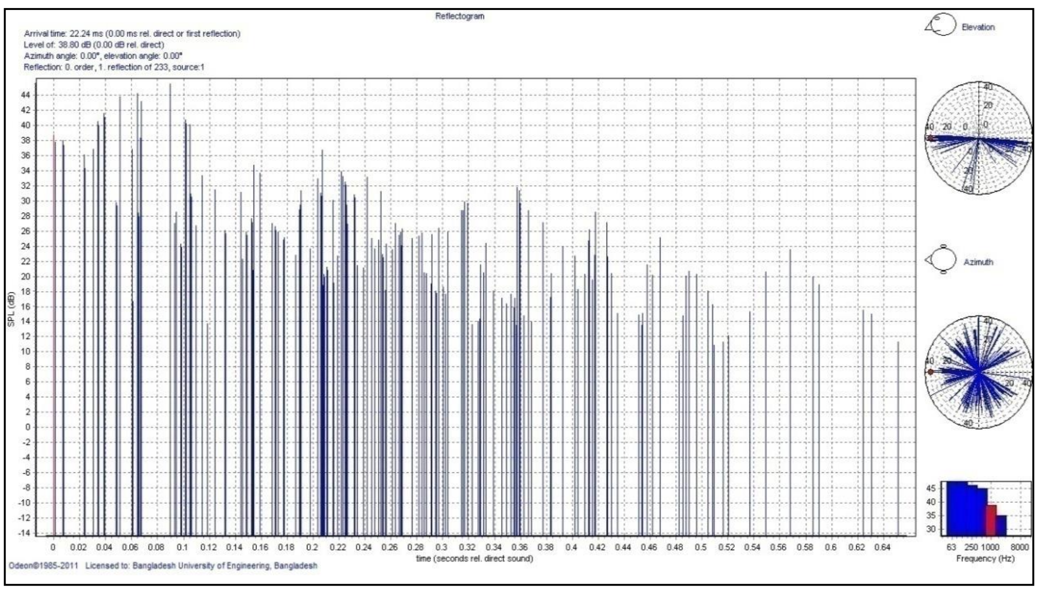
Reflector Coverage (Top View)



Energy Parameter

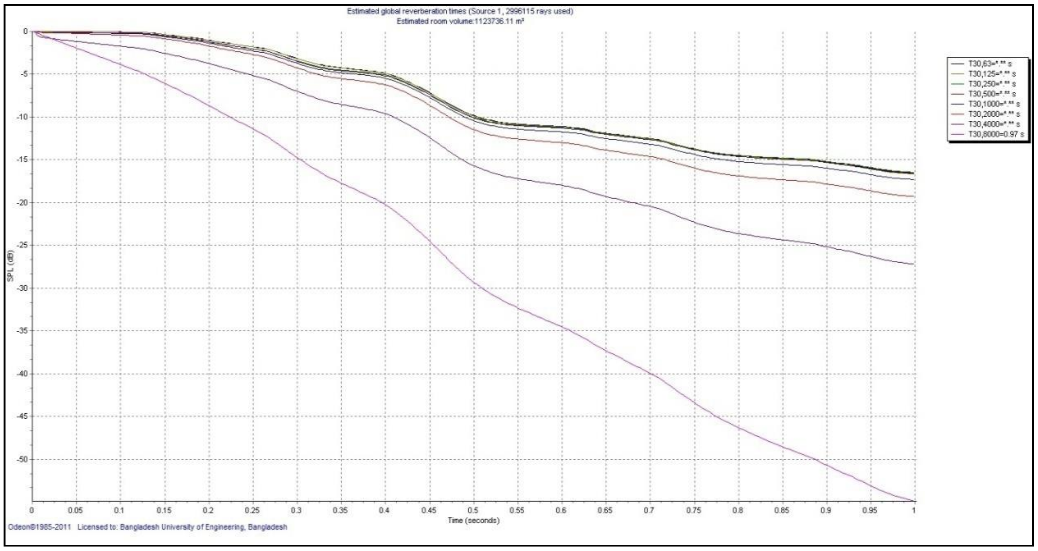


Reflection Density per 3.0 milliseconds

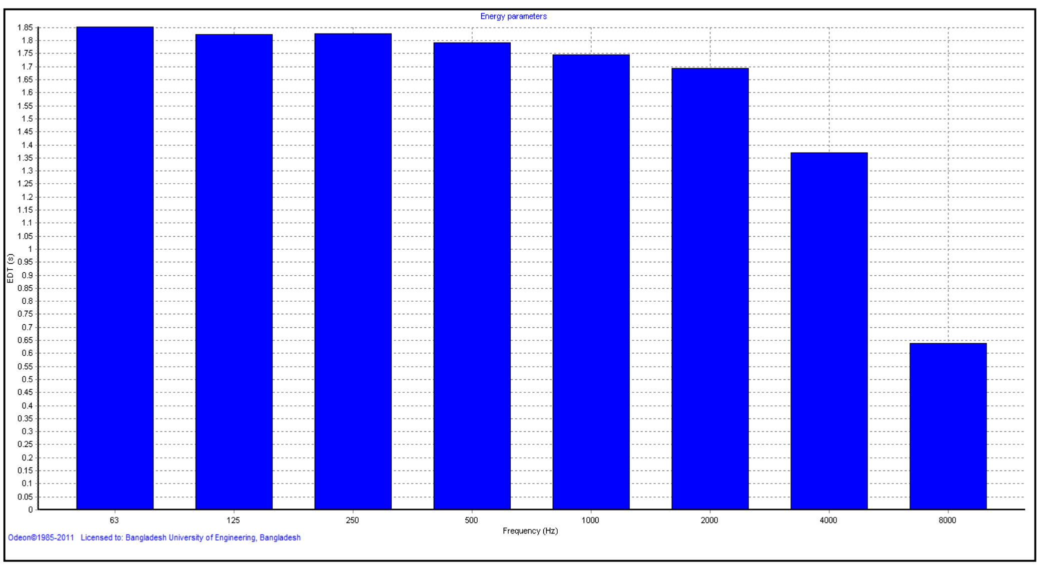


Reflectogram

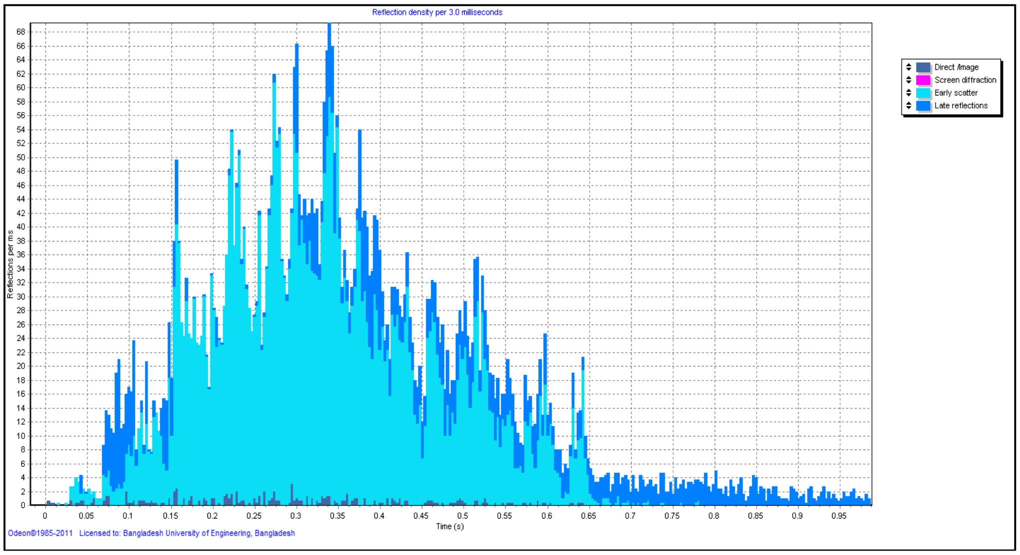
Material Type 2: Road Junction 1 – Gulshan 2 with smooth concrete, painted



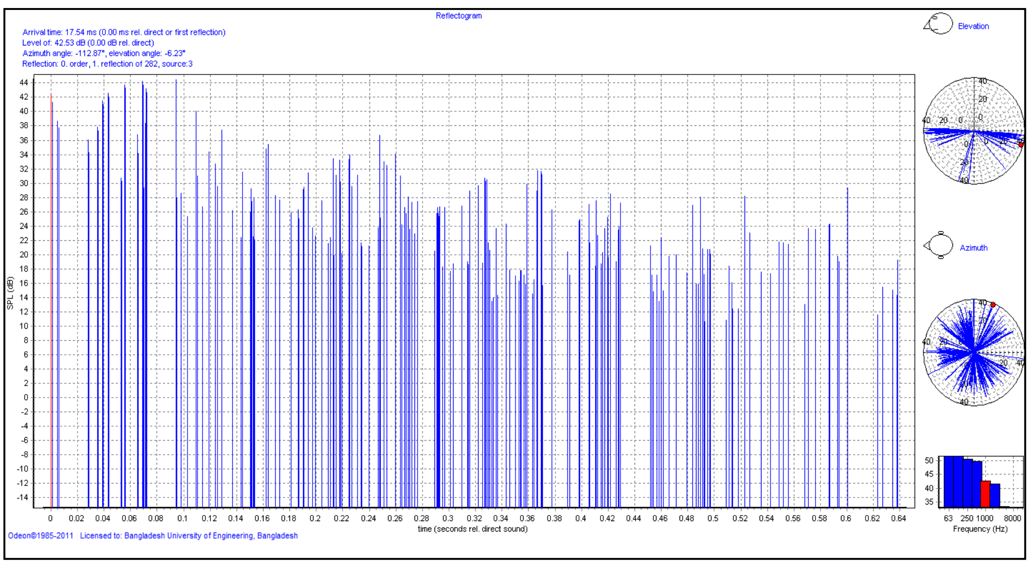
Estimated Global reverberation Time



Energy Parameter

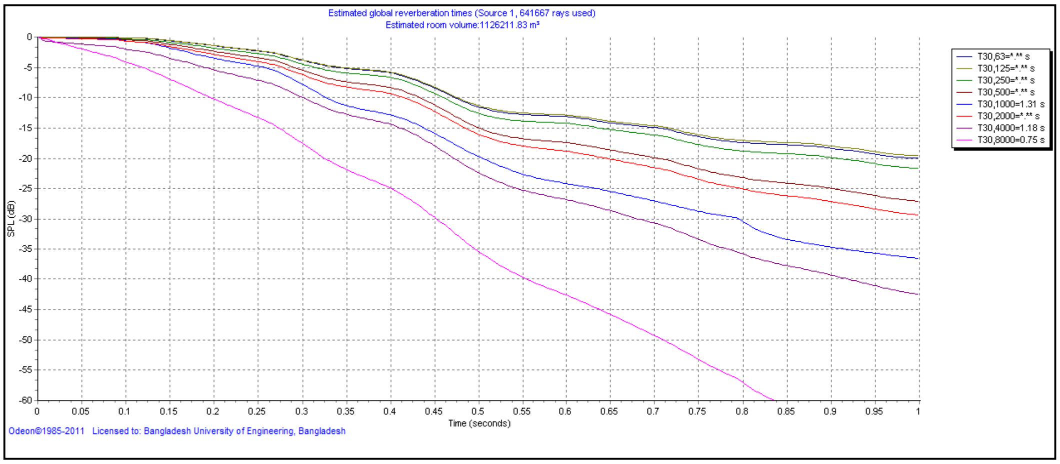


Reflection Density per 3.0 milliseconds

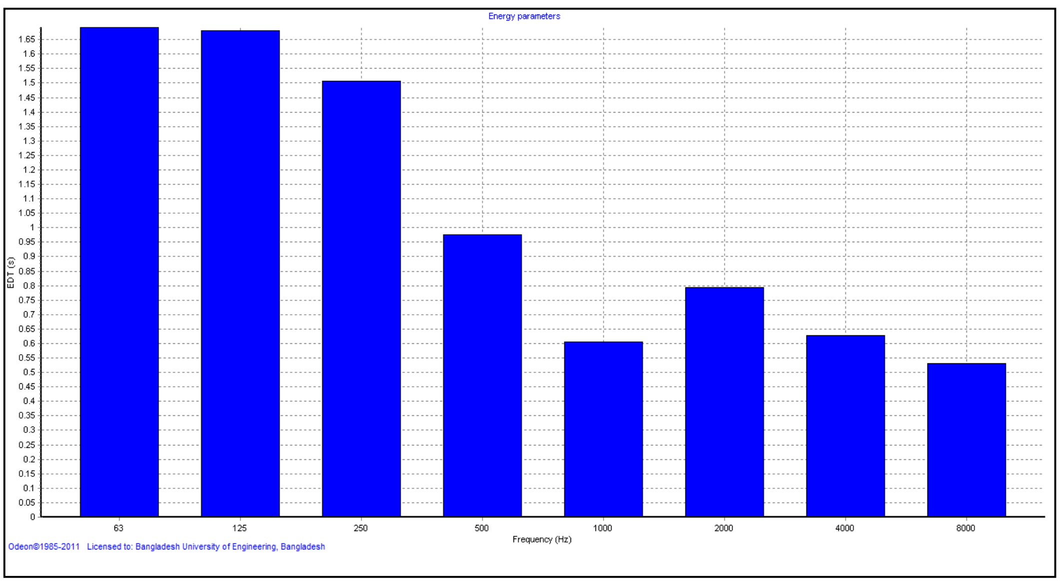


Reflectogram

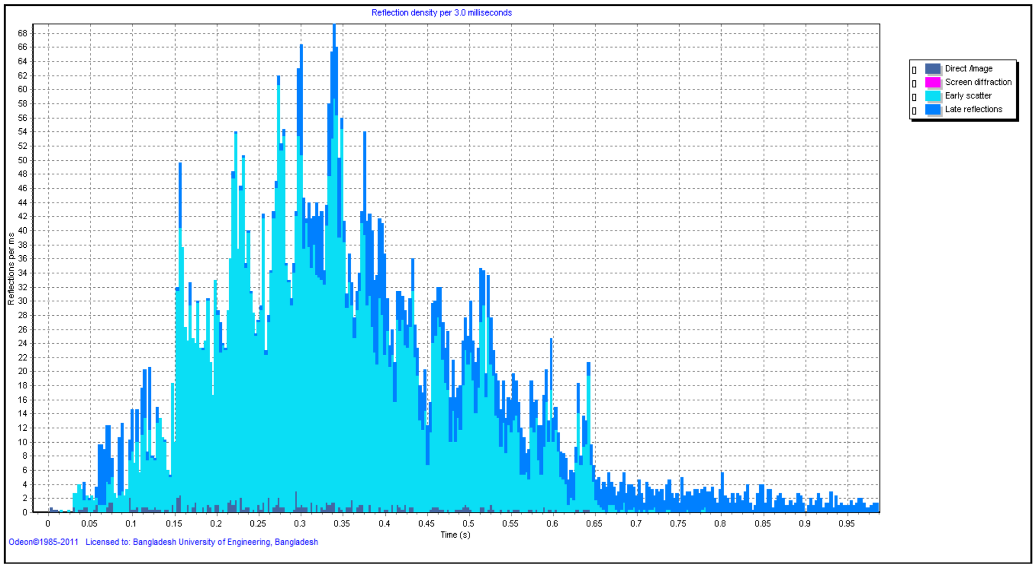
Material Type 3: Road Junction 1 - Gulshan 2 with Brick with 19mm holes, 60mm thick directly on concrete



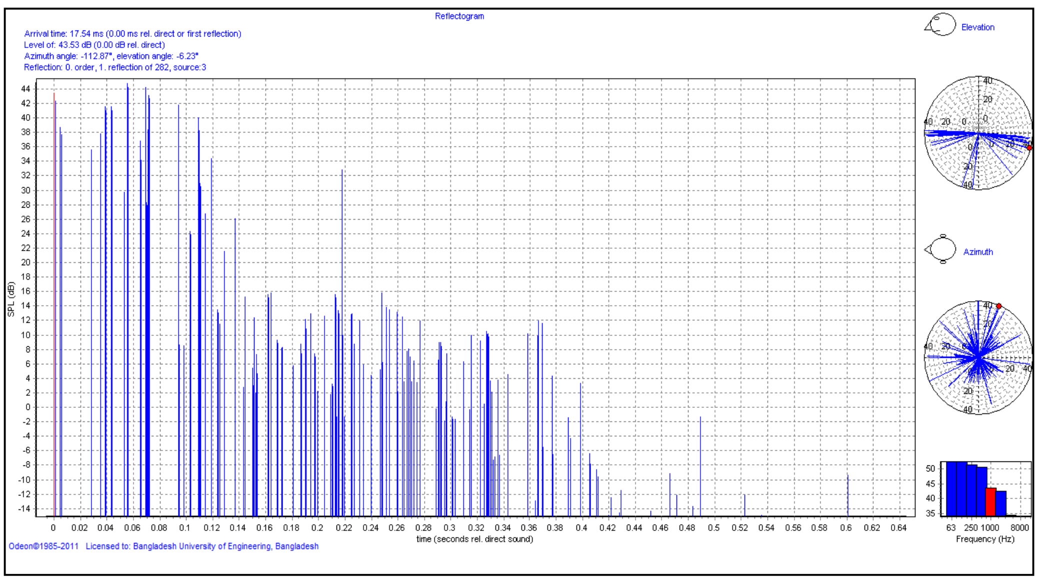
Estimated Global reverberation Time



Energy Parameter



Reflection Density per 3.0 milliseconds



Reflectogram