Introduction to Multimodal Urban Transportation System
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Lecture – 59
Urban Transport and Sustainability:
Environmental Concerns of Urban Transport

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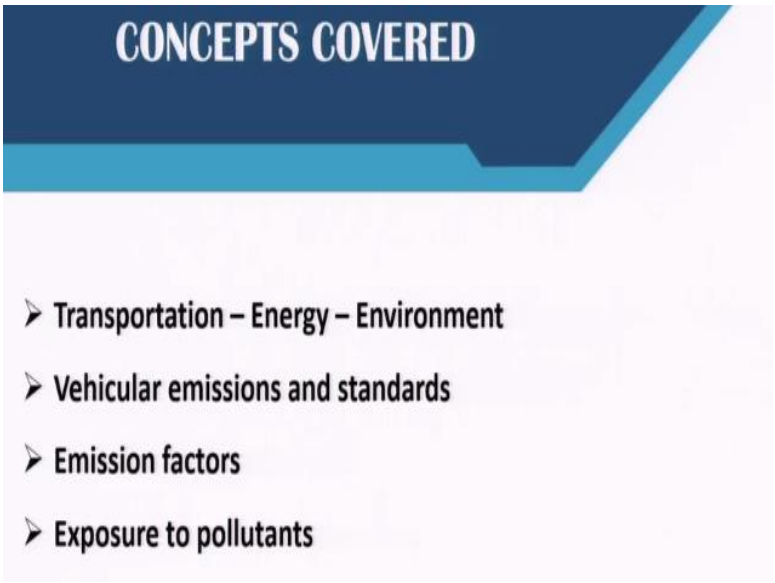

Welcome back friends. In the past lecture, we have looked at urban transportation and its impact on safety and now in the last module of this course we are going to introduce you to the urban transport and emissions issues as well as urban transport and noise issues. So, if you are working in the arena of urban transport, it is very important nowadays that you understand how transportation impacts the energy needs, the environment, what kinds of pollutants are coming out of the vehicles and how do you essentially estimate or measure those emissions.

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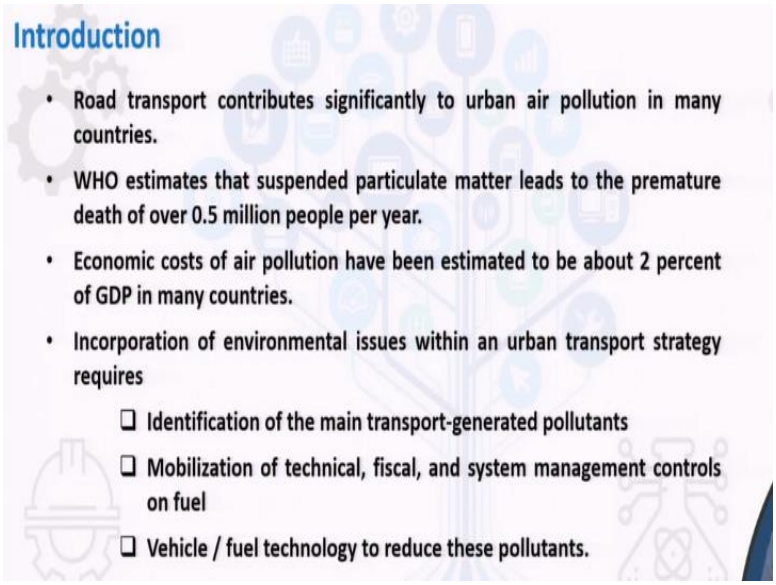

If we begin to look at a road transport and its contributions to air pollution, this is a very serious matter in most of the countries around the world and these emissions have a very high impact on human health. So the latest research where a lot of transportation professionals are now collaborating with actual medical doctors in order to understand what are the externalities of all the transportation that is taking place on our urban streets. And one of those externalities are its impact on human health. It has been estimated that the economic cost of air pollution is about 2% of the GDP in many of the countries. So when pollution impacts human health, the productivity of all of us goes down, we have to take a lot of medical leave, sick leave. So if you accumulate all of those at a national level, you would see that it has a very significant impact on the GDP as well. So not only does it impact your health, it impacts the GDP. So overall, air pollution, not only air pollution but in particular the emissions that comes out of vehicles is a major cause of concern in many of the developed as well as developing economies around the world. So in order to understand in a better manner which are the most polluting transport modes, which are the most environmental hotspots in your cities, there are different things that needs to be done.

Then the first of it is to identify the main transport-generated pollutants, so what are the gases that are emitted from the vehicles. Then you need to understand the different management controls of fuel. There are different new fuel technologies that are coming out. How do we implement these fuel technologies? And also for example a newer vehicle technologies that can comply with cleaner emissions standards, maybe electric vehicles, so on and so forth. So there are different strategies that need to be put in place in order to fight this externality of emissions and transport.

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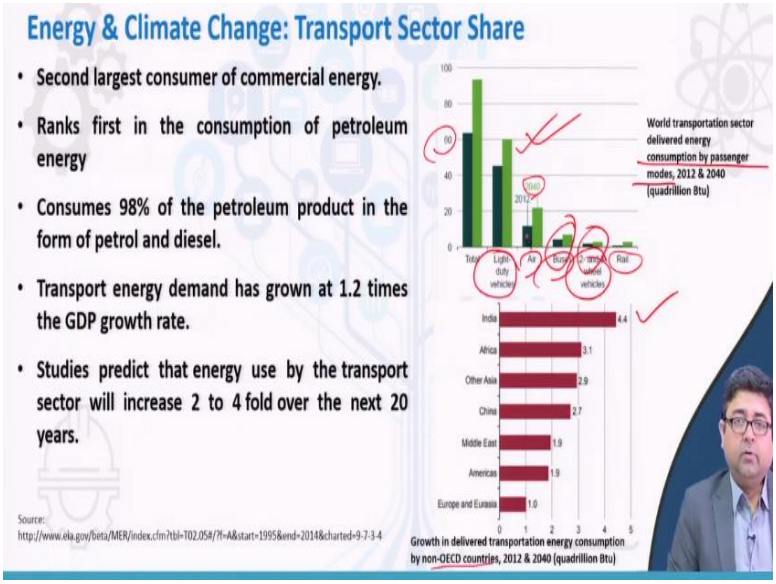

If you start looking at a global scenario you would see that the rate of increase of transport related emissions is the highest in India when you look at the non-OECD countries. So that is a cause of concern for us in India as well because and more people are now buying automobiles. Some of our commercial vehicles are also very old, so they may not be complying with the current standards, our driving distances are increasing.

So all of this put together is contributing to the poor air quality in our cities, and if you have been listening to a recent news you would always remember the condition that used to happen in our national capital New Delhi during the winter seasons where the air quality used to drop significantly and one of the major contributors to the drop in air quality was the emissions coming out of the motor vehicles.

So you would see that among the motor vehicles themselves, there are different types of emissions that happen from air transport, light duty vehicles, buses, two wheelers, three wheelers and also rail. So all of our cars essentially fall in the light duty vehicles. So if we do nothing, what is projected by 2040 is that there is going to be a steep increase in the quantum of emissions that is being emitted by the passenger modes, especially if you take into consideration the light duty vehicles.

Whereas if you just look at two or three wheelers, the impact is not much. Buses, the impact is not very high. So we have to be very careful when we see these figures of how much

quantum of energy is being consumed and how much emissions are being emitted into the atmosphere from all the car centric cities that we have in our country and the world currently.

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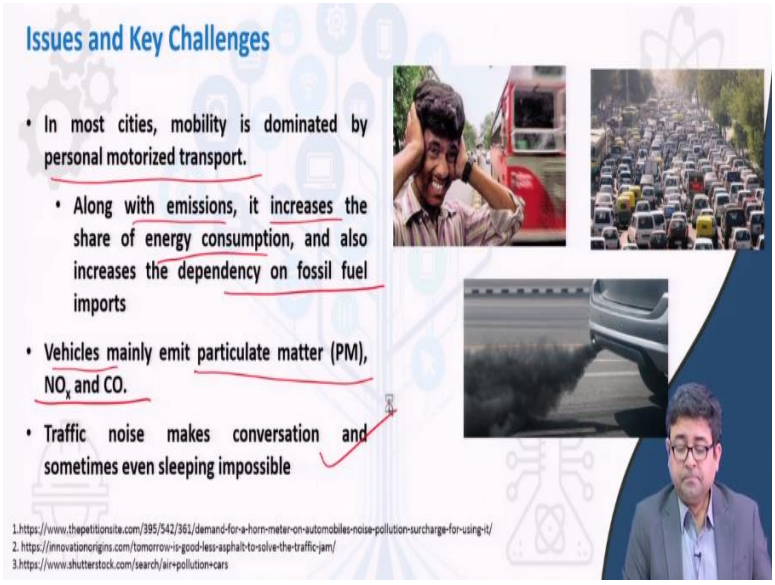

So as we said, along with emissions, so what is this personalized motorized transport? So personalized motorized transport means any cars or any two wheelers that we own, it not only has an externality on emissions but it also increases the energy consumption. So we need a lot of fuel to power these vehicles and all the gasoline that comes to the pumps they emit pollutants during the entire process of their movement from the coal mines to the refineries and so on and so forth.

So there is a lot of pollutants that is emitted during the generation of that energy and also subsequently when we use the fuel more and more in our vehicles, they also emit a lot of energy and it also is increasing our dependency on fossil fuel. We have not yet considerably gone to a cleaner fuel technology. Neither have we considerably moved towards renewable energy sources. So we are still very dependent on fossil fuels and emissions is a big concern in that sector.

So when we look at vehicular emissions, the major pollutants are your particulate matter, PM 10, PM 2.5, noxious gases NOx and also carbon monoxide. The other externality in case of transport fields is a traffic noise that is an externality which we really do not pay a lot of attention to, but we will tell you in this lecture or probably the last final lecture that how traffic noise also has a severe impact on our health and our hearing and it should be also taken into consideration when any new transportation project is being built.

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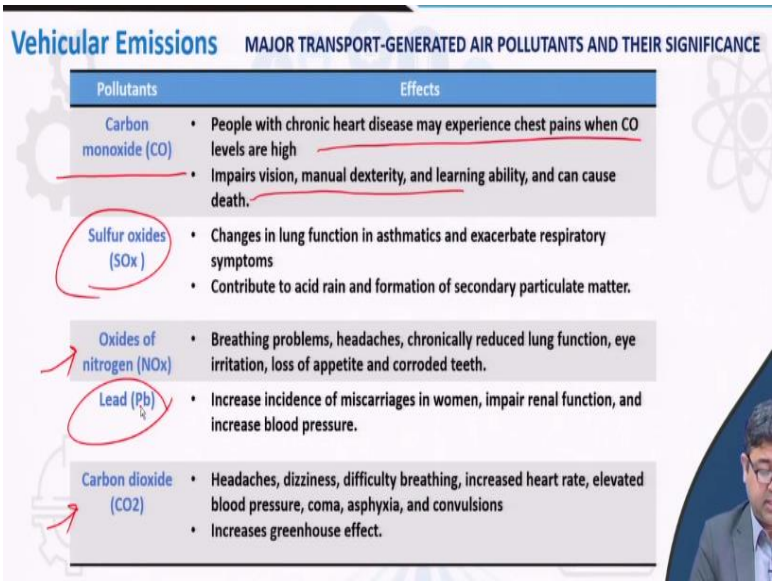

Like we already mentioned, what are the major pollutants, but if you look at how they can harm your health, then the situation would look even more alarming. For example if you are exposed to a lot of carbon monoxide, people with chronic heart disease may experience chest pains, it may impair your vision, dexterity and learning ability as well.

So there are a lot of these studies that are happening now that are actually relating the dosage or how much you inhale these gases and what kind of impact is it having on your health. So when people are usually told to not be outdoors that usually is pointing to the fact that there may be a high dosage that he or she may inhale because of the emissions coming out of the vehicles outdoors and that may cause damage to your internal organs or to your health overall.

Similarly, you can look at what noxious gases does, what carbon dioxide does. The emissions of sulfur dioxide from vehicular sources has been controlled to a large extent, so has been the emissions of lead. So these two I may say although they have some impact on your health, but if we are strictly talking about emissions from transportation sources, then these two have been taken care of to a larger extent.

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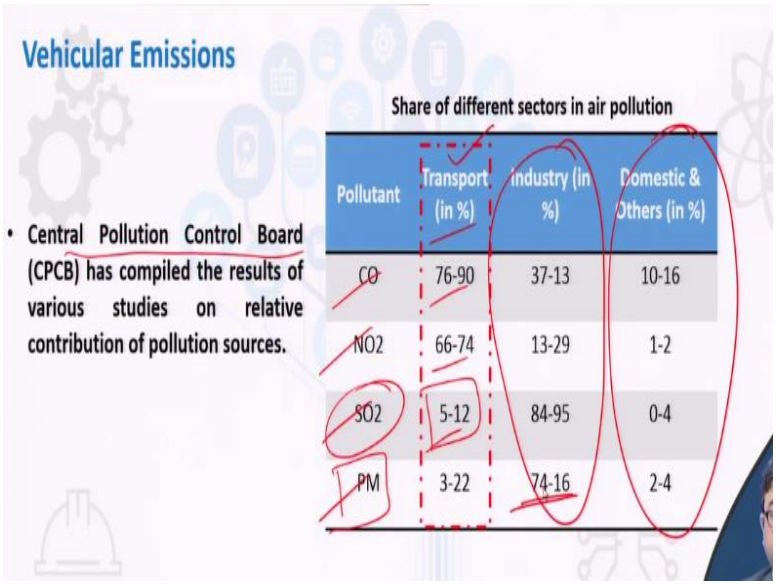

Now CPCB which is our central pollution control board brings out certain numbers or certain statistics which points towards transport sector being the major culprit when it comes to emissions of all of these gases. So you would say even when compared to any large industry or definitely from the domestic and other sectors, you would see transport has a higher share of emissions.

Sulfur dioxide as I just mentioned has been largely taken into control and particulate matter although it may not be directly coming out of vehicles, but due to the presence of road dust on either side of the pavement or on the pavement itself, so when the vehicles move at a high speed on the pavements those dust particles are again emitted into or they are picked up into the atmosphere and then they get circulated in the air and people may inhale those as well.

So in an indirect fashion, particulate matter is something that researchers in urban transport are concerned with, but it is usually the industries that emmit directly a lot of particulate matter.

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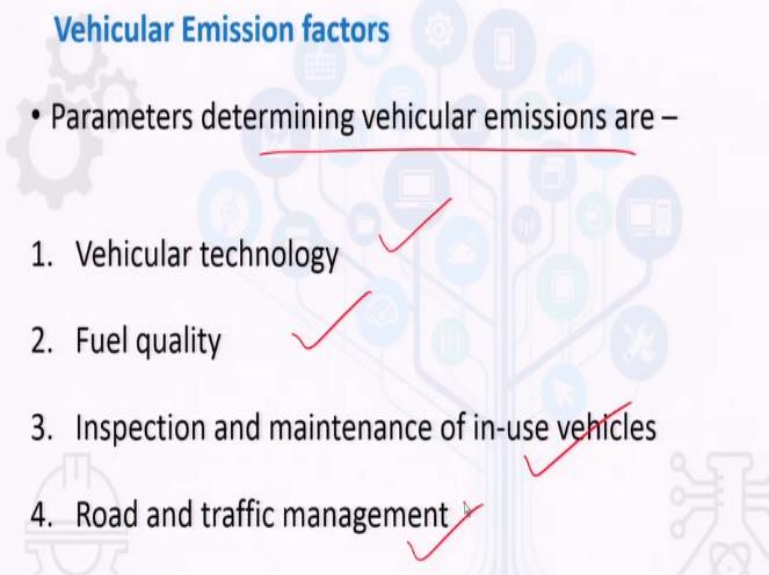

So when we look at the parameters that determine vehicular emission at a broad level, you would see that people usually talk about a vehicular technology, fuel quality, inspection and maintenance of the vehicles that are currently in use and also several road and traffic management strategies. So vehicle technology, we all know catalytic converters were the ones that completely changed the scenario.How poorly or what the quantum of poor emissions that used to happen in the early 1980s in India were were completely taken out of the equation by the catalytic converters that came in the early 90s. So vehicle technology has been improving ever since. Now we are adopting more and more technologies that can comply with Euro standards, for example all our Bharat stage 4, Bharath stage 6 standards are comparable to international standards.

So all our vehicle technology has improved a whole lot. So we have been able to control the emissions of these gases from the vehicles. Fuel quality as well, we have reduced lead content, unleaded fuel is now the norm which was not the case about 20-25 years ago. We used to have a lot of high content of lead in our fuel. Also alternative fuels like CNG is being used in many cities in our country. So that is helping reducing the amount of pollutants that is coming out of our vehicles.

The third point which is stressed often and many of us are guilty of not taking care of this is to properly maintain and inspect our vehicles for pollutants. So this is a very important measure that has to be taken very seriously and because the standards stated for the emissions from vehicles are usually met when the vehicles come out of the dealership. So the minute the vehicle starts running, it starts deteriorating.

There is a lot of friction in the body, in the parts of the engine and so the emission usually starts increasing. So you have to keep it lubricated well, oils have to be changed at regular intervals, tire pressures have to be maintained and more specifically speeds that you drive on the roads have to be also taken care of. So all of this has to be done periodically. Periodic maintenance is very, very necessary and it has to be enforced very strictly as well.

And finally road and traffic management also plays a very important role. You would see that emissions are highest around signalized intersections where the usually vehicles are idling and then when they start or they accelerate that is when a lot of pollutants are emitted into the atmosphere. So when traffic engineers usually design the roads, they make sure that a signalized intersection is the last option for a junction. Because one of the reasons for that being pollutants is very high at signalized intersections or they would rather have rotaries first or traffic circles first in order because they allow vehicles to go at lower speeds and the acceleration and deceleration is not that high and hence the pollutants are not emitted in a large quantity. So all of these 4 factors play a very important role when it comes to the emissions coming out of our vehicles**.**

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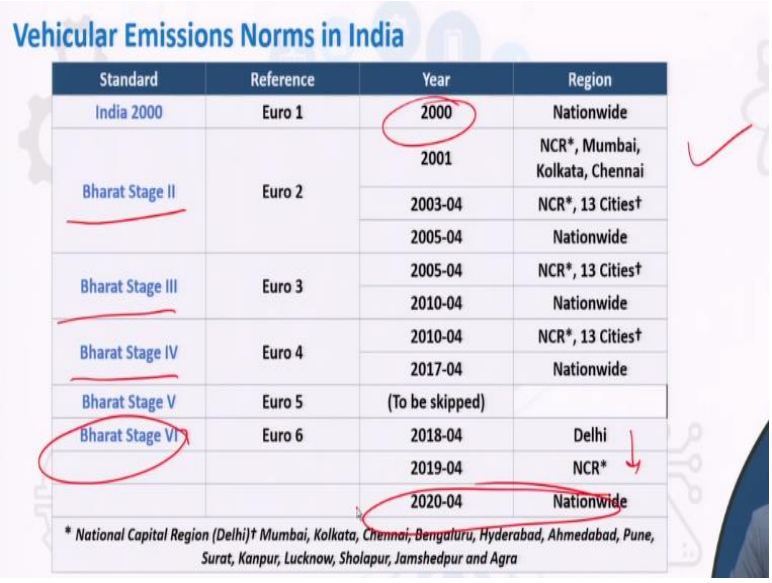

Given here are some Bharat stage norms that will help you understand how we have improved over the years. So the first norms came into place in the turn of the century in 2000 and ever since now we are moving towards Bharat stage 6 which will be implemented first in the national capital in the NCR region next and hopefully by the next 2 to 4 years we will get it nationwide in all of the cities vehicles that are compliant by Bharat stage 6.

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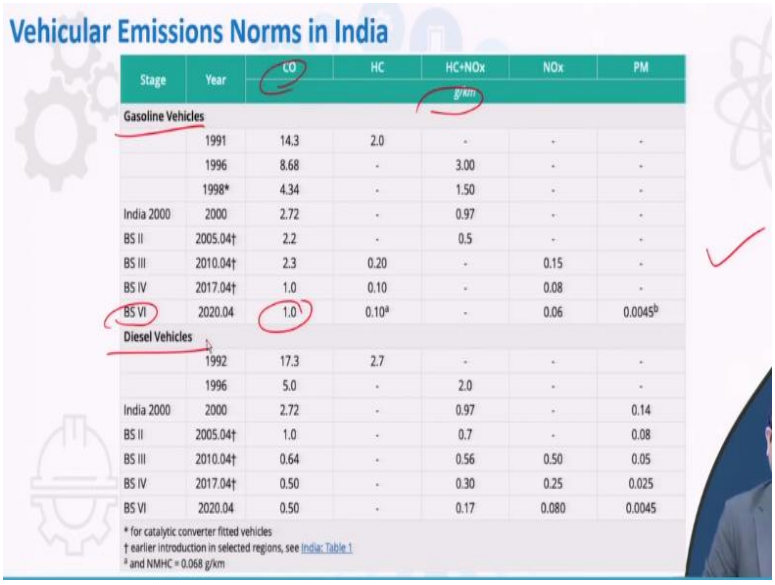

What all the compliance means is that there are some standards that all of these vehicles have to meet. For example if you just take the latest one that we are going to go into. So if any vehicle that is compliant with Bharat stage 6 can only emit 1 gram per kilometer of carbon monoxide while it travels. So there are strict standards that are in place, so that is what I was also mentioning in the previous slide that these are standards for vehicles that are when they are coming out of the dealership.

So once you have driven it, more and more maybe the carbon monoxide emissions would increase and hence you have to always maintain your vehicle and do periodic inspections so that they are within limits. So this chart shows you different standards for different gases and for gasoline vehicles as well as diesel vehicles. It gives you an idea of how you should maintain your vehicles.

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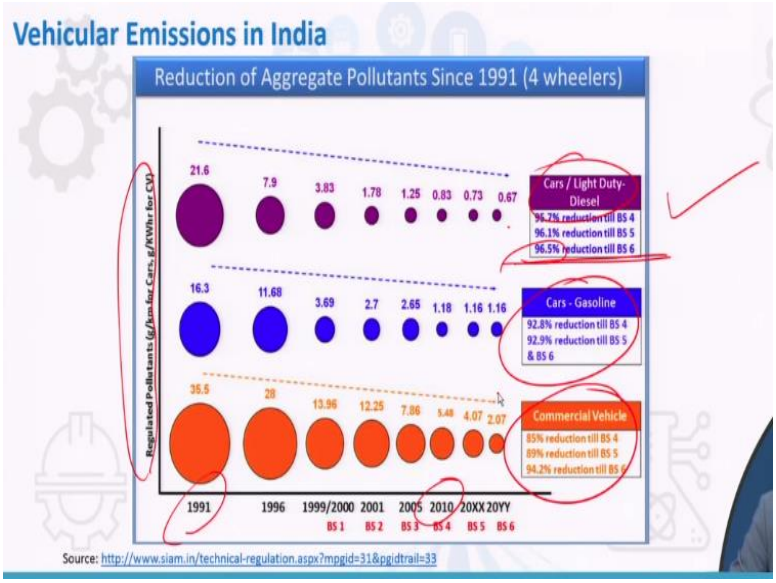

This is an interesting chart which tells you that we have come a long way in controlling the pollutants from the early 90s to where we are today because you would see that there has been almost, if you look at BS6, there have been almost 96.5% reduction of pollutants from cars and light duty diesel. Similarly, there has been a drastic reduction in other categories as well.

However, the cause of concern currently is even though each vehicle is emitting much lesser than in the early 1990s, but the number of vehicles have also risen to an alarming level. So in 1990s to 2020 where now we are, the number of vehicles have risen. So each vehicle although are emitting less, but when we add up now the quantum of vehicles, the emissions are a significant number.

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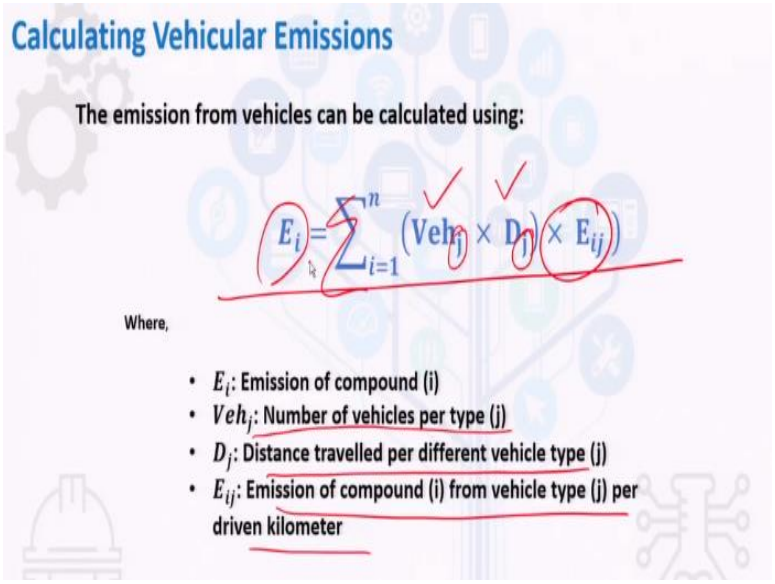

Usually if you are to calculate at a very macro level at a very corridor level emissions, so an entire street how much, what type of emissions is coming out for an entire street level, these are not microscopic, these are not at one vehicular or how much does one particular vehicle emit, but maybe a stream of vehicles on a particular road segment in your city, how much emissions are coming out of that, if you were to ask. If you were to calculate that at a macro level, what you would have to know is what are the number of vehicles per category. So different categories of vehicles emit different amount of pollutants. The distance traveled by each of those category vehicles. It depends upon how much they have traveled and then you multiply that with a factor called the emission factors which we will tell you how to measure.

There are some standards for Indian conditions as well. So you multiply those emission factors with the number of vehicles of particular category and the distance that they travel and you sum it over all the different types of vehicles to get a understanding. So maybe there will be a situation in the future where we will have maps just like how we have Google maps now.

Maybe we will have maps which will show that this corridor is an emission hotspot in the morning peak hour, whereas the other corridor is relatively better as far as air quality is concerned or vehicular emissions is concerned. So maybe you could make a choice just as you make a choice currently based on congestion on different corridors, maybe this is something in the future that you will be able to do.

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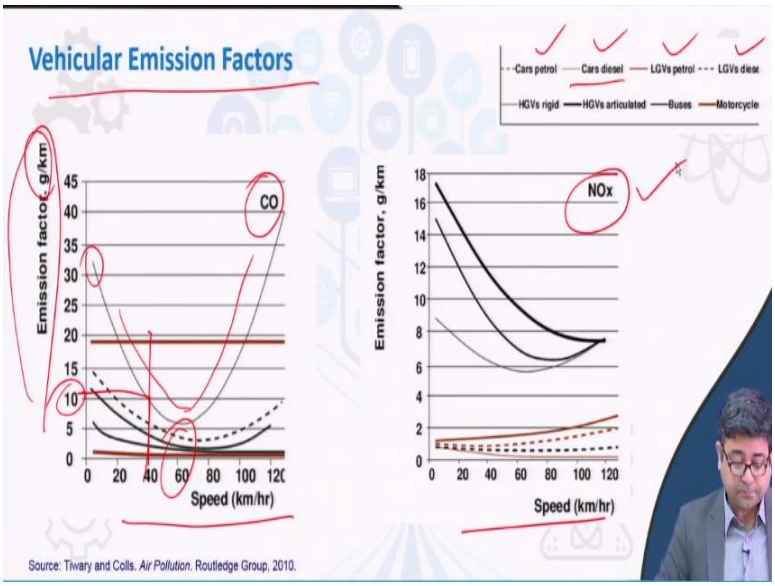

So when we talk about vehicle emission factors, various experiments have been conducted at different road segments with using different types of vehicles and models have been developed. Statistical models have been developed to show how the emissions vary based on speed. So speed essentially is a proxy to understand how much your vehicles are emitting. People have also gone at a microscopic level to understand the acceleration, which gives you even more detailed understanding of how each of the vehicles emit pollutants, but we have to be at a macro level, speed is a good enough proxy to understand. So you would see that the emissions are higher at lower speeds and as you pick up the speed the emissions go down, but it is not always a negative curve. If you go up beyond a certain speed again, the emissions picks up. So this is the case of carbon monoxide.

Similarly the case of NOx. So that is why when you are instructed to drive somewhere around 50 or 55 or 60 kilometers per hour, this is one of the factors because at that speed emissions coming out of your vehicles are also the minimum. So that is something that you have to keep in mind. So if you have to now know what are the emission factors, how much carbon monoxide is your car which is the light brown is emitting at 40 kilometers per hour.

So you would just go here, take the curve and you would know the factor, the number of grams per kilometer that it would emit. So that is the factor that you would multiply in the previous equation and you would be able to know the emissions at a macro level at a corridor level. There are similar charts for NOx and particulate matter and so on and so forth.

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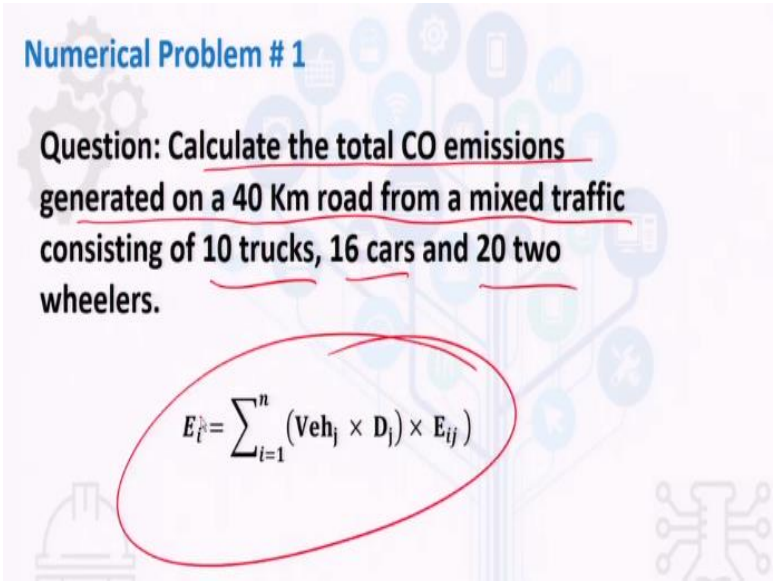

So for example if you are asked to calculate the total carbon monoxide emissions generated on a 40 kilometer road from a mixed traffic consisting of 10 trucks, 16 cars and 20 two-wheelers using this formula.

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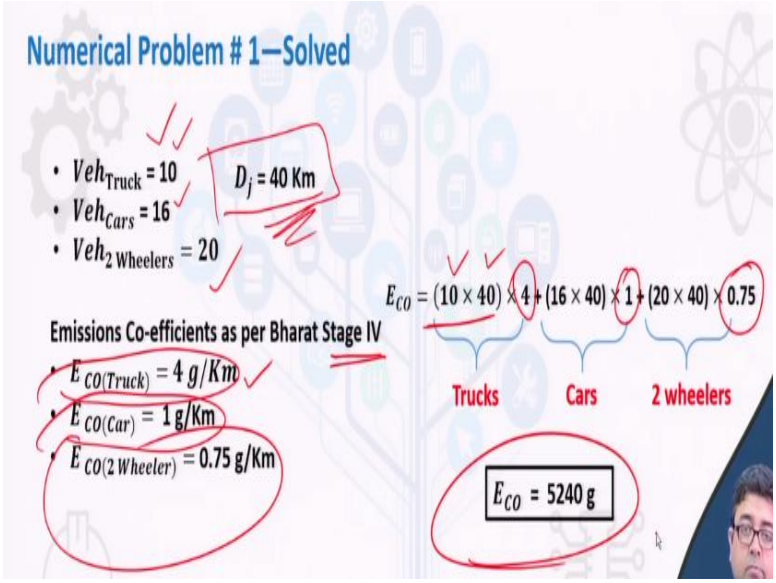

All you have to do is you know the total length of the segment, you know the proportion of the vehicles, then you multiply each and then you know how much of emissions is coming out for a truck, what is the emission factor for a truck based on a Bharat stage 4, what are the emissions carbon monoxide coming out from cars and similarly for two wheelers. Then you multiply all that and you would get, you are using these emission factors to multiply it with.

For example truck, there are 10 trucks for a 40 kilometer stretch and 4 grams per kilometer. So if you drive 40 kilometers, then you would get a gross level that there would be almost 5000 grams of carbon monoxide that will be emitted in that stretch based on the vehicular mix that is available. So that is a very simple calculation that will allow you to at least have an idea of how well or how poor the air quality or the vehicle emissions is on your road.

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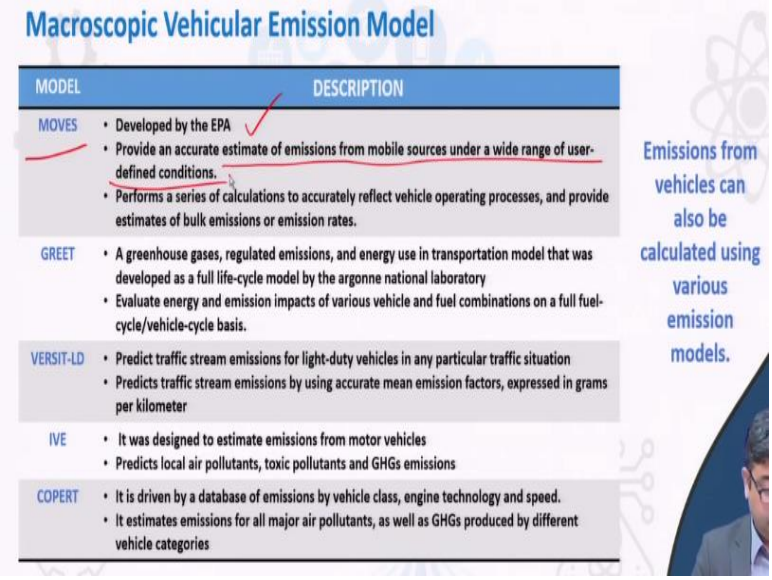

Now then you can make use of different kinds of models that are available, different kinds of softwares that are available that allows you to model these emissions in real time and then you can use these models to predict what would happen in the future. For example if the number of vehicles increase in the next year what would happen to the corridor level, what had happened to the corridor level emissions, vehicular emissions.

MOVES is something that is a very popular as developed by EPA in the United States. You can use these models to get an estimate of the emissions from mobile sources under a wide range of user defined conditions. So you can define the population of users that are using the vehicles because it depends upon if the users on the roads are commuters who are on that road every day, they would drive in a different manner, whereas, if they are tourists or visitors, then that corridor would have a different pattern of movement. They would be stopping and starting to see multiple sites, so maybe the emissions will be higher, whereas commuters want to just go quickly, maybe the emissions if they are following the speeds would be lower.

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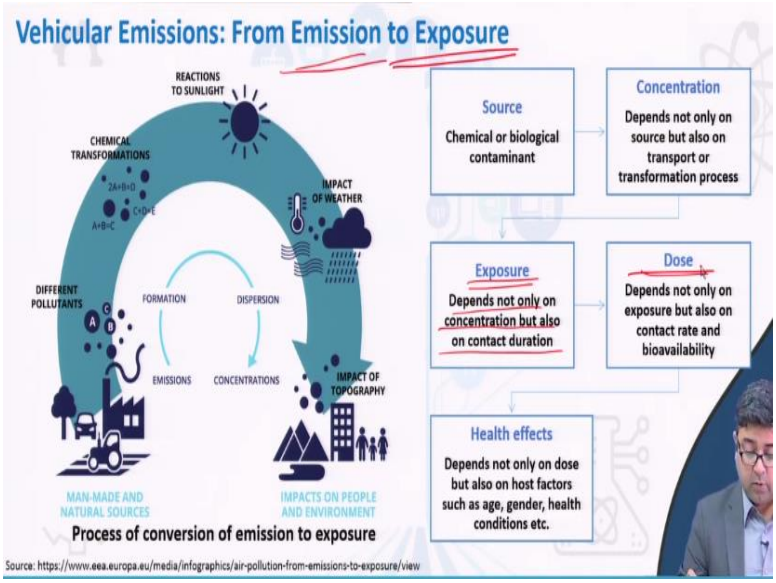

Now the next concept in vehicular emissions is the concept of exposure. So now what researchers and everybody is looking at is not only measuring or estimating how much of these pollutants are being emitted by the different types of vehicles, but as a result of those emissions what is happening to human health. Like I said in the opening slides it has a very poor impact on human health.

So people are now or researchers are now or studies are now moving towards taking the information about emissions and then calculating what is called exposure. It depends upon not only the concentration, but also the duration during which a person is in contact with this kind of environment. So if you are exposed every day to a very volatile environment of high emissions, then the impact on you would be different. Whereas a person is only exposed once in a week then the impact on his or her health would be different. So we are now moving a step ahead from just measuring or estimating emissions to actually estimating their impact on health by understanding how much is the exposure, and by understanding exposure you would also be understanding how much of dosage that you are good to inhale.

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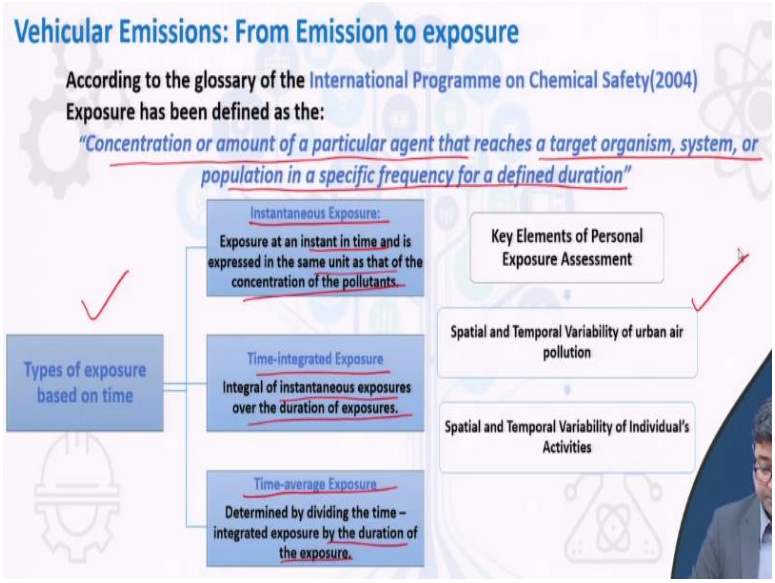

So we would quickly see how you could measure that, the exposures. When we say exposure it is defined as the concentration or the amount of a particular agent that reaches a target organism, system, or population in a specific frequency or a defined duration. So how frequently and for how long are you exposed to a situation where the emissions coming out of vehicles since we are talking about vehicles. This can be done for any other type of emissions as well. But since we are talking about vehicles, if you are say for example your house is right next to a very busy street and you have a window that opens into your living room. So how much of that air are you exposed to versus if your house is on a very residential street and the street alongside is not busy. So that is called exposure.

The other type of exposure is obviously when you are walking on the street or when you are using a two wheeler or an autorickshaw where you are actually exposed to the environment versus your car when you can roll up your windows and turn up the AC but that is a different type of exposure then. So exposures can be instantaneous exposures, at any instant in time and is expressed in the same unit as the concentration of pollutants. So it is just gram per kilometer or gram per minute of how much you are exposed to a particular type of pollutant. Whereas time integrated exposure is the integral of instantaneous exposures over the duration of exposure. So you are exposed for 10 minutes here during the day, 20 minutes there, 5 minutes there. So if you add all of those up for different types of emissions that gives you a time integrated exposure. Whereas you can then average that time integrated exposure by dividing it by the duration of the exposure to give you their time average exposure. So what happens is you have zones where spatially there is a big variation in your city as far as

vehicle emissions are concerned, and not only spatially, spatially meaning your CBD area or your central business district area might have higher emissions.

Whereas your purely residential areas may have lower emissions, so that is a spatial difference. Whereas there may be temporal difference also like during the office peak hours, the morning and the evening, you may have higher emissions because lot of vehicles are on the road and a lot of people are moving, whereas during off-peak hours in the afternoon or the late night, you may have lower emissions. But then the environment also, the temperature also plays a role. So there are multiple factors that get into play when we are actually talking about the exposure to these pollutants.

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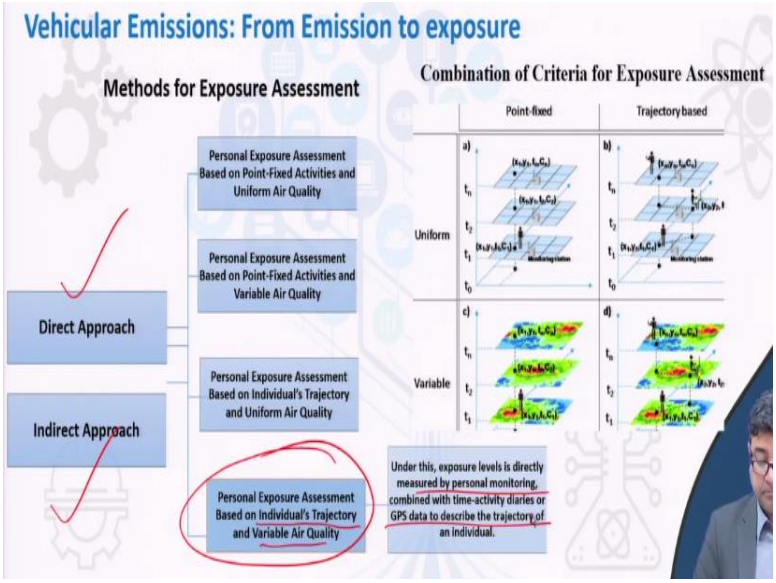

This is just another slide that tells you there are direct and indirect ways of measuring the exposure and what we are looking at especially is a personal exposure assessment based on individuals trajectory and variable air quality. Because as a person moving in a transportation mode, person is hardly stationary. So we want to track how a person's movement along the urban street or urban street network is affecting his or her exposure to the emissions coming out of the vehicle.

So we have to be not only looking at the trajectory of the people moving, but also the variable air quality in the different areas that the person is moving. So that is our primary interest. It can be done directly by using a personalized air quality monitor and then having GPS data on individual's movements that will tell us that spatially he or she was here for 5 minutes, then he or she moved to another location.

So you have the GPS location and you have in your hand air quality monitor that can then show your trajectory as you are moving from point A to point B to point C to point D throughout the day.

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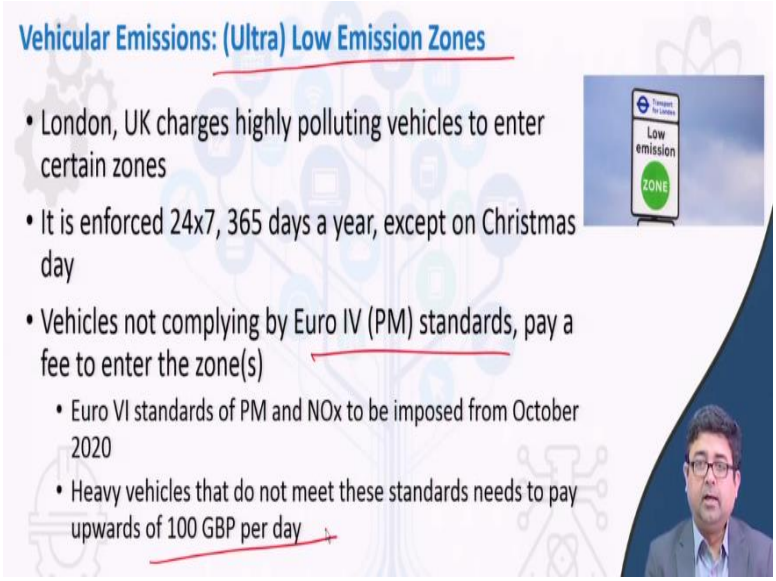

So this is an example of what is happening in some of the developed countries, now the situations has become so alarming that London for example has created what are called these low emission zones or they are also trying to move towards ultra low emission zones or they have already moved towards some zones called as ultra low emissions zones. So what they usually do is they will charge vehicles that do not meet the Euro 6 or Euro 4 standard for example. So if your vehicle does not match Euro 4 or Euro 6 standards and you are entering a particular zone that is a hotspot for vehicular emissions, meaning that it is a very concentrated location and a lot of people are coming in there with their vehicles, so if there are vehicles that are not meeting the standards then you may be liable to be charged a penalty or a fees, very steep fees which will then either do one or two things. Discourage you from traveling into the zone or the area or be encouraged you to improve the maintenance of your vehicle and maybe make them compliant to the standards. So in both cases whichever path you decide to it is a win-win situation for everybody. So this is something that London has already gone towards, many other developed cities especially cities in developed countries are actually looking towards these things so as to reduce the amount of vehicular emissions in certain hotspot areas that are there.

So this is a practical application of implementing what you call emission based pricing or emission charging in urban area.

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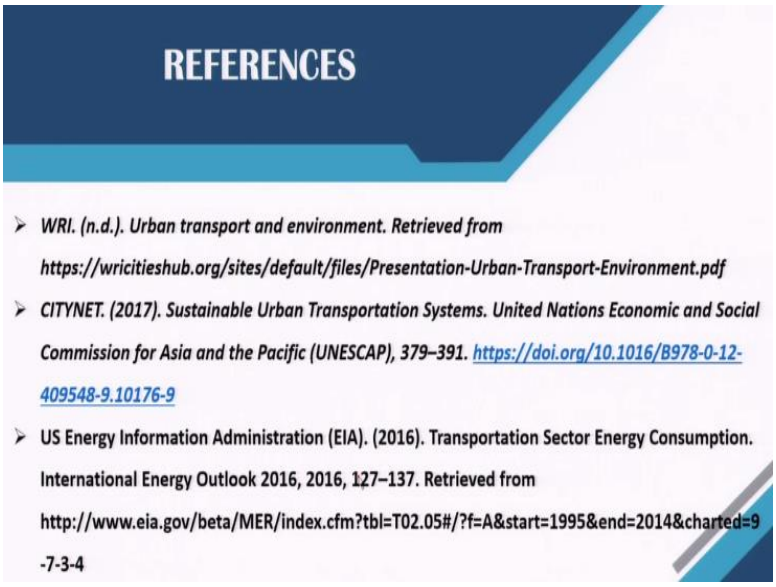

So that brings us to the end of this lecture. These are some of the references that you can go through and read more about this. This is a very growing area in transportation and hopefully many of you will get encouraged to take up this as your career in the future.

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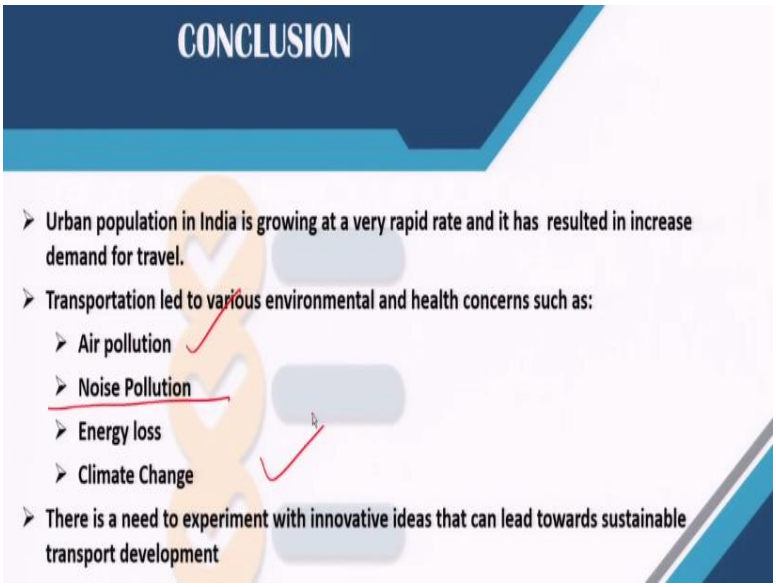

So in conclusion what we have looked at is we have given you understanding of how transportation and emissions are related, how energy consumption, transportation and energy and environment are related. What are some of the air pollution or gases that are coming out of the vehicles. We have just introduced you to noise pollution, we will tell you more about it in the next following lecture. And we have also told you about how energy losses occur when

you use a lot of vehicular modes and what it does to climate and your human health. Thank you.