Metropolitan Traffic Noise and Abatement Measures

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ABSTRACT: Traffic noise is an inevitable phenomenon associated with traffic operation in metropolitan areas. Due to rapid urbanization and corresponding increase in vehicular population, the noise levels in most of the metropolitan cities in India are above the acceptable threshold levels of 50 to 60dB(A). Interrupted flow traffic noise from the urban area has different characteristics from traffic noise generated by the free flow in a rural area. Provision of transport infrastructure such as flyover will undoubtedly contribute to the benefit of community at large. In urbanized areas the most effective reduction of traffic noise disturbances would be obtained by provision of noise barriers or enclosures. This paper aims at the development of an analytical model for designing a noise barrier at flyover locations in Delhi. Noise Barriers can have a substantial effect on the visual environment of a highway and its surrounding environment.

RÉSUMÉ : Le bruit de la circulation est un phénomène inévitable associé à l'exploitation du trafic en zones urbaines. En raison de l'urbanisation rapide et l'augmentation correspondante du parc de véhicules, les niveaux sonores dans la plupart des villes métropolitaines en Inde sont au-dessus des niveaux de seuil acceptables de 50 à 60dB (A). Le bruit de la circulation du flux interrompu en zone urbaine a des caractéristiques différentes du bruit de la circulation produit par le flux libre en zone rurale. La mise à disposition d'infrastructures de transport comme l'autopont contribuera sans aucun doute au bien-être de communauté en général. Dans des secteurs urbanisés, la réduction la plus efficace des nuisances sonores dues à la circulation serait obtenue par la mise à disposition de murs ou de clôtures antibruit. La communication vise à développer un modèle analytique pour concevoir un mur antibruit aux emplacements d'autopont à Delhi. Les murs antibruit peuvent avoir un effet substantiel sur l'environnement visuel d'une route et son environnement.

1 INTRODUCTION

1.1 *Background*

Traffic related noise pollution accounts for nearly two-third of the total noise pollution in a metropolitan city. Noise, a by-product of urbanization and industrialization, is increasingly recognized as an environmental nuisance that affects human health and wellbeing. Highway traffic on existing urban roadways lowers the quality of life and property values for persons residing near these roadways. In urbanized areas the effective reduction of traffic noise disturbances would be obtained by provision of noise barriers or enclosures. In India, the number of vehicles is growing at an annual rate of more than 7 percent per annum.

1.2 *Pressure on road traffic*

Road traffic is a complex system in which wide varieties of road user, vehicle and environment interact. In Delhi, proliferation of vehicular population from 5 lakh in 1980 to 40 lakh in 2001 is a matter of great concern [www.teriin.org]. The congestion at road intersections is due to the motorization boom and increase in single occupancy vehicle. Provision of transport infrastructure like flyover in Delhi will contribute to the benefit of the community at large. The flyover is a grade-separated structure carrying high volume road i.e. major road over the signalized intersection. Nevertheless, due to the limited availability of land resources and finances, it is inevitable that in flyover scheme there will be some adverse environmental effects such as intolerable noise levels, fumes and dust to those living in close proximity to the flyovers.

1.3 *Noise environment in Delhi*

Similar to other major metropolitan cities, noise is an issue in Delhi. Poor planning in the past and cramped development have resulted in such thorny problems such as highways running just outside people's living rooms. Continued growth of metropolitan highway system combined with an increase in public awareness of environmental issues has focused on a need to evaluate the impact of traffic noise associated with highway systems on neighboring communities. When noise levels exceed acceptable limits, community action generally alerts governmental bodies to the problem or potential problems. Governmental bodies then investigate measures to prevent or alleviate noise problems. The ambient noise levels in Delhi are given Table 1.

Table 1. Ambient Noise Levels in Delhi

Zone	Prescribed* (dB(A))	Delhi (dB(A))
Residential	55	53-71
Commercial	65	63-75
Sensitive	50	62-68
Industrial	75	65-81

* Ambient noise standards prescribed by Central Pollution Control Board.

1.4 *Abatement Measures*

Measures that must be considered in traffic noise analysis when a highway project will result in a noise impact include:

- Traffic management
- Alteration of horizontal and vertical alignments
- Acquisition of real property to serve as a buffer zone
- Insulation of public use or nonprofit institutional structures
- Construction of noise barriers

2 NOISE BARRIER

The installation of noise barriers between noise sources and noise-sensitive areas along major roads and freeways is another way to combat traffic noise. This paper deals with the design of cantilever barrier to protect the receiver adjacent to a flyover.

2.1 *Types of barriers*

The effectiveness of a barrier depends on how well it diffracts and absorbs the noise. A high performance barrier has negligible noise transmission and reflection. This is controlled by two coefficients: Absorption (α) and Sound Insulation (R) [Kugler et al.(1976)].

2.1.1 *Absorptive Barriers*

An absorptive barrier works by absorbing some of the traffic noise energy into the porous facing and also reflecting some of the noise energy up into the air. An efficient absorptive barrier can give approximately 3 dB(A) noise reduction in excess of that provided by a reflective barrier of the same height. In future, to achieve more stringent community noise standards, the absorptive barrier offers significant benefits.

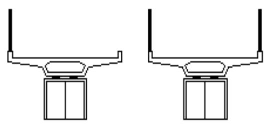
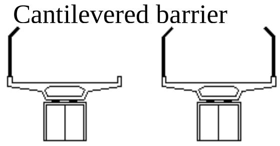
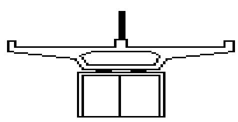
2.1.2 *Reflective Barriers*

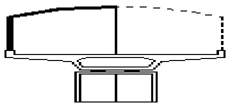
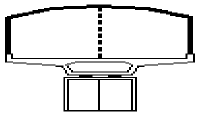
Reflective barrier works by reflecting traffic noise up into the air. The higher the barrier, the more noise is reflected upwards, and the less noise is propagated laterally toward nearby residences. For practical purposes, the noise reduction from reflective barriers is in the order of 10 to 14 dB(A) under neutral weather conditions.

2.2 *Shape of noise barrier*

The alignment and profile of the flyover and nearby roads in relation to the configuration of the receivers would influence the form of the barrier. The configurations and its characteristics are summarized in Table 2.

Table 2. Summary of Characteristics of Noise Barriers

Vertical barrier 	• Simplest form of noise screening structure • Effective in protecting low-floor sensitive receivers • Can be installed on one side or both sides of carriageway
Cantilevered barrier 	• Effective in protecting low to mid-floor sensitive receivers • Can be installed on one side or both sides of carriageway
Central barrier 	• Effective in protecting low to mid-floor sensitive receivers from wide dual carriageways • Installed in the central reserve of dual carriageway

Semi-Enclosure barrier 	• Effective in protecting high-rise sensitive receivers
Full-Enclosure barrier 	• Effective in protecting high-rise sensitive receivers on both sides of carriageway

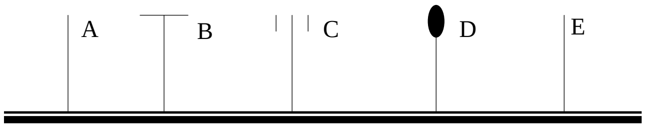


Figure 1. Simple and capped barriers
A: simple vertical barrier B: T-shaped
C : Multi-edge barrier D : Absorptive cylinder
E : Interference device

2.3 *Barrier materials*

Potential barrier materials are Precast Concrete Panel/ Steel Post, Precast Concrete Panel/ Concrete Post, Precast Stacked Concrete Panels, Carsonite, Plexiglass, Noshield Aluminum Sheets, Noshield Steel Sheets, Durisol and Plywood Panels.
The cost of barriers varies from place to place because of local cost of materials, cost of labour and land. Table 3 gives approximate TL values for some common materials, tested for typical A-weighted traffic noise frequency spectra. They may be used as a rough guide in acoustical design of noise barriers. For accurate values, Highway Agency (1992) prepared material test reports by accredited laboratories.

Table 3.Transmission loss values for barrier materials

Material	Thickness mm	Weight kg/m^2	Transmission Loss dB(A)
Concrete block 200x200x405mm light weight	200	151	34
Dense Concrete	100	244	40
Light Concrete	150	244	39
	100	161	36
Steel, 18 ga	1.27	10	25
Steel, 20 ga	0.95	7.3	22
Steel, 22 ga	0.79	6.1	20
Steel, 24 ga	0.64	4.9	18
Aluminum Sheet	1.59	4.4	23
	3.18	8.8	25
	6.35	17.1	27
Wood, Fir	12	8.3	18
	25	16.1	21
	50	32.7	24
Plywood	12	8.3	20
	25	16.1	23
Plexiglas	6	7.3	22

2.4 *Aesthetical aspect*

Roadside barriers itself could also affect the aesthetical perception of both road users and residents. The visual impact of roadside barriers on adjoining communities, as well as on the motorists is a major consideration in the design of roadside barriers. A tall roadside barrier placed close to the low rises could have severe visual effect as a tall barrier creates unwanted shadows and blocks panoramic views. On the motorist side of the barriers the emphasis should be on the overall form of the barrier, its colour and texture. Small details will not be noticed at normal highway speeds. However, the emphasis should be on avoiding a tunnel effect through various forms and visual treatment.

Elements to be considered;

- Architectural: - The overall appearance of barriers could be further articulated through applying of architectural concepts such as rhythm, proportion, order, harmony and contrast (not in any priority order).
- Visual impact: - The fundamental is to design the barriers with appropriate scale and character compatible and matches with the local environment.
- Compatibility with local features: - To some extent, local residents would tend to accept the barriers, which have relationship with its surroundings and are compatible with the appearance of the adjacent neighbourhood.
- Transparent Barriers: - Where a barrier is required to provide noise protection to properties in close proximity to the highway there are likely to be adverse effects due to the loss of view, loss of daylight, and enclosure effects.
- Use of Colour: - It is of general consensus that the appearance of a barrier can be toned down to help it merge with its surroundings, or made to stand out as a striking and highly visible addition to the environment by the use of colour.

3 APPROACH AND METHODOLOGY

3.1 *Traffic noise model*

Prediction is a very important part of noise impact assessment. The basic prediction procedure involves consideration of the nature and noise level of the sources, propagation along the paths between sources and receivers and the location of the receivers, as shown Figure 2

Source characterization including sound power and directivity → Propagation conditions: topography, barriers, reflections & climate → Receiver location: free-field, facade or internal level

Figure 2. Basic noise prediction procedure

The traffic noise model, Haris (1991), predicts the 1-hour average noise level for a flow of vehicles traveling along an infinitely long line. The algorithms are based on the concept of a series of adjustments to a sound level. This reference level is taken at a distance of 15.2 m for a single vehicle traveling along an infinitely long straight level roadway with no shielding of the source. Adjustments are then made for traffic flow, receptor distance from the road, the extent of the road segment, type of ground cover between receiver and source, any shielding of the source, and, if applicable, the gradient of the road. Many prediction methods are source specific and empirical. The formal models used for traffic noise in UK and USA are Calculation of Road Traffic Noise (CRTN) and Federal Highway Administration Model (FHWA).

All the noise prediction algorithms [Bhattacharya et al. (2001)] for this work has been developed in the lines of FHWA model. The value of L_{Aeq} is determined from the equation;

$$L_{Aeq} = L_o + \sum L_i \tag{1}$$

Where, LAeq = continuous steady noise level on A-weighted scale; L_o = basic noise level for stream of vehicles and L_i = adjustments for each vehicle category.

The total 1-hour average sound level for each vehicle type $[(L_{eq})_i]$ is computed by arithmetically summing the various adjustments:

$$(L_{eq})_i = [(L_0)_E]_i + [10 \log (N_i \pi d_o/S_i T)] + [10(1+\alpha)\log(d_o/d)]_i + (6.6 - 5.31 \log S_i + G) + (\Delta_{shielding})_i + [10\log (\psi_\alpha(\phi_1,\phi_2)/\pi]_i + (\Delta_{barrier})_I \tag{2}$$

Where, $[(L_0)_E]_i$ = the basic noise level contribution of a given class of vehicle; $(10(1+\alpha)\log(d_o/d)^{1+\alpha})_i$ = traffic flow adjustment for a given class of vehicle; $(10(1+\alpha)\log(d_o/d))_i$ = distance adjustment for a given class of vehicle; α = site parameter (0 or ½); $(6.6-5.31\log S_i + G)_i$ = grade adjustment for a given class of vehicle; S_i = average speed of i^{th} class of vehicle; G = grade of roadway; $(\Delta_{shielding})_i$=shielding adjustment for a given class of vehicle; $[10\log(\psi_\alpha(\phi_1,\phi_2)/\pi]_i$ = finite segment adjustment for a given class of vehicle; ψ_α = adjustment for finite length of roadway; ϕ_1,ϕ_2 = angles of roadway that contributing the noise (angles) and $(\Delta_{barrier})_i$ = barrier adjustment for a given class of vehicle.

The noise contribution from different classes of vehicles may be combined by addition of sound intensities, which is equivalent to the expression

$$L_{eqH(combined)} = 10\log\sum_{i=1}^{n} 10^{LeqH/10} \tag{3}$$

where, $L_{eqH(combined)}$ = hourly equivalent sound level due to all categories of vehicles flying on road and L_{eqH} = noise level contribution from each vehicle class.

The approach adopted for this study is summarized in Figure 3.

3.2 *Traffic noise assessment*

The working tool for traffic noise assessment involves set of procedures, which can serve as a quick tool. Elements of strategy are applied systematically to

- Identify the noise problem;
- Select the noise barrier form;
- Identify the road safety problems such as visibility and obstruction of vehicular access;
- Ascertain the acoustic performance of the identified form.

3.2.1 *Identify the noise problem*

The identification is based on the number of lanes and the distance of receiver from the subject road. If the flyover is identified as a possible noisy (1) flyover, the next step should be to identify the form of noise barrier for the particular site conditions and the type of receiver and furthermore, the chance of providing such barrier is an effective manner. If the subject road is not found to be a noisy flyover, no immediate noise mitigation.

3.2.2 *Noise barrier form*

When a flyover has been identified as noisy, the next step is to determine the form of noise barrier. Plain noise barrier is effective up to 5th floor receivers above carriageway

- Cantilever barrier is effective from 5th to 10th floor receivers above carriageway
- Semi-enclosure is effective above 10th floor receivers.

3.2.3 *Identify road safety*

Installation of a barrier along a bend on road may obstruct the sight line for safe stopping. Junction visibility requirements need to be observed and the material would need to be modified accordingly.

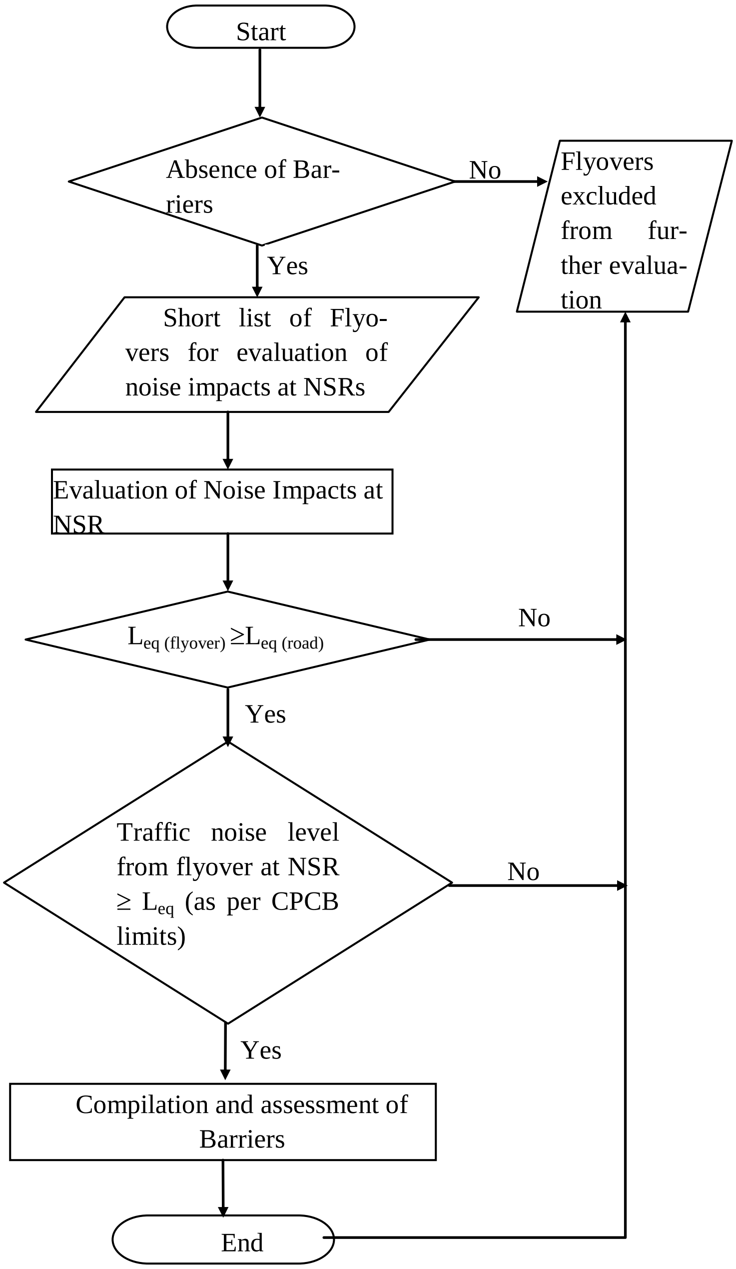


Figure 3. Approach of the study

3.2.4 *Acoustic performance*

A noise impact assessment is conducted to evaluate the acoustic effectiveness of the noise barrier for the particular road section. For high rise buildings, the barrier geometry should ensure that the road traffic noise levels at over 50% of exposed facades on any vertical section are reduced to below 65 dB(A). This is based on the criteria that the upper floor receivers are not protected. For low rise buildings, scattering of spreading out over a long stretch of the road, it is necessary to reduce the noise levels at over 50% of exposed facades along the road stretch, This is based on the criteria that upper floor receivers of low rise buildings can be readily protected by relatively shirt barriers, the horizontal extent of barrier also protect at least half of dwellings along the road stretch.

4 FIELD STUDIES AND ANALYSIS OF DATA

4.1 *Data collection*

Data for this study was collected from Ashram and Moolchand flyover sites in Delhi, which include traffic characteristics and traffic noises. The study locations are shown in Figure 4. In order to obtain data for a wide range of noise abatement measures/legislations, three different zones are included in the study-industrial, residential and sensitive characteristics. The geometrical dimensions of road sections at data collection points are also measured. All the roads had asphalt surfaces and no ground cover existed between measurement point and road. The highway traffic noise was measured using a sound level meter with L_{eq} A-weighted decibel scale dB(A) for one hour periods.

In the traffic noise source analysis, the traffic noise data for each vehicle type, which appeared on these road stretches, was collected in the field with on-road running conditions. These vehicle types include the two popular vehicles on highways in India, namely, light commercial vehicle and motor cycle in addition to the other vehicle types of automobiles, truck (light, medium and heavy) and bus (medium and normal). The measurements of spot speed and traffic noise generated by this particular type of vehicle were measured under real vehicle running conditions. This data was used in the traffic noise source analysis to generate the reference energy mean emission level (L_o) model for each type of vehicle in the traffic stream.

At each site following data was collected;

i Traffic volume
ii Traffic speed
iii Ambient noise levels
iv Geometries of flyover like gradient, number of lanes, lane width, width of median (if present) and type of pavement.
v Geometries of adjoining road like number of lanes, lane width, width of median (if present) and type of pavement.

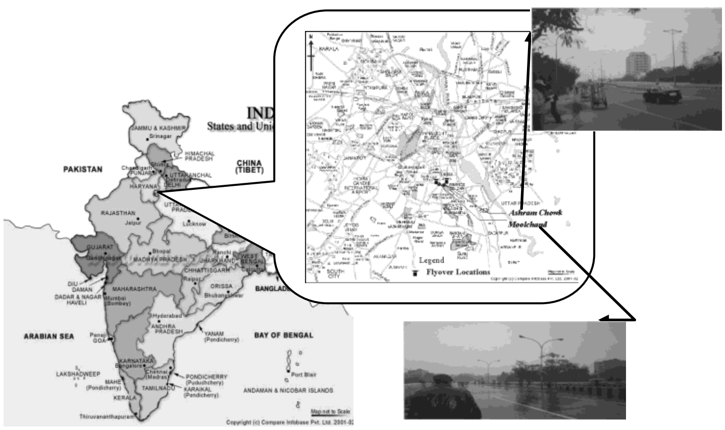


Figure 4. study locations in Delhi for noise assessment

Traffic flow diagrams for the two study flyovers are shown in Figure 5(a) and 5(b).

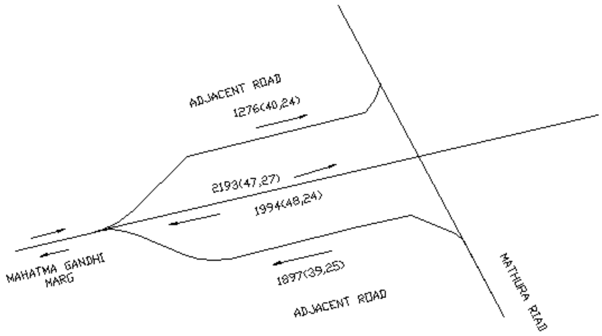


Figure 5(a). Traffic flow for Ashram flyover location

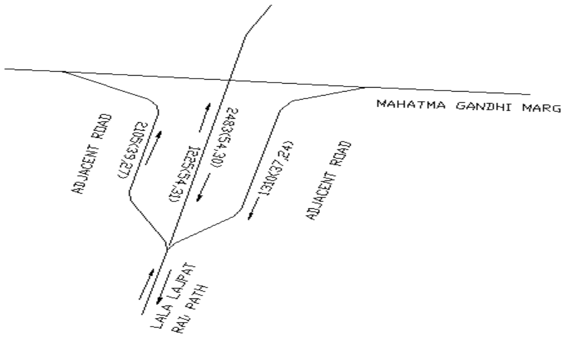


Figure 5(b). Traffic flow for Moolchand flyover location

4.2 *Noise exposure*

The existing noise level measurements shall yield the worst hourly noise levels occurring on a regular basis under normal traffic conditions. If on-site noise meter measurements are not possible, then estimates must be made according to the FHWA Highway Traffic Noise Prediction Model. Noise is to be measured in units of dBA Leq(h). The basic traffic noise model, called reference energy mean emission level (L_o) is analyzed for each vehicle type. In this analysis, the previous log speed model as introduced by FHWA for U.S. vehicles as reference energy mean emission level (L_o) was firstly tested against the collected data. The test showed no significance results for any model type of L_o as given by the FHWA when fitted to any specified class of vehicles in India. Therefore, using a regression analysis in order to fit L_o for the Indian traffic noise sources tests a new model.

Predicted noise levels should be obtained according to the FHWA Highway Traffic Noise Prediction Model. Currently, a Computer Highway Traffic Noise Program in C++ environment is used. Input such as volume, speed and truck percentages for modeling should reflect the set of traffic characteristics, which yield the worst hourly traffic noise impact on a regular basis under normal conditions.

Figure 6 shows predicted versus observed noise levels for Ashram and Moolchand locations.

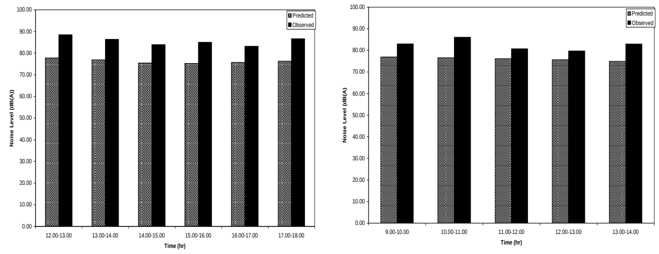


Figure 6. Predicted Vs observed noise levels for Ashram and Moolchand

Table 4 Predicted Noise Levels

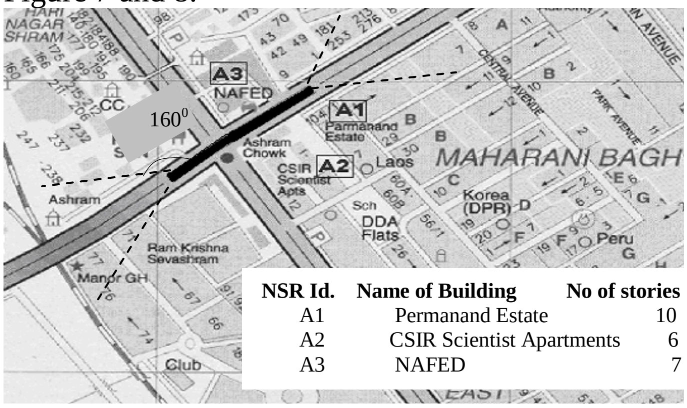
Location	on flyover	on adjacent road
☞ Ashram		
Towards Lajpat nagar	81.00 dB(A)	80.36 dB(A)
Towards Sarai kale khan	81.12 dB(A)	80.93 dB(A)
☞ Moolchand		
Towards ITO	79.24 dB(A)	79.18 dB(A)
Towards Madan gir	80.71 dB(A)	81.54 dB(A)

5 ABATEMENT MEASURES

Traffic noise impacts occur if either of two conditions are met: 1) the predicted levels approach or exceed the noise abatement criteria (CPCB Permissible noise levels-in Table 1); or, 2) the predicted traffic noise levels substantially exceed the existing noise level.

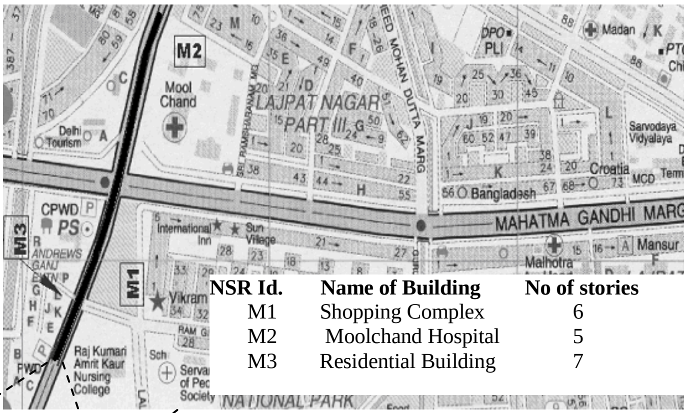
Observed noise levels are exceeded CPCB Permissible noise levels and at-grade noise levels on adjacent roads However, in urbanized areas the most effective reduction of noise disturbances would be obtained by using noise tolerant buildings as screening structures or the provision of noise barriers/enclosures, rather than by means of the separation between road and receiver, which may not be achievable.

Based on site surveys, existing noise sensitive receivers (NSRs) have been identified along the alignment of the two flyovers namely Ashram flyover and Moolchand flyover and they are shown in Figure 7 and 8.



NSR Id.	Name of Building	No of stories
A1	Permanand Estate	10
A2	CSIR Scientist Apartments	6
A3	NAFED	7

Figure 7. Representative NSR along Ashram flyover



NSR Id.	Name of Building	No of stories
M1	Shopping Complex	6
M2	Moolchand Hospital	5
M3	Residential Building	7

Figure 8. Representative NSR along Moolchand flyover

The height of the noise barrier has been calculated from the noise model. The vertical heights of the barrier for two flyovers are, at Ashram location, the height of barrier on flyover is 3.63m on Sarikale Khan to Lajpat Nagar and 3.65m on other side. At Moolchand location, the height of barrier on flyover is 3.41m on Madangir to ITO side and 3.22m on other side of flyover.

Alternative configurations were examined and mitigation options that can achieve noise protection were identified. The typical configuration of the cantilever shaped barriers on both side of the carriageway is shown in Figure 9 and 10.

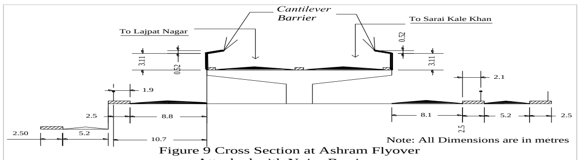


Figure 9 Cross Section at Ashram Flyover Attached with Noise Barrier

Barrier Details:
Material: Plexiglass
Thickness: 6 mm
Height:
On Lajpat Nagar
vertical barrier 3.63 m
cantilever barrier:
vertical height=3.11 m
Cantilever height=0.52
inclination with horizontal=15°

On Madangir
Vertical Barrier 3.65m
No need for catilever or vertical barrier because, NSR is in bright zone
Optional
cantilever barrier:
vertical height=3.63 m
Cantilever height=0.52m
inclination with horizontal=15°

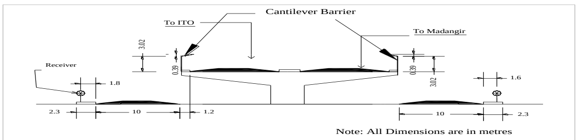


Figure 10 Cross Section of Moolchand Flyover Attached with Noise Barrier

Barrier Details
Material: Plexiglass
Thickness: 6 mm
Height:
On I.T.O.
vertical barrier 3.41 m
cantilever barrier:
vertical height=3.02 m
Cantilever height=0.39
inclination with horizontal=15°

On Madangir
Vertical Barrier 3.22m
No need for catilever barrier bcz, NSR is in shadow zone
Optional
cantilever barrier:
vertical height=3.02 m
Cantilever height=0.39
inclination with horizontal=15°

6 CONCLUSIONS

Many people in Delhi are being exposed at home to high noise levels traffic noise above the Central Pollution Control Board (CPCB) in India. This is due to the factors including scarcity of habitable land, immense demand for housing, commuter and freight transport. The government has also taken various steps including implementation of abatement programs to tackle traffic noise. To ensure individual vehicles do not produce excessive noise, all vehicles including lorries and buses are required to comply with stringent noise emission standards. While the measures planned to implement could not rectify all the noise problems caused by the large fleet of vehicles on roads. One possible way to do so is to retrofit barriers on noisy roads to abate the noise. A set of simplified assessment procedures is recommended for the use as a working tool to enable for an assessor to perform a desktop study without going through lengthy calculations to determine the feasibility of mitigation measure. Field studies were carried out to quantify the noise generated by road traffic. At Ashram location, the noise level on flyover is 81.12 dB(A) which is higher than the noise level 80.93 dB(A) due to adjacent road. At Moolchand location, the noise level 80.71 dB(A) which is higher than the noise level 79.18dB(A) due to adjacent road. The suggested mitigation measures at the studied flyovers are summarized as follows:

- Cantilever barrier of vertical height 3.11 m with 0.52 m canopy at 15^0 with horizontal are to be erected on both sides of the carriageway on Ashram flyover.
- Cantilever barrier of vertical height 3.02 m with 0.39 m canopy at 15^0 with horizontal are to be erected on both sides of the carriageway on Moolchand flyover.

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