Design of Cost Effective Noise Barrier in Dhaka

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ABSTRACT

As in recent years, traffic noise - the unpleasant, unwanted sounds generated on our nation's streets and highways - has been of increasing concern both to the public and to local and government officials. At the same time, modern acoustical technology has been providing better ways to lessen its intensity and the adverse impacts of traffic noise, but its implementation in Bangladesh is poor. Main focus of this research was concentrated to analyze noise levels in major arterial road of Dhaka city from Saidabad Rail Crossing to Shanir Akhra. Noise levels were collected in and were analyzed for 41 locations in the study area. Almost in every location, average noise level was found more than the acceptable limit set by the Department of Environment (DoE), Bangladesh. To make this research more policy oriented a cost effective design of noise barrier is proposed to mitigate the effects of ambient noise on activities near the study area. In this regard, height of noise barrier was selected using two different ways e.g. Insertion loss calculation from known path length difference and determination of path length from known attenuation value. Relationship between insertion loss with height of barrier, position of barrier from receiver, frequency, Fresnel number, path length difference and temperature was also observed. Barrier thickness was selected depending on the material used in barrier. Cost of barrier was estimated depending on the price quoted by different vendors and following the method proposed by MDOT. Finally, a survey was conducted to solicit people's perception regarding noise barrier and its effects in these areas. The responses were analyzed in this research.

Keywords – **Average noise levels, Barrier costs, Insertion loss, Noise barriers.**

I. INTRODUCTION

Now a days the need and desire for noise abatement increases due to the increasing highway capacity, improvements of existing highways, increase of residential communities and other noise-sensitive development and the increase of traffic on highways. The only feasible measure to reduce highway noise is construction of a noise barrier. Highway traffic noise has been a National, State, and local concern in Bangladesh. However, there are no wide ranging methods and techniques to reduce the noise emission in Bangladesh whereas the amount of noise pollution is rapidly increasing. The study area in this research is one of the busiest roads in Dhaka city which connects this capital district with Chittagong and Sylhet divisions, other two major divisions in Bangladesh. Daily it generates a huge number of traffic including heavy vehicles and therefore, noise pollution is becoming a potential nuisance in this area.

To lessen the amount of noise pollution a cost effective design of noise barrier is proposed in this research. In order to identify any potential impact on and any potential change to the natural and socio-economic environment, this research is carried out following novel ways:

1) Noise level data were collected in and analyzed for forty one locations in the study area,
2) Calculation of insertion loss for different barrier heights and calculation of path length difference for known attenuation value,
3) Cost estimation, and
4) Solicit people's perception regarding noise barrier.

Noise level was measured both for day and night and every day of a week. Data were recorded not continuously in a week but were recorded for different days in different week to gather total overview of noise level data of a whole week. Day time was considered from 8:00 am to 6:00 pm and night time was considered from 6:01 pm to 11:59 pm. Data were taken at one minute interval spread over fifteen minutes. Latitude and longitude of each and every data collection point was recorded using a GPS. Once the noise levels have been measured, computation of average noise level Leq was done.

In first approach, we calculate insertion loss using the model proposed by Kurze and Anderson [1]. And in second approach, height of noise barrier was estimated from the proposed table using Fresnel Diffraction Theory as applied by the CORTN algorithms [2]. Once height was fixed thickness of barrier was determined and then cost of barrier was estimated from the method proposed by MDOT [6].

II. INTRODUCTION TO NOISE BARRIER

2.1 BARRIER FUNDAMENTALS

Noise barriers are solid obstructions built between the roads and homes along a road to protect inhabitants of sensitive land use areas from noise pollution. Noise barriers are considered the most reasonable method of mitigating roads, railways and industrial noise sources. They do not completely block all noise. They only reduce overall noise levels [3]. Noise barriers reduce the sound which enters a community from a busy road by absorbing the sound, transmitting it, reflecting it back across the road or forcing it to take a longer path over and around the barrier (Fig. 1). A noise barrier must be tall enough and long enough to block the view of a highway from the area that is to be protected the receiver. Noise barriers provide very little benefit for homes on a hill side overlooking a highway or for buildings which rise above the barrier. A noise barrier can achieve a 5 dB noise level reduction, when it is tall enough to break the line of sight from the highway to the home or receiver. After it breaks the line of sight, it can achieve approximately 1.5 dB of additional noise level reduction for each meter of barrier height [3].

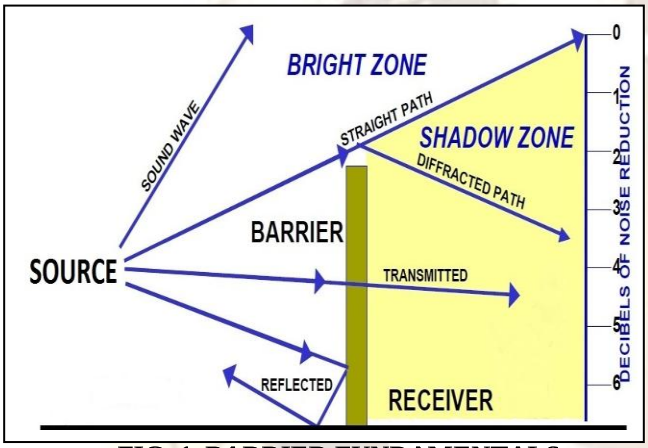

FIG. 1. BARRIER FUNDAMENTALS

2.1 CLASSIFICATION OF NOISE BARRIER

Noise barriers are generally classified into two basic categories depending on its structure a) Ground-Mounted and b) Structure-Mounted.

There are three basic types of Ground-Mounted noise barriers systems. These are a) Noise berm, b) the noise wall and c) combination of noise berm and noise wall.

Structure-Mounted noise barriers systems can be classified in two categories. These are a) Noise wall on bridges and b) Noise wall on retaining wall.

There are three subcategories for both Structure-Mounted and Ground-Mounted noise barriers: Double-Sided Sound Absorptive Noise Barriers; Single-Sided Sound Absorptive Noise Barriers; and Reflective Noise Barriers [4].

2.2 BARRIER MATERIALS

There are different types of materials which can be used in a noise barrier. Commonly used materials are: Masonry Block, Brick, Concrete (Cast in place), Concrete (Precast), Earthen Berm, Shotcrete or Gunite on Chain Link Fence, Vegetation, Timber (Wood Products), Plastic, Metal, Recycled , Composites, Transparent, Proprietary and Others [4].

III. PROBLEM IDENTIFICATION

3.1 STUDY AREA

It is located between 23^0 41' and 23^0 48'north latitudes and between 90^0 22' and 90^0 31'east longitudes. The surroundings of this road covers an area about 55.5 sq.km and there are more than one million people will directly or indirectly be affected by it. Noise level data were collected in and analysed for 41 locations in this area (Fig. 2).

FIG. 2. AERIAL VIEW OF DATA COLLECTION POINTS IN STUDYAREA

The study area covers Shabujbag, Sutrapur, Jatrabari and some portion of Demra suburbs. From the field survey the approximate number of infrastructures was found in the study area are shown in Table 1.

TABLE 1. INFRASTRUCTURES ALONG THE ROUTE IN STUDY AREA

Property Type	Number
Residences	34
Hospitals and Clinics	4
Educational Institute	9
Banks	7
Religious Institute	8
Government Offices	3
Commercial places	7
Petrol stations	7
Common facilities	3

3.2 NOISE MEASUREMENT AND DATA ANALYSIS

Sound level data was obtained using a sound level meter (SL-4001, Lutron made). The sound level meter was suitably calibrated before taking the measurements. The sound level meter was placed on a stand at a height of about 4 ft above the existing road level and at a distance of 5.0 to7.0 ft from the edge of the roads. During the measurement period, the irregular noise events such as low-flying planes, dogs barking, passing of ambulances, fire service and VIP vehicles, etc. were measured and marked in different colour for easy identification of them [5]. Once the noise levels have been measured, computation of Leq was done. Leq of a number of discrete A-weighted noise levels for a specified time period. From the study it is observed that average noise level at every location varies within the range of 75-90 dB(A) for both day (Fig. 3) and night (Fig. 4) which far exceeds the acceptable limit of 60 dB set by DoE, Bangladesh considering the road side as mixed area. In most places minimum sound level also exceeds the acceptable limit.

IV. BARRIER DESIGN

To determine the barrier height and insertion loss two method was applied. In first method insertion loss was calculated from known path length difference and barrier height and in second method path length was calculated for known attenuation value.

4.1 INSERTION LOSS CALCULATION

Insertion loss can be estimated by using the model proposed by Kurze and Anderson [1] given in equation (1)

$$IL = 5dB + 20\log\left(\frac{\sqrt{2\pi N}}{\tanh\sqrt{2\pi N}}\right)dB \quad \text{up to } N = 12.5$$
$$IL = 20\,dB \qquad \text{for } N > 12.5 \tag{1}$$

Where, N is defined as the Fresnel number, a non-dimensional measure of how much farther the sound must travel as a result of the barrier. It is calculated with the equation (2)

$$N = \frac{(a + b - \ell)f}{c_o} \tag{2}$$

Where, *l* is the original length of the direct path from source to receiver,
a and *b* are the lengths of the two straight-line segments comprising the path as modified by the noise barrier (Fig. 5)

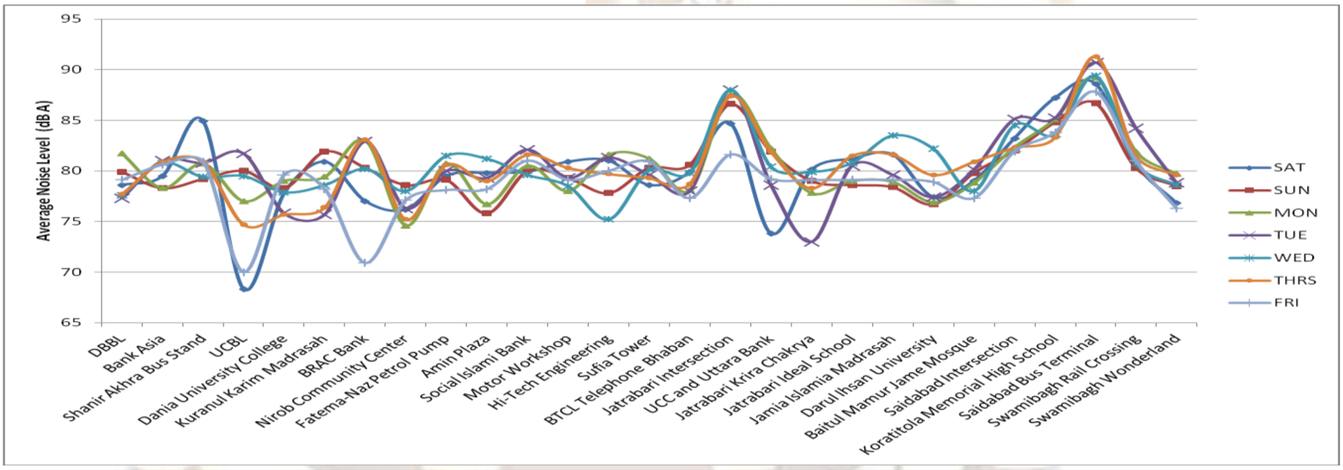

FIG. 3. WEEKLY L_{eq}VARIATION (DAY) IN THE STUDY AREA

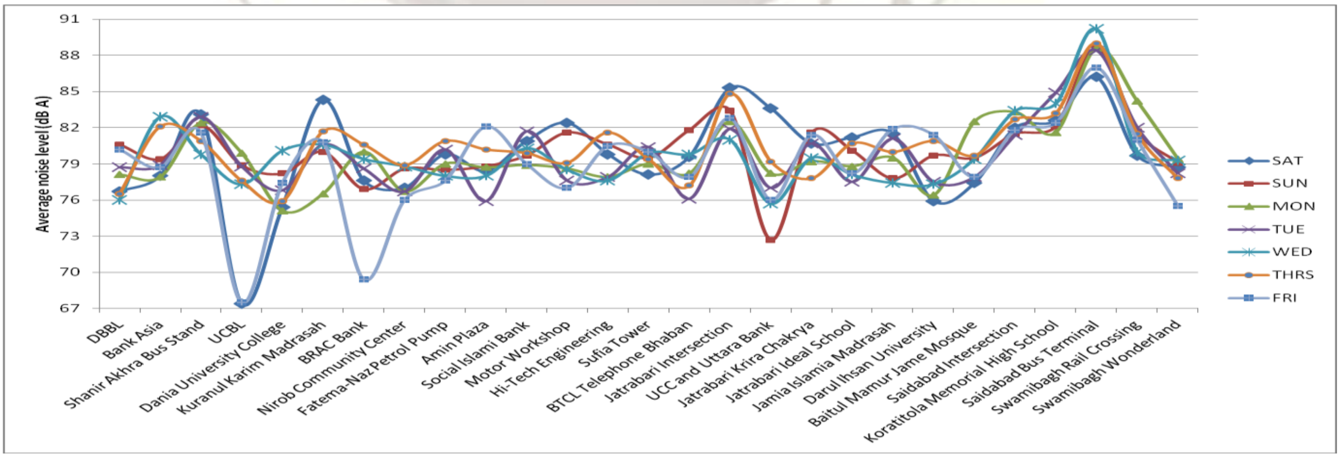

FIG. 4. WEEKLY L_{eq} VARIATION (NIGHT) IN THE STUDY AREA

f is the sound frequency in Hz,
Co is the speed of sound propagation in air which can be calculated by equation (3)

$$Co = 1087.27 + 0.6\ Tc\ \text{ft/s} \qquad (3)$$

Where, Tc is the atmospheric temperature in Celsius.

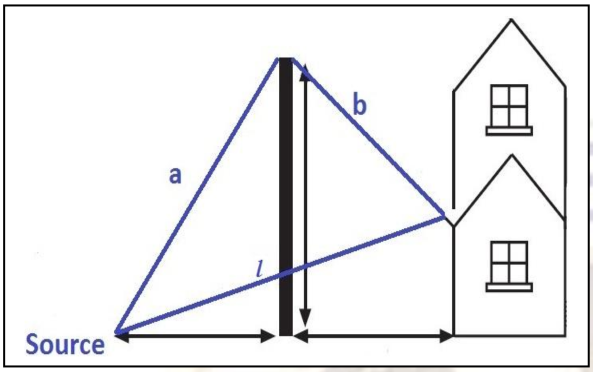

FIG. 5. MODIFIED PATH LENTH OF SOUND DUE TO BARRIER

4.2 BARRIER HEIGHT CALCULATION

Height of noise barrier was estimated from the proposed Table 2 using Fresnel Diffraction Theory as applied by the CORTN algorithms [2]. Once the required attenuation is known, the required path length difference can be determined .To use this table:

1. Search the body of the table to find the cell containing the required attenuation.
2. Traverse horizontally from that cell to the left-most column which gives the required path difference with a resolution of 0.1m.
3. Then traverse vertically from the cell to the top row which gives the second decimal place [2].

TABLE 2. ATTENUATION dB (A) DUE TO DIFFRACTION

Meters	Meters x 0.01									
	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	5.0	6.4	7.1	7.6	7.9	8.2	8.5	8.7	9.0	9.2
0.1	9.3	9.5	9.1	9.8	10.0	10.1	10.3	10.4	10.5	10.6
0.2	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7
0.3	11.7	11.8	11.9	12.0	12.1	12.1	12.2	12.3	12.4	12.4
0.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1
0.5	13.1	13.2	13.3	13.3	13.4	13.4	13.5	13.5	13.6	13.6
0.6	13.7	13.7	13.8	13.8	13.9	13.9	14.0	14.0	14.1	14.1
0.7	14.2	14.2	14.3	14.3	14.4	14.4	14.5	14.5	14.5	14.6
0.8	14.6	14.7	14.7	14.7	14.8	14.8	14.9	14.9	14.9	15.0
0.9	15.0	15.1	15.1	15.1	15.2	15.2	15.3	15.3	15.3	15.4
1.0	15.4	15.4	15.5	15.5	15.5	15.6	15.6	15.6	15.7	15.7
1.1	15.7	15.8	15.8	15.8	15.9	15.9	15.9	16.0	16.0	16.0
1.2	16.1	16.1	16.1	16.2	16.2	16.2	16.3	16.3	16.3	16.3
1.3	16.4	16.4	16.4	16.5	16.5	16.5	16.6	16.6	16.6	16.6
1.4	16.7	16.7	16.7	16.8	16.8	16.8	16.8	16.9	16.9	16.9
1.5	16.9	17.0	17.0	17.0	17.1	17.1	17.1	17.1	17.2	17.2
1.6	17.2	17.2	17.3	17.3	17.3	17.3	17.4	17.4	17.4	17.4
1.7	17.5	17.5	17.5	17.5	17.6	17.6	17.6	17.6	17.7	17.7
1.8	17.7	17.7	17.8	17.8	17.8	17.8	17.8	17.9	17.9	17.9
1.9	17.9	18.0	18.0	18.0	18.0	18.1	18.1	18.1	18.1	18.1
2.0	18.2	18.2	18.2	18.2	18.3	18.3	18.3	18.3	18.3	18.4

But the limitation of this approach is, attenuation of sound is restricted only up to 20 dBA. Once path length difference is calculated, height of barrier can be estimated from basic geometrical equation. In this method height of source and receiver were considered at the same level.

4.3 BARRIER THICKNESS

Thickness of noise barrier varies between 0.025 inch – 8.00 inch (0.64 mm – 200 mm) depending on the material used and the amount of transmission loss [4].

4.4 BARRIER COSTS

Costs of barrier mostly depend on the materials used in the barrier. Some vendor includes the transportation cost to job site with the unite price of the product. Unit costs generally are affected by quantity and transportation distance [4]. Generalized cost ranges for barrier materials are shown in Table 3 [4].

TABLE 3. BARRIER MATERIAL UNIT COST

Material Type	Reflective/ Absorptive	Generalized Cost Range (per sq. ft)
Concrete – Precast	Absorptive	\$10 - \$23
Concrete – Precast	Reflective	\$16 - \$19
Concrete – Machine made	Reflective	\$12
Metal	Absorptive	\$10 - \$40
Metal	Reflective	\$10 - \$40
Wood	-	No products reported

V. RESULTS AND DISCUSSION

5.1 INSERTION LOSS VARIATION

Average noise level varies within the range of 75-90 dBA almost at every location whereas the limit set by DoE is 60 dBA for mixed area. To achieve the limit at least 20-25 dBA of sound must be attenuated. In order to do this insertion loss was estimated for different barrier height, position of barrier from receiver, frequency, Fresnel number, path length difference and temperature. In this study, horizontal distance between source and receiver is 25 feet on both sides of road and it was assumed that the receiver is located 4 feet higher than that of the source. Variation of insertion loss with respect to these mentioned factors are shown from Fig. 6 to Fig. 10.

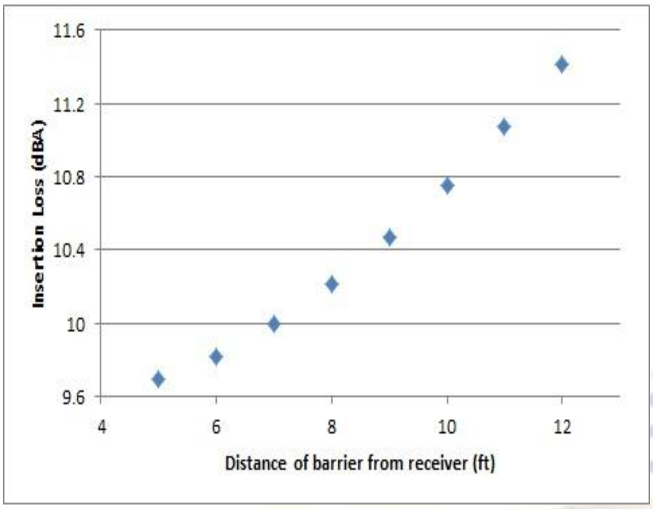

FIG. 6. BARRIER DISTANCE FROM RECEIVER VS. INSERTION LOSS

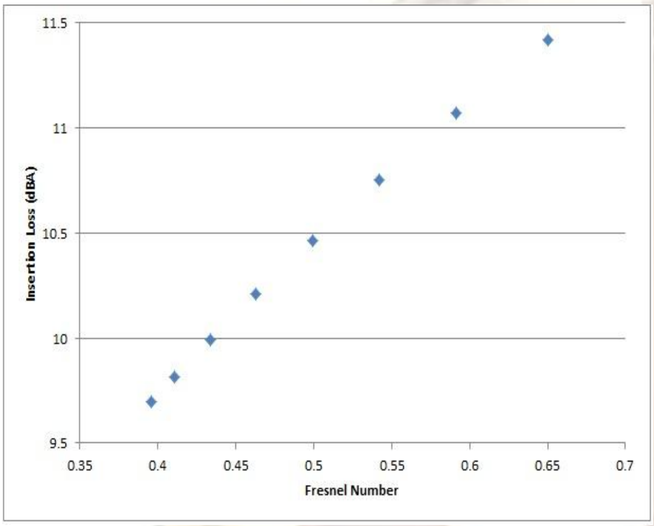

FIG. 7. FRESNEL NUMBER VS. INSERTION LOSS

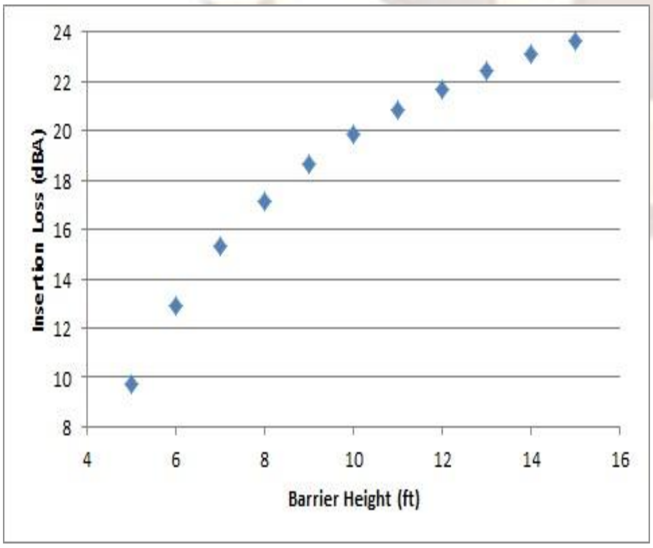

FIG. 8. BARRIER HEIGHT VS. INSERTION LOSS

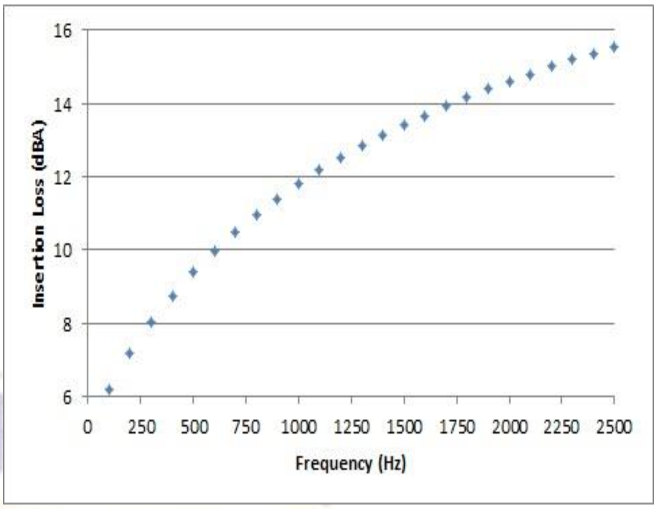

FIG. 9. FREQUENCY VS. INSERTION LOSS

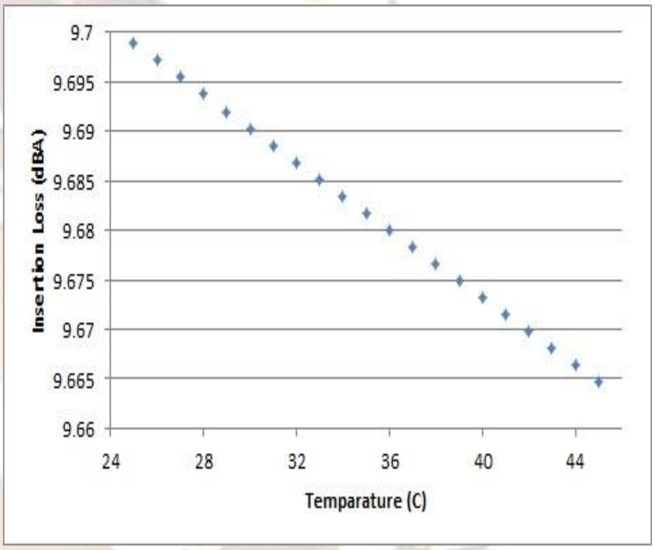

FIG. 10. TEMPARATURE VS. INSERTION LOSS

5.2 HEIGHT OF BARRIER

Height of barrier was chosen 12ft for an insertion loss of 22 dBA. Where barrier should be placed at 5ft away from receiver and frequency of sound wave was 550 Hz at a temperature of 27°C.

5.3 COST ESTIMATION

Based on various barrier cost data calculated and/or obtained by MDOT, the cost index factor assumed for the manufacturing and installation of noise barriers shall be $45.00 per sq. ft. The square footage (measured from the finished grade line at the base of the noise barrier to the top of the noise barrier) of the recommended noise barrier should be multiplied by $45.00 to get the cost of the noise barrier [6]. The $45.00 per sq. ft. amount includes the cost of the noise barrier panels, posts, foundations, right-of-way, and grading. The square foot amount also includes additional costs required solely for the construction of the noise barrier (i.e., right-of-way/property acquisition/utility relocation); these costs will be added to the cost calculations of the noise barrier [6].

The cost effectiveness of noise abatement is determined by dividing the total cost of the noise abatement (based on $45.00 sq. ft.) by the number of benefiting receptor units. The quotient is compared to the allowable cost per benefited unit (CPBU) [6]. MDOT has chosen an allowable CPBU of $42,509 (2012) where noise mitigation was determined to be reasonable. Although $42,509 per benefited receptor unit is the allowable upper limit in the reasonableness determination, a reasonable (and possibly optimized) noise barrier may cost much less than $42,509 per benefited receptor. Where, a receptor that receives a 5 dB (A) or greater insertion loss as a result of the proposed noise barrier will be considered a benefited receptor unit. Table 4 is showing the rreasonable Cost of Abatement.

TABLE 4. ALLOWABLE COST ESTIMATION OF NOISE BARRIER

	Criteria	Units	Barrier
1	Length of proposed barrier	ft	26250
2	height of proposed barrier	ft	12
3	Multiply item 1 by item 2	Square feet	315000
4	the average amount of time that a person stays at the site per visit	hours	4
5	Enter the average number of people that use this site per day that will receive at least 5 dB(A) benefit from abatement at the site	people	92
6	Multiply item 4 by item 5	person-hr	368
7	Divide item 3 by item 6	ft^2/person-hr	855.98
8	Multiply $ 45 by item 7	$/person-hr/ ft^2	38,520
9	Does item 8 less than the "CPBU" of $ 42,509		Yes
10	If item 9 is yes, abatement meets reasonable criteria		
11	If item 9 is no, abatement does not meet reasonable criteria		X

VI. PEOPLE'S PERCEPTION

A questionnaire survey was conducted to solicit people's perception regarding noise barrier and its effects in these areas. This survey was conducted in different households, hospitals, educational institutions, offices, commercial places etc. and also the road users. Total 101 persons responded in the survey.

Noise and air are the two major environmental parameters. As the study area is a mixed area including a national highway, continuous emission of sound from vehicles and other sources cause problems almost all the time of the day. From the survey it has been seen that noise pollution becomes more intense in evening due to commuter flow. Many of the respondents opined two or more options. Air pollution is another major problem indicated by the respondents. Traffic police, road side vendors, pedestrians, and road users are the most vulnerable group affected.

A number of health problems have been also found due to the degradation of the standard of living in the study area. About 33.69% of respondents have complained suffering from loss hearing due to noise pollution and about 43.38% are having asthma caused from air pollution.

From the survey we found that majority of the respondents are having problems with noise and air pollution. More than 70% people agreed that both noise and air quality exceeds tolerable limit and noise is becoming more annoying day by day. Most of the interviewees replied shadow problem due to barrier would not be any considerable matter. But their perception regarding this trouble was confusing. In spite of these mentioned troubles people are ready to relocate during construction period. Almost every person supports this particular project for the sake of greater interest of the nation (Fig. 11).

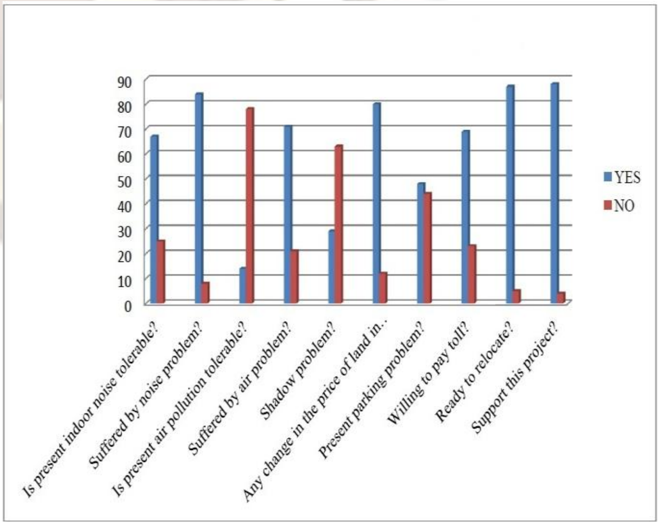

FIG. 11. RESPONDENTS OPINION IN SOME IMORTANT ISSUES

VII. CONCLUSION

Effectiveness of noise barrier largely depends on the height, thickness and material used. The following results conclusions were arrived from that plots.

a) The insertion loss increases with increased distance of barrier from receiver.

b) The insertion loss increases with increased value of Fresnel number.

c) The insertion loss increases with increased height of barrier.

d) The insertion loss increases with increased frequency.

e) The insertion loss decreases with increased surface temperature.

Barrier costs also depend on the material used and there is no such guideline regarding construction of noise barrier in Bangladesh, so that methods proposed by MDOT were used to calculate the costs of barrier. In some places noise levels were far exceeds the acceptable limit which cannot be completely attenuated but proposed barrier will reduce a significant amount of noise in the surrounding areas. Cost of the barrier showed its effectiveness with respect to the benefited units. From people's perception it is clear that almost every person supports this particular project for the sake of greater interest of the nation.

VIII. SCOPE OF FUTURE RESEARCH

1. In this study, only average noise level L_{eq} was considered. Other statistical parameter may generate different results.
2. Only diffractive propagation of sound wave was considered in this work. Results may be improved by considering reflective propagation of wave.
3. Ground-mounted Noise wall type barrier was only taken into account, but different types of barriers may show diverse results.
4. Only unit cost of material was considered. Results may be improved if installation cost, labor cost, maintenance cost was taken into account.
5. In this work ground effect was not measured. It will be more practical to consider ground effect.
6. Noise level was measured only at grade. Measuring noise level in grade separated condition may show a different result.
7. Data can be analyzed using advanced softwares to present the noise pollution intensity maps after construction of barrier and compare with the present situation.

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