Mustansiriyah University
College of Engineering
Highway and Transportation Eng. Dept.

Transportation Engineering
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Lecture No (10)




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Mathematical models to calculate the Level of Transportation Noise

The Overall Equation

$$L_{eq}(h)_i = \underbrace{(L_o)_{Ei}}_{\text{reference energy mean emission level}} + \underbrace{10\log_{10}\left(\frac{N_i \pi D_0}{S_i T}\right)}_{\text{traffic-flow adjustment}} + \underbrace{10\log_{10}\left[\frac{D_0}{D}\right]^{1+\alpha}}_{\text{distance adjustment}} + \underbrace{10\log\left(\frac{\psi\alpha(\phi_1,\phi_2)}{\pi}\right)}_{\text{Finite roadway adjustment}} + \underbrace{\Delta_s}_{\text{shielding adjustment}}$$

Where:

$L_{eq}(h)_i$ = hourly equivalent sound level for the i^{th} vehicle class

$(L_0)_{E,i}$ = reference energy mean emission level for vehicle class *i*,

N_i = number of class *i* vehicles passing a specified point during time T (1hr)

S_i = average speed for the i^{th} vehicle class, km. per hr

T = time period over which L_{eq} is sought, in hours (typically 1 hr.)

D = perpendicular distance traffic lane centerline to receptor

D_0 is the reference distance at which the emission levels are measured. In the FHWA model, D_0 is 15 meters

α = site condition parameter reflecting hardness or softness of terrain surface

Ψ = an adjustment for finite length roadways

Δ_s = shielding attenuation parameter due to noise barriers, rows of houses, densely wooded area, etc., in dBA

10.1. Type and size of vehicles

Reference energy mean noise emission level (REMEL)=$(L_0)_{Ei}$

10.2. Traffic flow characteristics

Typically, transportation noise emanates from a continuous stream of vehicles and not a single vehicle. Therefore, the noise effect of this situation is as follows:

$$10\log_{10}[(N_i \pi D_0)/(S_i T)]$$

N_i = number of class ***i*** vehicles passing a specified point during time *T* (1hr)

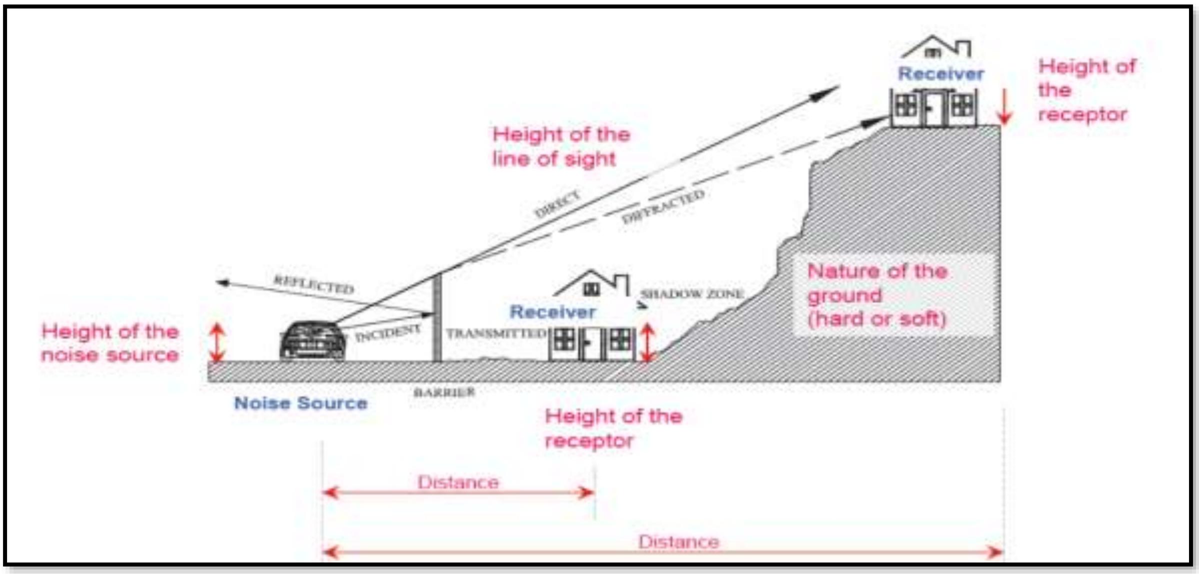
S_i = average speed for the ***i^{th}*** vehicle class, km. per hr.

T = time period over which ***L_{eq}*** is sought, in hours (typically 1 hr.)

D = perpendicular distance traffic lane centerline to receptor

D_0= is the reference distance at which the emission levels are measured. In the FHWA model, ***D_0*** is 15 meters

Distance between Noise Source and Receiver and Other Factors



10.3. The distance adjustment factor

<u>The distance adjustment factor is:</u>

$$10\log_{10}(D_0 / D)^{1+\alpha}$$

- **<u>α = 0</u>**

-If the <u>noise source or receptor</u> is <u>located >3m</u> above the ground irrespective of ground hardness, or

-If <u>the line-of-sight</u> (a direct line between the noise source and the receptor) <u>averages > 3 m above the ground</u>, or

-If the top of the <u>noise barrier</u> (if any) is >3 m in height irrespective of source or receptor height or ground hardness

-If the height of the line-of-sight is < 3 m but there is a clear (unobstructed) view of the highway, the ground is hard, and there are no intervening structures.

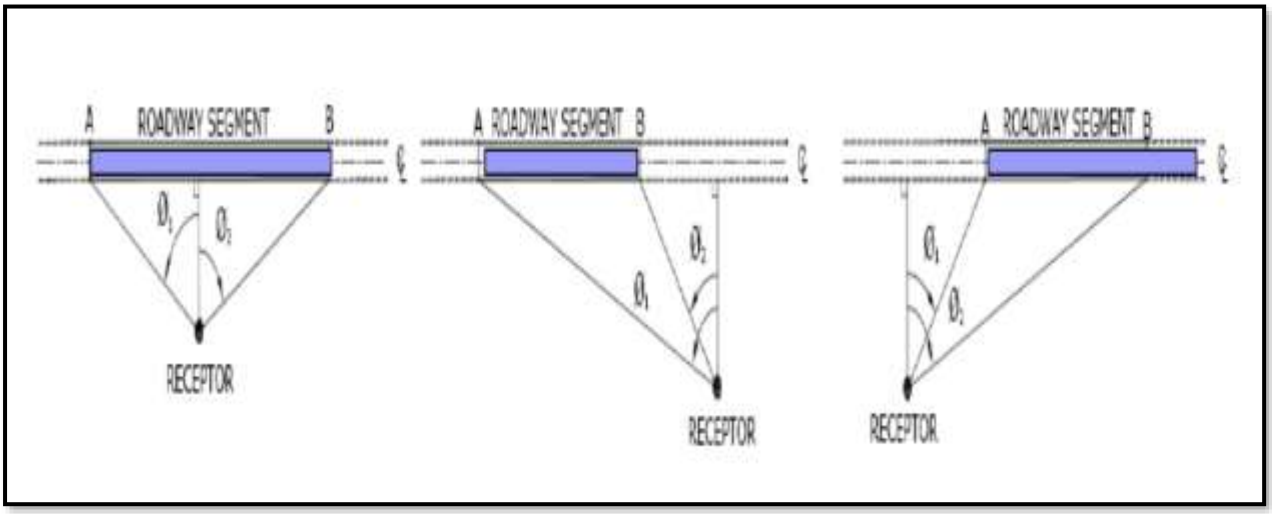
- **$\alpha = 0.5$**

-If the view of the roadway is interrupted by isolated buildings, clumps of bushes, scattered trees, or

-If the intervening ground is soft or covered with vegetation.

10.4. Effect of finite length roadways

- Noise level also influenced by "how much section of the roadway is visible to the receptor"
- Useful to separate a roadway into sections to account for changes in topography, traffic flows, shielding, etc.



(Ground shielding effect)

- The nature of ground affects noise propagation
- Adjustment factor is

$$10\log_{10}[\psi\alpha(\phi_1,\phi_2)/\pi]$$

Where:

$\psi\alpha(\phi_1,\phi_2)$ is a factor related to the finite length of roadway, ϕ_1,ϕ_2 are the angles defined in previous slide, and **α** = the ground hardness parameter.

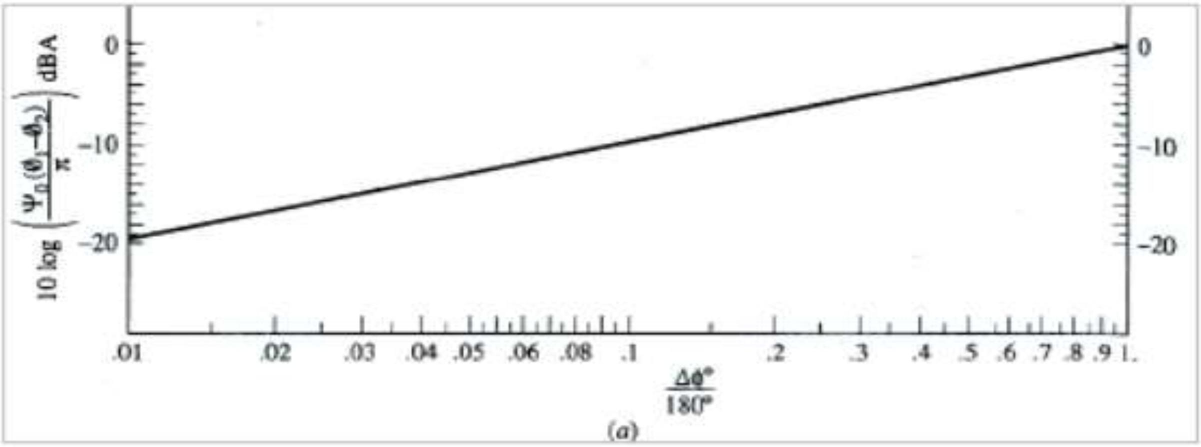
- For a terrain with hard (perfectly reflective) ground, **α= 0**, and the adjustment factor becomes:

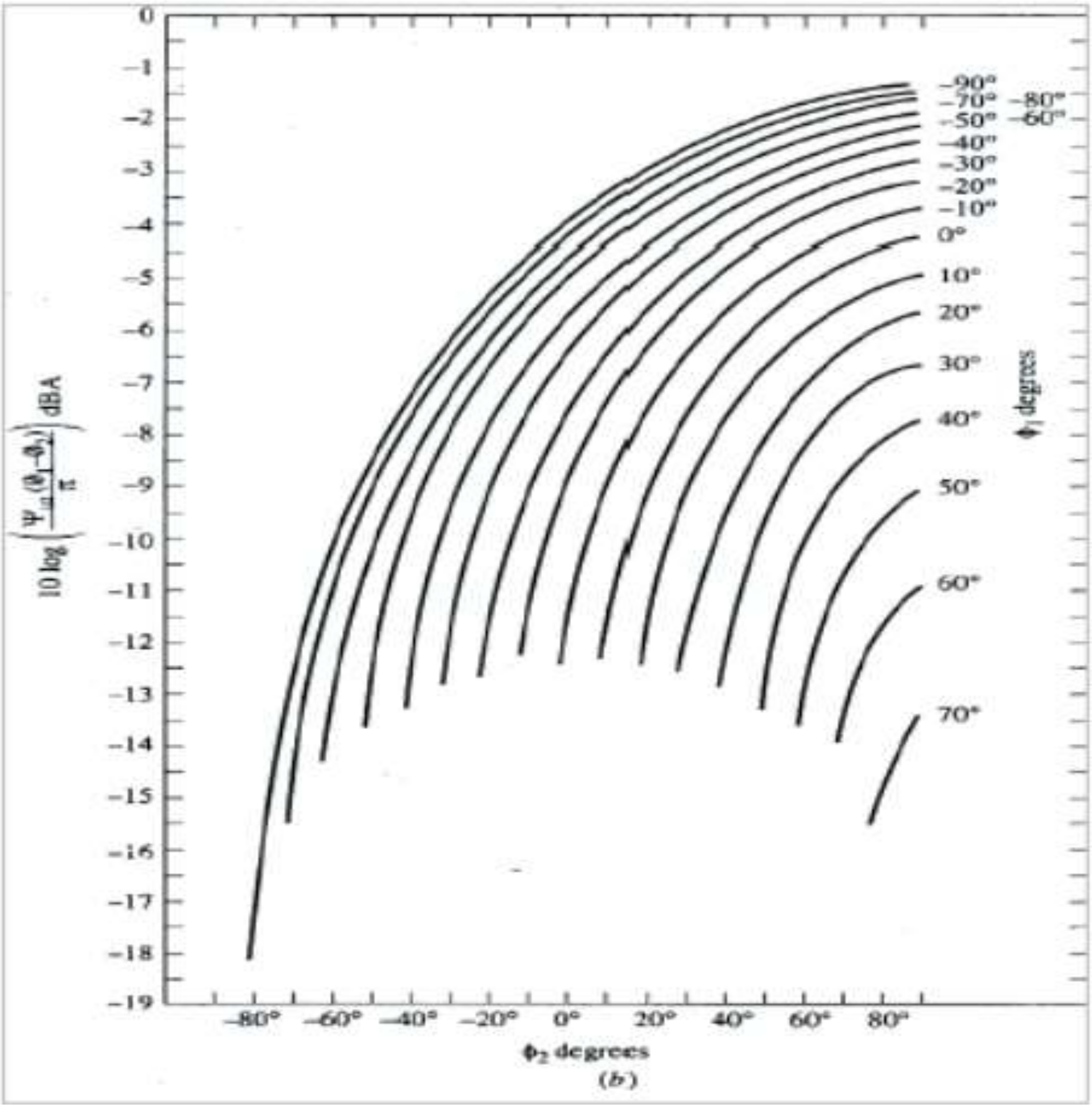
$$10\log_{10}[\Delta\phi/\pi]$$

- For terrains with soft (absorptive) ground, the adjustment term reduces to a complex function that yields a family of curves that are used to obtain the values of the adjustment factor.

Adjustment Factors for Finite Length Roadways and Ground Effects

(Barry and Reagan, 1978) للاطلاع





10.5. ***Effect of Any Existing Noise Shield***

- Noise level reaching receiver can be affected by physical object located between the noise source road and the receiver
- Such "barriers" interfere with sound wave propagation, create "acoustic shadow zone" and reduce noise level reaching receptor.

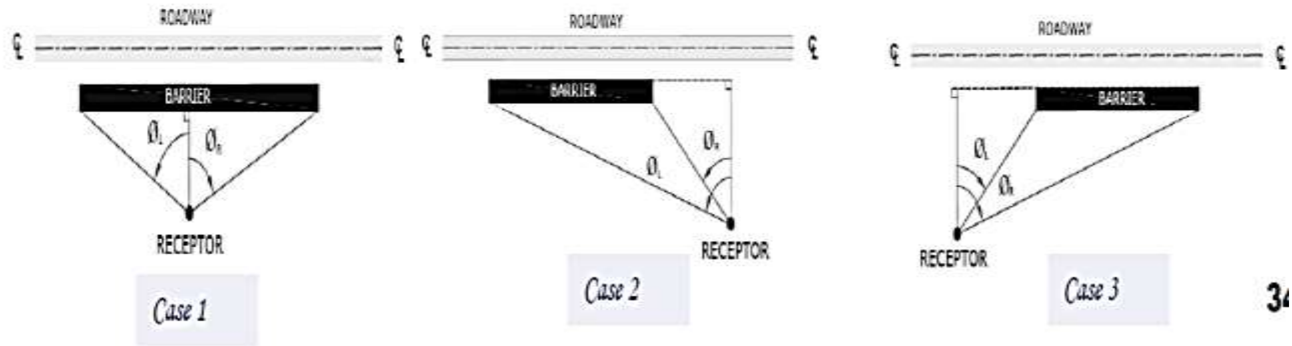
- May be natural or man-made, intentional (earth berms, noise barriers, walls, etc.) or unintentional (large buildings, rows of houses, dense woods, hills, etc.).

- Δ_{B_i} the change in noise levels (attenuation) provided by the barrier for the ith class of vehicles is given by:

$$\Delta_{B_i} = 10\log\left[\frac{1}{\phi_R - \phi_L}\int_{\phi_L}^{\phi_R} 10^{\frac{-\Delta_i}{10}} d\phi\right]$$

Where:

Φ_R and Φ_L are angles that establish the relationship (position) between the barrier and the receptor



Δ_i is the point source attenuation for the i^{th} class of vehicles and is given by:

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$$\Delta_i = \begin{cases} 0 & N_i \le -0.1916 - 0.0635\,\varepsilon \\ 5(1+0.6\varepsilon) + 20\log \dfrac{\sqrt{2\pi |N_o|_i \cos\phi}}{\tan\sqrt{2\pi |N_o|_i \cos\phi}} & (-0.1916 - 0.0635\,\varepsilon) \le N_i \le 0 \\ 5(1+0.6\varepsilon) + 20\log \dfrac{\sqrt{2\pi (N_o)_i \cos\phi}}{\tanh\sqrt{2\pi (N_o)_i \cos\phi}} & 0 \le N_i \le 5.03 \\ 20(1+0.15\,\varepsilon) & N_i \ge 5.03 \end{cases}$$

$N_i = (N_0)_i \cos \varphi$;

ε (a barrier shape parameter) = 0 for a freestanding wall,
= 1 for an earth berm.

N_0 is the Fresnel nr. determined along the perpendicular line between the source and receptor.

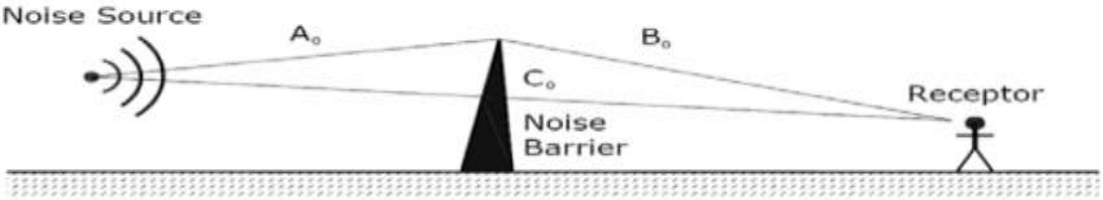
$(N_0)_i$ is the Fresnel nr. of the i^{th} class of vehicles determined along the perpendicular line between the source and receptor.

Mathematically, the Fresnel number is defined as follows:

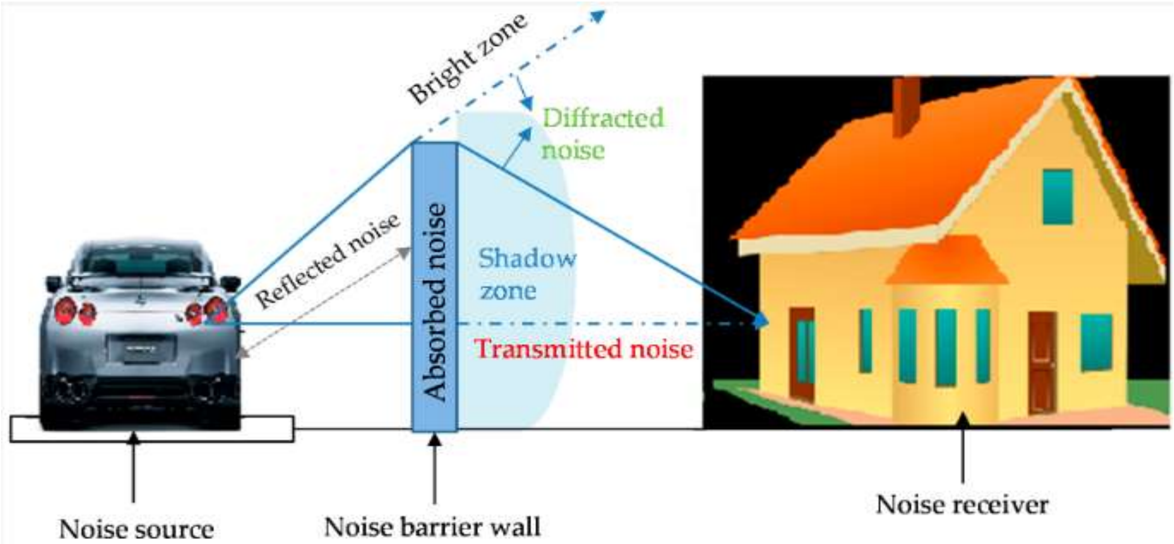
$$N_o = 2\left(\frac{\delta_o}{\lambda}\right)$$

Where δ_0 is the path length difference measured along the perpendicular line between the source and receptor,

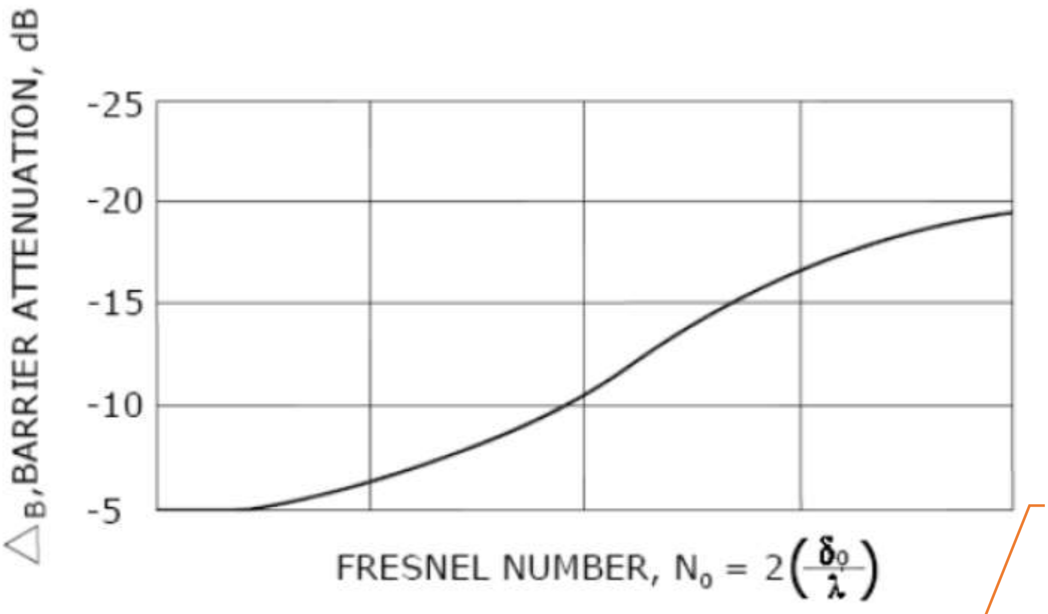
λ is the wavelength of the sound radiated by the source.



$$\text{Path Length Difference, } \delta_0 = A_0 + B_0 - C_0$$



Sketch showing noise distribution due to barrier wall



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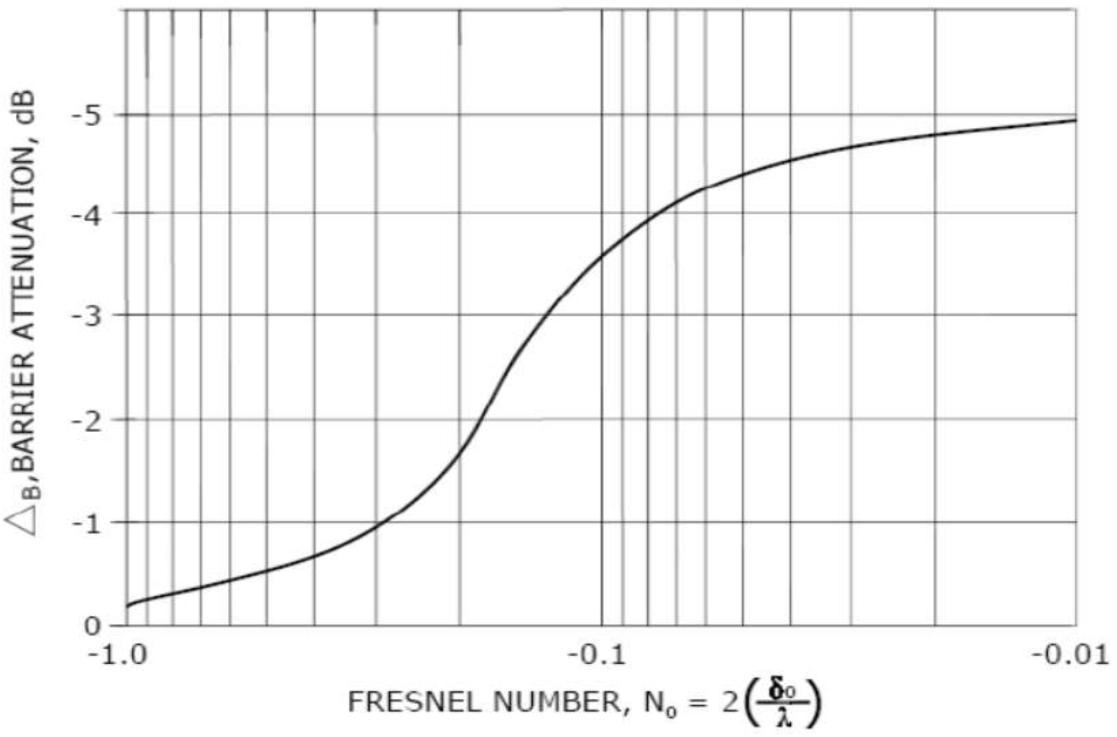


Barrier Attenuation vs. Fresnel Number for Noise Barriers of Infinite Length

Using graphs to calculate the Level of Transportation Noise

10.6. Noise Level Parameters

a- The sound levels

If the amplitude of pressure fluctuations is **P** the sound level in decibel(dB) is given by:

$$L = 10 \log [P/Po]$$

Where $Po = 2*10^{-5}$, N/m_2 (amplitude of audible pressure wave)

The overall sound pressure is denoted by dB(A)

b- Percentile exceeded sound Level (Lx)

The noise level exceeded for **x** percent of the time is denoted by L_x.

The most common noise exceeded level used is L_{10} = noise level exceeding for 10 percent of time. It is an indication of the peak level of the intruding noise,

whereas L_{90} level is an indicator of the background noise level.

c- Traffic Noise Index (TNI)

This index attempts to make an allowance for noise variability with respect to L_{10} level.

$$TNI = 4(L_{10}-L_{90}) + L_{90} - 30 \text{ dB(A)}$$

Traffic levels are monitored over a 24-hour period and TNI is derived by combining the NOISE LEVELs exceeded in dBA 10 % and 90 % of the time. This takes into account the very noisy vehicles weighted against the general traffic noise

d- *Equivalent (A Weighted) Sound level (Leq)*

It is combined index of common measure of environmental noise. This is the steady noise which in the measurement period would carry the same energy as the time.

$$L_{eq} = L_{50} + (L_{10} - L_{90})/4.25$$

e- *Noise Pollution level (LNP)*

It is found that ***Leq*** on an energy basis is not sufficient to describe the degree of annoyance caused by fluctuating noise. A new parameter noise pollution level.

$$LNP = Leq + (L_{10} - L_{90})$$

10.7. Noise Level Survey

Noise level survey was undertaken along roads by using sound level meter at the edge of road for every interval of ***15 Sec***. Data collection period is ***30 sec***. at each station of data collection during peak hour of traffic further volume survey was also carried out all the site.

10.8. Data Analysis

After collection of field data for road, the analysis step is beginning. First the data should be collected in statistical interval and then find the percentage and accumulation percentage of frequency for each interval. The value of L_{10}, L_{50} and L_{90} for each set of observation are obtained by plotting the graph with sound level in dB(A) on X axis as and cumulative percentage of time of the observation period for which that sound level is exceed on Y-axis.

Example:

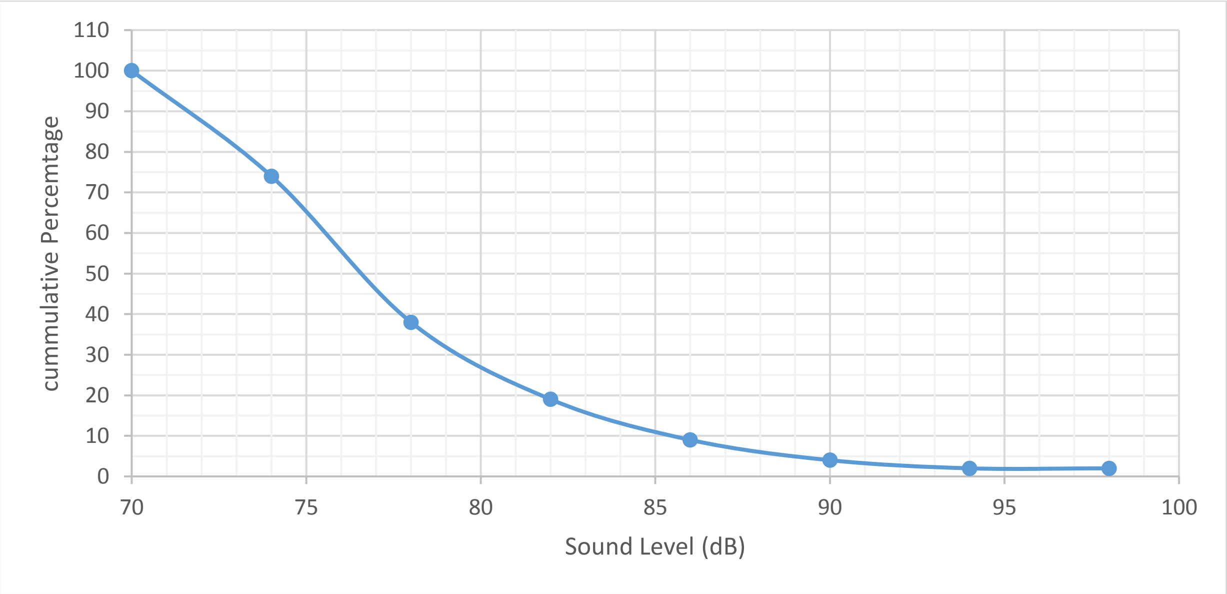
In one city noise, level survey was undertaken for road, 120 reading in 30 minutes were collected at peak hour of traffic. Reading as observed is shown in Table 1. *Find Noise Pollution level (LNP), Equivalent Sound level and Traffic Noise Index.*

Table 1
Sound Level in dB(A)

75.3	81.3	75	69.8	69.8
70.6	77	73.8	72.9	71.3
81.3	72.7	72.6	96.7	78.5
69.8	74.2	71.2	77.8	70.3
72.5	71.9	80.9	72.7	27.8
76.3	78.8	75.7	77.6	85.3
85.6	72.2	75.4	73.8	82.6
71	74.8	72.1	91.6	79.8
74.4	78.4	71	70.9	78.3
98.3	71.3	81	68.9	71.2
73.9	73	73.9	69.8	68.6
71.4	79.5	80.1	75.6	72.9
90.2	76.3	76.4	70.6	73.1
69.3	84.7	71	73.3	78.3
71.2	73.7	74.3	78.4	75.3
73.4	72.6	80.5	71.3	75.3
75.2	81.2	78.9	82.3	74.8
78.4	75.3	80.6	75.6	79.3
69.4	72	68.2	84.2	72.3
72.3	70.9	87.6	72.5	75.8
69.3	86.3	76	73.8	71.1
76.2	83.2	71.6	78.5	69
69.8	73.5	76.6	89.1	80.2
79.6	76.9	70.8	74.2	75

Solution:

Noise level interval (dB)	Middle of Interval	no. of Frequency	Percentage of frequency %	Approximate Percentage of frequency %	Cumulative percentage of frequency %
68-72	70	31	25.8	26	100
72-76	74	43	35.8	36	74
76-80	78	23	19.2	19	38
80-84	82	12	10.0	10	19
84-88	86	6	5.0	5	9
88-92	90	3	2.5	2	4
92-96	94	0	0.0	0	2
96-100	98	2	1.7	2	2



From above graph the value of **L_{10}=86, L_{50}=76.6, L_{90}=71.4**

TNI = 4(86-71.4) +71.4 – 30 = 99.8

Leq = 76.6+ (71.4-86)/4.25= 80.04

LNP = 80.04+ (86-71.4) = 94.64

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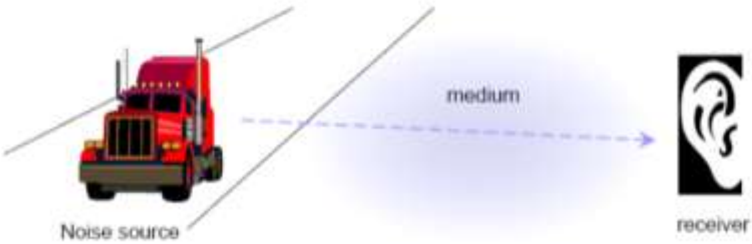
Permissible noise intensity (noise intensity standards)

Usage type	Day	Night
Residential areas	60	50
City Center	65	60
Industrial areas	75	65
Other uses	70	65

Traffic Noise Mitigation

- Categories of techniques for noise mitigation :
  - At the noise source
  - At the path (medium) of noise propagation, or/and
  - At the receptor.



Procedures to decreasing noise at urban area

Traffic noise intensity can be controlled through the following points:

- ***Noise Control (Vehicle):*** Noise reduction is achieved by making improvements to the main parts of noise such as the engine and cooling fan and selecting the appropriate size and quality of the exhaust silencer pipe that has a significant impact on reducing the vehicle's noise, as well as choosing the appropriate quality of tires that come into contact with the road surface and generate noise.

- ***Road Design and Furnishing:*** Noise levels are controlled and reduced by placing certain limiters along the road that reduce or eliminate noise from access to buildings overlooking the road. Trees, different filters and barriers on the road significantly reduce noise as well as the quality of the road section (its height, shoulders, and surroundings) affect the style and extent of sound transmission as higher roads from neighborhoods usually transmit sound more to the surrounding area, unlike low roads surrounded by high shoulders that isolate them from the surrounding and help absorb most of the noise.

- ***Land-Use Planning:*** as planning and regulation of land use and grading of roads from the main and secondary contribute to reduce the intensity of noise affecting buildings and residential areas Perhaps the solution of the comprehensive formula is one of the best ways to reduce noise and its negative effects on the urban population, as well as reduce noise, such solutions reduce the vibrations caused by traffic and cause damage to buildings overlooking the road. The planning proposals for highway Bypass come as an organizational solution that avoids the city's passage and contributes to maintaining calm in the city center and reduce noise and vibrations affecting the population and buildings with the presence of some traditional buildings, especially the old buildings in the centers of some cities that may be adversely affected by the passage of vehicles, especially heavy vehicles near them.

Traffic Noise Mitigation – Noise Barriers