IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

Architectural Acoustics

Lecture 36: Environmental Acoustics-I

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Learning Objective

Classify different types and sources of environmental noise

Discuss the effect of noise

Demonstrate some standard noise measurement index

Noise

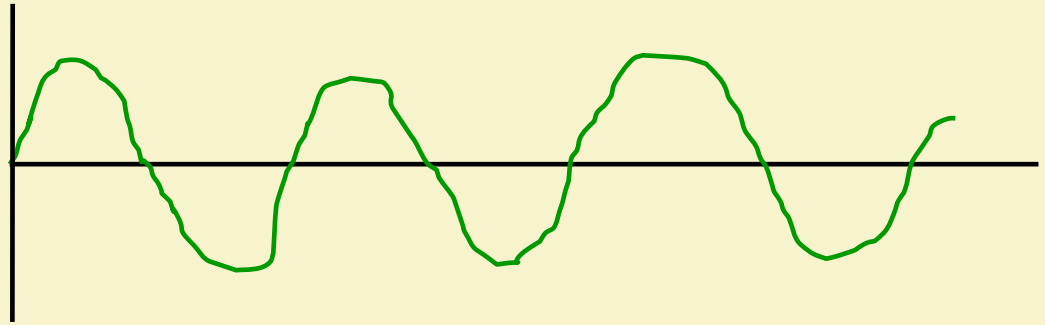
Noise is often refer as ‘unwanted sounds.’

There are three different types of noise:

- **Unwanted sound**
- **Unmusical sound**
- **Loud sound**

Noise perception is subjective. Many factors such as the **magnitude of sound, characteristics, duration, and time of occurrence** may affect one's subjective impression of the noise.

Noise is also considered a **mixture** of **different sound frequencies** at **high decibel levels**.



Music

Complex Tone
More Harmonic or Octave
Steady Character

Noise

Complex Tone
No Harmonic or Octave
Unsteady Character

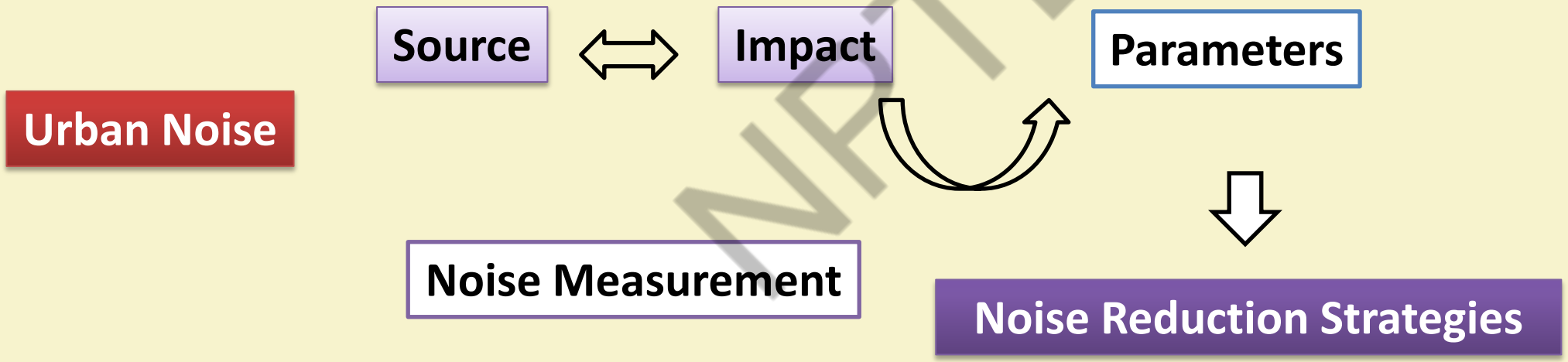
Noise Pollution

Noise pollution refers to sounds in the environment that are **caused by humans** and that **threaten the health** or welfare of human or animal inhabitants.

Noise pollution is generated mostly due to outdoor noise and is mainly caused by **Transportation Systems, Construction, Community and Industry**.

Noise pollution derives from **several sources**, and in order to better understand about urban noise, it is important to **know about its source**.

Its impacts should be carefully consider on humans and more **effectively investigate methods for reducing noise** and its negative consequences.



Types of Urban Noise

The different classification of noise sources are as follows:

Traffic Noise

Noise from surface transport, mainly road, rail and aircraft.

Industrial Noise

Noise from workshops, industrial plant

Construction Noise

Noise from construction equipment like, hammer, pile driver, concrete mixer

Community Noise

Street noise, noise from political/social gathering, children's noise, loud-speaker noise, barking of dog.

Road Traffic Noise

Road Traffic is one of the most widespread source of urban noise in all over the world.

Increase in population and the **traffic volume** proportionally increases the road traffic noise.

The major causes of road traffic noise in any automobile are due to:

Exhaust, Engine, Fan, Tires and Speed.

Road traffic noise depends upon several factors like

- **Road Condition**
- **Traffic clearance and congestion**
- **Condition of vehicle**
- **Speed of the vehicle**
- **Driving rules and monitoring system**
- **Common sense**

Rail Traffic Noise

Noise from railway trains are due to Diesel Exhaust, Engine, Cooling fans, Wheel-rail friction, Electric motor, Siren or horn, breaking system.

The overall noise generated from rail traffic is mostly depends upon:

- **Track-observer distance**
- **Train length**
- **Amount of loads in the train** (particularly for goods train or freight)
- **Condition of track**
- **Condition of coaches**

Air Traffic Noise

Noise from commercial aircraft is confined near the airports. Noise pollution due to an aircraft is depends on its **speed and distance from the observer.**

Taking off and landing of an aircraft produces unbearable noise.

The **supersonic jet planes** creates **extremely high level** of noise even from a large distance.

Sometimes it may break the windowpanes, crack the building wall due to sonic vibration.
Continuous aircraft noise creates bad effect on human health

Industrial Noise

Industrial noise is produced in every stage of an industrial activity like:

Hammering,
Running machines,
Motors,
Sheet metal work,
Operation of cranes,
Grinding,
Fabrication work,
Lathe work,
Steaming,
boiling work etc.

It creates very serious and large scale noise problems and significantly **affect the working people inside** the industry and outside people as well

Construction Noise

It is **originated** due to various **construction activities** in and around any city.

Each and **every stage** of the **construction activities** involves noise.

This noise sustains for a longer duration for the **surrounding areas** of new construction site.

People staying in the **upcoming and developing localities** are mostly affected by the construction noise

Construction Noise

It generally occurs due to various construction activities like:

- Earth moving work
- Demolition of existing structures
- Driving pile
- Concrete mixing and pumping
- Welding and riveting
- Hammering
- Cutting of tiles
- Polishing of floor

Community Noise

Community noise is one of the major source for affecting a large number of people (particularly, infant, kids, people with illness and elderly) living within a community.

It generally occurs due to various community activities like:

- **Use of loudspeakers during religious activities, marriages and public functions, political gatherings**
- **Noise from the commercial establishments (playing music, announcement)**
- **Noise from stadiums**
- **Noise from barking of street dogs**

Effects of Noise

Noise health effects are both health and behavioural in nature. This unwanted sound can damage physiological and psychological health. Noise pollution can cause various harmful effects and they may be categorised into following three ways:

Auditory

- Hearing Loss
- Threshold Shift

Physiological

- Stress
- Metabolic Change
- Hormonal Change

Behavioural

- Changes in normal Behavioural patterns (mostly on wildlife)

Parameters

Source geometry and type (point, line, coherent, incoherent)

Meteorological conditions (wind and temperature variations, atmospheric turbulence)

Atmospheric absorption of sound

Terrain type and contour (ground absorption of sound, reflections)

Obstructions (buildings, barriers, vegetation, etc)

Central Pollution Control Board, Delhi : Noise Measurements Norms

Case Specific Locations

- DG Sets up to 800 kW at about 1 m distances from all sides.
- DG Sets more than 800 kW at about 1 m distance of acoustic enclosure.
- Fire crackers 4 m from the bursting point, there shouldn't be reflecting surface around 15m radius.
- Vehicle 0.5m from the exhaust point.

Positioning of the Instrument

- Microphone must be placed 1.2 -1.5m above the ground level.
- In dry conditions with a wind speed of less than 5 m/s.
- Isolate the instrument from strong vibration and shock.

Total Noise Level

Combination of Noise Levels

Combination of noise from various (say, n numbers) sources can be computed by:

$$L_{Tot} = 10 \log \sum_{i=1}^{n} 10^{L_i/10}$$

The SIL of source 1,2,3 are L_1, L_2, L_3, dB respectively

L_{Tot} is the Total Noise level for such 'n' number of noise sources

$$L_{Tot} = 10 \log \left[10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots \right]$$

Average Noise Level

Average of noise from various (say, n numbers) sources can be computed by:

$$L_{Avg} = 10\log\frac{1}{n}\sum_{i=1}^{n}10^{L_i/10}$$

The SIL of source 1,2,3 are L_1, L_2, L_3, dB respectively

L_{avg} is the Average Noise level for such 'n' number of noise sources

$$L_{Avg} = 10\log\frac{\left[10^{L_1/10}+10^{L_2/10}+10^{L_3/10}+\ldots\right]}{n}$$

Combination of Noise Levels

Five sets of data is obtained from a noise source:

Sl. No	SPL	Li/10	10^(Li/10)
1	75	7.5	31622776.6
2	30	3	1000
3	50	5	100000
4	90	9	1000000000
5	65	6.5	3162277.66
		Total:	1034886054
		n= Number of Sample:	5

$$L_{Tot} = 10\log\left[10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots\right]$$

L_{Tot} = 10log(**1034886054**) = **90 dB**

$$L_{Avg} = 10\log\frac{\left[10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots\right]}{n}$$

L_{Avg} = 10log(**1034886054/5**) = **83 dB**

A-weighted Scale

Human **hearing** sensation is **not equally sensitive** to all the frequencies.

To account these variation in sound or noise measurement a **weighting network system** is adopted.

This weighting network system incorporates **adjustments for different Octave** band frequencies.

This is called **A-weighting measurement** of sound or noise, and generally follows for any type of **environmental acoustical measurements**.

A-weighted Scale

The following Table gives the dB correction to the respective Octave band frequencies

Octave	31.5	63	125	250	500
Correction (dB)	-39.4	-26.2	-16.1	-8.6	-3.2
Octave	1000	2000	4000	8000	16000
Correction (dB)	0	+1.2	+1	-1.1	-6.6

After the correction the Total Sound or Noise Level is calculated

A-weighted Scale

Frequency wise SPL of a specific noise data is given below:

Octave	31.5	63	125	250	500
SPL Measurement	60	55	35	85	75
Octave	1000	2000	4000	8000	16000
SPL Measurement	75	60	45	55	40

Calculate the A-weighted Scale noise level

A-weighted Scale

Octave	SPL Measurement	Correction (dB)	dB level after correction	Li/10	10^(Li/10)
31.5	60	39.4	20.6	2.06	114.8
63	55	26.2	28.8	2.88	758.6
125	35	16.1	18.9	1.89	77.6
250	85	8.6	76.4	7.64	43651583.2
500	75	3.2	71.8	7.18	15135612.5
1000	75	0	75	7.5	31622776.6
2000	60	1.2	61.2	6.12	1318256.7
4000	45	1	46	4.6	39810.7
8000	55	1.1	53.9	5.39	245470.9
16000	40	6.6	33.4	3.34	2187.8
				Total:	92016649.4

$$L_{Tot} = 10\log\left[10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots\right]$$

L_{Tot} = 10log(92016649.4) = **79.6 dBA**

Home Work

Differentiate between:

(i) Music and Noise,

(ii) Total Sound Intensity level and A-weighted Level

Estimate the (i) Total and (ii) Average sound level for the following threenoise data: 80dB, 50dB and 65dB

Bibliography

1. **Acoustics in the Built Environment**, Duncan Templeton, Architectural Press; 2nd Edition
2. **Protocol for Ambient Level Noise Monitoring,** Central Pollution Control Board, Delhi,2015
3. **Requirement and Procedure for Monitoring Ambient Noise Level due to Aircrafts,** Central Pollution Control Board, Delhi,20108
4. **National Building Code of India 2016 (Volume 2),** Bureau Of Indian Standards, New Delhi

End of Lecture 36: Environmental Acoustics-I

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Lecture 37: Environmental Acoustics-II

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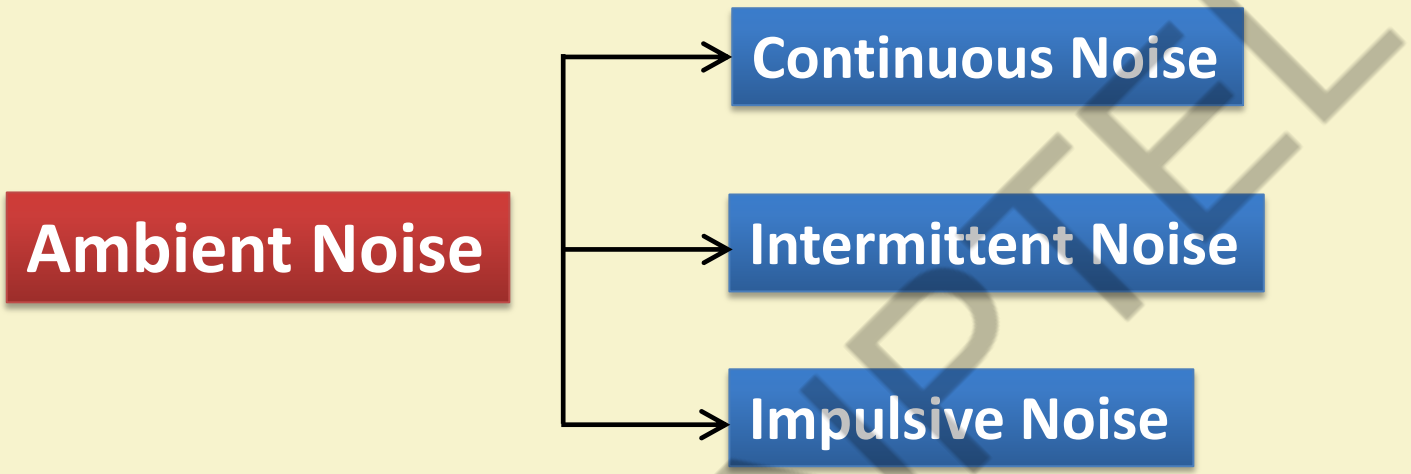
Learning Objective

Categorize the ambient noise

Demonstrate the noise exposure and its index

Ambient Noise

Ambient sound means the background sounds which are present in any specific location due to the various sound source like Traffic, Community, People, Industry etc.



Continuous Noise

Continuous noise operates **without interruption** in the almost same mode of frequency and sound level.

Measuring for few minutes with manual equipment is sufficient to determine the noise level

Example: Blower, Pump

Intermittent Noise

When a noise **operates for certain fixed time** in periodic order, the noise is called Intermittent Noise.

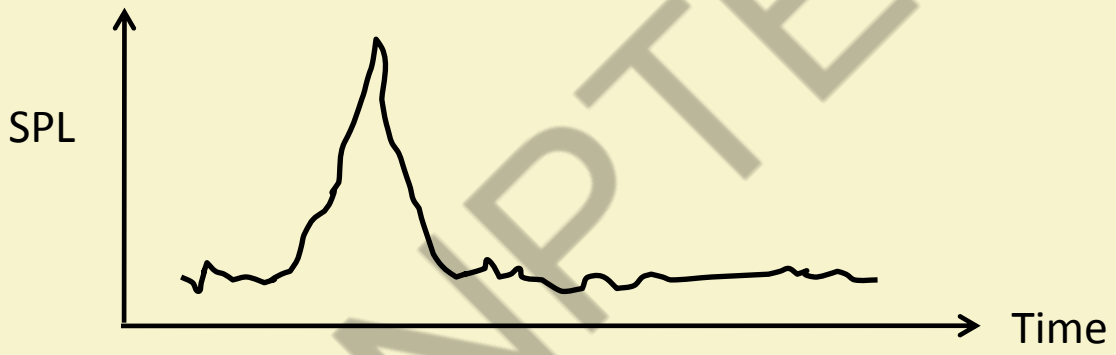
Intermittent noise should be measure for a longer duration in different time in a day and night to get the exact sound level and relative variation.

Example: Periodic running of machine, Specific traffic rush hours, Single passing of vehicle or train, Take off or landing of aircrafts

Impulsive Noise

Impulsive Noise **operates for few seconds** and mostly unexpected or not in any pre-fixed time.

Impulsive noise should be measure for the expected possible longer duration, may be in few. It is mostly recorded through a data-logger equipped digital recorder.

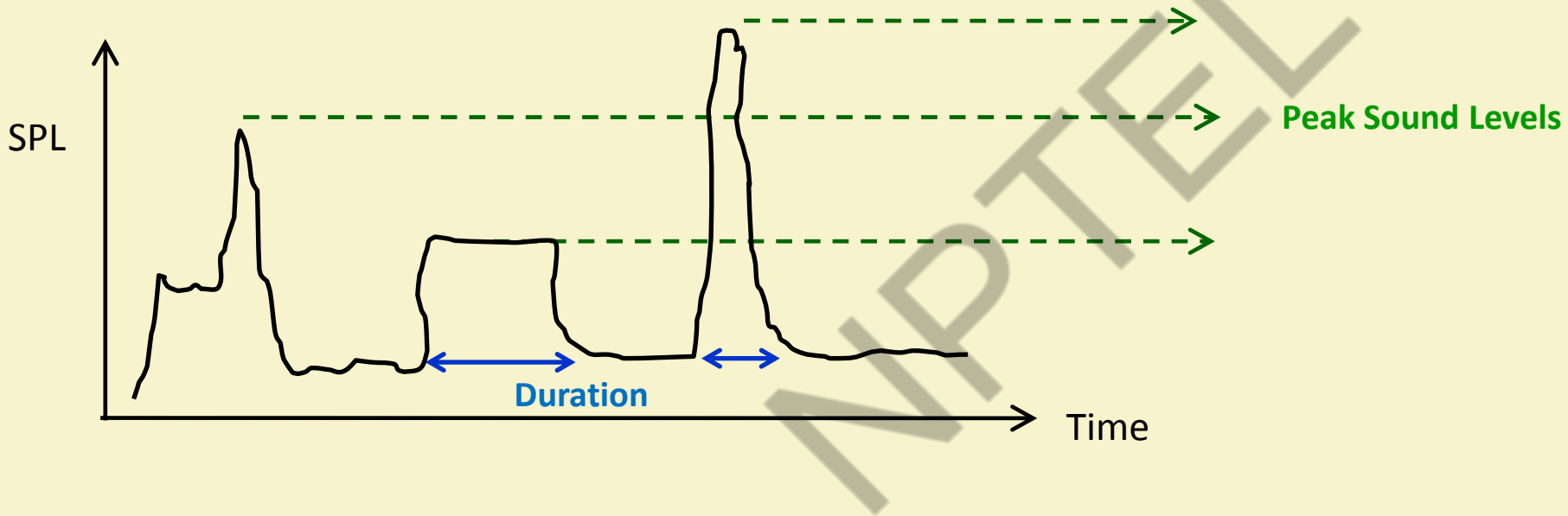


Example: Blasting in mines, punching machine operation, Gunshot

Noise Exposure

The ambient environmental noise is strongly time dependent.

It also consist of various sound levels and the respective duration.



Equivalent Continuous Sound Level (L_{eq})

The time dependent **variation of sound level** within a **specified time duration** is expressed in Equivalent Continuous Sound Level

It indicate the steady sound level for a specific time, that has the same energy of actual sound fluctuation

$$L_{Eq} = \frac{1}{T} \times 10 \log \left[t_1 \times 10^{L_1/10} + t_2 \times 10^{L_2/10} + t_3 \times 10^{L_3/10} + \ldots \right]$$

Where, **L_1, L_2, L_3 SPL** sound stay for **t_1, t_2, t_3 hours** respectively

$T = (t_1 + t_2 + t_3 + \ldots)$

Example:

The sample of noise for a Industrial was measured for 75 minutes

SIL (L)	t (min)
60	30
70	20
85	15
90	10

Find the (i) Average Sound Level (L_{avg})

(ii)Equivalent Continuous Sound Level (L_{eq})

Average Sound Level (L_{avg})

$$L_{Avg} = 10\log\frac{\left[10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + \ldots\right]}{n}$$

SIL (L)	L/10	10^(L/10)
60	6	1000000
70	7	10000000
85	8.5	316227766
90	9	1000000000
Total		1327227766

$$L_{Avg} = 10\log\frac{[1327227766]}{4} = 85.2$$

Average Sound Level (L_{avg}) = 85.2 dB

Equivalent Continuous Sound Level (L_{eq})

$$L_{Eq} = \frac{1}{T} \times 10 \log \left[t_1 \times 10^{L_1/10} + t_2 \times 10^{L_2/10} + t_3 \times 10^{L_3/10} + \ldots \right]$$

SIL (L)	t (min)	t (hr)	L/10	10^(L/10)	t X 10^(L/10)
60	30	0.500	6	1000000	500000
70	20	0.333	7	10000000	3333333.333
85	15	0.250	8.5	316227766	79056941.5
90	10	0.167	9	1000000000	166666666.7
T	75	1.250	Total		249556941.5

$$L_{Eq} = \frac{1}{1.25} \times 10 \log [249556941.5] = \frac{1}{1.25} \times 83.97 = 67.1$$

Equivalent Continuous Sound Level (L_{eq}) = **67.1 dB**

The L_n concept

If measurements are made over a period of time, the parameter L_n represents as to **how frequently** a particular sound level is **exceeded a particular noise level**.

So, if L_{30} = 75 dB A, then it represents that 75 dB was exceeded 30 % of the measuring time.

L_{10} is the level exceeded for 10% of the time.

L_{90} is the level exceeded for 90% of the time and

L_{50} is the level exceeded for 50 % of the time.

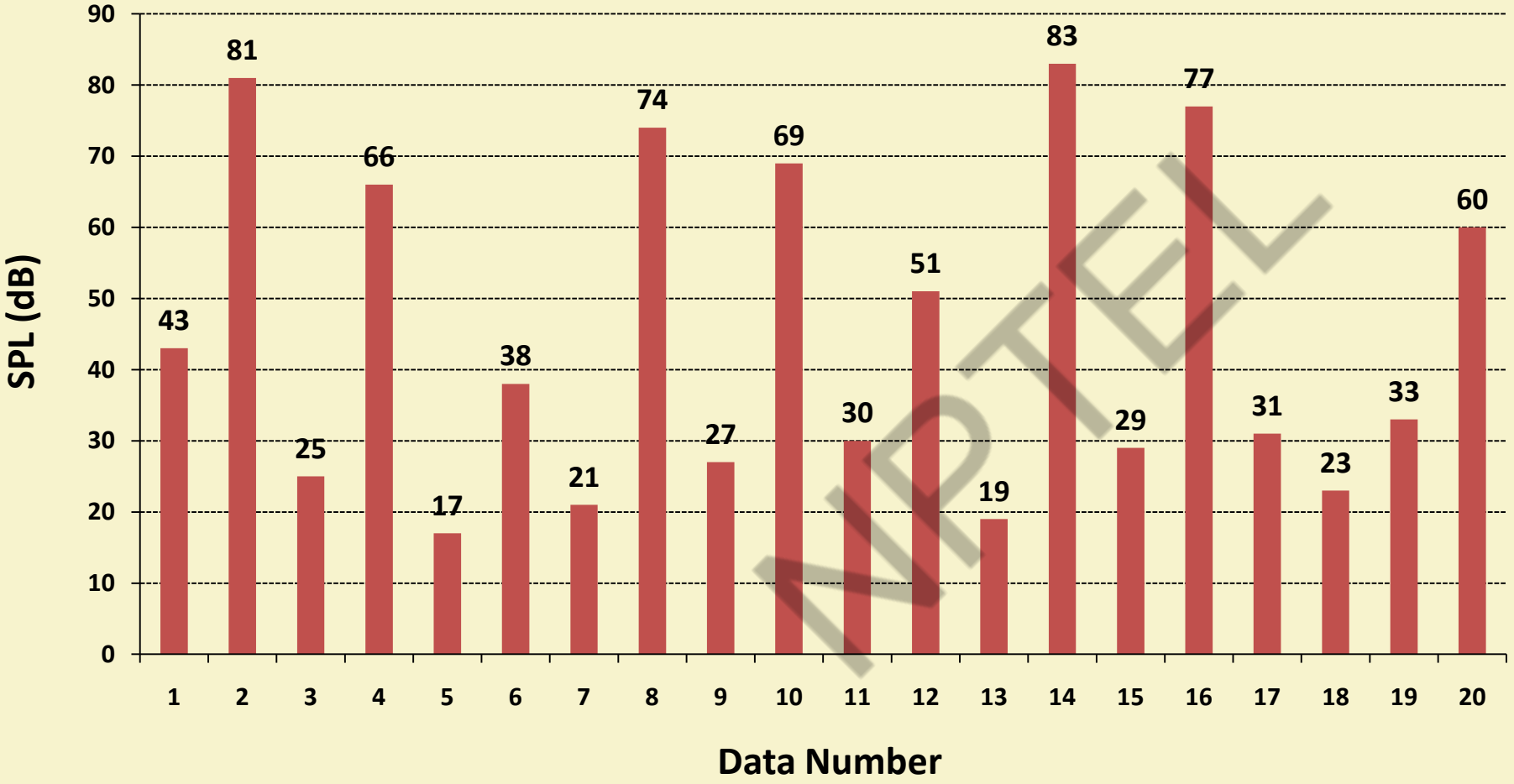
Example

Twenty noise sample data are obtained from a busy road junction.

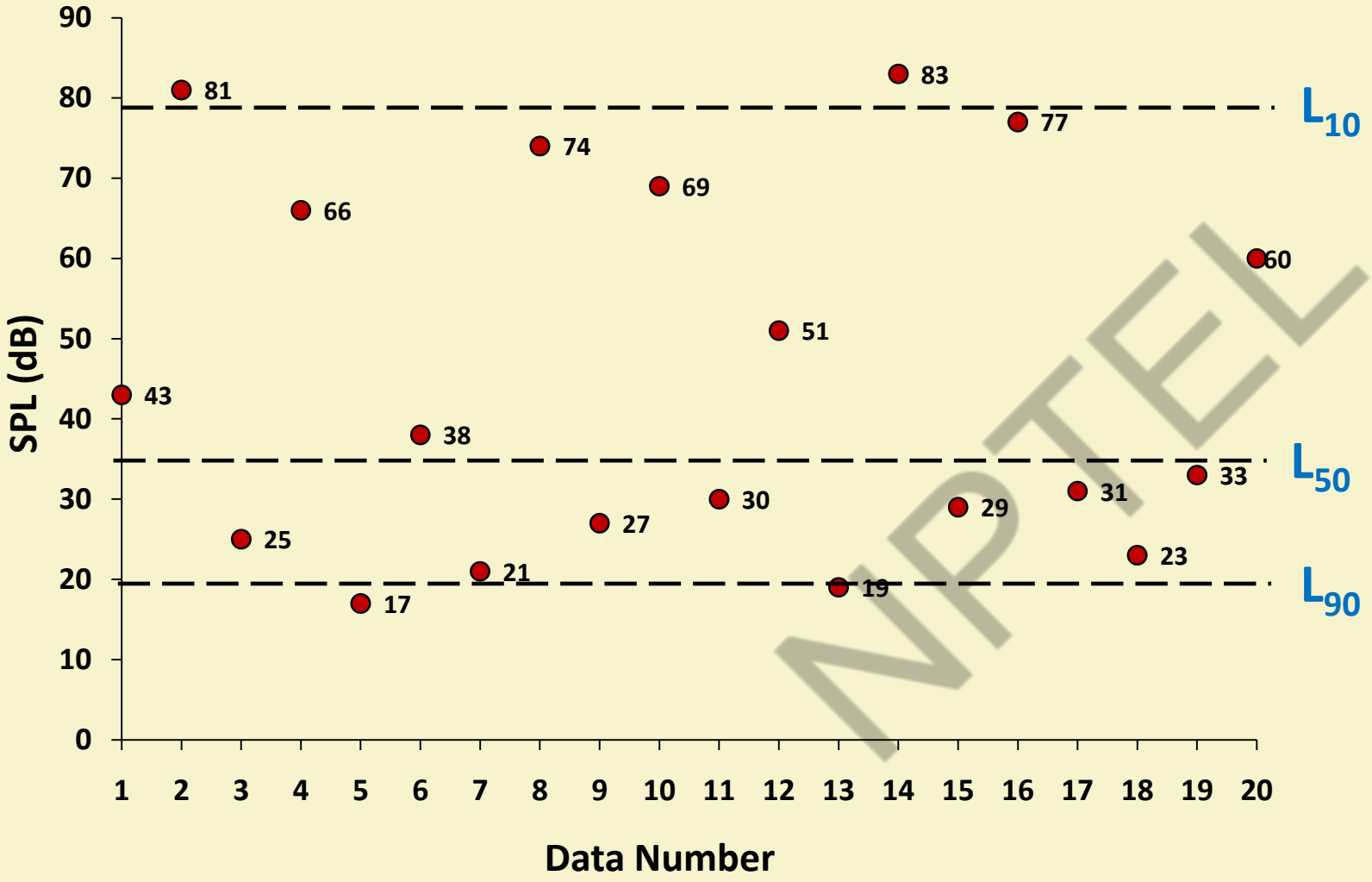
Data No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SPL	43	81	25	66	17	38	21	74	27	69	30	51	19	83	29	77	31	23	33	60

Rearrange the data set and find the (i) L_{10} (ii) L_{50} (iii) L_{90}

An average noise level data per minute, total 20 samples:



Noise Exposure

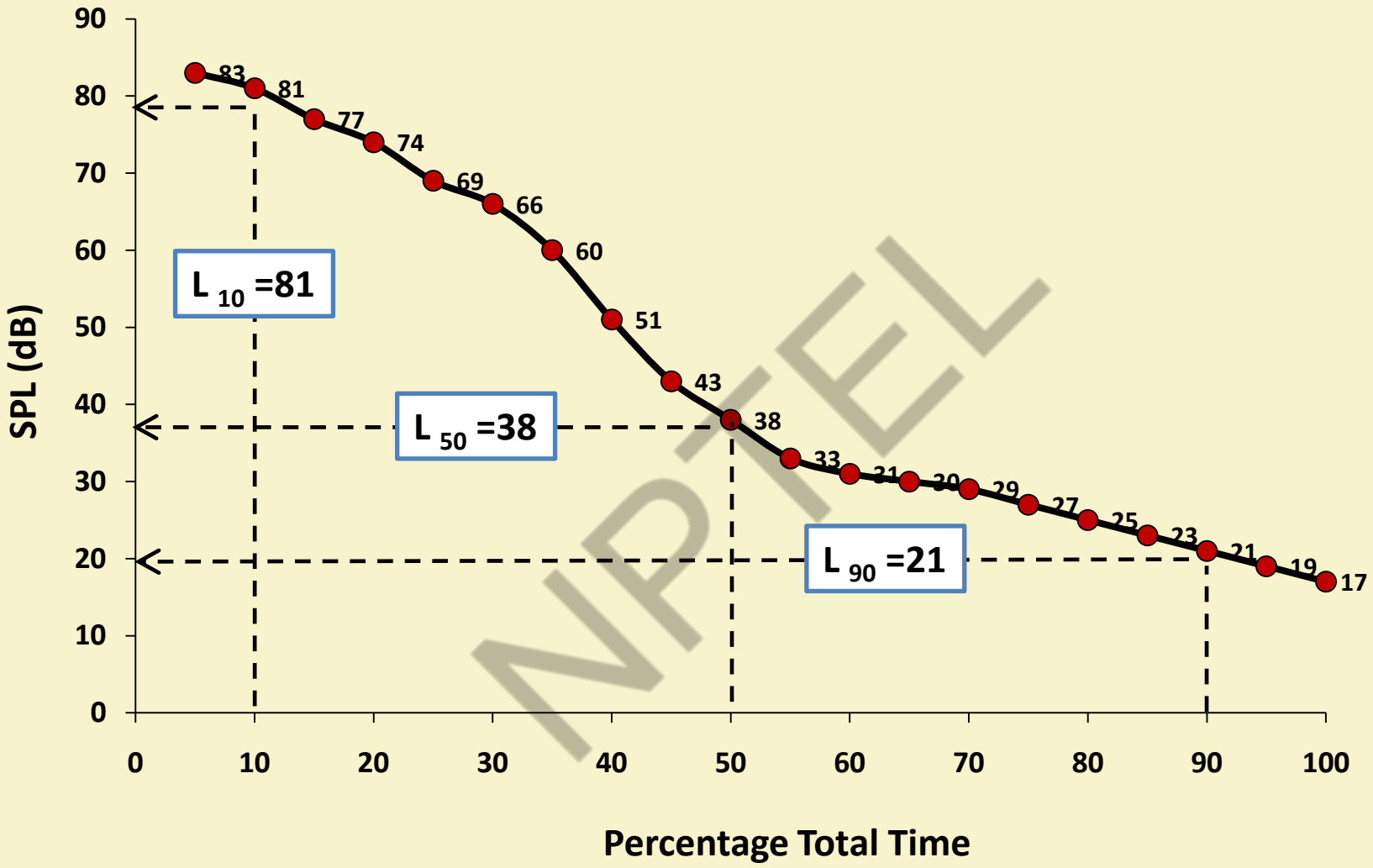


L_{10} : Sound levels exceeded for 10% of the total time

L_{50} :Sound levels exceeded for 50% of the total time

L_{90} :Sound levels exceeded for 90% of the total time

Noise Exposure



Traffic Noise Index

Traffic noise index is a parameter, which indicates the degree of variation (degree of annoyance) in a traffic flow. This is also expressed in dBA and can be computed using the relation:

$$TNI = 4 \times (L_{10} - L_{90}) + (L_{90} - 30)\ dBA$$

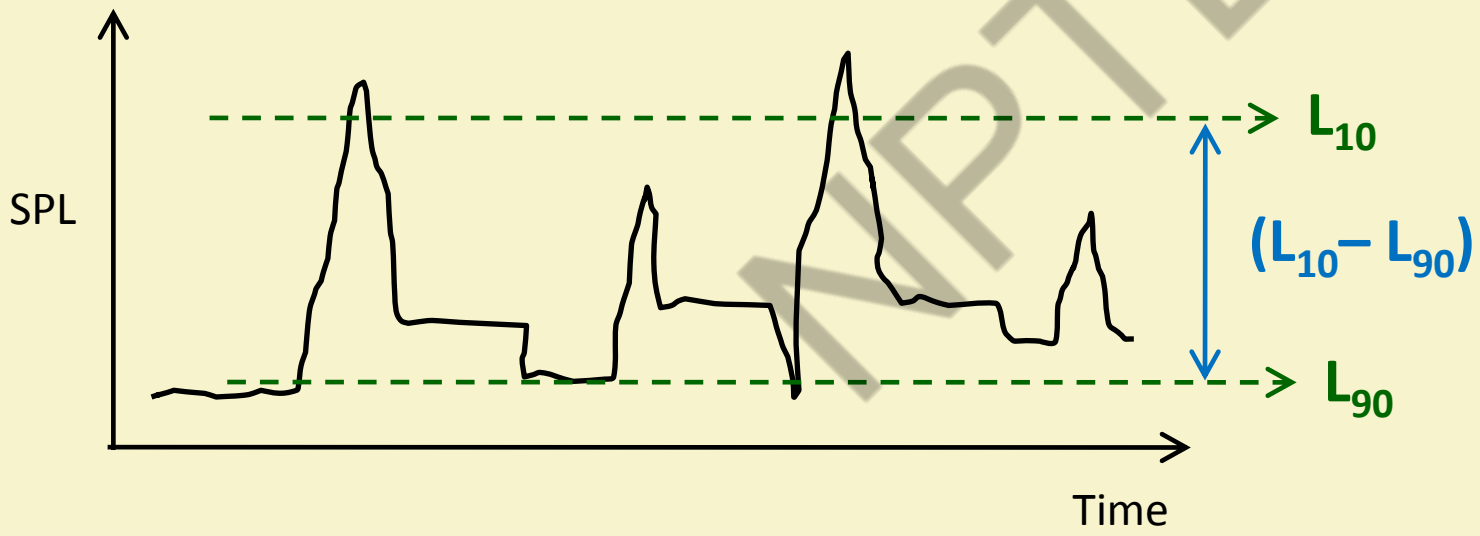
L_{90} represents the background noise level

Range between L_{10} and L_{90} fluctuating noise is commonly assumed to be more annoying

Noise Climate

Noise Climate is the range over which the sound levels are fluctuating in an interval of time and is given by the relation

Noise Climate = (L_{10}– L_{90})



Noise Dose

Noise Dose is the total sound exposure of certain place normalized to an 8-hour working day.

If anyone is exposed to a time weighted average noise level of 85 dBA during an 8-hour period, the normalised equivalent Noise Dose is kept as 100%.

The other noise exposure can be normalised to Noise Dose using the following relationship

$$\text{Noise Dose} = 100 \times \left(\frac{T}{8}\right) \times 10^{\left(\frac{L_{Eq}-85}{10}\right)}$$

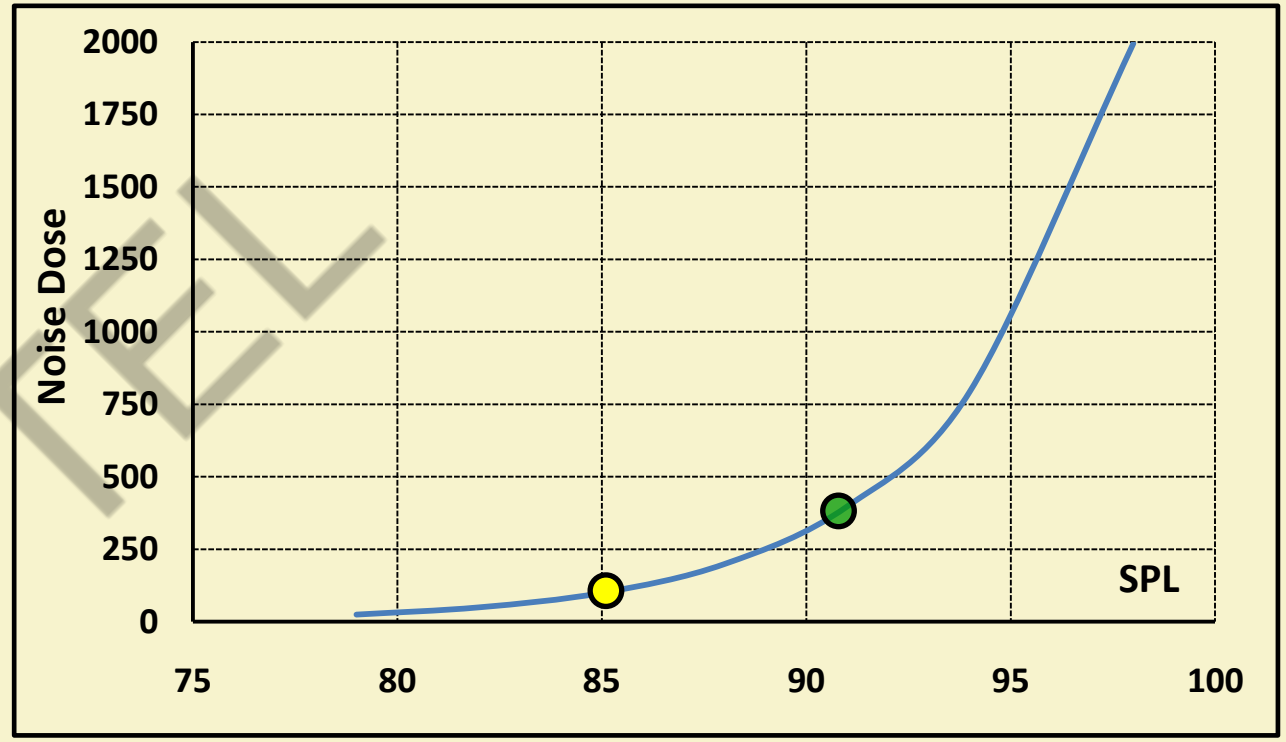
L_{Eq} is the Equivalent Noise level in dBA for 'T' hours duration.

Noise Index

For, L_{Eq} = 85 dBA and T = 8 hours

$$\text{Noise Dose} = 100 \times \left(\frac{8}{8}\right) \times 10^{\left(\frac{85-85}{10}\right)} = 100 \times 1 \times 10^{0} = 100$$

SPL	Time	Noise Dose
79	8	25
82	8	50
85	8	100
88	8	200
91	8	398
94	8	794
98	8	1995



For, L_{Eq} = 91 dBA and T = 8 hours

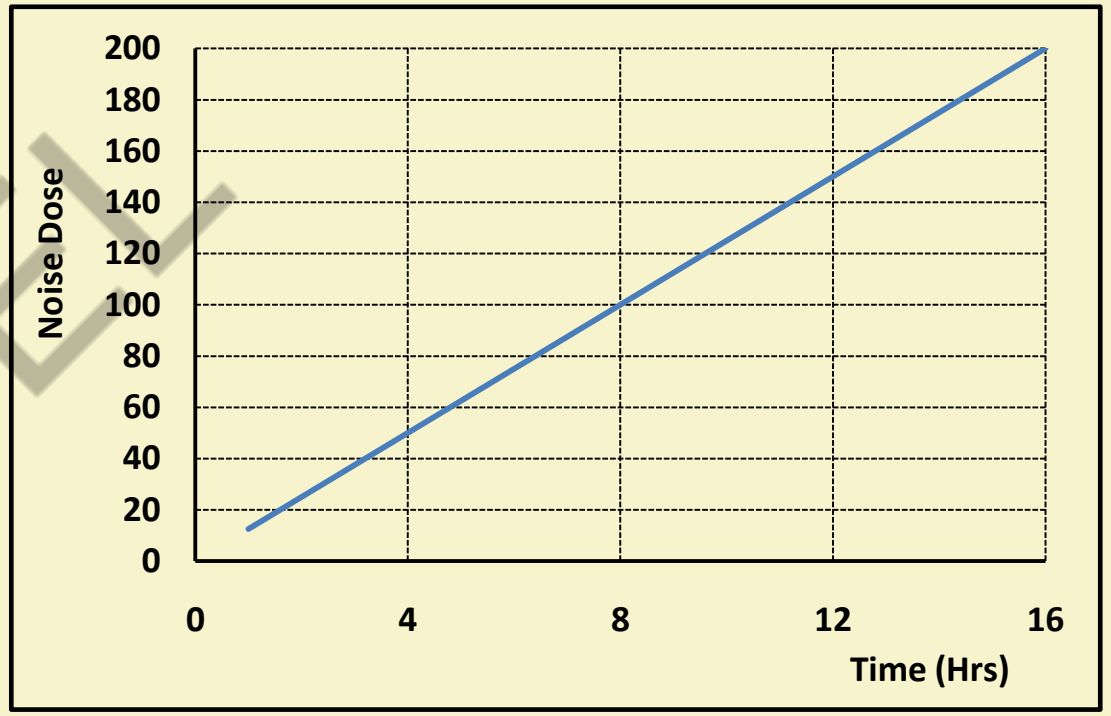
$$\text{Noise Dose} = 100 \times \left(\frac{8}{8}\right) \times 10^{\left(\frac{91-85}{10}\right)} = 100 \times 1 \times 10^{0.6} = 398$$

Noise Index

For, L_{Eq} = 85 dBA and T = 4 hours

$$\text{Noise Dose} = 100 \times \left(\frac{4}{8}\right) \times 10^{\left(\frac{85-85}{10}\right)} = 100 \times 0.5 \times 10^{0} = 50$$

SPL	Time	Noise Dose
85	16	200
85	14	175
85	12	150
85	8	100
85	4	50
85	2	25
85	1	13



For, 8 hours duration first 4 hours: L_{Eq} = 80 dBA and last 4 hours: L_{Eq} = 90 dBA
Find the Noise Dose

$$\text{Noise Dose} = 100 \times \left(\frac{T}{8}\right) \times 10^{\left(\frac{L_{Eq}-85}{10}\right)}$$

$$\text{Noise Dose} = \left[100 \times \left(\frac{4}{8}\right) \times 10^{\left(\frac{80-85}{10}\right)}\right] + \left[100 \times \left(\frac{4}{8}\right) \times 10^{\left(\frac{90-85}{10}\right)}\right]$$

$$\text{Noise Dose} = \left[100 \times 0.5 \times 10^{-0.5}\right] + \left[100 \times 0.5 \times 10^{+0.5}\right]$$

$$\text{Noise Dose} = \left[100 \times 0.5 \times 0.316\right] + \left[100 \times 0.5 \times 3.16\right]$$

$$\text{Noise Dose} = \left[15.8\right] + \left[158\right] = 174$$

Ambient Noise Level due to Aircrafts

Noise monitoring shall be carried out at all civil airports, which has more than **50,000 aircraft** (Civil) movements **per year** (a movement being a take-off or a landing).

Day-Night Average Sound Levels (DNL): Day-Night Average Sound Levels (DNL) is the Energy-Averaged Sound Level (L_{eq}) measured over a period of 24 hours, with a 10 dB penalty applied to night-time (10:00 PM and 6:00 AM) sound levels to account for increased annoyance during the night hours.

Noise Index

$$DNL_{Total} = 10\log\left(\frac{1}{T}\right)\left[10^{(L_{Eq,Day})/10} + 10^{(L_{Eq,Night}+10)/10}\right]$$

10 dB penalty applied to night-time

$L_{Eq, Day}$ = Equivalent A-weighted Sound Level, for one second, in day time (6 AM to 10 PM), in dB.

$L_{Eq, Night}$ = Equivalent A-weighted Sound Level, for one second, in night time (10 PM to 6 AM), in dB

T = Total period of time under consideration, in seconds

Home Work

Differentiate with examples the various form of ambient noise

Estimate the (i) Noise Climate and (ii) Traffic Noise Index (TNI) for the following road traffic noise data:

L_{10} = 80dBA, L_{50} = 60dBA, L_{90} = 40dBA,

Bibliography

1. **Acoustics in the Built Environment**, Duncan Templeton, Architectural Press; 2nd Edition
2. **Protocol for Ambient Level Noise Monitoring,** Central Pollution Control Board, Delhi,2015
3. **Requirement and Procedure for Monitoring Ambient Noise Level due to Aircrafts,** Central Pollution Control Board, Delhi,20108
4. **National Building Code of India 2016 (Volume 2),** Bureau Of Indian Standards, New Delhi

End of Lecture 37: Environmental Acoustics-II

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Architectural Acoustics

Lecture 38:Urban Noise Control: Planning Consideration - I

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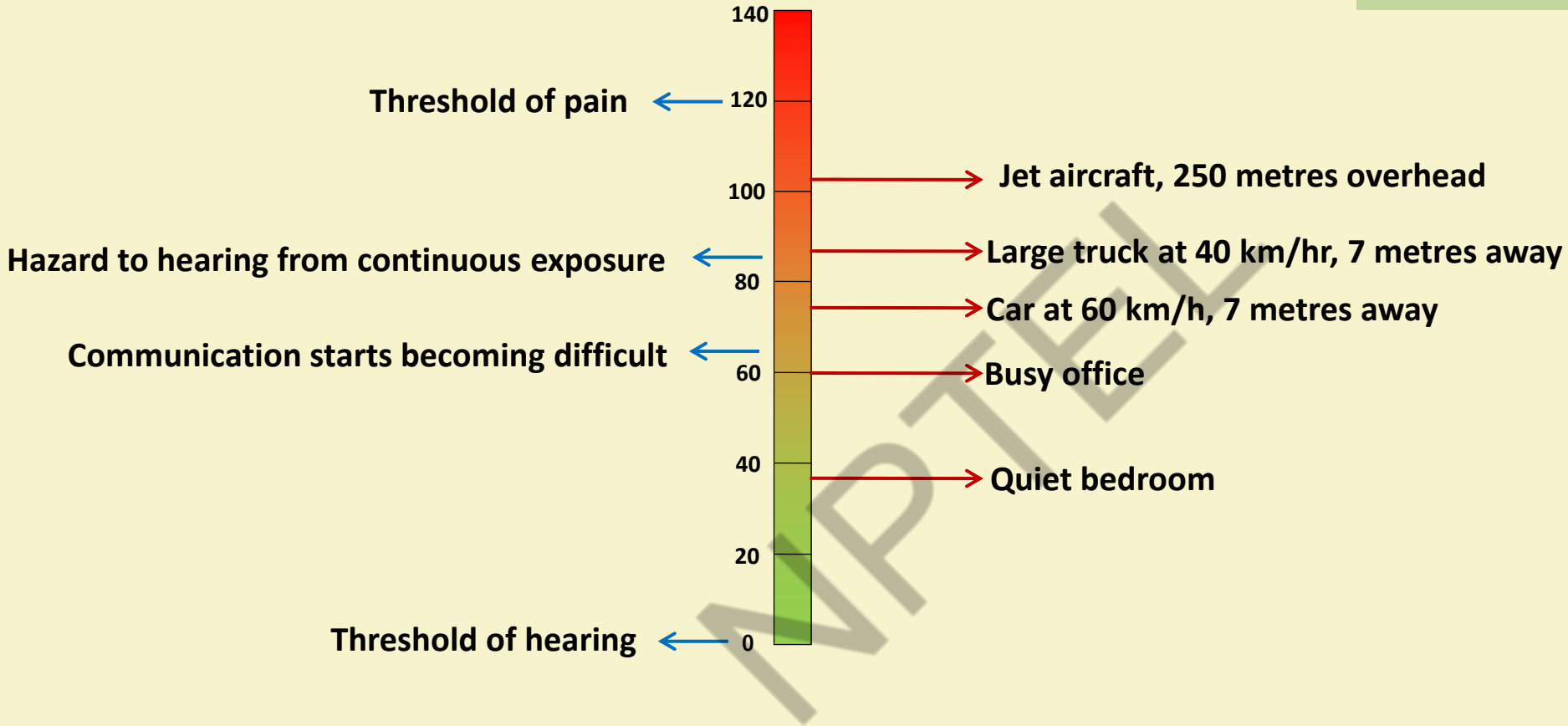
Learning Objective

Outline the source, classification and nature of urban noise

Discuss the urban noise mitigation strategies

Comparative Sound Level



Source: www.vicroads.vic.gov.au

Types of Road Noise

There are two types of road traffic noise:

From Bulk Traffic Flow

- It Is occurs on **busier roads** and received as a continuous backdrop of noise.
- It is the **aggregate noise** of all the vehicles in the **traffic stream**.
- Although it can have peaks and troughs according to the traffic flow.

From Individual Noisy Vehicles

- It is produced by **single vehicles** and can occur **anywhere** and at **any time**.
- Examples: high-speed motorbike, commercial vehicle's exhaust brakes
- This may be loud enough to rise above bulk flow traffic noise and can be **extremely disruptive**, particularly at night in quiet residential areas where sleep can be disturbed.

Factors Influencing Road Traffic Noise Generation

Individual vehicle noise is a combination of noises produced by:

- **The Engine;**
- **The Transmission;**
- **The Exhaust;**
- **The Interaction of Tyre And Road Pavement;**
- **Air Turbulence; and**
- **Body and Load Rattles.**

Traffic Noise

Apart from individual vehicle noise, there are **five main factors** upon which the **level of traffic noise** depends:

- **Traffic Volume;**
- **Traffic Speed;**
- **Traffic Composition (The Number of Commercial Vehicles);**
- **The Road Gradient, and**
- **The Pavement Surface Type and Texture.**

Traffic Noise Propagation

There are **six major factors** which influence the **propagation** of traffic noise:

- **The Road Profile** (at grade, depressed or elevated);
- **The Distance from the Source to the Reception Point**;
- **The Nature of the Ground Between the Source and the Reception Point;**
- **The Angle of View of the Traffic Stream from the Reception Point;**
- **The Presence of Screening** (by fences, earth mounds, barriers or buildings), and
- **Meteorological Effects, Particularly Wind Strength and Direction.**

Traffic Noise Mitigation Measures

There are several ways in which the impacts of road traffic noise can be reduced. The **mitigation measures** can be classified into **three** following **categories**:

At the Source

Controlling the noise emitted by the vehicle

Traffic Guideline, Act

Along the Transmission Path

Reducing the noise level by providing intervening barriers or buffer zones

Town Planning Act, Urban Design Guidelines

At the Reception Point Itself

Protecting the Building by building location and architectural design details to reduce the transmission of noise into the interior.

Architectural Design

Noise Control at Source

Noise control at source is the **most effective** way of reducing the impacts of road traffic noise.

This is accomplished by means of the relevant **City Traffic Rules implementation and Traffic Management System.**

Control at source can reduce both **bulk flow noise and individual vehicle noise.**

It can be further classified into following sub divisions

- **Research and Innovations**
- **City Planning**
- **Traffic Management**
- **Change of Citizen Attitude**

Noise Control at Source

Research and Innovations

Development of new low noise emitting automobile machines, Tyre technology, Innovation in road surface material

City Planning

Noise sensitive land use planning, Development control, Activity separation, Micro-zoning

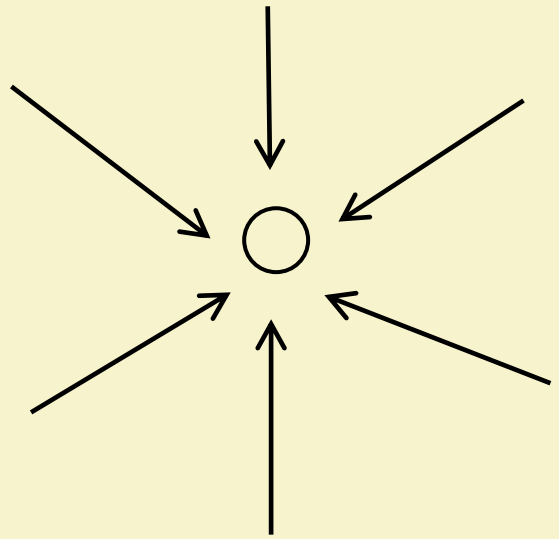
Traffic Management

Traffic rules, like: Over Speeding, Driving a noisy vehicle, No horn zones
City traffic movement: no entry re-routing
Development regular maintenance of roads

Change of Citizen Attitude

Citizen sensitization, participatory activities

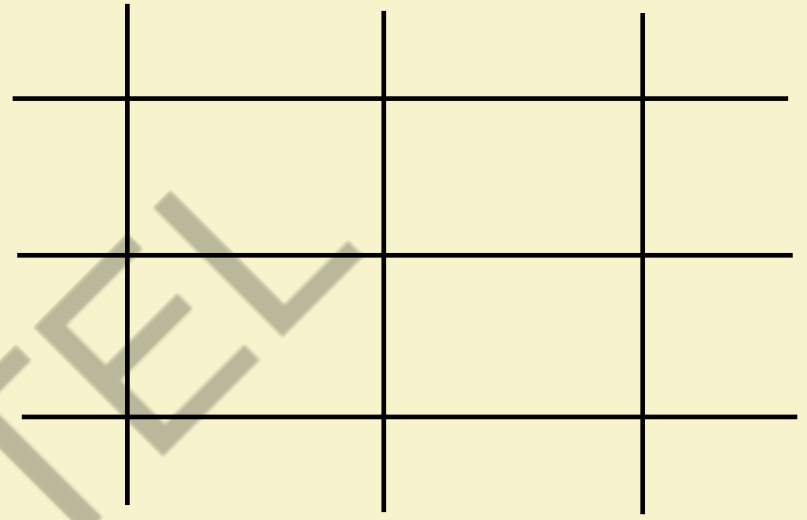
Radial Road Pattern



More Concentration of Noise

✗

Grid Iron Road Pattern



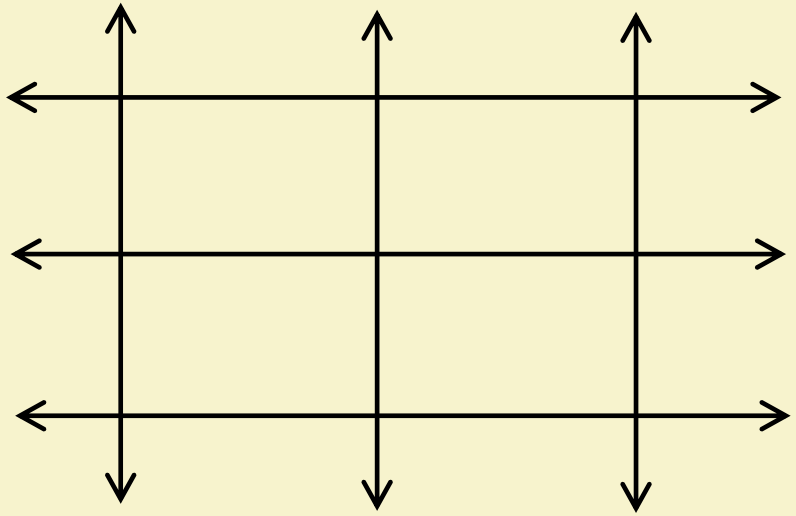
Less Concentration of Noise

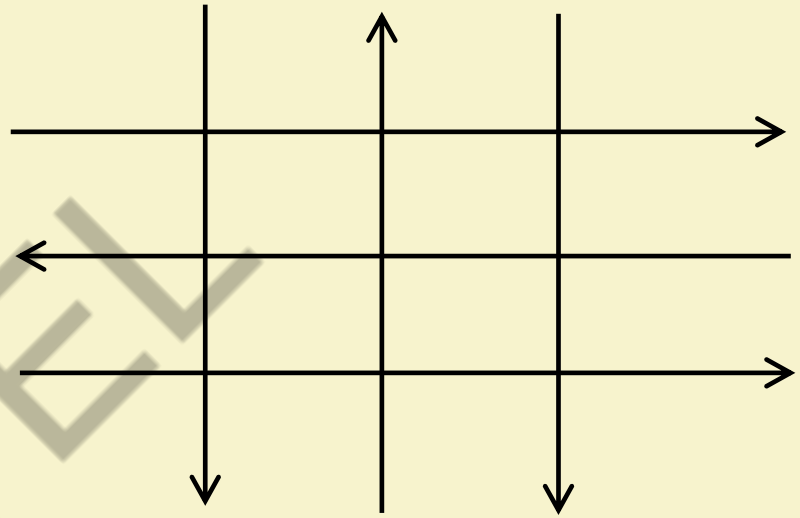
✓

Two-way Traffic

Grid Iron Road Pattern

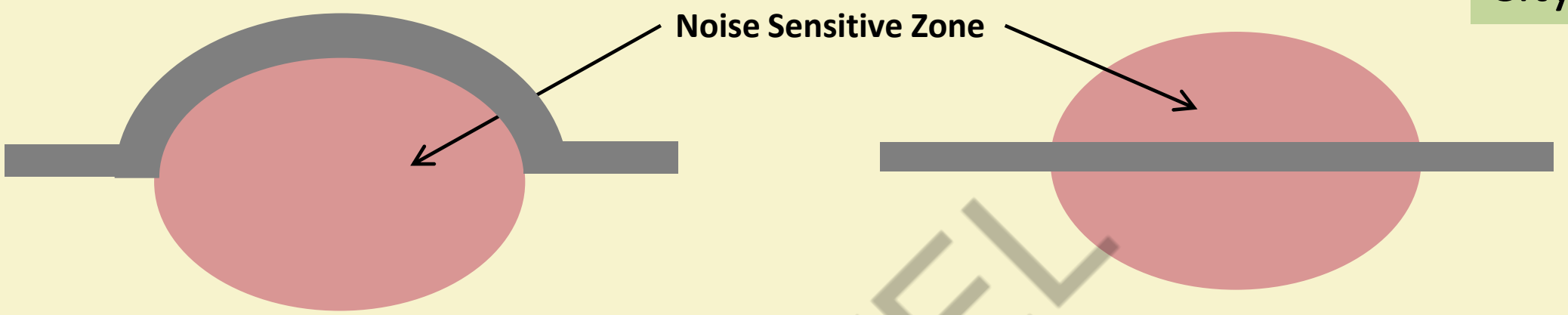
One-way Traffic





Less Concentration of Noise
More Noise free space

More Concentration of Noise
Less Noise free space

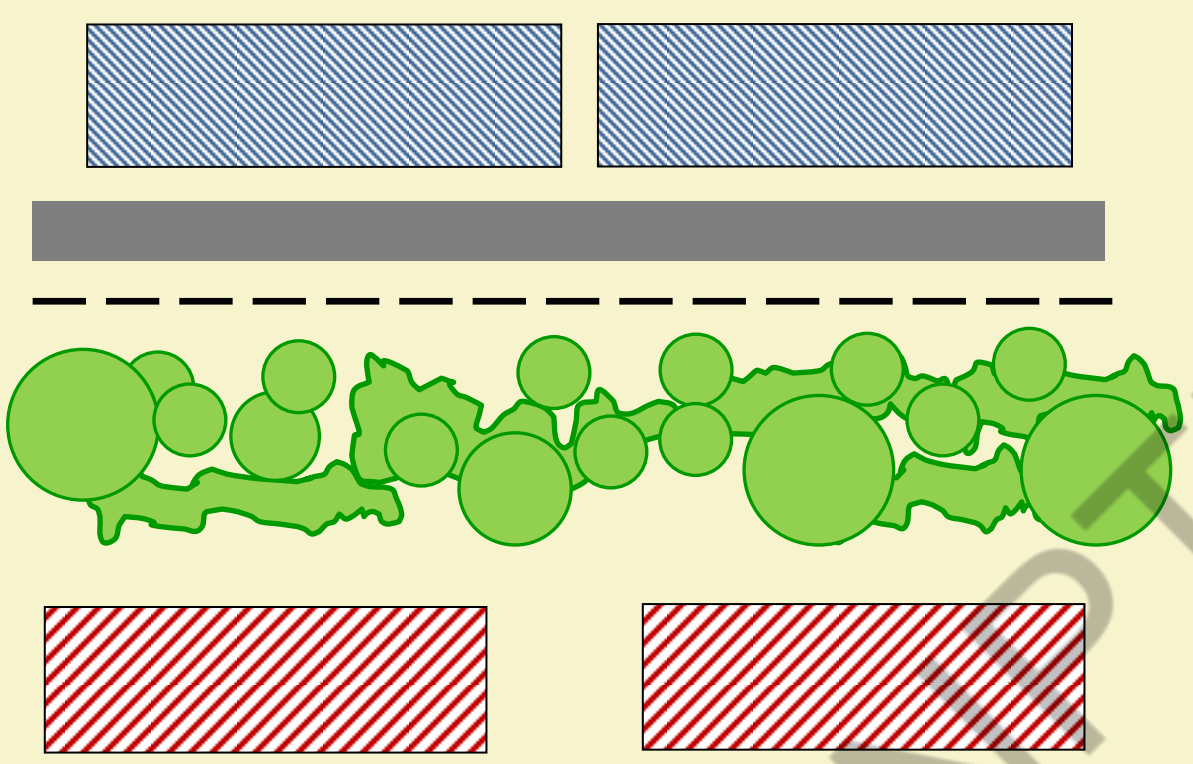


Bypass Road

Less Noise Interference

Through road

More Noise Interference

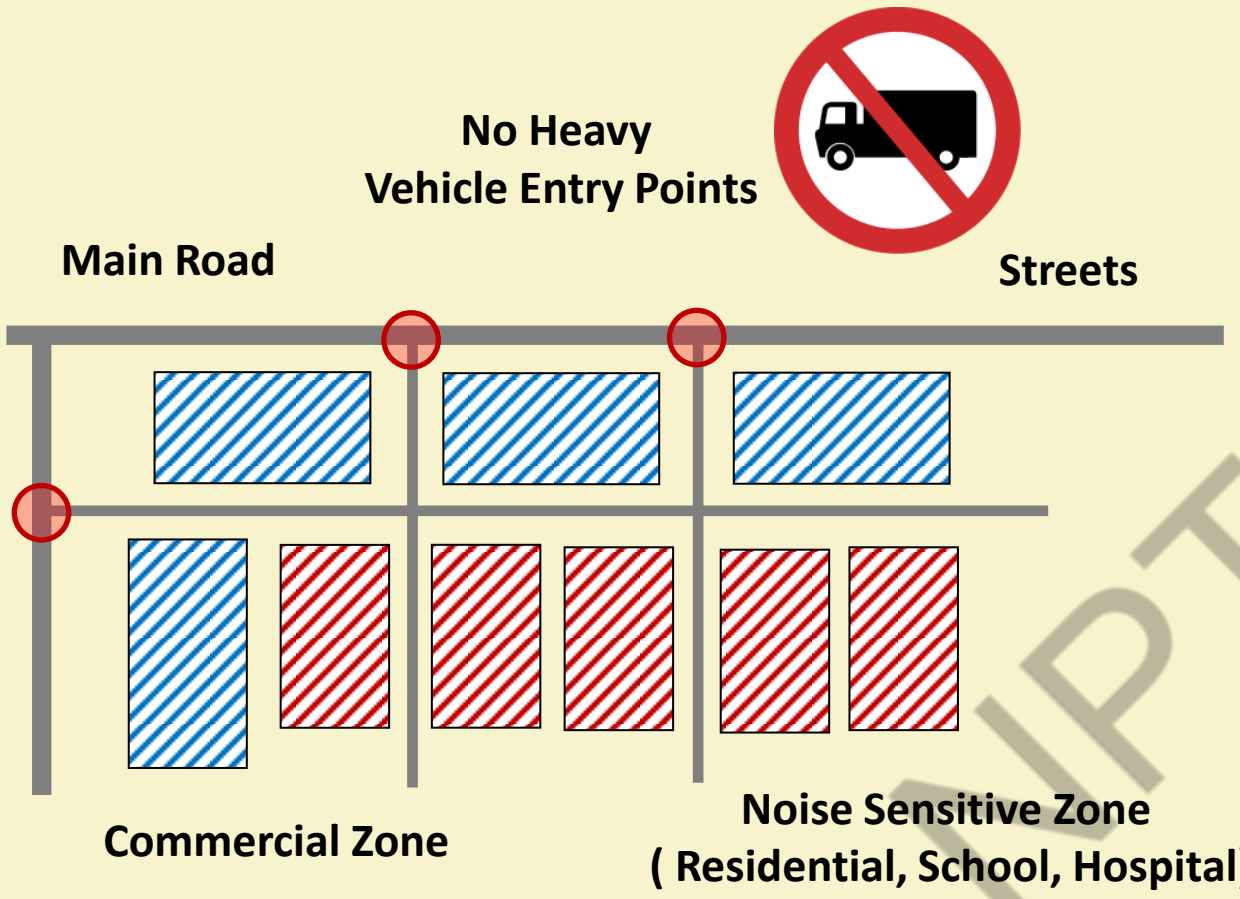


Industrial Zone

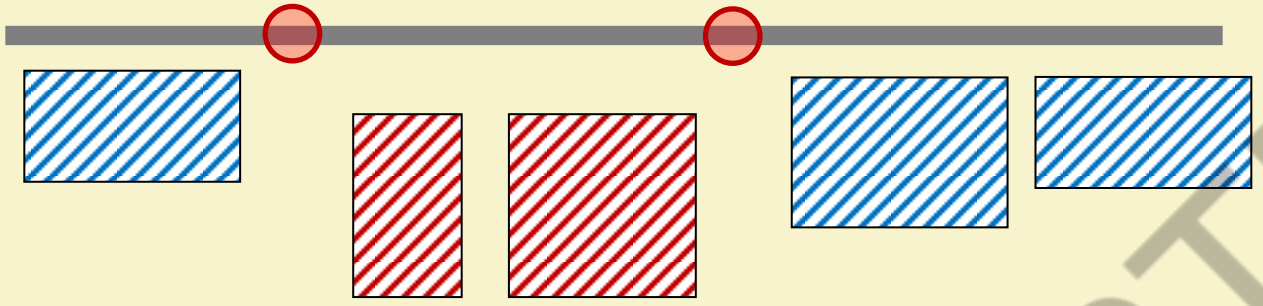
Express Way / Railway

Dense Green Belt

Noise Sensitive Zone


No Heavy
Vehicle Entry Points
Main Road
Streets
Commercial Zone
Noise Sensitive Zone
(Residential, School, Hospital)

Speed Breaker Points



Speed Breakers / Hump

Rubber / PVC Speed Breakers

Noise Limit

The **Central Pollution Control Board, New Delhi (CPCB)** recommended noise standards for various categories of area for automobiles, domestic appliances and construction equipments

	Noise limit in dB(A)	
Category of Area	**Day Time**	**Night Time**
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	50	40

- Day time is in between 6 a.m. and 9 p.m. and Night time is in between 9 p.m. and 6 a.m.
- **Silence zone** is referred as areas up to 100 meters around such premises as **hospitals, educational institutions and courts.**
- Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.

Noise Limit

Noise standards for automobiles as per Central Pollution Control Board, New Delhi

Category of Vehicle	Noise limit in dB(A)
Motor-cycle, scooters and three wheeler	80
Passenger Cars	82
Passenger or commercial Vehicles up to 4 mt	85
Passenger or commercial Vehicles above 4 mt and up to 12 mt	89
Passenger or commercial Vehicles exceeding 12 mt	91

Type of Train	Noise Level at 30 m, measured on the side or in the Direction of Train, dB (A)
Steam train, 60 km/h	85
Diesel train, 60 km/h	83
Electric train, 60 km/h	77

Near airports following two sources of aircraft noise should be considered:

Flyover Noise

Flyover noise is that which occurs under flight paths close to airports.
As the aircraft passes overhead the noise level at any particular location rises to a peak and then decreases.

Ground Noise

The ground noise is that which emitted by an aircraft during ground operations. This is not sharply vary like flyover noise, but is usually of a longer duration.

Aircraft Noise

- **Fly over noise** will depend upon the **type of aircraft** and go as much as **100-110 dB(A)**

- Aircraft noise (particularly Flyover noise) is **very disturbing** during communication, rest and sleep.
- It is also considered potentially **harmful to health**.

- It is important to have very **strong development control act** within areas where the expected noise levels is very high.

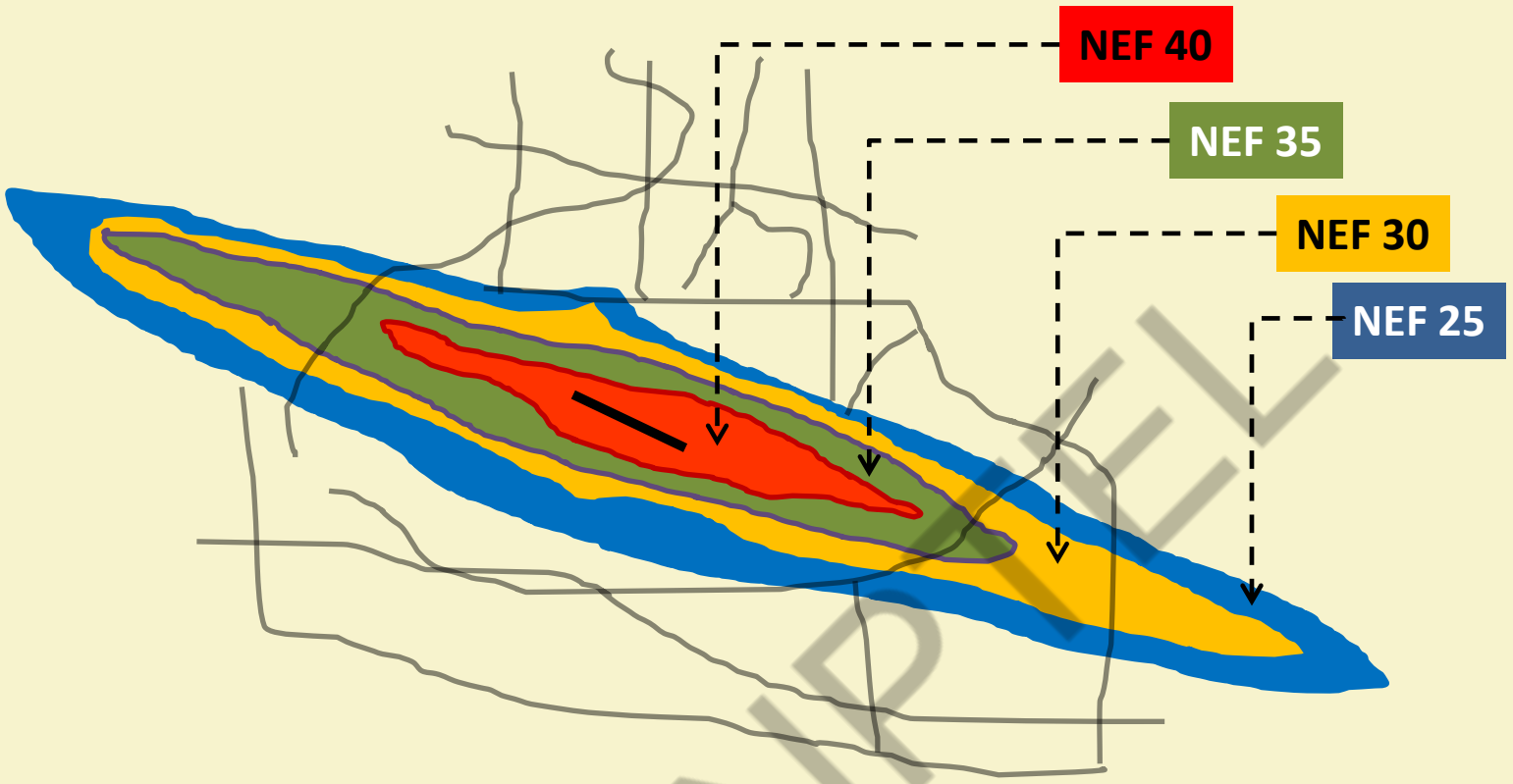
- In case of any development in such areas, it is essential to have **adequate sound insulation for the building**.

Aircraft Noise

- A number of **methods** have been devised for **evaluating noise exposure** in the **vicinity of airports**.
- They all combine many factors into a **single number evaluation**.
- U.S. Federal Aviation Agency developed a method to predict the degree of community annoyance from aircraft noise. This is called **Noise Exposure Forecast (NEF).**

- The **NEF** is used primarily to **develop noise contours** for areas around airports.
- Generally noise exposure forecast levels greater than **NEF 40** are **unacceptable** to people.
- NEF **less than 25** are normally **acceptable**.

Aircraft Noise



NEF ≥ 40	High Impact	≥80 dB(A)
35≥NEF ≥25	Medium Impact	65-75 dB(A)
NEF≤20	Low Impact	≤55 dB(A)

Mitigation Process

Mapping the Noise Level in the City

Specific location along the roads and: L_{eq} , L_{10}, L_{50}, L_{90}

Identify the Noise Hot Spots

Road Crossing, Narrow Roads, Roundabout, Mixed traffic zones, Busy Roads

Overlay the city habitat and the noise map

Hospital, School, Residential Zone, Park

Demarcate the conflict zones

Noise zone – Quite Habitat

Suggest Noise reduction strategies

Entry Control, One way re-routing, No parking, Restricted entry

Home Work

What are the major noise source in your city / town. Take a map of your city / town and locate the noise hot spot points

Discuss the methods with example to reduce the impact of urban noise

Bibliography

1. **Acoustics in the Built Environment**, Duncan Templeton, Architectural Press; 2nd Edition
2. **Protocol for Ambient Level Noise Monitoring,** Central Pollution Control Board, Delhi,2015
3. **Requirement and Procedure for Monitoring Ambient Noise Level due to Aircrafts,** Central Pollution Control Board, Delhi,20108
4. **National Building Code of India 2016 (Volume 2),** Bureau Of Indian Standards, New Delhi

End of Lecture 38: Urban Noise Control: Planning Consideration - I

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

Architectural Acoustics

Lecture 39:Urban Noise Control: Planning Consideration - II

Dr. Shankha Pratim Bhattacharya

Department of Architecture & Regional Planning

Learning Objective

Discuss the urban noise mitigation measures through landscaping and barriers

Outline the fundamentals of noise barrier design

Noise Control at Path

Noise control along the transmission path is one of the effective technique to reduce urban noise. The mitigation measures include:

Providing **geometrical changes** between the source and the receiver

Changing the **road formation** level to shield the sound from source.

Providing **noise berries** (Natural or man made)

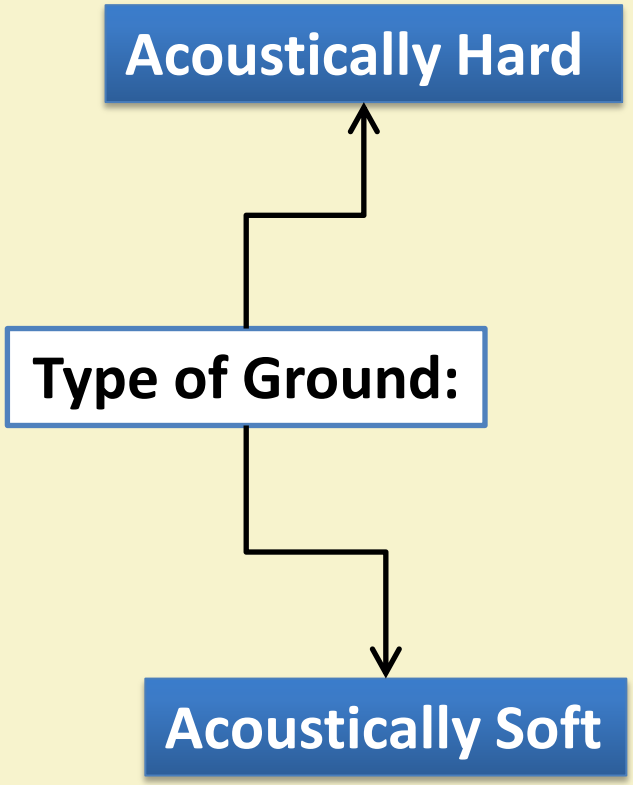
Ground Effect

Ground effect refers to the change in sound level (increase or decrease), due to the **nature of ground** between source and receiver.

Ground effect is a **complex acoustic phenomenon**. Ground effect mostly depends due to the parameters like:

- **Ground characteristics,**
- **Source-to-receiver geometry, and**
- **The spectral characteristics of the source**

Ground Effect



Highly reflective surfaces like water, asphalt, and concrete are considered as hard ground. The sound energy is essentially preserved upon **reflection** and **increment in the sound level** is noticed.

Highly absorptive surfaces like grass cover, terrain covered with dense vegetation are considered as Soft ground. The sound energy is essentially undergo **absorption** and **decrease in the sound level** is noticed.

Atmospheric Effect

Atmospheric effect refers to the change in sound level (increase or decrease), due to the **prevailing condition of atmosphere** between source and receiver.

Atmospheric effects is further classified into three sub categories:

- **Atmospheric Absorption**
- **Atmospheric Refraction**
- **Air Turbulence**

Atmospheric Absorption: The sound absorption by air and moisture

Atmospheric absorption is a function of

- **The frequency of the sound,**
- **The temperature,**
- **The humidity, and**
- **The atmospheric pressure between th source and the receiver.**

Atmospheric Refraction: The sound refraction caused by temperature and wind gradients

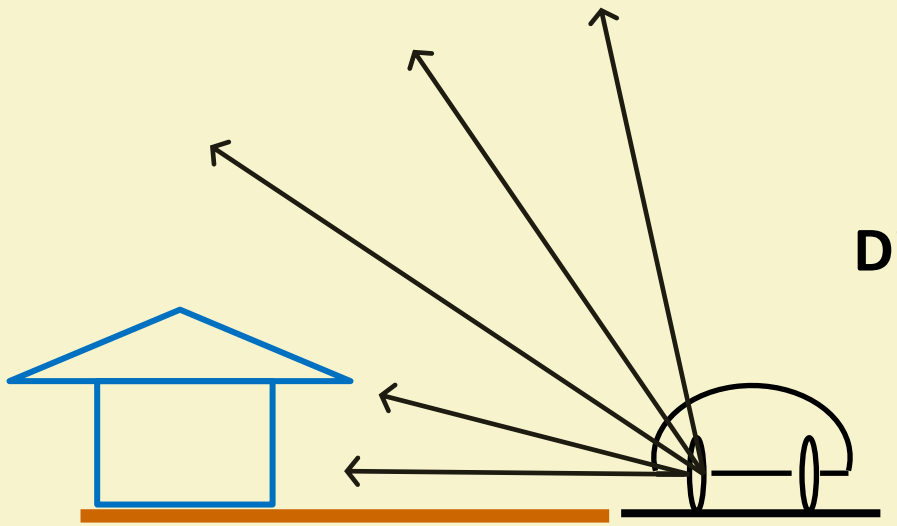
Atmospheric refraction is the **bending of sound** waves due to **wind and temperature gradients**.

Upwind conditions tend to refract sound waves **away from the ground** resulting in a **decrease in sound levels** at a receiver.

Downwind conditions tend to refract sound waves **towards the ground** resulting in an **increase in sound levels** at a receiver.

Air Turbulence: Turbulence in the air has an unpredictable effect on the fluctuation in the sound level.

Geometrical Changes



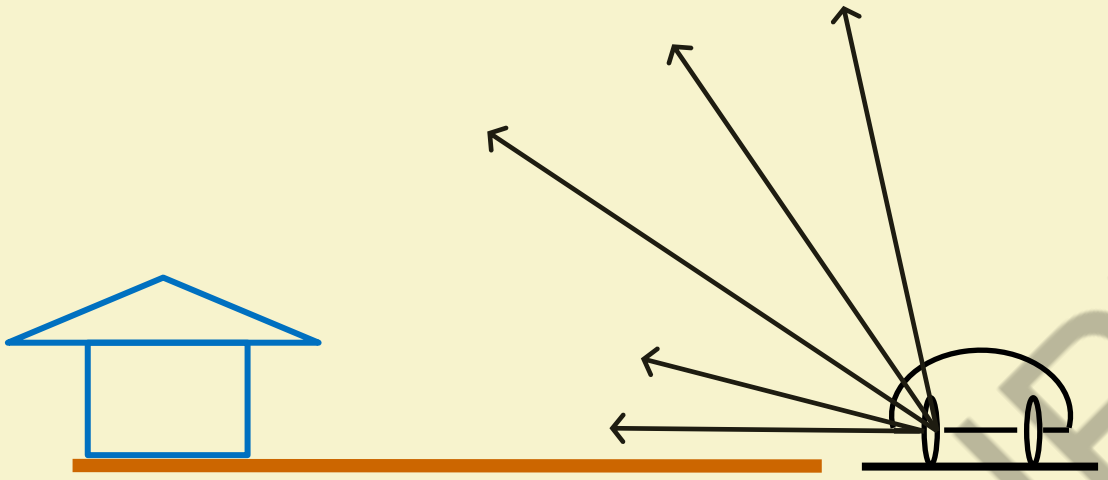
The building is directly exposed to road noise

Direct line of vision between noise source and receiver

Need to block the line of vision to reduce noise

Changing geometry between the noise source and receiver

Increase the distance between noise source and receiver

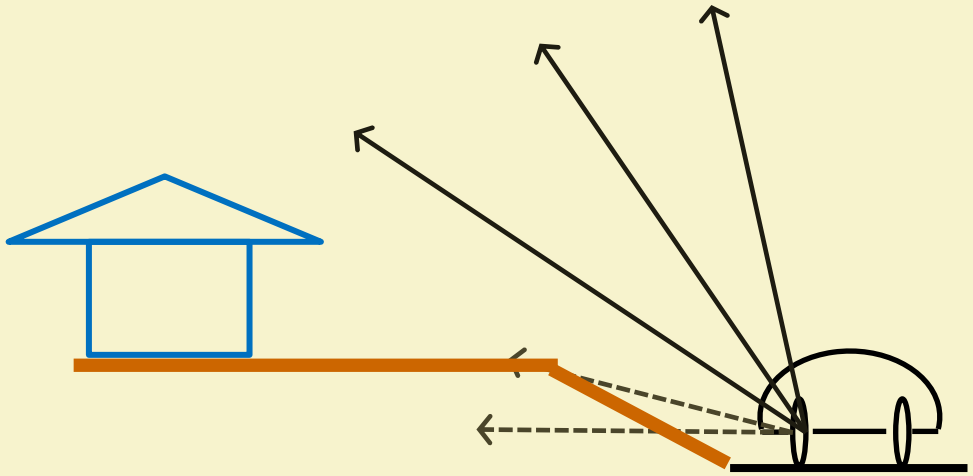


Direct line of vision between noise source and receiver remain unchanged

There is an inverse square relationship between sound intensity and distance.

Noise will be reduced by 3 dB if the distance from the source is doubled

Change the level between noise source and the receiver



Change the level such a way that

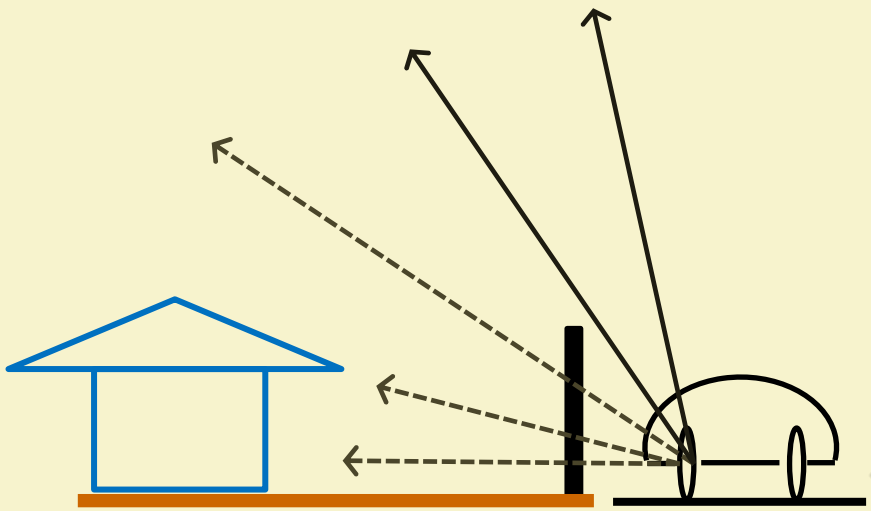
Direct line of vision between noise source and receiver is blocked

Portion of the direct noise will cutoff

Receiver will fall under sound shadow zone

Efficiency of noise reduction will depend upon the relative level difference and distance between noise source and receiver

Provide a physical barrier between noise source and receiver



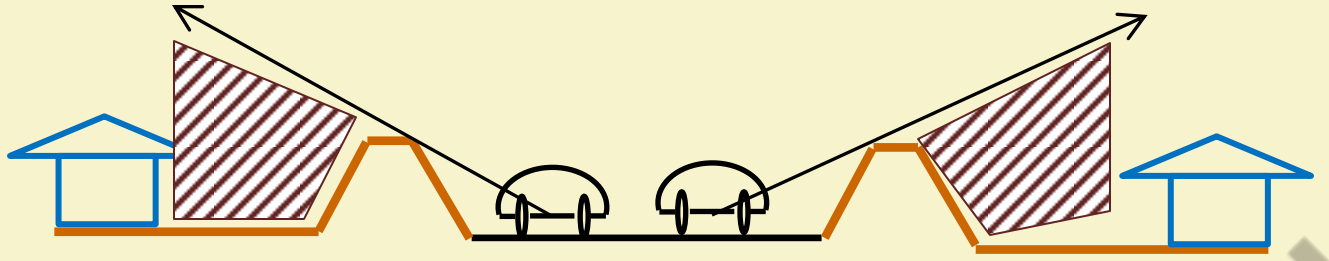
Direct line of vision between noise source and receiver is blocked

Portion of the direct noise will cutoff

Receiver will fall under sound shadow zone

Efficiency of noise reduction will depend upon the
relative distance between noise source & receiver
and
the position and height of the barrier

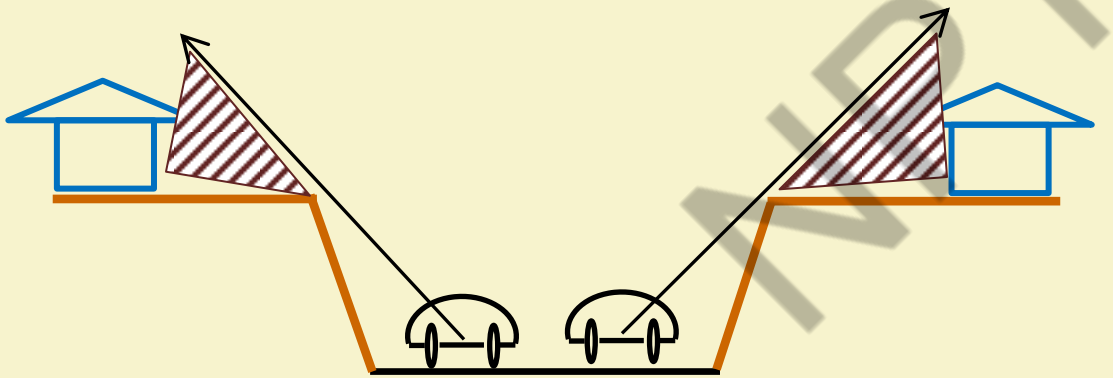
Road Formation



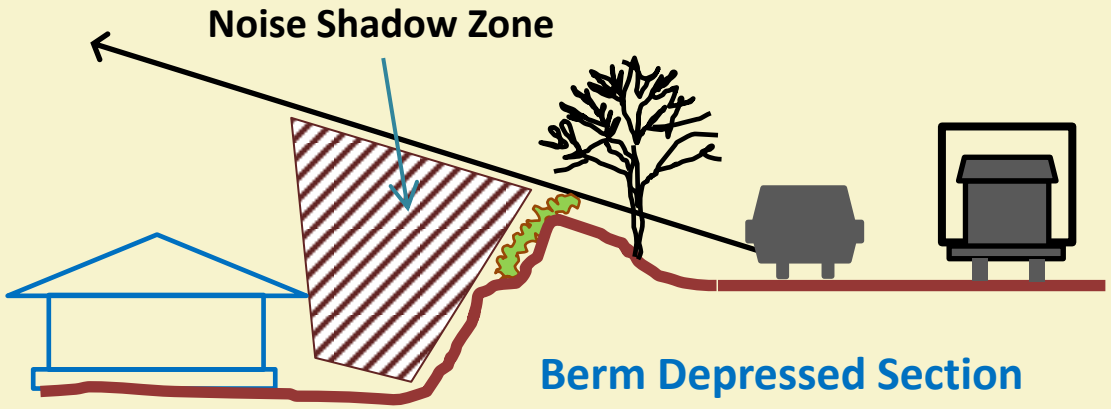
Raised portion in the sides of the road

Cut off the direct propagation of sound

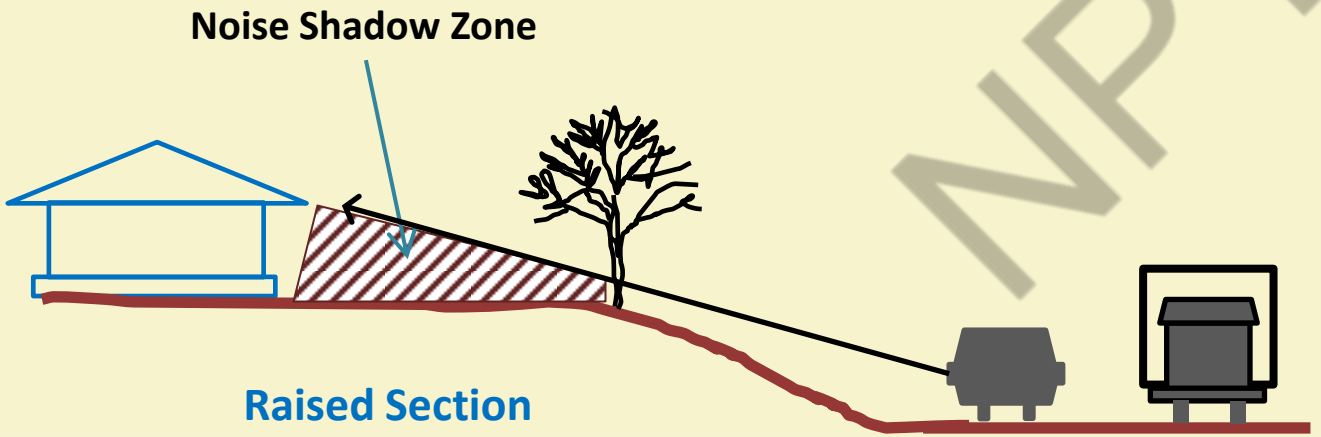
Nearest building comes within the sound shadow



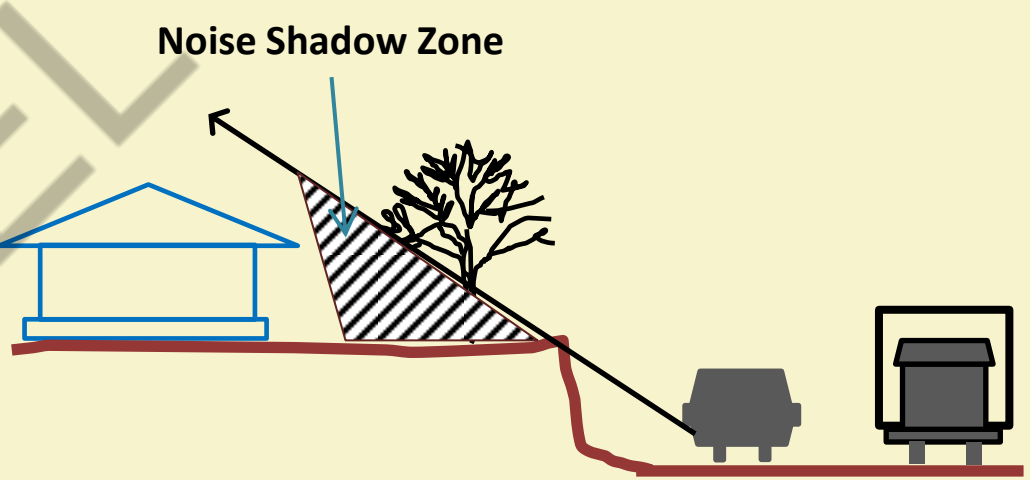
Sunken road formation level



Berm Depressed Section



Raised Section



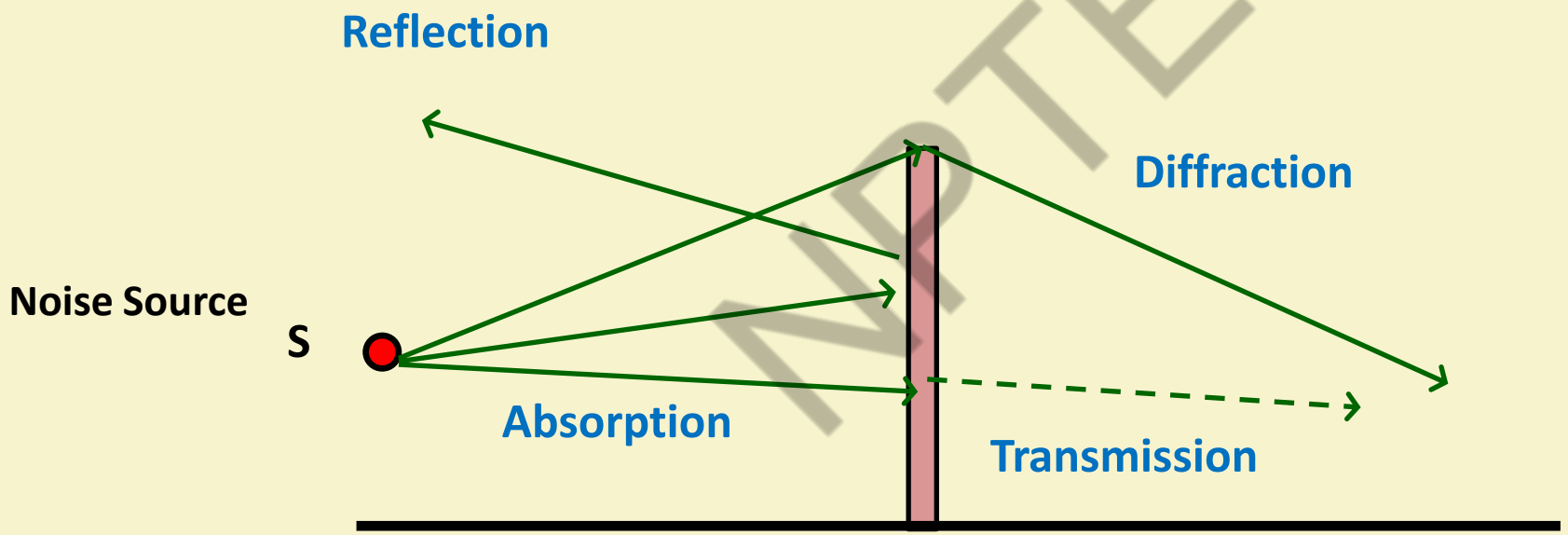
Retaining Wall Section

Noise Control Through Cut and Fill

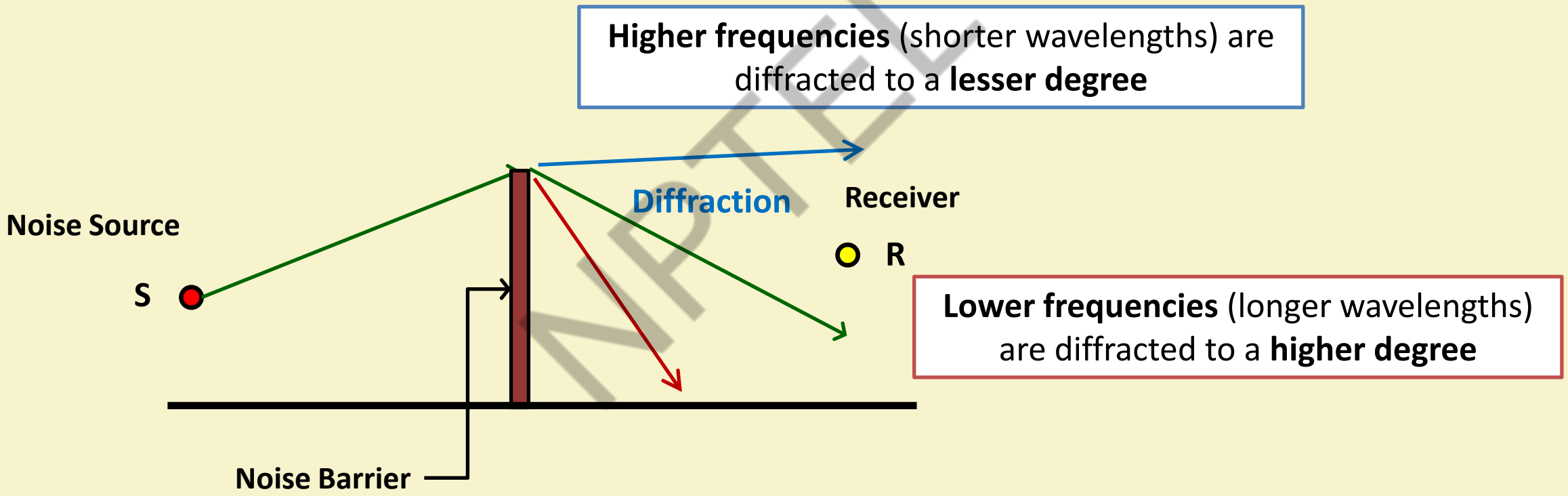
Noise Barrier

Noise Barriers reduce the sound which enters a community from a busy highway by either by reflection, absorption, transmission or forcing it to take a longer path (Diffraction).

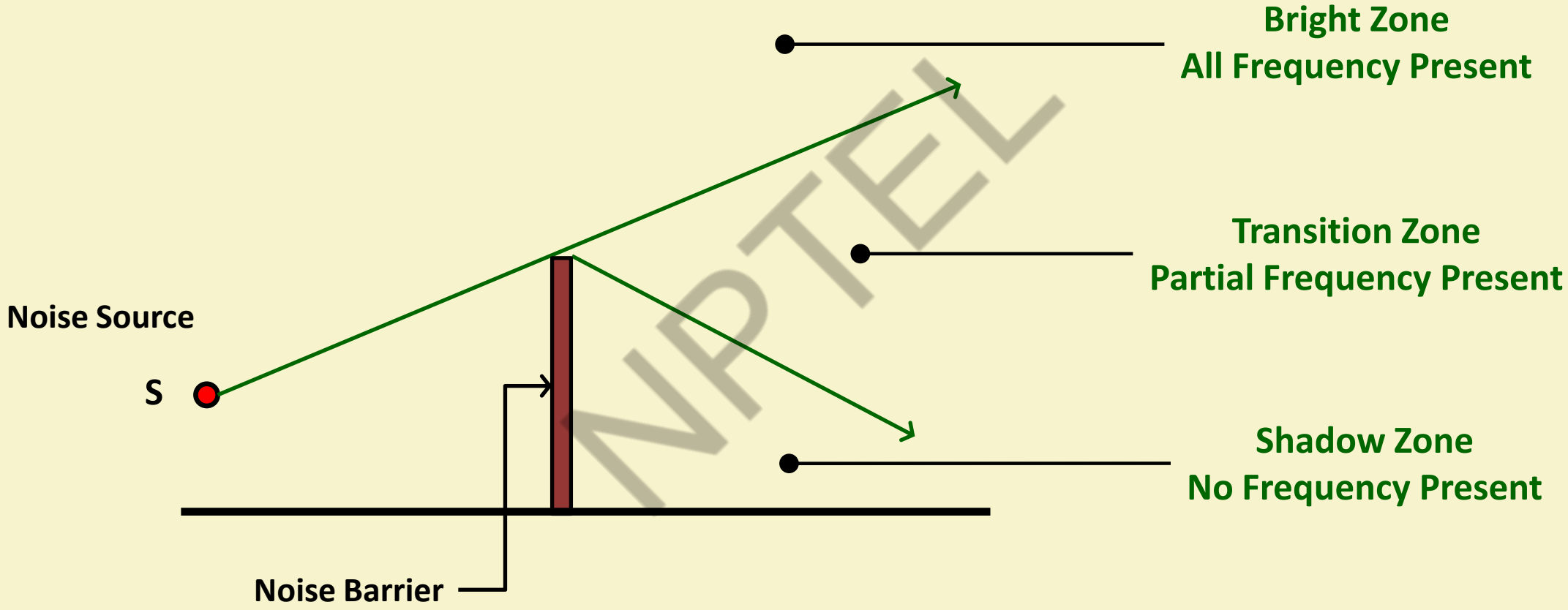
This longer path is referred to as the diffracted path.



The diffraction does not bend all frequencies uniformly.

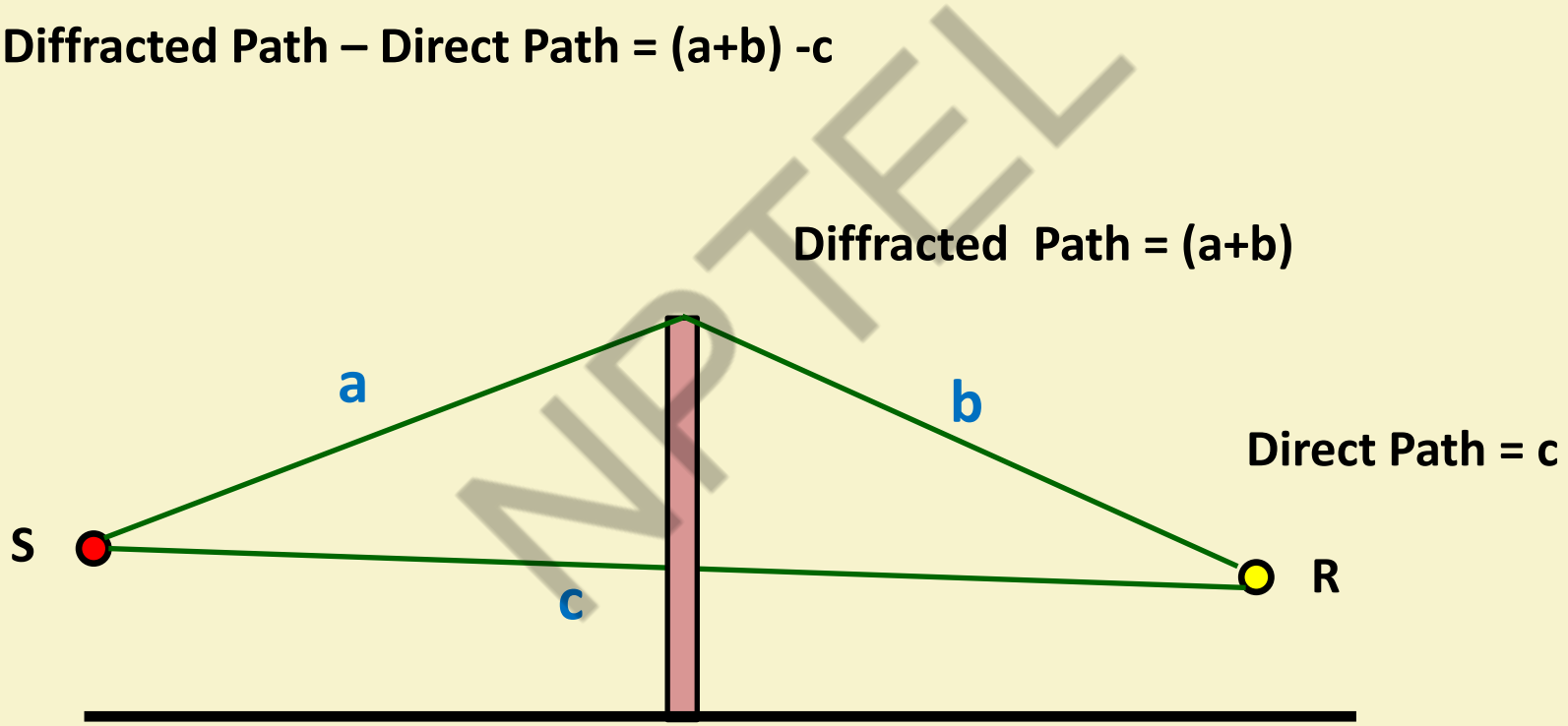


The diffraction of sound creates three different zones



An important aspect of diffraction is the path difference (δ) between the diffracted path, and the direct path from source to receiver as if the barrier were not present

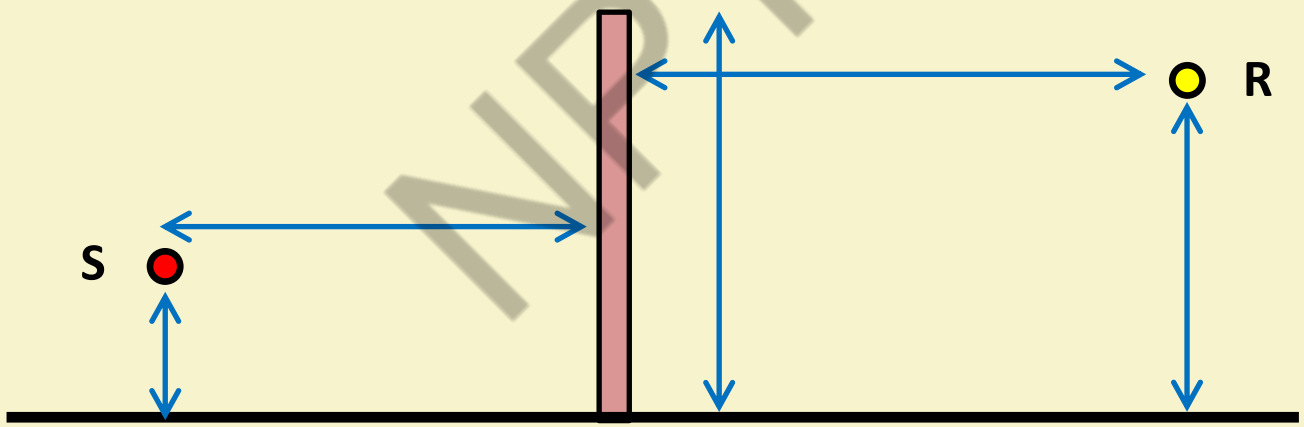
Path Difference = Diffracted Path – Direct Path = (a+b) -c



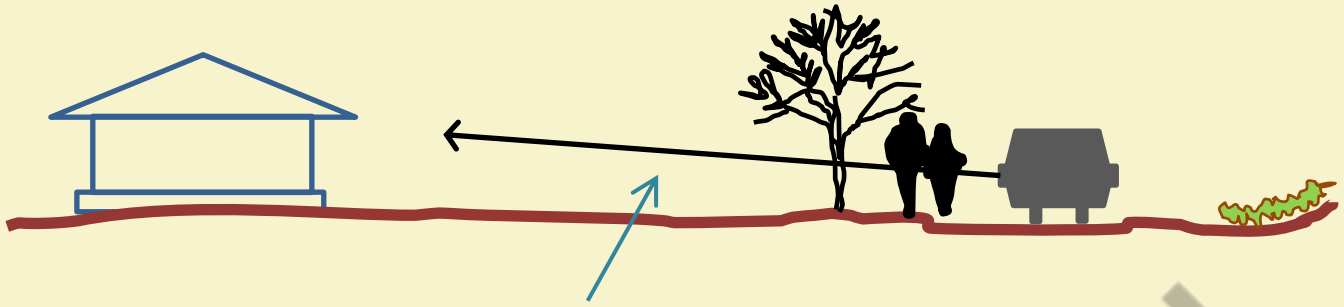
Noise Barrier

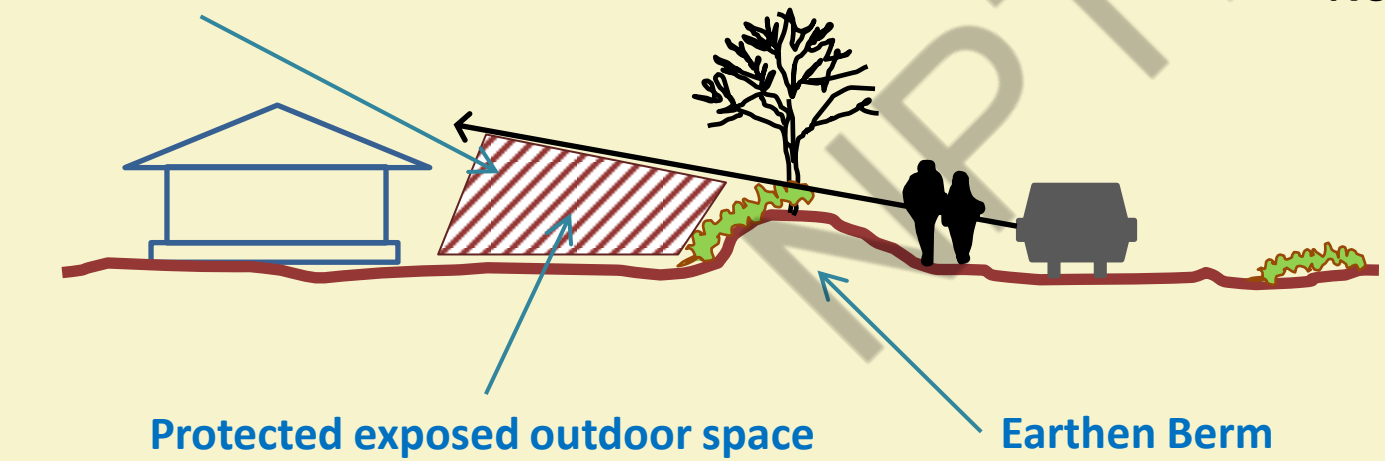
Factors

- Distant Between the Source to Barrier
- Distant Between the Receiver to Barrier
- Height of the Source
- Height of the Receiver
- Height of the Barrier
- Frequency of the sound
- Porosity of the Barrier
- Punchers in the Barrier



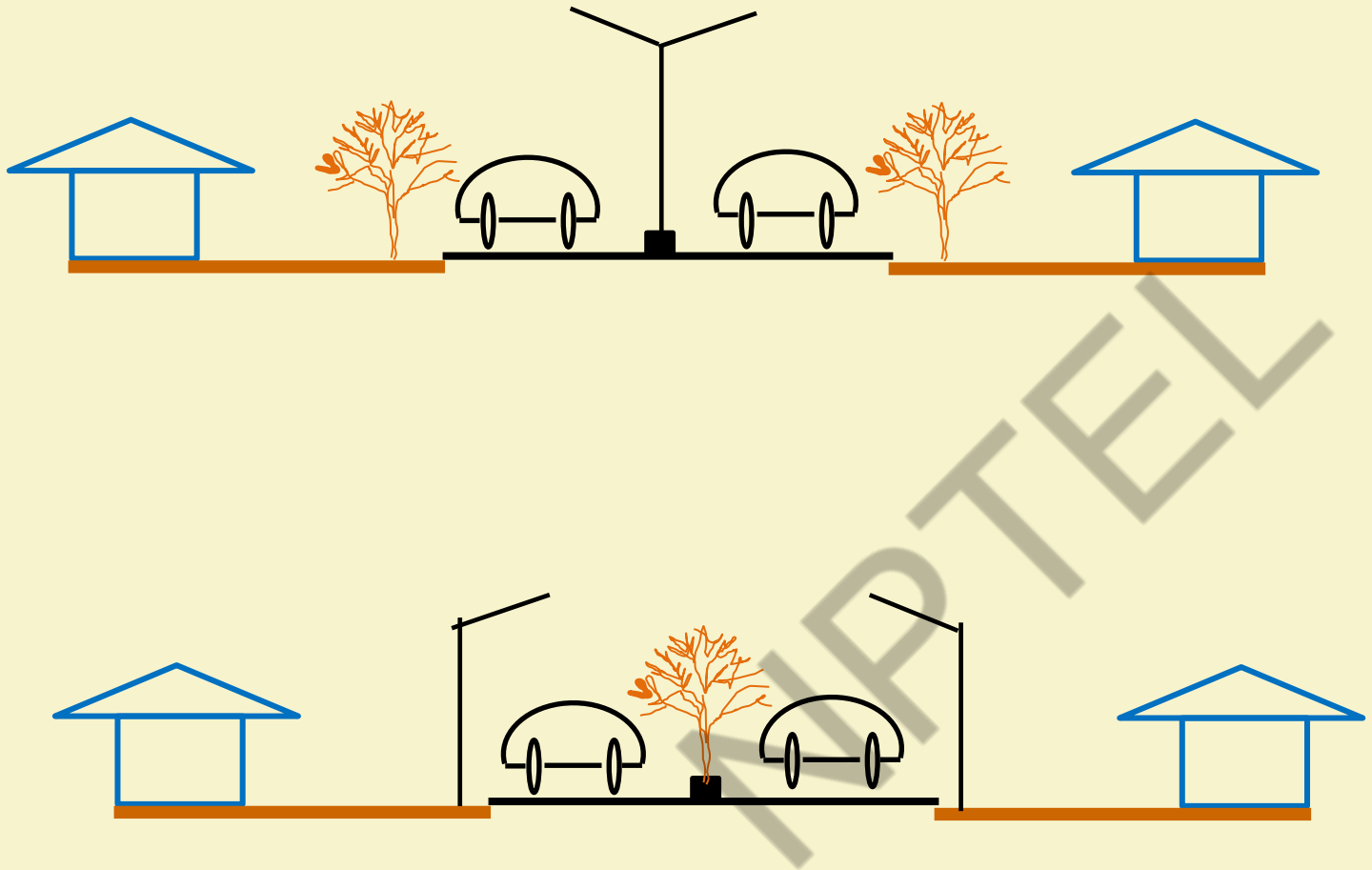
Noise Barrier





Noise Control Through Earth Berms

Noise Barrier



Home Work

Take an example of a housing society next to a busy street.
Develop a schematic noise mitigation strategy for the housing.

Prepare a list for design a effective noise barrier

Bibliography

1. **Acoustics in the Built Environment**, Duncan Templeton, Architectural Press; 2nd Edition
2. **Protocol for Ambient Level Noise Monitoring,** Central Pollution Control Board, Delhi,2015
3. **Requirement and Procedure for Monitoring Ambient Noise Level due to Aircrafts,** Central Pollution Control Board, Delhi,20108
4. **National Building Code of India 2016 (Volume 2),** Bureau Of Indian Standards, New Delhi

End of Lecture 39:Urban Noise Control: Planning Consideration - II

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

Architectural Acoustics

Lecture 40: Urban Noise Control: Architectural Consideration

Dr. Shankha Pratim Bhattacharya

Department of Architecture & Regional Planning

Learning Objective

Discuss the outdoor noise mitigation measures through architectural design

Outline the control mechanism for building noise

Noise Control at Receiver

Control at the reception point can be achieved by

Site Planning and Building Placement and Orientation

Layout Planning and Space Segregation

Applying Architectural Acoustic Treatments

Hospitals, educational building and residential buildings should be located in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

Building should be located at a distance of about 30 m from the road, but a distance of 45 m or more, where possible, should be aimed at for greater relief from noise;

Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

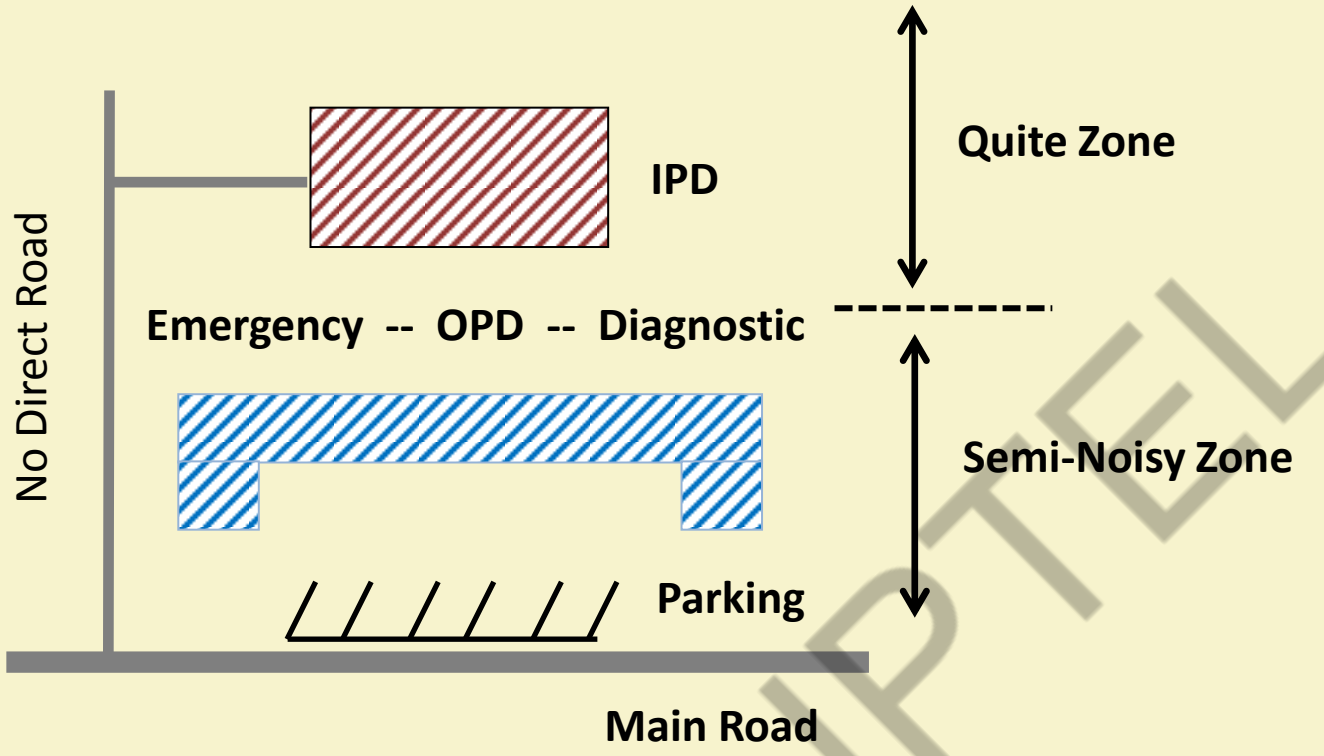
In case of hospitals sensitive areas like wards, consulting and treatment rooms, operating theatres and staff bedrooms need to be placed away from outdoor sources of noise, if possible, with their windows overlooking areas of acoustic shadow.

To minimize ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing.

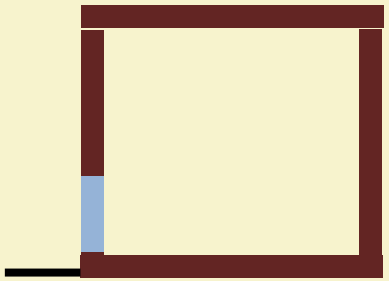
Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings.

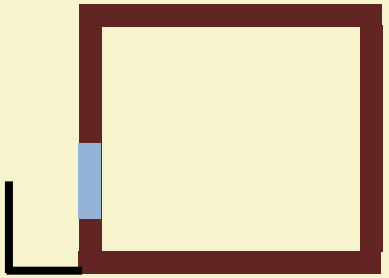
Site Planning



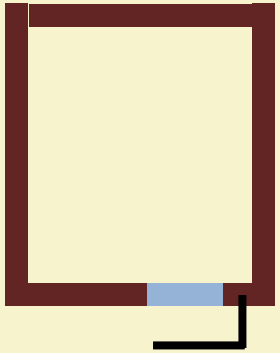
Orientation



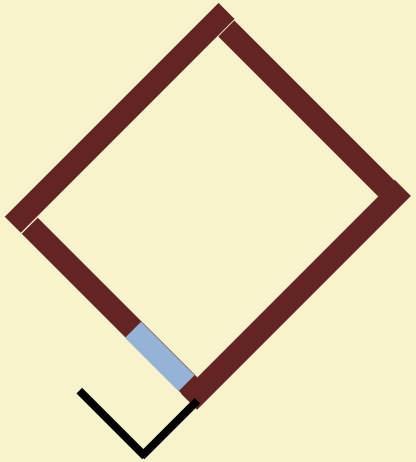
Road



Road



Road



Road

The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

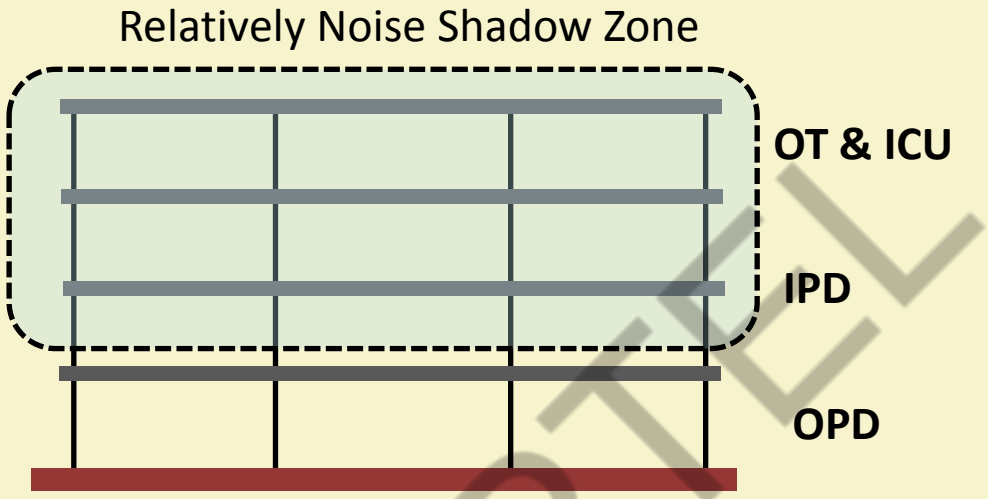
Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together

Windows and doors should be kept away from the noisy side of the building as given below, wherever possible

Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Skylights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors.

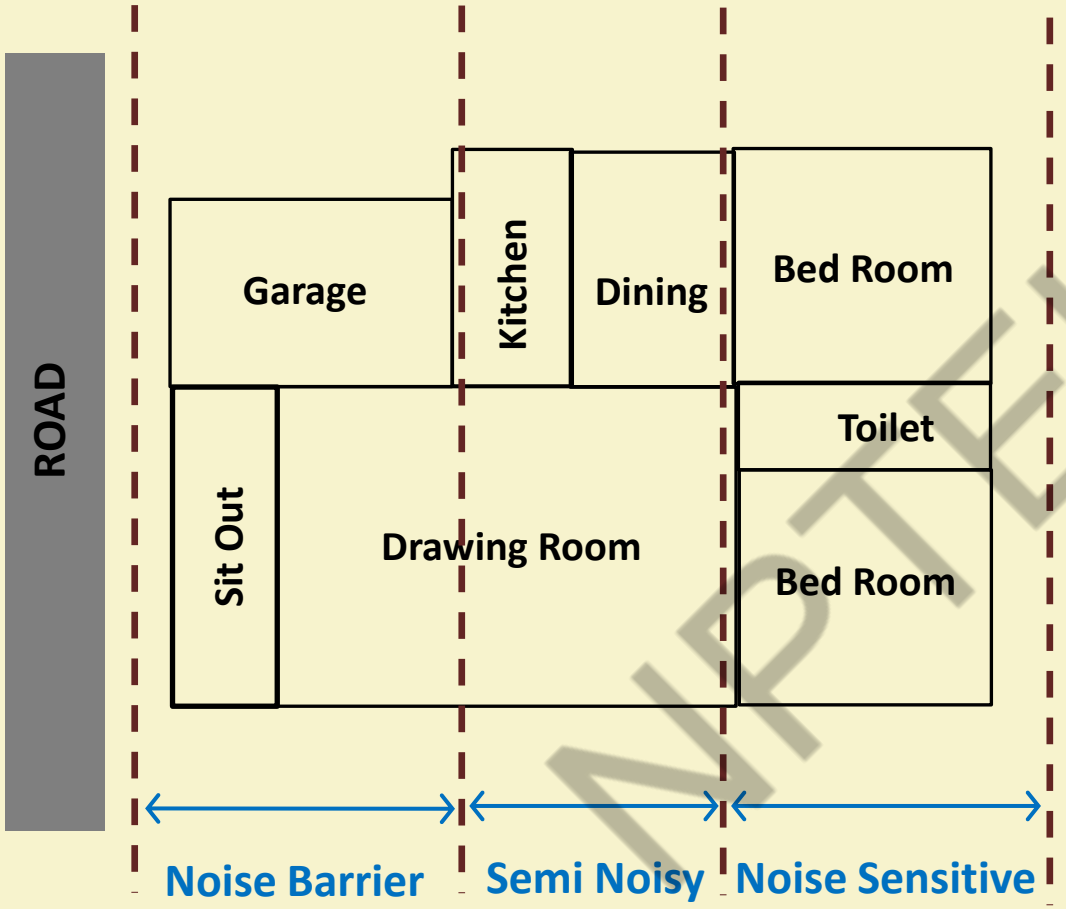
Unloading bays, refuse disposal areas, boiler houses, workshops and laundries are examples of service units which should be as far from sensitive areas as possible.

The kitchen is a constant source of both air-borne and structure-borne noise and should preferably be in a separate building away from or screened from the sensitive areas.



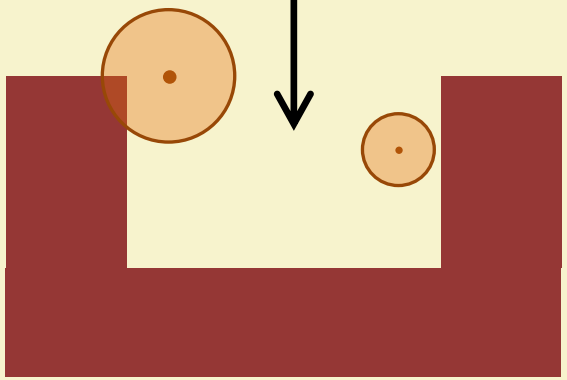
Vertical Separation

Internal Planning



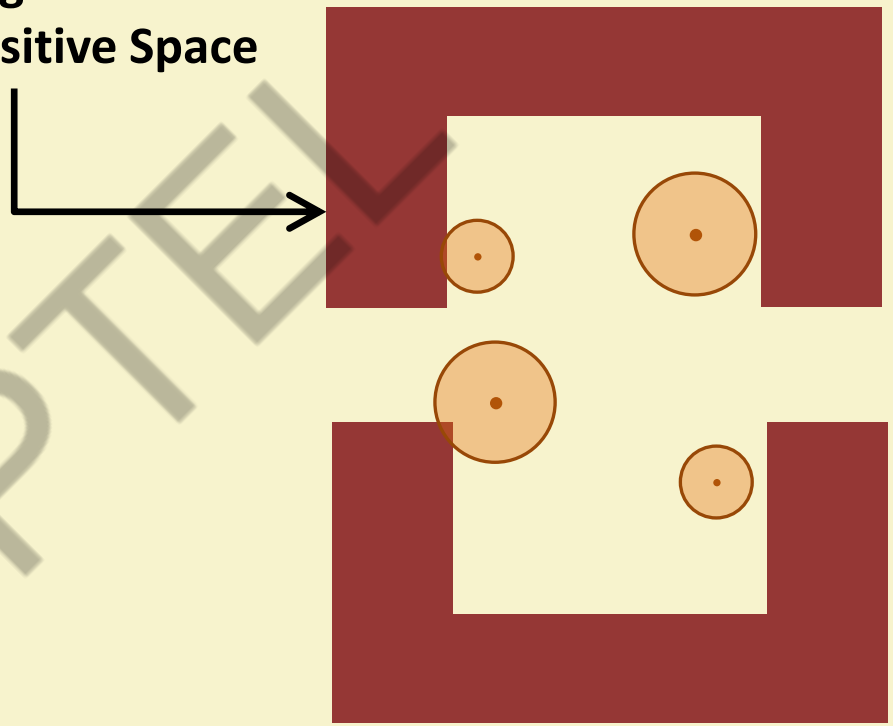
Internal Planning

Use Courtyard area for Quite Outdoor Space



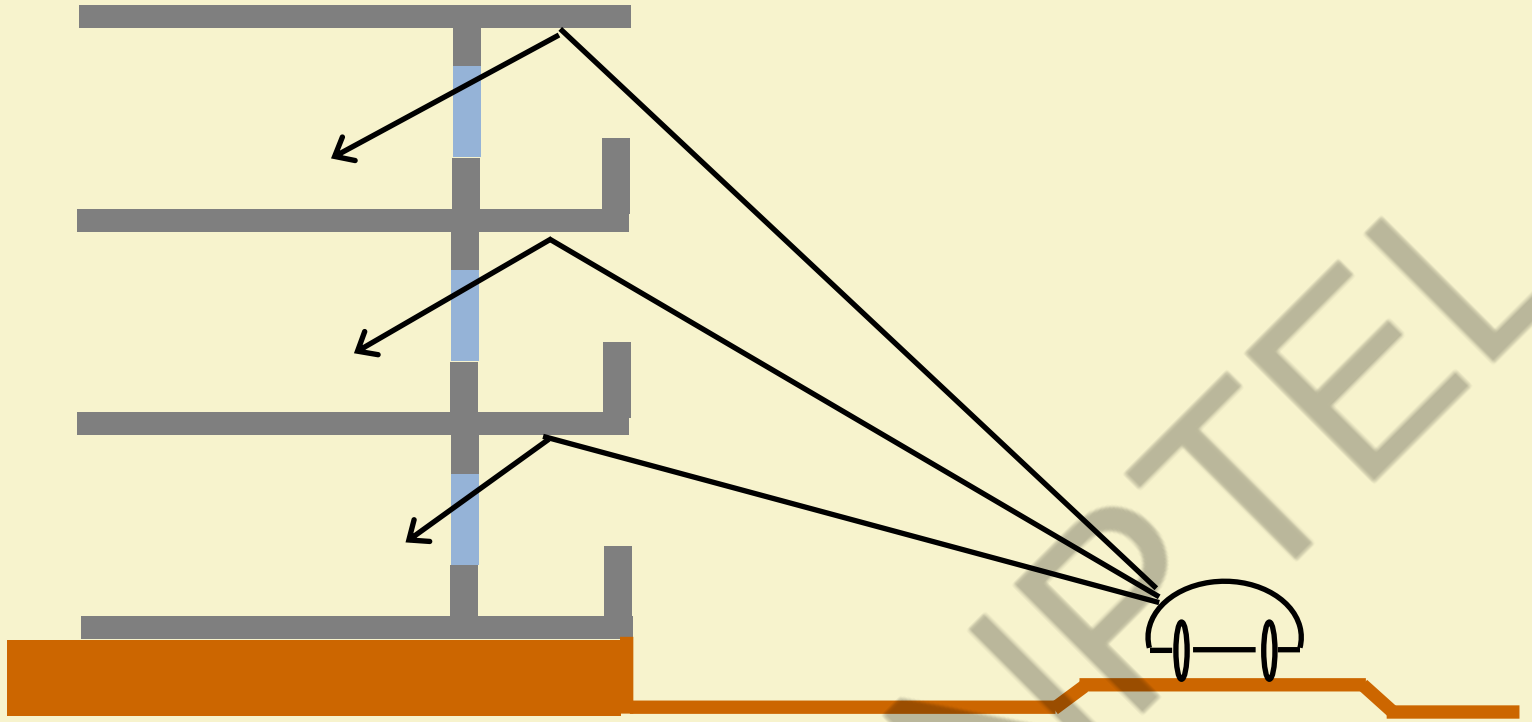
Road

A building block other side of Courtyard can be designed to host Noise Sensitive Space

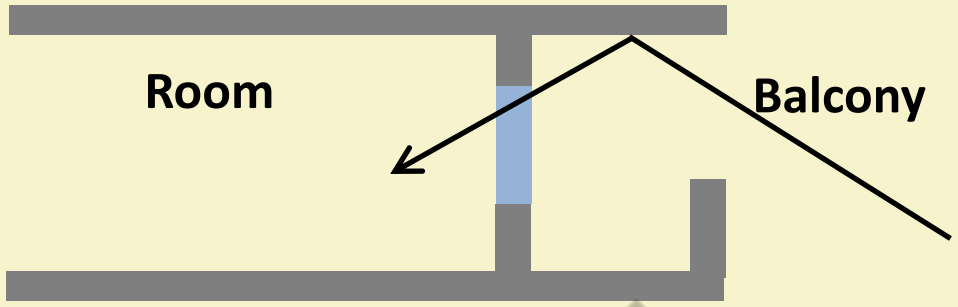


Road

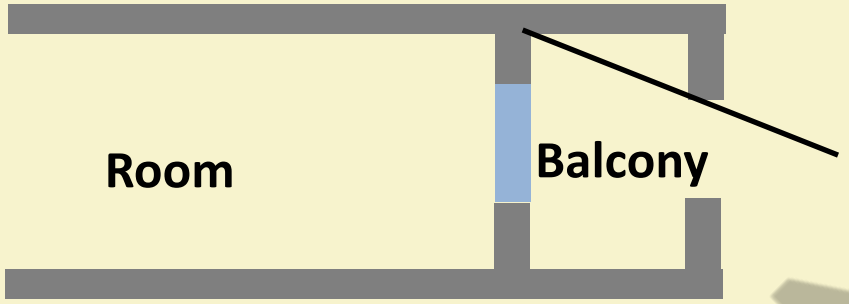
Balcony Protection



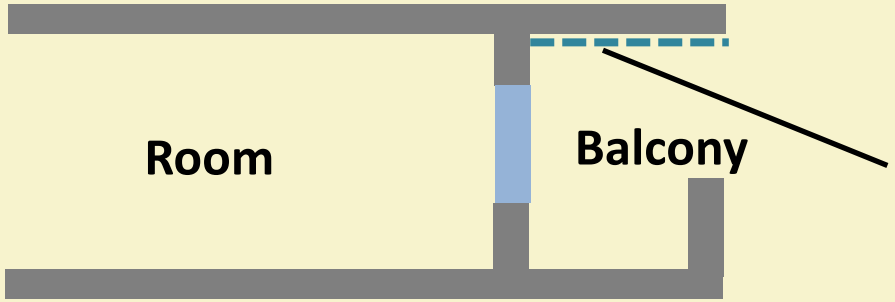
Balcony Protection



SOLUTIONS



Vertical down projection
Cut off the sound from reflection entry



Sound Absorptive Board in the Soffit of the balcony ceiling, do not allow the sound to reflection entry

Acceptable Indoor Noise levels for Various Buildings as per NBC-2016

Location	Noise Level dB(A)
Auditoria and concert halls, Radio and TV studios	20-25
Cinemas, Music rooms	25-30
Apartments, hotels and homes Hospitals, Conference rooms, small offices and libraries	35-40
Court rooms and class rooms	40-45
Large public offices, banks and stores	45-50
Restaurants	50-55

Sources of Plumbing Noise:

- Turbulent Flow of water
- Water Hammering caused by sudden interruption of flow due to entrapped air
- Pump Noise
- Loose / defective plumbing fixtures [water drops from tap]
- Flow noise from drains – bathroom floor, sink, toilets rain water pipe
- Overflowing of water from Tank

Precautions from Plumbing Noise:

Separate or acoustically conceal noisy areas (Bathroom, Toiler, Kitchen) from the quite noise sensitive areas.

Reduction of air-borne Sound Transmission: Use of masonry partition wall (in place of light weight walls) between toilets and other rooms.

Minimize Structure-borne sound Transmission : Wrap the Main pipe along the wall (must in case of light weight partition wall) with resilient material like Felt sheet, rubber , mineral wool.

Precautions from Plumbing Noise:

To minimize the noise from turbulent flow and water-hammer effect, conceal the pipe line into masonry wall / for exposed pipeline concealed it into small shaft or duct.

In high rise buildings pressure valve, flow regulatory valves are to be concealed within a shaft.

The sanitary lines must conceal into a masonry duct . The operating door to the duct should be air-tight through some gasket arrangement.

Regular maintenance of plumbing and sanitary system is highly necessary.

Sources of Air Conditioning System Noise:

- Noise from Mechanical equipment in Central Unit
- Air flow generate noise in duct
- Fan noise in duct
- Noise from grilles and diffusers
- Air-borne sound transmission from source to receiving room through duct

Precautions from Air Conditioning System Noise:

Division of ducts in several branches to minimize the source noise [but the overall installation and maintenance cost will be higher]

Keeping noise sensitive rooms with a large vertical and horizontal separation from AHU

Support the duct by resilient hanger.

Use gypsum-board enclosure out side the duct.

Introduce a air-space between duct and the enclosure

Precautions from Air Conditioning System Noise:

Provide Gradual reducer from the main duct to branch duct. Do not provide single step reducer.

Provide acoustical absorptive material layer inside the duct

Use streamline shaped grilles at discharge end with slow air velocity.

In highly noise sensitive rooms ducts can be fixed with silencers.

Air Conditioning Unit Noise

Air Conditioning Unit Noise

Public Address System

Introduce license system to use loudspeakers or public address system for any occasion.

Restriction of using public address system and loudspeakers during night between 9 p.m. to 6 a.m. except in closed premises.

Loudspeakers should be directed at the audiences and not away from audience (i.e. not towards the neighbourhood).

The permitted strength of power amplifier should be just adequate to cover the audience, and noise level beyond the boundary limit of the noise source.

Premises should not be increased by more than 5 dB(A) above the ambient noise level.

Construction Activities

The maximum noise levels near the construction site should be limited to 75 dB(A) L_{eq} (5 min.) in industrial areas and to 65 dB(A) L_{eq}(5 min.) in other areas.

Acoustic barriers should be placed near construction sites.

There should be fencing around the construction site to prevent people coming near the site.

Materials need not be stockpiled and unused equipment to be placed between noisy operating equipments and other areas.

Constructing temporary earth bund around the site using soil

Burning of Crackers

Manufacture and sale of crackers having an impulsive noise having an impulsive noise of more than 90 dB at 5 meters distance from the site of bursting should be banned.

Bursting of crackers during night between 9 p.m. and 6 a.m. should be banned.

Bursting of crackers may be permitted only during public festivals.

Home Work

Take an example of an old age home located at the edge of a busy urban road. Prepare a schematic layout plan considering outdoor noise mitigation

Prepare a checklist for control air-condition plant noise

Bibliography

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3. **Requirement and Procedure for Monitoring Ambient Noise Level due to Aircrafts,** Central Pollution Control Board, Delhi,20108
4. **National Building Code of India 2016 (Volume 2),** Bureau Of Indian Standards, New Delhi

End of Lecture 40: Urban Noise Control: Architectural Consideration