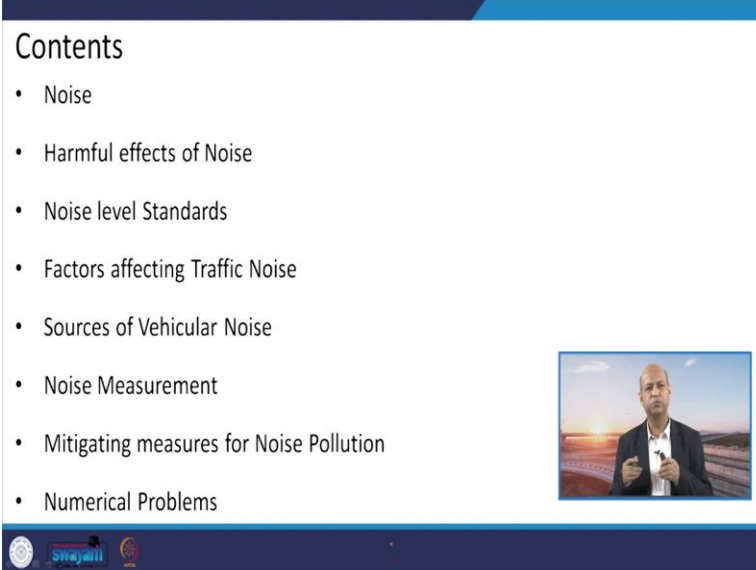


Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Engineering
Indian Institute of Technology Roorkee
Lecture 10
Impacts of Transportation Systems - V

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Contents

- Noise
- Harmful effects of Noise
- Noise level Standards
- Factors affecting Traffic Noise
- Sources of Vehicular Noise
- Noise Measurement
- Mitigating measures for Noise Pollution
- Numerical Problems

Hi friends, so in the series of impacts of the transportation systems, now we will look into the impact through noise of the transportation activities, that is also one big part of impacts of the traffic and activities of the transportation. So, these are the contents for today's this lecture, we will see what is noise everybody knows, but still we will see how noise is defined and then what are the harmful or negative impacts or effects of the noise.

And what are different standards which we measure that this noise is acceptable and this must is not acceptable and then what are different factors which affect the traffic noise or vehicular noise and how do we measure them or then what are the ways to mitigate or reduce the noise like barriers etc., we will see and a few numerical problems have also been incorporated, I think you will find them interesting to hand to do hands on practice to measure the noise related parameters.

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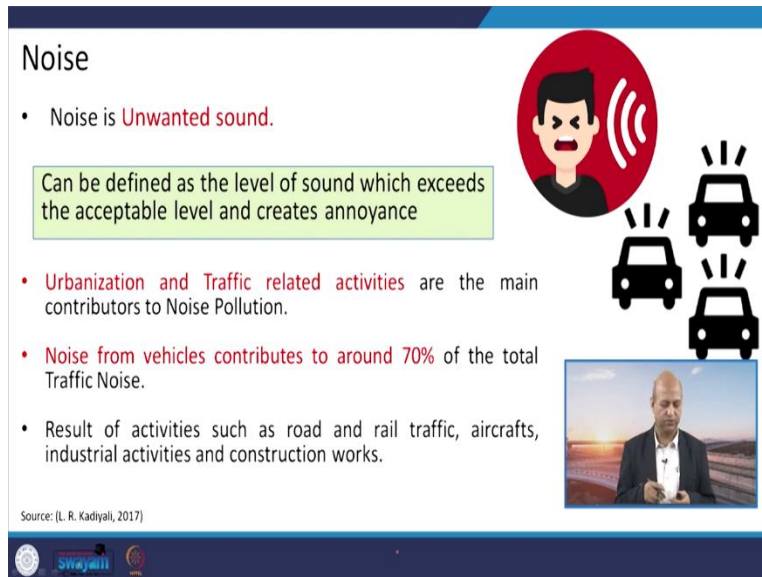
Noise

- Noise is **Unwanted sound**.

Can be defined as the level of sound which exceeds the acceptable level and creates annoyance

- **Urbanization and Traffic related activities** are the main contributors to Noise Pollution.
- **Noise from vehicles contributes to around 70%** of the total Traffic Noise.
- Result of activities such as road and rail traffic, aircrafts, industrial activities and construction works.

Source: (L. R. Kadiyali, 2017)



Well, any unwanted sound is noise as it is said, but in old days there was an ad on TV one anecdote I would like to share with you that they used to have this kind of advertisement that owners' pride and neighbour's envy something like that, so noise also is like that sometimes a particular kind of frequency and particular kind of wavelengths of the sound some people enjoy they call it music and for others it may be irritating thing or noise.



So, that way noise definition is also a little bit different, but of course in terms of energy means a beyond a level of some pitch or something which is harmful for our eardrums then whether it is music lover or other that will influence our total system of hearing and feeling.

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Harmful Effects of Traffic Noise

The negative effects of Noise can be categorized into three major groups:

- Subjective effects
- Behavioral effects
- Physiological effects



Source: (L. R. Kadiyali, 2017)

So, there may be effects, symptoms of subjective and behavioral effects also interpersonal behaviour and physiological impacts may be or effects may be there, which damages our certain parts of the body or which creates some sort of diseases or illness. For example, we may not be able to sleep, if there is a lot of noise and when you are not sleeping properly your whole system becomes of very low efficiency.



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Harmful Effects of Traffic Noise

Subjective effects

- Can be described by terms such as **Annoyance, disturbance, or noisiness.**
- **Difficult to be measured precisely**, as different subjects perceive a “disturbing or annoying” level of sound differently.

Noise level which is annoying or disturbing for some subjects might be comfortable for some other groups.
(Music Vs Noise)



Source: (L. R. Kadiyali, 2017)

So, the subjective effects are like some sort of annoyance, some sort of disturbances, but it depends on the person to person, so as I wrote here music versus noise means there are certain kinds of

music like rock and lot of drumming and those kinds of things are there, and people enjoy it, but for other people it may be kind of very chaotic situation, they do not like it, they call it, it is not music but noise. So, from person to person, it depends, how do you feel that particular sound note, whether it is rhythmic, or whether it is completely out of beat and it is for your liking or not all those things are subjective.




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Harmful Effects of Traffic Noise

Behavioral effects

- Behavioral effects of Noise are related to its **interference with speech, sleep or any other tasks performed.**

Disturbance in sleep is common in high Noise areas, such as dense traffic areas or near railway tracks or airports.



Source: (L. R. Kadiyali, 2017)



But then behavioral also like we get irritated and if there is a lot of noise in the background we have to shout to communicate our things, so a lot of interference is there in the speech, also like sleeping pattern, our sleeping behaviour can be disturbed by a lot of noise around us, so that is why nowadays people have a good windows which have these insulation effects those kind of glasses people use, and it is otherwise difficult to perform our tasks, for example we are studying or we are doing some other work and irritating noise is there, so we cannot focus on that. So, that is very negative impact, so we do not need the disturbances caused by the noise.

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Harmful Effects of Traffic Noise

Physiological effects

- Physiological effects of Noise are those that can cause a **sudden shock or frightening effect**.
- May **cause harmful effects on various parts of the body, e.g., headache**.
- Exposure to extremely high level noise for longer duration **can even cause deafness**.





Source: (L. R. Kadiyali, 2017)

Of course, physiological effects may be there because it can induce or cause the headache or some other problems heartbeats or blood pressure etc., maybe induced by these kinds of environment where lot of noise is there.

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Harmful Effects of Noise on Human Beings

- **Interferes with speech.** (Ex. A person may not be able to follow or understand what the other person might be saying)
- **Emotional and Behavioral Stress.** (Ex. A person might feel disturbed or stressed due to annoying sounds)
- **Permanent hearing loss.** (Ex. Continuous and prolonged exposure to large noise can severely impact human eardrum)
- **Potential to cause diseases.** (Ex. Headache, blood pressure, heart failure etc.)
- **Potential to cause disturbing health effects.** (Ex. Increased heart beat, constriction of blood vessels, dilation of pupil etc.)
- **Problematic for patients** who needs rest.
- **Potential to damage** liver, brain and heart.



Source: (Prof. Anil Kumar, IIT Roorkee)

So, in nutshell you can list them like it can interfere with the speeches, because when we are talking to someone then we are not hearing or we are not able to communicate properly and emotional and behavioral stress maybe there, a person might feel disturbed and stressed up due to annoying sounds and or you might be finding that person very polite, but on a particular day you will find

that he is not so in happy mood is, a little bit annoyed, so maybe he is coming from some annoying atmosphere where his mental state has been affected.


So, that way means even permanent hearing loss may be there if you are exposed to very high level of noise continuously, so our drums may be damaged and it may be difficult to regain that kind of stage where you can hear properly, all sorts of those noise or sound related and that spectrum which we are naturally able to listen or hear. So, there may be problems for like patients etc., who are in the need of rest and if there is a noise they cannot rest and then they can also damage our liver or heart or brain depending upon what is our health condition, and how much noise level we are exposed to.

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Noise Level Standards

| S. No | Area description | Noise level in dB(A) | | | |
|-------|---|-----------------------|-------------------------|------------------------------|--------------------------------|
| | | FHWA | AASHTO | CPCB, India | |
| | | | | Day time (6.00 AM – 9.00 PM) | Night time (9.00 PM – 6.00 AM) |
| 1 | Sensitive areas such as Parks, schools, hospitals, and silent zones | 60 | 55-60 | 50 | 40 |
| 2 | Residential areas | 70 (Interior max. 55) | 70 Exterior 55 Interior | 55 | 45 |
| 3 | Mixed areas | 70 | 70 | --- | --- |
| 4 | Commercial areas | 75 | 75 | 65 | 55 |
| 5 | Industrial areas | 75 | 75 | 75 | 70 |

FHWA: Federal Highway Administration (USA)
AASHTO: American Association of State Highway and Transportation Officials (USA)
CPCB: Central Pollution Control Board (India)



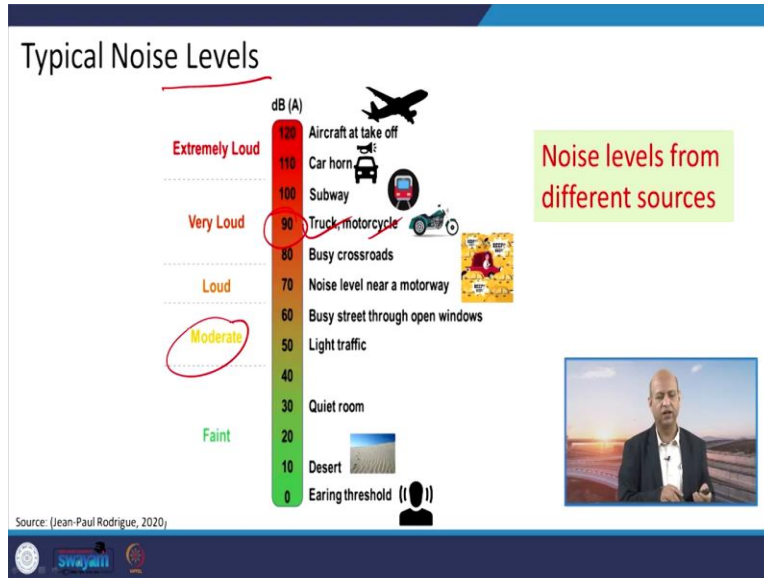
Source: [Prof. Anil Kumar, IIT Roorkee]

Well, if we compare the standards we in India have very good standards in comparison to other for example one is Federal Highway Administration of USA, this one and another one is American Association of State Highway and Transportation Officials, they also have certain standards, almost it is same basically. But in India, we have better standards means we allow only the lower level, but unfortunately as you know people say that we are very good in having laws, regulations, but implementation is not so good.

So, that is why even at the nights when those hours were noise is not permitted, even by the court's orders but people you know our behaviour is that we sometimes do not care, so that is not good

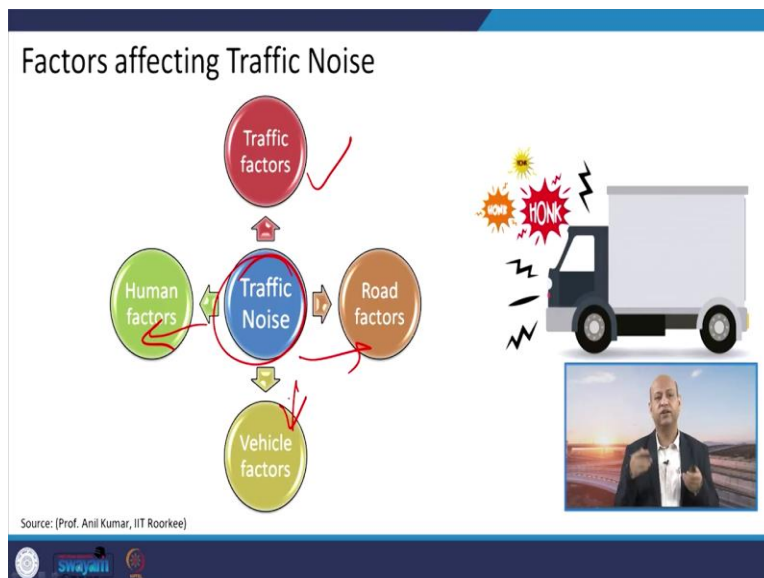
thing, but this is part of our life and we have to really learn to respect our laws and we should not increase the background noise or in the environment, which is beyond the permissible limits.

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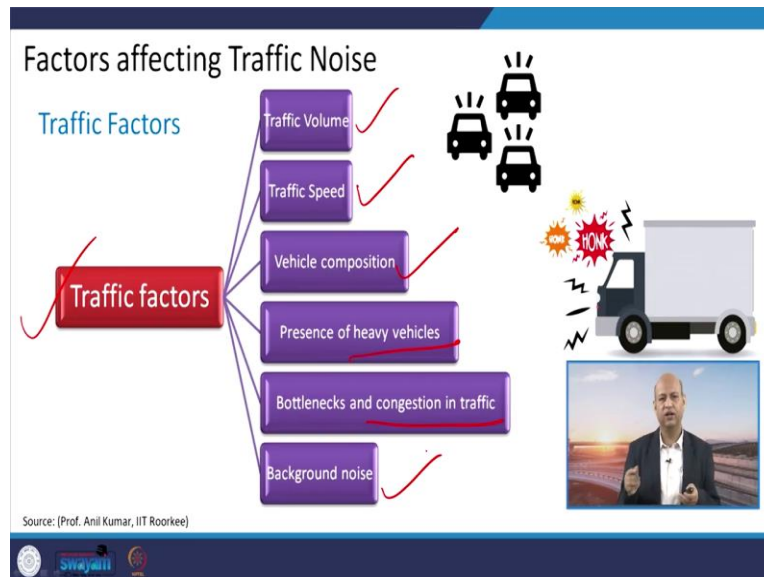
Here are some levels which you can relate with different activities, for example, in our truck or motorcycle when it is going through and making a particular sound level that is known as very loud, it is around 90 decibels, so that is a unit of the noise and the light traffic will cause only moderate quiet room it is very means calm and that is very very nice, so different kind of activities are linked with different levels of sound or noise.

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Then if you want to understand in terms of what are the factors which cause the noise, so the traffic related factors may be there, and this means we are talking about traffic noise, so traffic noise also has different factors, traffic related, then human related factors, than road factors, surface etc., we will see and then vehicle that condition of the vehicle or type of the vehicle those are also the factors, so these four factors will contribute to the traffic noise.

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So, if you want to see like traffic factors, so we can further classify them in terms of like traffic volume, if lot of traffic is there and some people are honking or some even you know other noise levels may multiply or it can add into higher level of noise. Similarly, traffic is speed related noise means higher speed, because of certain parts or window vibrations etc., passengers may feel a lot of noise.

Then vehicle composition also can contribute to different types of noises. And also like heavy vehicles' presence or there are congestion, so again a lot of honking and disturbances and also it can add to the background noise. So, if already background noise is there, then the traffic related factors will add into it and the noise level will increase.

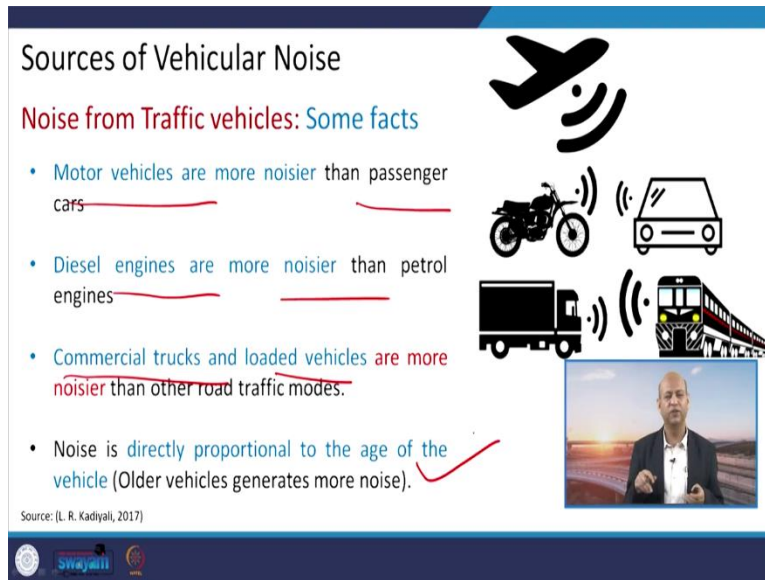
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Sources of Vehicular Noise

Noise from Traffic vehicles: Some facts

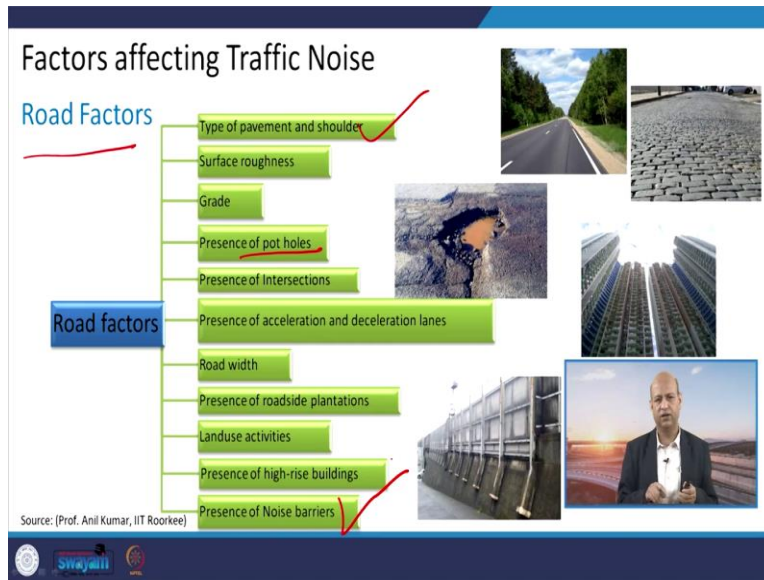
- Motor vehicles are more noisier than passenger cars
- Diesel engines are more noisier than petrol engines
- Commercial trucks and loaded vehicles are more noisier than other road traffic modes.
- Noise is directly proportional to the age of the vehicle (Older vehicles generates more noise).

Source: (L. R. Kadiyali, 2017)



So, these are some facts related to traffic factors. For example, motor vehicles are noisier than passenger cars, diesel engines are more noisier than petrol engines, although a lot of research has gone and even diesel engines nowadays are quite, very calm nowadays, but still means petrol engine and diesel engines working is different and diesel engine makes more noise or more sound. Similarly, commercial trucks, loaded vehicles heavy vehicles, etc., they will make a lot of noise, there will be very high friction between road and tyres, so that contribute to the noise. Similarly, age of the vehicles, when parts are loose, vibrations are more, so again the noise level may increase.

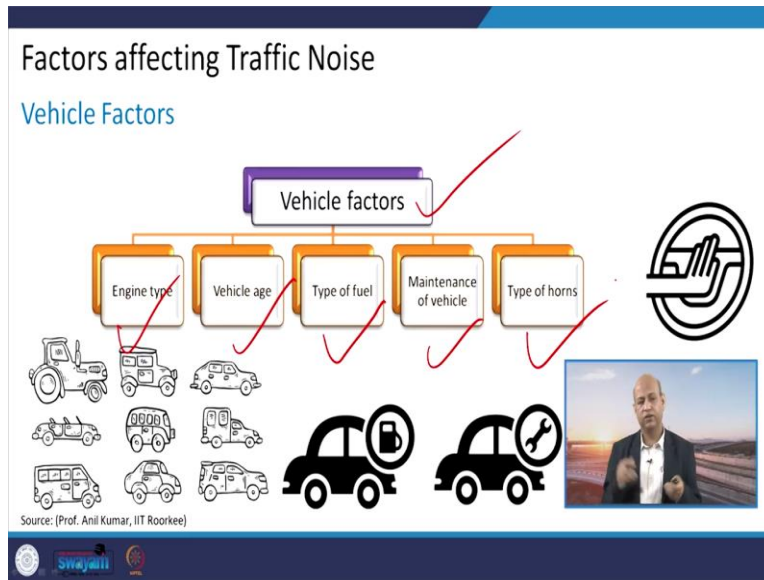
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If we talk about the road factors, then again condition of the road, its type of pavement and the shoulders, surface roughness, all these will add into the noise or sound levels, what kind of grade it is and if there are potholes, then there will be jumping and breaks and all those kinds of screeches, they will add to the noise or sound levels. Then if there are intersections, so lot of change in the speed and gear all these activities may contribute to the noise.

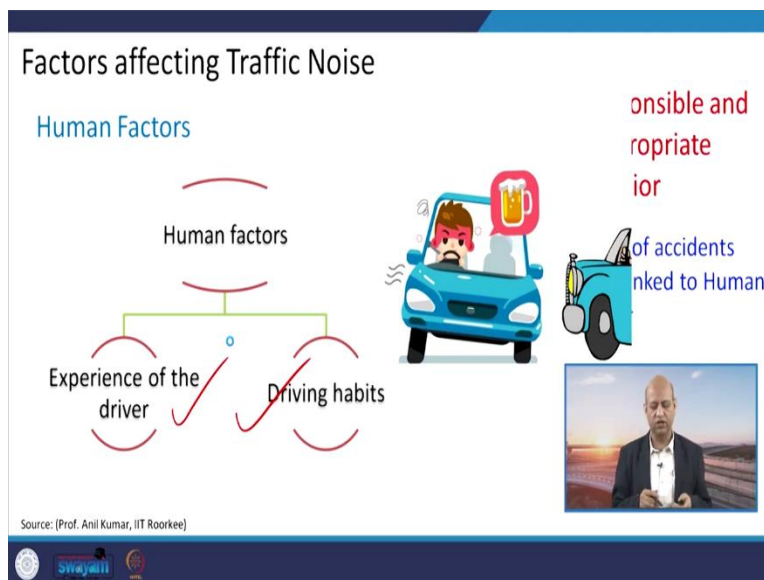
How much width of the road is there, so that will decide congestion happens or not and then there are other parts like noise barriers, if there are noise barriers then maybe the people on the other side they may not face a lot of noise because barriers will reduce the noise level. We will see how it is reduced by barrier levels.

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Then there are vehicle factors. So, engine type as we have seen, vehicle age or type of fuel, maintenance of the vehicle, type of horns, some people have very loud horns, so it is quite a very high pitch and high sound and it is very irritating sometimes you know, when you are thinking and walking on the road and some vehicle comes and they push horn very loud level you feel completely shocked what happens what has happened.

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Then human factors like driving habits some people apply brakes very frequently or they have habit of honking although in the European countries or you go developed countries like Germany,

Japan etc., the traffic is calm there you know passengers behaviour is totally different and honking is not allowed and it is assumed as very bad behaviour.

But here our behaviour is quite different and we are habitual of honking and all those things, so they contribute to the noise, and experience of the driver means if driver is very experienced he knows when to apply brake, when to not, when to change the gear etc., so the noise level can be reduced accordingly.

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The infographic is titled "Factors affecting Traffic Noise: Human Factors". It features a blue header and a main content area with several statistics and illustrations. A red circle highlights the text "90% of accidents are linked to Human error".

90% OF ALL ROAD ACCIDENTS ARE LINKED TO HUMAN ERROR
THE BEHAVIOUR OF ROAD USERS IS THE AREA WITH BY FAR THE BIGGEST POTENTIAL FOR IMPROVING ROAD SAFETY

- IN 30% OF FATAL ACCIDENTS SPEEDING IS THE MAIN FACTOR** (Illustrated with a speedometer and a 30 km/h sign)
- DISTRACTION CAUSES 10-30% OF ROAD DEATHS** (Illustrated with a driver looking at a mobile phone)
- 25% OF ALL ROAD FATALITIES IN EUROPE ARE ALCOHOL-RELATED** (Illustrated with a hand holding a green bottle)
- ABOUT 65% OF FATAL ACCIDENTS ARE CAUSED BY VIOLATIONS OF TRAFFIC RULES** (Illustrated with a car running a red light)

EDUCATION AND TRAINING ARE CRUCIAL IN INSTALLING APPROPRIATE BEHAVIOUR AND ATTITUDES IN ROAD USERS (Illustrated with a person at a presentation board)

CRACKING DOWN ON TRAFFIC OFFENCES WILL MAKE A DIFFERENCE (Illustrated with a hand holding a gun pointing at a car)

Source: (<https://www.intechopen.com/books/noise-and-environment/traffic-noise>)

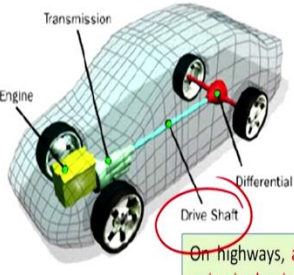
Human factors again like because of these different kinds of behaviour or irresponsible and inappropriate behaviour, they can contribute into accidents. So, the human factor is very, very important because if you are not in a healthy mental framework, and if you are not driving properly, then it can cause accidents, it can harm yourself, it can harm other people.

So, the 90 percent of accidents are linked to human error, means of course there are contributing factors of other things like potholes and bad road or some poor signage etc., but still the human alertness may prevent all those things. So, human error is the predominant factor into causing traffic accidents etc.

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Sources of Vehicular Noise


Noise from Traffic vehicles on Road



Two major sources from vehicles:

- **Power plant and Transmission Noise** sources: Engine, exhaust, intake, cooling system etc.
- **Running gear Noise** sources: Tyre-road interaction, differential and propeller shaft etc.

On highways, at lower speeds, Engine-exhaust noise is dominant and at higher speeds, noise from road-tyre interaction becomes dominant sources



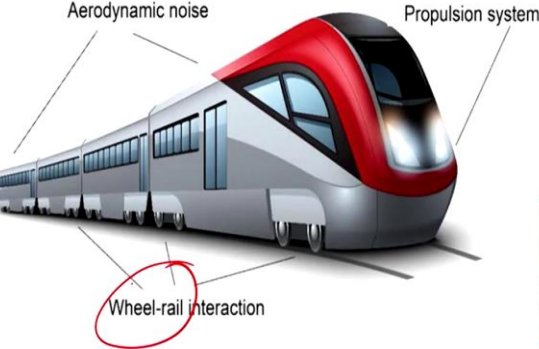
Source: (Prof. Anil Kumar, IIT Roorkee)

And the noise is one of the important factor to change the human behaviour, because if somebody is not calm and cool irritated by high noise level, so his responses and reflexes will not be proper and that will result into some accidents. And if you see these traffic vehicles on the road how these noise is generated, so you can see this drive shaft, which is rotating and then the gear system, transmission of the energy and the friction with the road of the these tyres etc., and the type of the road tyres interaction, they all contribute to the sound level.


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Sources of Vehicular Noise

Noise from Traffic vehicles on Rail

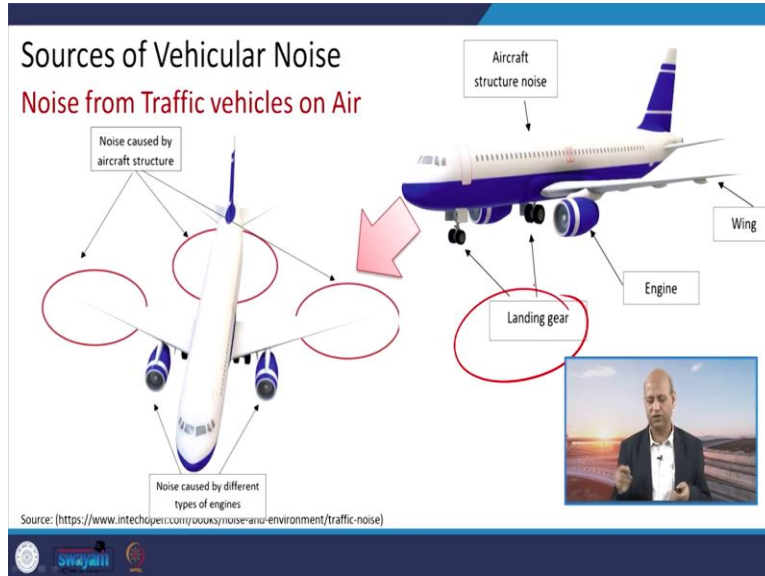


Source: (<https://www.intechopen.com/books/noise-and-environment/traffic-noise>)



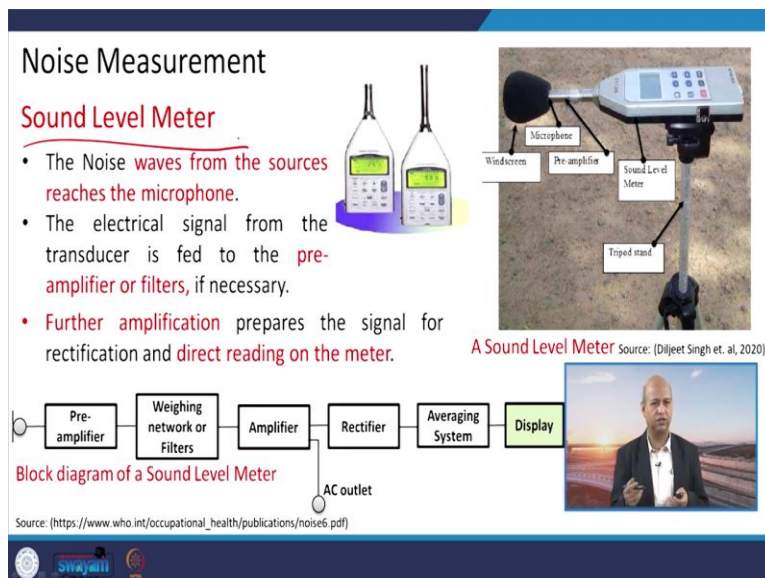
Similarly, like aerodynamics noise because when air is striking or hitting the body and that body also then release some sort of noise, so the propulsion systems and the wheel and road interaction like in case of car or in case of these road vehicles, the interaction of wheel and road is there, so that cause noise, similarly in trains the wheel and rail they also cause, they also produce some sort of noise.

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In air traffic also again engines and then these landing gears all lot of noise is produced because of jet engines, it is very high noisy environment outside.

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And that is why sometimes near airports or aerodromes the property rates are not so high, some people do not want to live there, because of this noise and they do not find as a healthy condition to live. So, all these things sometimes increase or decrease the property prices depending upon what kind of facilities we are having around us.

Well, then how to measure the noise because when we want to reduce the noise, then we should measure it first and compare with the standards, so there are instruments they like sound level meters, they can measure the noise and there are different units of the noise measurement, we will see in later slides.


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Noise Measurement

Acoustic Arrays



- Number of microphones are arranged in various patters.
- Omnidirectional
- Can receive sound from a wide range of area.



Source: (Prof. Anil Kumar, IIT Roorkee)

swayam

Then these kind of acoustic arrays are used for capturing the noise in and around of a particular site location, so these kind of several sensors can be used for catching the sound, a wide range of a spectrum of the sound.

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Noise Measurement


DeciBel (dB)

- Sound pressure level (SPL) or acoustic pressure level is a logarithmic measure of the effective pressure of a sound relative to a reference value.
- SPL, denoted by L_p and is measured in decibels (dB).

$$L_p = \ln \left(\frac{p}{p_0} \right) N_p = 2 \log_{10} \left(\frac{p}{p_0} \right) B = 20 \log_{10} \left(\frac{p}{p_0} \right) \text{dB}$$

Where,
P = root mean square sound pressure
 p_0 = reference sound pressure
1B = 10 dB

The commonly used reference sound pressure in air is $p_0 = 20 \mu\text{Pa}$, which is considered as the **threshold of human hearing** (roughly the sound of a mosquito flying 3m away)



Source: (Prof. Anil Kumar, IIT Roorkee)

As you know, decibel is the unit and then if you want to convert the sound pressure level, the sound pressure level, so you can this SPL can be measured or denoted by L_p and L_p can be represented by the ratio of the this square sound pressure and reference sound pressure.

$$L_p = \ln \frac{p}{p_0} N_p = 2 \log_{10} \frac{p}{p_0} B = 20 \log_{10} \frac{p}{p_0} \text{dB}$$

So, root mean square of the sound pressure of different ranges and then the reference sound pressure means a reference sound pressure is also there like here this 20 micro Pascal, so, that ratio will decide how much this SPL value is there.

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Noise Measurement

Equivalent continuous Noise level (Leq)

Leq is the preferred method to describe sound levels that vary over time, resulting in a single decibel value, which takes into account of the total sound energy over a period of time of interest.

- Noise levels fluctuates over a wide range with time.
 - Ex. Sound levels fluctuates over a period of 24 hours, going as low as 30 dB(A) at night time, rising to 70 dB(A) with passing of occasional vehicles and to higher levels in day time.

How to measure an overall value for all these noise levels ?

Answer to the question is the "Equivalent continuous Noise level meter (Leq)"

Source: (Prof. Anil Kumar, IIT Roorkee)



Then we also convert it into some other units like Leq equivalent continuous noise level, because noise fluctuates from one level to another like wind direction fluctuates or wind velocity fluctuates similarly this noise is also one energy and this energy fluctuates from low to high middle something like that. So, some of them average them out not automatically very simply average that is logarithmic and then sum them up as equivalent noise means, like fluctuating noise is there for let us say one hour and if you measure a Leq means if that level of noise is for one hour, then the same energy is there.

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Noise Measurement

Equivalent continuous Noise level meter (Leq)

- Equivalent continuous Noise level meter reads all the fluctuations over a period of time, stores them in its memory and at the end of measurement, calculates an "Average energy" or "Leq value".

The "average" values are not arithmetic average, as we are measuring sound, in decibels, which are logarithmic values.

- The decibel (dB) values are converted to Sound pressure levels (SPL), adds these values and then divide by the number of samples and is finally converted back the equivalent level to decibels (dB).

Source: (Prof. Anil Kumar, IIT Roorkee)



So, this is basically the representation of the equivalence of the energy level.

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Noise Measurement

Equivalent continuous Noise level (Leq) Calculation

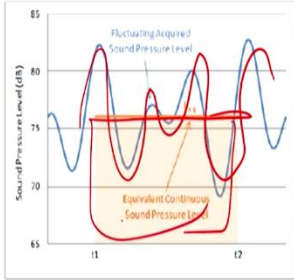
- Equivalent continuous Noise level

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2}{p_0^2} dt \right]$$

where,

- L_{eq} = equivalent continuous sound pressure level in dB
- p_0 = reference pressure level (typically 20 μ Pa)
- p_A = acquired sound pressure
- t_1 = start time for measurement
- t_2 = end time for measurement

The equation divides the integrated, normalized sound pressure by the duration of interest of the signal. The result is expressed in decibels:



Source: (Prof. Anil Kumar, IIT Roorkee)

And here it is very nicely represented.

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2}{p_0^2} dt \right]$$

Like it is these kind of noise levels are fluctuating and we if you calculate this Leq, so, this much of energy is equivalent to that energy which is being given by fluctuation of the sound.

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Noise Measurement

Energy Average (Effective or rms sound level), Lrms Sound level

Equivalent Continuous sound level (Leq) the steady sound level of a noise energy-averaged over time

Energy-average

The energy-average (effective or rms value) of sound level is:

$$L_{rms} = 10 \log_{10} \left\{ \frac{1}{n} [10^{L1/10} + 10^{L2/10} + 10^{L3/10} + \dots + 10^{Ln/10}] \right\}$$

Example:
The averages of three sound levels 88, 93 and 97 dBA are:

Arithmetic Mean: $L_{mean} = \{88 + 94 + 97\} / 3 = 93$ dBA

Energy-average: $L_{eq} = 10 \log_{10} \{[10^{8.8} + 10^{9.4} + 10^{9.7}]^{1/3}\} = 94.3$ dBA

Source: (Prof. Anil Kumar, IIT Roorkee)

And you can see some examples like you can try them at leisure, so very simple numerical problems are there for energy average means you convert the sound level into energy and then

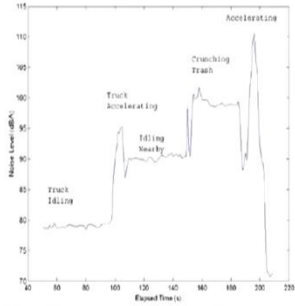
back energy to the sound level, then you can get what is this decibels, how much decibels are there because of contribution from one source to another.

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Noise Measurement

A-Weighting, dB(A)


A-weighting cuts off the lower and higher frequencies that an average person cannot hear



- Most common weighting used in Noise measurements.
- Unit of measured A-weighted values are expressed as dBA or dB(A).

Sound Level Meter reading vs time for a passing truck dBA or dB(A)

Source: (Prof. Anil Kumar, IIT Roorkee)



Similarly, A-weighting is very important because beyond a limit we do not hear and those kind of cut off sound levels are removed and A-weighting is done.

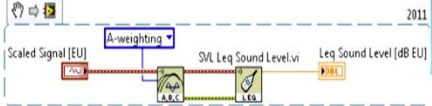
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Noise Measurement


A-Weighting, dB(A)

The human ear responds more to frequencies between 500 Hz and 8 kHz and is less sensitive to very low-pitch or high-pitch noises.

- Equivalent continuous A-weighted sound pressure level is commonly used to measure noise levels in loud environments.
- Imitates the hearing profile of the Human ear.
- The frequency weightings used in sound level meters are often related to the response of the human ear, to ensure that the meter is measuring pretty much what you actually hear.



Source: (Prof. Anil Kumar, IIT Roorkee)



So, this dB(A) is also one way of representing the sound pressure levels from our human ear response viewpoint, because between this only we hear here 500 hertz to 8 kilohertz.

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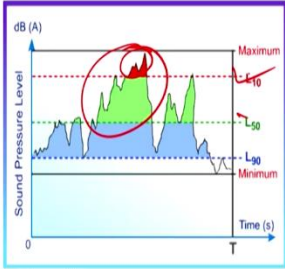
Noise Measurement

The n-Percent Exceeded Level, L_n

- The n-percent exceeded level, L_n , is the sound pressure level exceeded for n% of the time.
- The fluctuating sound pressure levels are higher than the L_n level.

$$L_{10} > L_{50} > L_{90}$$

- L_{10} : The sound level exceeded for 10% of the time. (Rest of the time, the sound or noise has a pressure level at or below, L_{10}). Due to sporadic or intermittent events.
- L_{50} : The sound level exceeded for 50% of the time. Represents median or fluctuating noise.
- L_{90} : The sound level exceeded for 90% of the time. Represents background or ambient level of noise.



Source: (Prof. Anil Kumar, IIT Roorkee)






Then n percent exceeded level like L_n means, this much percent is exceeding that particular level is exceeding, so many times or so many percentage, for example this much is L_{10} means only 10 percent time this much of noise will be available in that particular measurement series. So, this is known as the L_{10} because the sound level exceeded for 10 percent of the time only.

So rest of the time the sound or noise has pressure level at or below that L_{10} , so this is L_{10} . Similarly, L_{50} means 50 percent of the time this is exceeding, so L_{90} is 90 percent of time. So, basically that is you can see background noise, because all the time that this much of level will be present, so L_{90} is less than L_{50} and L_{10} is highest one.

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Mitigating measures for Noise Pollution

- **Green plantations:** Planting bushes and trees around noise generating sources
- **Regular servicing:** Regular servicing and tuning of automobiles
- **Green Buildings:** Use of suitable noise absorbing materials for walls, windows and ceilings
- **Wearables:** Equipments such as ear plugs and earmuffs for hearing protection



Source: (Prof. Anil Kumar, IIT Roorkee)

swayamii



When we want to talk about mitigating noise pollution then we also should learn about different materials or different infrastructures which adds into reducing the noise like green plantation that is good for the environment as well as they also absorb the noise or they reduce the noise. Then regular servicing of the automobiles, because if you are not maintaining it properly, then some loose end parts will create the noise and engine or braking system etc.

Green buildings having suitable absorbing material for the noise on the walls and windows they are also in nowadays and wearables equipments like if you are working in a very noisy environment then better you apply some earplugs, otherwise you will be exposed to high level of noise and it will harm your physiological balances.

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Mitigating measures for Noise Pollution

- **Lubrication and regular servicing of machinery**, similar to automobiles
- **Policy regulations**: Policy measures to restrict use of loudspeakers in crowded and public areas
- **Soundproof materials**: Use of soundproof doors and windows to block unwanted outside noise.
- **Land use**: Factories and industries should be located far from residential areas



Source: (Prof. Anil Kumar, IIT Roorkee)


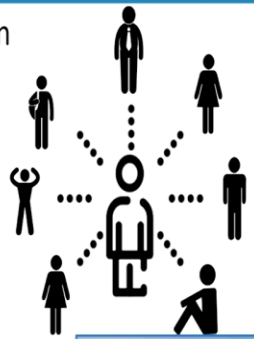
Logos: IIT Roorkee, Swayamii, and other institutional logos.

Also, we should apply lubrication and regular servicing of our vehicles or machinery and some policy regulations which are like loudspeakers, so if there is a law that beyond 10pm we should not use the loudspeakers, then we should use that policy and we should follow that law. If we are not following then we are basically adding to the noise level to other people also. And soundproof materials can be used, like as I said there are new windows which have very good material which absorbs a lot of sound and they do not allow to sound enter into the indoor environment.

(Refer Slide Time: 21:44)

Mitigating measures for Noise Pollution

- **Community development programs**: Community development or Urban management should be done with long term planning to reduce noise pollution
- **Social awareness programs**: To educate and to create awareness among public for long term noise reduction



Source: (Prof. Anil Kumar, IIT Roorkee)

Logos: IIT Roorkee, Swayamii, and other institutional logos.

And land use planning is also important because you should not plan any noisy activity near to like schools or hospitals, means sensitive communities, they should be kept off switch off these kind of noisy activities and there must be proper signage, so that people become alert and they should not use any honking kind of horns etc.

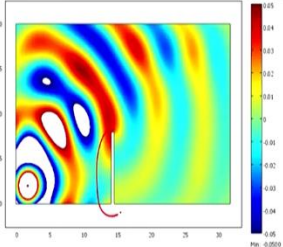
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Noise Barriers

- Noise barriers **reduce the sound level** by blocking the straight-line path from the source to the receiver.
- Noise **level can be reduced by about 5dB.**
- The noise levels can **further be reduced by 3 dB** by **forcing the sound to travel a longer distance** by making the barrier much higher.
- The combined effect (**noise reduction by 8dB**) is equivalent to reducing the traffic by a factor of 6.


Source: (Prof. E. Rajasekar, IIT Roorkee)

Barrier height $h = \lambda$



Diffraction over a Noise barrier varies with the ratio of barrier height (h) to wavelength (λ)

Source: (https://mypages.iit.edu/~muehleisen/acs_demos/diffraction/diffraction.html)

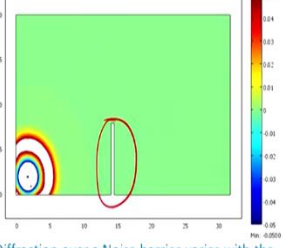


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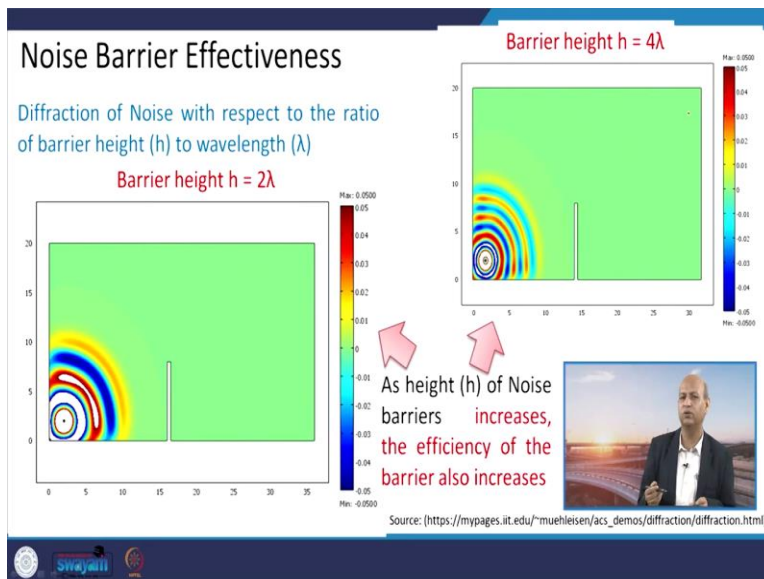
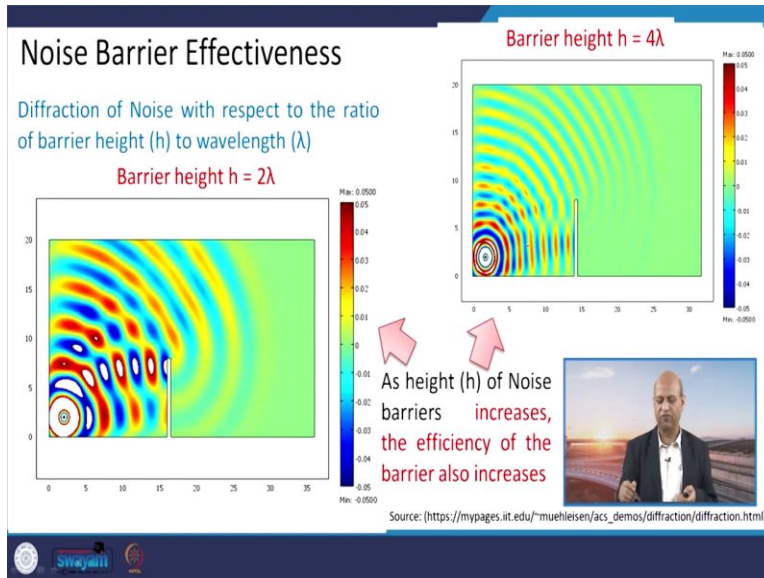
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Diffraction over a Noise barrier varies with the ratio of barrier height (h) to wavelength (λ)

Source: (https://mypages.iit.edu/~muehleisen/acs_demos/diffraction/diffraction.html)





Well, this is like one barrier means barrier how to use the barrier, for example this is the barrier here and as noise is going to this side, so it loses its energy because of barrier height and in next slide you will see that we increase the height of the barrier from this must to four times then how this energy level reduces because of different heights.

So, very low energy remains after a certain distance, so barriers contribute a lot of in reducing the noise and there is particular exercise of designing barriers depending upon the traffic noise level and traffic activity, frequency those kind of things.

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Noise Barrier Effectiveness

Noise Barrier heights Source: (CEDR, 2017)

- Min. permissible height: 1-2.5 m ✓
- Max. permissible height: 4-10 m or more if needed ✓
- Average height: 2-5 m (Most common)

The diagram shows a blue car on the left emitting sound waves. A red barrier is placed between the car and a yellow house on the right. The diagram illustrates the following paths: 'Incident' waves from the car, 'Reflected' waves from the barrier, 'Direct' waves from the car to the house, and 'Diffracted' waves from the top of the barrier to the house. The area behind the barrier is labeled 'Shadow Zone'. A small inset video shows a man speaking.


So, average height of the barriers is 2 to 5, but minimums generally 1 to 2.5 and maximum is 4 to 10 meter depending upon as like in cities on the highway, expressway or simple roads etc., you can see and if there is hospitals, then you need to have a very good barrier and there must be some signage that people should not honk there.

So, if you can increase the distance between the source of the sound and the receptor, so even naturally when the sound energy is traveling to it, it gets dissipated and it will reach in a very low value or low energy, so means it directly goes without barrier then for example this much is the distance, but if you are having this barrier then this will travel like this, so the total distance increases and the sound dissipation occurs more.


(Refer Slide Time: 23:49)

Noise Barrier: Examples

Timber acoustic fencing




Hedging, foliage



Good quality acoustic fencing will stay impermeate over time

Dense, deep foliage will provide some acoustic benefit but line hedges are ineffective



Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)


Swayamii

Similarly, the material also has important role for example, these hedges etc., they are porous and they are not able to reduce noise, so effectively and these kind of good quality acoustic fencing may be better rather than these simple hedges.


(Refer Slide Time: 24:12)

Noise Barrier: Examples

Brick walls




Green screens



Good, but expensive compared to timber fencing.

Gaps render green screens acoustically transparent




Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)


Swayamii

Similarly, these timber fencing is good, but if there are gaps then again because these rendered green screens they look nice, but they are not good in protecting yourself from noise.

(Refer Slide Time: 24:28)

Noise Barrier: Examples


Transparent acoustic screens (Glass or acrylic) 

Hit & miss fencing 

Good where visual amenity is important

Ineffective due to gaps


Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)




Similarly, because of gaps these hit and miss fencing is not so good, but if you have like visual kind of some screen of the glass or some acrylic or there are so many metal nowadays, they can even, you know do not stop this beauty of the surrounding area, so aesthetic value is also there and also you can reduce the sound levels.

(Refer Slide Time: 24:55)

Noise Barrier: Examples


Concrete 

Light weight metal fencing 

Low maintenance, but expensive.

Ensure minimum mass of 10kg/m^2 .

Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)



Well concrete structures maybe good in low maintenance kind of but they are expensive when we are constructing and I mean it is difficult afterwards when if you want to change the location

then it is very difficult. Some kind of lightweight metal fencing can also be there which can be used depending upon the seriousness of the site.

(Refer Slide Time: 25:25)

Noise Barrier: Examples

Bunding



Suited to larger projects where spoil can be used to form bunds.

Trellising



Ineffective due to gaps




Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)

But as because of due gaps these kinds of infrastructures are not good and but if there are kind of very high bendings and slopes, so again the distance will increase, so the very less noise will go to that side where people may be walking or cycling etc.

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Noise Barrier: Examples

Gabion walls




Important that the wall is thick and the aggregate is small to be acoustically effective.

Loosely lapped fencing



Some screening will be provided, but gaps will affect the performance. Gaps tend to increase over time.



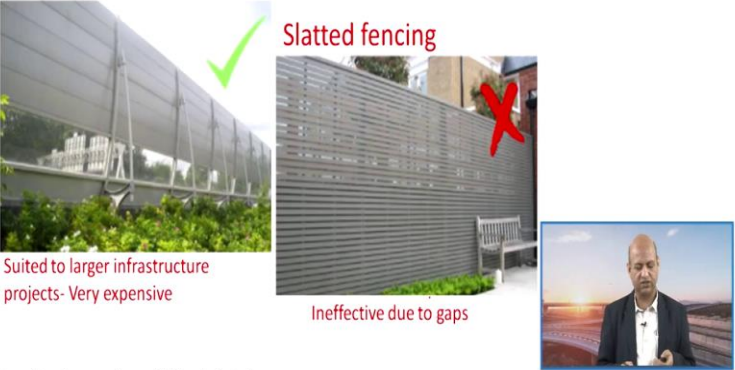
Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)

Similarly, again this wall thickness is good and that is a good solid wall with aggregate etc., that will prevent you from the noise, but these kind of screening with gaps will not help as we have seen.

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Noise Barrier: Examples

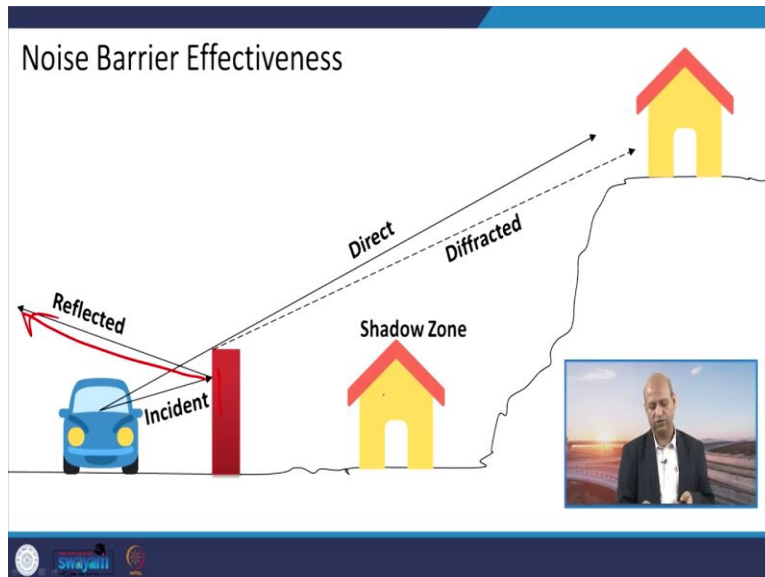
Fully bespoke/engineered solutions



Source: (<https://www.cassallen.co.uk/guide-noise-barriers>)

Similarly, these kind of structures are suitable and these slatted fencing are not suitable.

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So, again that effect as I know these reflectors these barriers also reflect the sound, so lot of sound goes away and only remaining one goes to the receptor. So, this is again we are showing to you.

(Refer Slide Time: 26:25)


Noise Barrier Losses

Transmission Loss ✓

- The transmission loss is the sound level that gets reduced, when it is forced to travel through the barrier.
- A 30 dB transmission loss means practically all (99.9%) of the sound is being blocked.

Insertion Loss ✓

- Insertion level is the difference in sound levels, if there were no barrier present and the resultant sound level after a barrier is installed between the noise source and the receiver.



Source: (Prof. E. Rajasekar, IIT Roorkee)

Well, noise barriers losses are there two types like transmission losses because of distance etc., it loses, sound loses the energy and this insertion losses, which are depending upon the initial sound and the sound which is reaching there, so that because of barrier presence that lot of difference is there, which is known as the insertion losses. So, these losses sum up and we get the net result of low sound.

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Insertion Loss and Fresnel Number


- Insertion loss (IL) is estimated by using the model proposed by Kurze and Anderson.

Insertion Loss, $IL = 5 \text{ dB} + 20 \log \left[\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}} \right] \text{ dB}$ for (N upto 12.5)

Insertion Loss, $IL = 20 \text{ dB}$ for $N > 12.5$

- N is the Fresnel Number, a non-dimensional measure of how much farther the sound must travel to reach the receiver, as a result of the barrier.
- N is calculated using the equation,
$$N = \frac{(a+b-l)f}{C_0}$$

where,
 l = original length of direct path from source to receiver
 a and b are the lengths of two straight line segments, comprising the path as modified by the barrier
 f is the sound frequency in Hertz (Hz); C_0 = speed of sound in air (approx. 1125 ft/sec or 343 m/s)



Source: (Prof. E. Rajasekar, IIT Roorkee)

Again how to calculate these insertion losses? So, a very simple empirical formulation is there, which you can use and you can practice at leisure.

Insertion loss, $IL = 5 \text{ dB} + 20 \log\left[\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}}\right] \text{ dB}$ for (N upto 1.25)

Insertion loss, $IL = 20 \text{ dB}$, for $N > 12.5$

$$N = \frac{(a+b-l)f}{c_0}$$

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Numerical problem

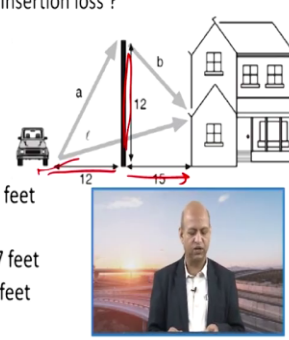
Question:
A 12 ft tall Noise barrier is installed 12 ft from the vehicle. A house is 15 ft beyond the barrier and has a window at a height of 4 ft. Calculate the Insertion loss ?

Solution:

The length of the original path of sound (l)

$$l = \sqrt{27^2 + 4^2} = 27.3 \text{ feet}$$

The length of the segments (a & b)

$$a = \sqrt{12^2 + 12^2} = 17 \text{ feet}$$
$$b = \sqrt{15^2 + 8^2} = 17 \text{ feet}$$


Source: (Prof. E. Rajasekar, IIT Roorkee)

It is very interesting to see that like 12 feet tall noise barrier is there installed, 12 feet from the vehicle, so this is the barrier 12 feet high, 12 feet away from the vehicle, 15 feet from the house, so how much energy losses will be there, and there is like a window of 4 feet height, so all these parameters you can use to calculate the total path length.

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Numerical problem

Solution (cont'd):

$$\text{Fresnel number, } N = \frac{(a+b-l)f}{C_0}$$

Hence,

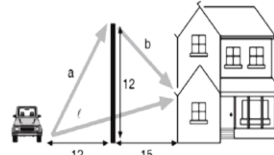
$$(a + b - l) = 34 - 27.3 = 6.7 \text{ feet}$$

At $f = 100$ Hz, the Fresnel number, N is;

$$N = \frac{6.7 \times 100}{1100} = 0.61$$

The Insertion loss (IL) can be calculated by:

$$IL = 5 + 20 \log \left[\frac{\sqrt{2\pi \times 0.61}}{\tanh \sqrt{2\pi \times 0.61}} \right] \approx 10 \text{ dB}$$



Source: (Prof. E. Rajasekar, IIT Roorkee)





And then how much energy losses will be there. So, this is kind of your homework.

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Conclusion

- Loud and regular exposure to Noise can have significant impacts on living beings including humans from slight disturbances to even death.
- Measures to reduce Noise emissions should be introduced from the planning stage of a project.
- Use of Noise absorbing materials such as trees and shrubs on road-sides, installation of noise barriers etc. can reduce the impacts of Noise.



And at last we conclude that these loud and regular exposure of loud noise to people working people, they can reduce your efficiency, they can make negative changes in the physiology, they can irritate us, they can change our behaviour and they can damage our health also. So, we should not allow noise levels very high in our surrounding.

And these noise emissions should be kept minimum as well as from the planning stage itself, we should be proactive in terms of using certain materials, which reduces the noise and maybe we can use some structures and barriers, we can design them according to the need of the that location and we can make the surrounding much noise free or calm and good location, where you can enjoy your other activities.

(Refer Slide Time: 28:46)

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So, references are there for again to have additional knowledge about different numerical problems or design parameters and all those things if you want to know more about. So, again thank you. So, this is all for impacts of the transportation sector on the environment, human beings and other activities.

Now, we will see like environmental impact assessment, because the impact is there, so we should assess it, otherwise how would we plan to reduce the impact. So, there are techniques which are used for environmental impact assessment of different activities and the transportation sector is one of the important activity, which also influence the environment, so we should know the EIA or environmentally impact assessment techniques and procedures. So, in next lecture we will see that. Thank you again for your kind attention and see you again.