Sustainable Transportation Systems
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Lecture 06
Impacts of Transportation Systems - I

Hi, friends. So, now, last time we discussed about climate change related issues because climate change is directly related to emissions of greenhouse gases and as you know lot of quantity of greenhouse gases are emitted by transportation sector. So, not only the climate change, but there are other impacts of the emissions of transportation sector plus in addition to the emissions, there are several other activities of the transportation system, which also affects the environment. So, let us see what are different environmental impacts of the transportation systems.

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So, in today's presentation we will cover like the linkages of transportation and the environment means how a transportation related activities and environmental components interact with each other. Also, we will include in these like energy consumption means fossil fuel-based transportation system at present is dominating.

So, how much energy consumption is there from the perspective of transportation systems and what are the emissions means, how much emissions are coming out of this sector because there are so many sectors like industrial sector, residential sector, transportation sector, thermal power plants.

So, we can divide if we want to study like emissions, so, we can divide into different sectors, sources of emissions you can say, so in this particular presentation, we will also focus on emissions from transportation sector. Then, we will see means environmental impacts direct or indirect of the transport and how this transport sector and climate change again we will, means very briefly, in detail we have already discussed climate change related aspects in previous lecture. So, in this lecture, we will only see briefly that how climate change and transportation sector affect each other, that is also interesting part we will see.

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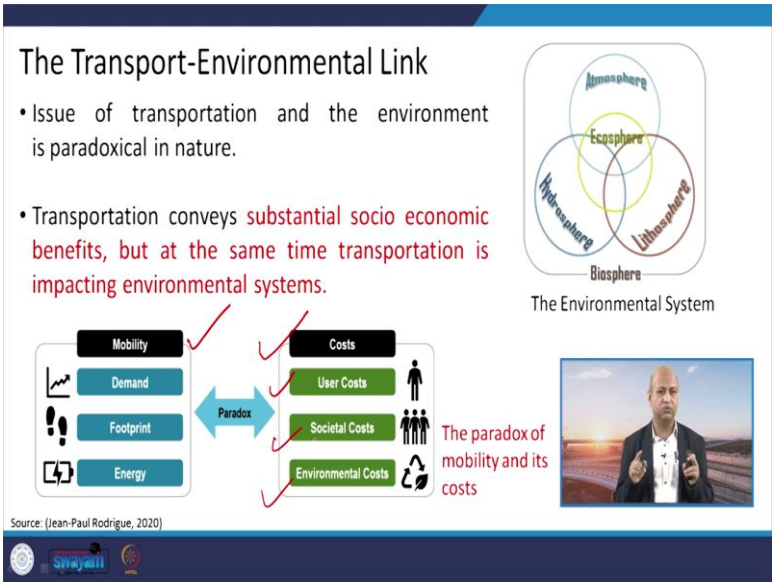

So, from the perspective of transportation and environmental linkages, you can see, like hydrosphere, lithosphere, ecosphere, all these parts of the biosphere, these are the environmental systems and we are living in troposphere. So, whatever activities we are doing in this troposphere, where different spheres are there, so emissions or activities related to the transport sector, they come in direct contact with these components of the environment, and when they come into contact, then they influence it in good or bad way whatever.

So, like mobility we need there is demand because we want to travel from one place to another. And, it also like, it will require some sort of infrastructure systems so cost is involved, it is not free, then user cost means, so cost in total is comprised of user cost and this social costs, because it affects different segments of the society community level to the country level, then environmental costs, as we generally call it, externalities and we sometimes we ignore it, but that is very tremendous cost to our life basically.

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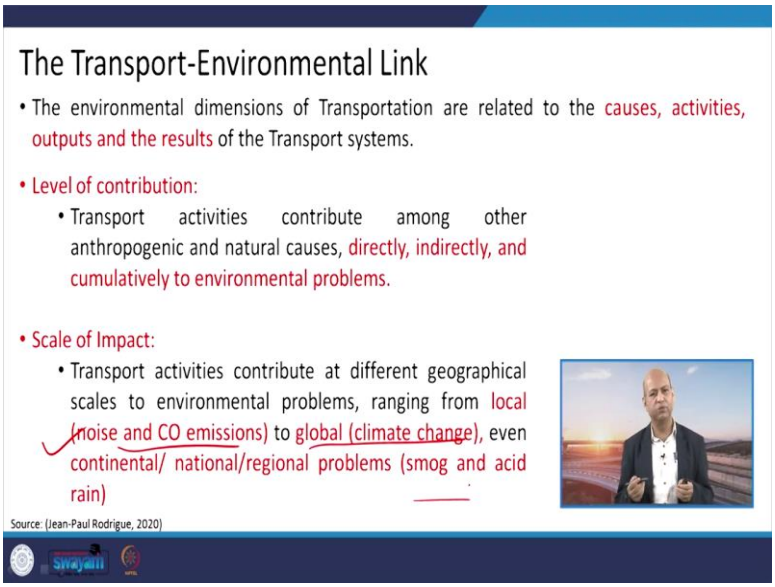

So, these are the linkages in terms of their relationship, but if you want to see like level of the contribution of different activities, so, directly or indirectly, these are contributing in the emissions, which are not only the natural, but anthropogenic. So, we are talking about anthropogenic activities related to transport. So, their level and their scale, scale can be like local scale, regional scale or global scale.

At local scale, for example, noise and CO emissions. Why it is local? Because CO emissions, carbon monoxide emissions, they have very small life, in the sense they get converted into CO2 oxidized, quickly oxidized; noise is also local problem, because it dissipates beyond a certain distance. So, it is a localized problem. Global scale problems, climate change, as ozone hole, those kind of things.

And national, regional or continental problems could be like smog formation or acid rain. Again, these are related to some sort of emissions whether primary pollutants, secondary pollutants, secondary pollutants means which are derived out of interaction or primary pollutants or for example, ozone, it is a secondary pollutant, which is generated or created by photochemical reactions.

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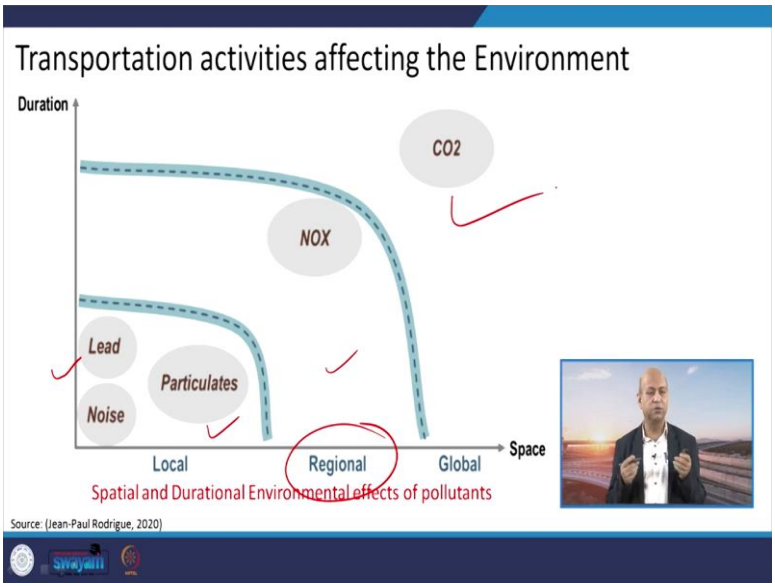

So, again, if you want to see in a very clear way, this local regional and global scale impact of transportation activities. So, noise or like lead or particulate matters, they do not travel for longer distances. So, they are localized impact you can call them. NOX emissions, because NOX emissions get converted into nitric acid, they can convert it into some sort of nitrates, they interact with atmospheric moisture and so, so they can contribute into secondary aerosols also particulate matter, phase transformation means gaseous components can be converted into particulate matter.

So, phase transformation can take place and that can travel from 100 kilometers to 1000 kilometers. So, it is a reasonable scale problem or it can contribute to acid rain also, because when HNO3 is there or these NOX emissions are converted into nitrates then they can contribute into acid rain and that is a regional scale problem.

Global scale like CO2, this is the greenhouse gas having longer lifetime and it can travel from one place to the entire globe. So, through global circulation, that is why we measure it average, global average of CO2 content in that atmosphere, although quantity is very less, but its effect or its impact is very high in terms of global warming and climate change.

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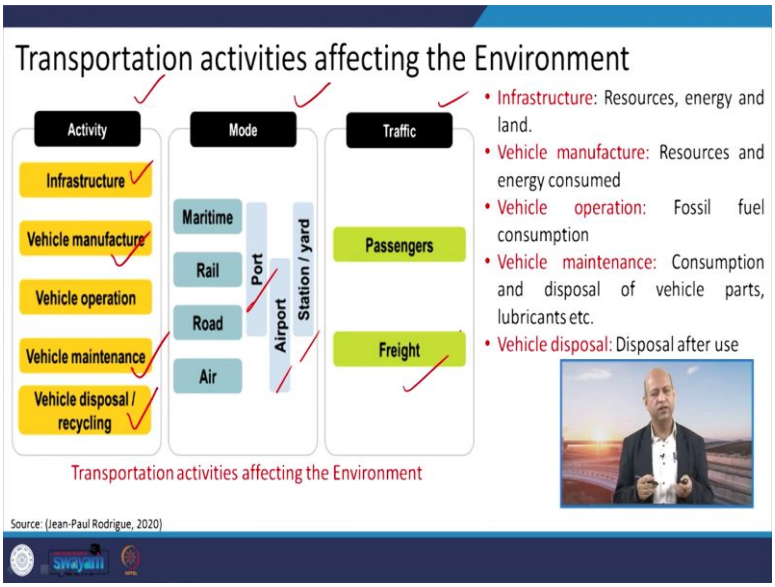

Now, the way different activities related to transportation that affect the environment. So, we can divide into three mode like activities, modes and traffic. Activities could be like we have to have infrastructure, if you want to travel through road, so not only the car or vehicle you need to have, you need to have proper roads. So those kind of, or if you want to use public transportation system like buses, so you need to have bus stand and those kind of things. So, infrastructure system needs to be there for railway, railway tracks you need, railway stations you need.

For aviation, you need airports and then to reach there different kinds of ways. So, vehicle manufacturing activity has to be there. How will you get? You want to have two-wheeler or three-wheeler. So, you need to buy it and when market is providing you that means it is also manufacturing. So, for manufacturing, there will be industry which will produce vehicles, then vehicle will operate and maintenance will also be needed.

So, operations and maintenance needed activities and then when vehicle is discarded, it is to be disposed off or recycled, all these activities have some sort of energy exchange or some sort of environmental impact. If we divide them in terms of modes like maritime, rail, road, air, so we need ports, airports, stations yards for those maintenance, etc.

Then from traffic perspective, whether it is passenger or freight luggage or goods, etc. to transfer them from one place to another, so you need this management of traffic and passengers. So, all these infrastructure or vehicle manufacturing, then having raw material for manufacturing vehicle all these have the impact on the environment.

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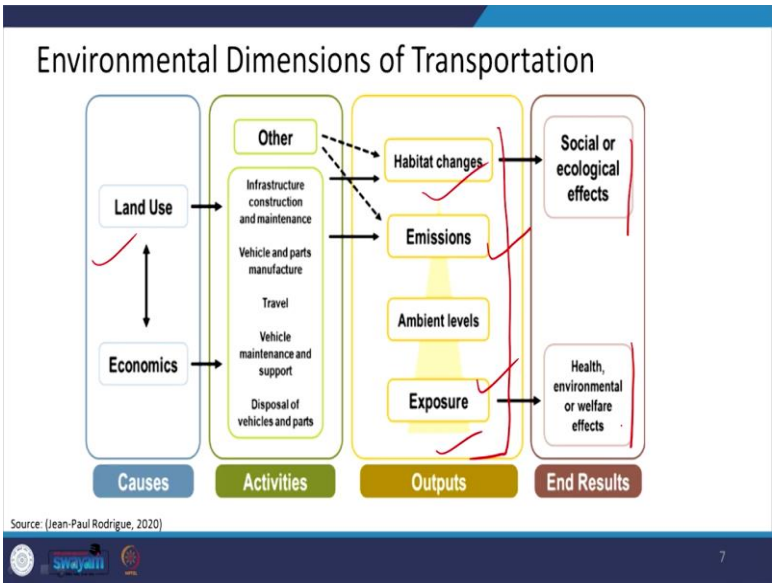

Well, again, so different dimensions of the transportation system when we try to understand it in a better perspective. So, their land uses, means roads and inland waterways or aviation and its economic aspects, because you need to manage it. So, you need people, you need like, there is a terminology in management like men, money, machinery, so all these three Ms are needed for operational purposes of all these activities.

So, we have seen in earlier slide also like infrastructure and travel all these things, they give a output of some sort of changes whether it is in terms of air quality, out of emissions, and exposure because when we are inhaling air, so we are also inhaling pollutants which are emitted by transport sector.

Well habitat changes, because when we have to have infrastructural facilities like roads rails, etc. So, we need to do some land use and changes in the geographical dimensions. So, they will impact society they will impact the ecology and this exposure related dimensions will impact our health or the ecological aspects or welfare related issues.

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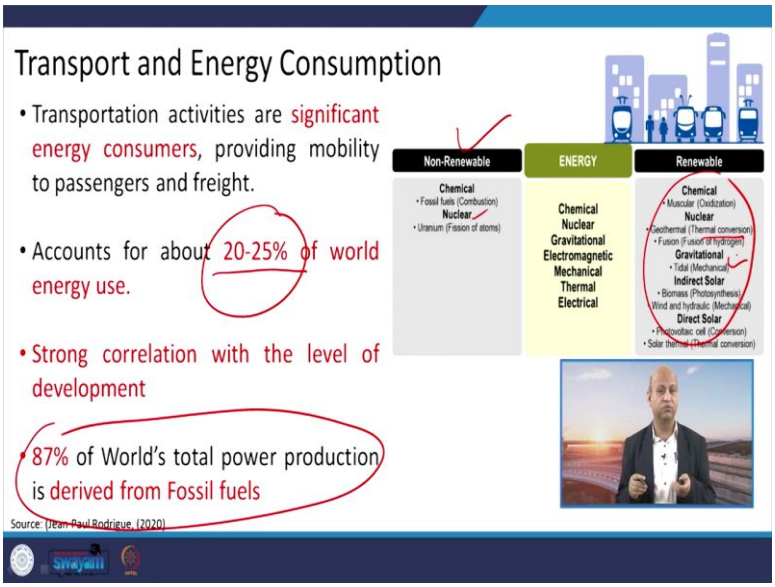

Next is like, transport is driven by energy, energy of any sort if we are walking, then we are using our own energy, we are taking food and we are deriving energy out of these again that is oxidation process within our body at the cell level. So, we get energy and energy is used for walking, if we are trying to use those fossil fuel-based energy systems, so IC engines or other way of producing some energy, so, energy is related for mobility purposes.

And you see around 20 to 25 percent of world energy use is related to transportation sector and 87 percent of the total world's power production is derived from fossil fuels, that is the real story, means fossil fuel for all major activities and within this fossil fuel a significant part is used for transportation sector. Energy can come from like non-renewable sources, chemical or nuclear, etc.

Then renewable sources may also be there like muscular those are also chemical kind of energy you can say geo thermal, thermal conversion, and then gravitational means, like potential energy you can convert into kinetic energy or so. So, and then solar energy all these renewable energy resources, one can harness to produce energy, but their share is very less at present, but there are a lot of policies in favour of those resources. And maybe in future we will use much more renewable energies in comparison to the fossil fuel, but at present fossil fuel is dominating the energy resources where we get all types of energy.

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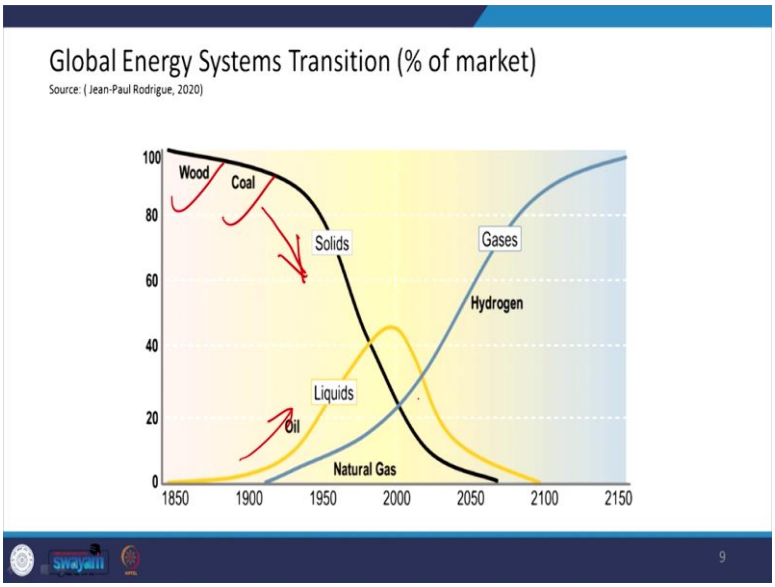

But, there is one interesting thing in the global energy system. As we improve or as we develop whatever present model is, but as we improve upon economy as we develop in terms of economy, we have more wealth more money to invest, then what we do we go for cleaner fuels earlier like wood, coal etc. these were the dominating fuels, all railway tracks were, means all railway systems used to have steam engines and the steam used to be produced by coal, but now, diesel based or means even electric based trains are there.

So, slowly what happens, like these solid fuel related energy resources uses or share came down and oil like liquid, liquid energy we started use means as economy grows then gas, natural gas etc., like in mega city, Delhi, the entire public transport system of road based public transport system is based on CNG.

So, from liquid fuels, we are shifting to gas because they are less polluting in comparison to those liquid fuels, liquid fuels are less polluting in comparison to the solid fuels. So, that way we are improving but still because population is growing and our demands is growing for energy access and usage of different things. So, naturally emissions in total becomes very high.

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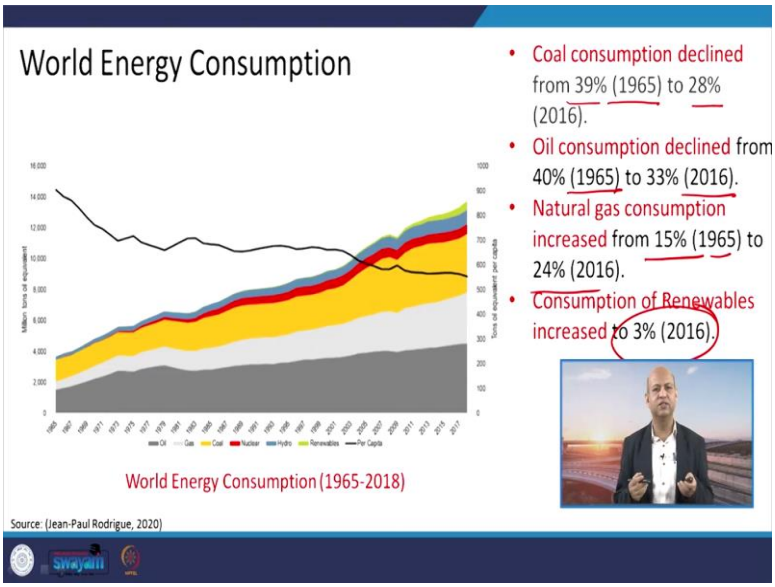

But see, these data which energy consumption at the world level gives like in 1965, it was 39 percent coal-based consumption. It declined to 28 percent in 2016 from 65 to, means slowly, but it declined. Similarly, oil consumption from 1965 to 2016 it declined from 40 to 33 percent, natural gas consumption increased from 15 in 1965 to 24 in 2016. And consumption of renewables is very less 3 percent around of total, but means it is picking up because of awareness increase and because of negative externalities or fossil fuel based energy resources we know, so we are investing lot of into renewable resources.

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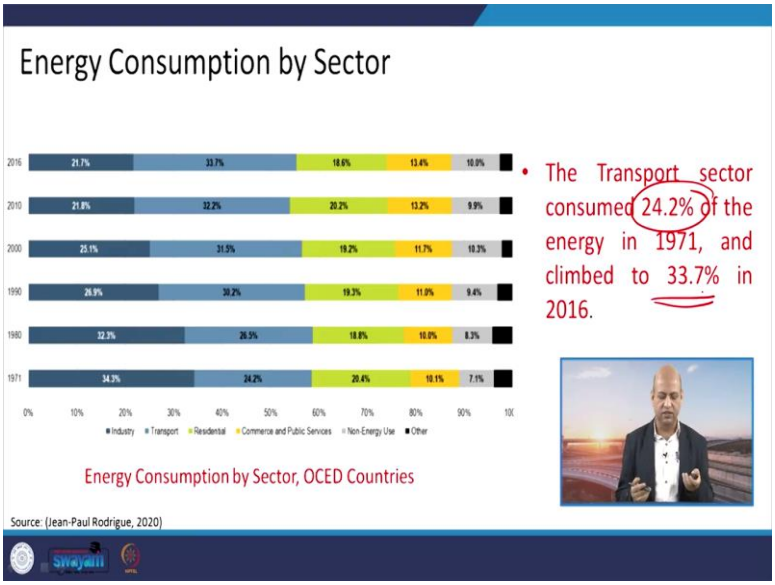

Sector wise consumption of energy also gives you one another perspective. For example, in 1971, it was around 24 percent, share of transport sector, and it increased to around 34

percent in 2016 means more people are using transport sector. Demand is increasing because population is increasing. So, demand is increasing, those transportation sectors related all infrastructure or weaker categories are increasing. So, naturally it share of uses of energy is also increasing.

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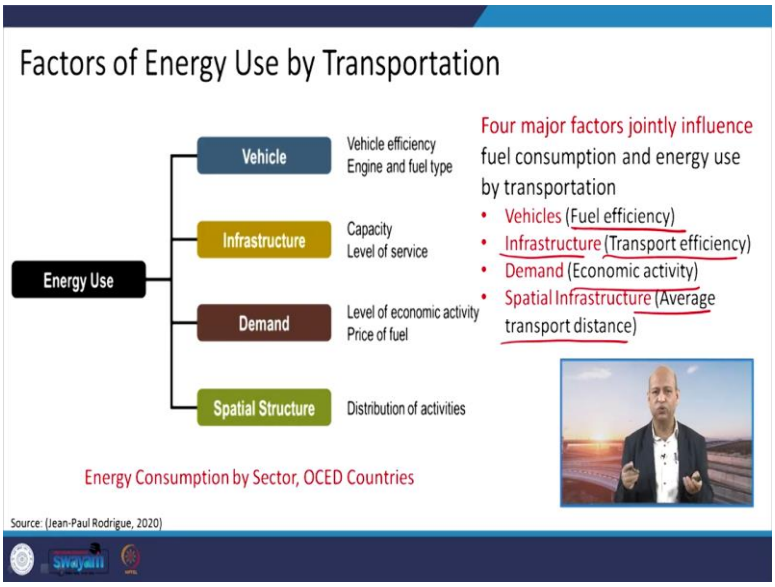

Then, what are the factors which are affecting this transportation related emissions. These are like vehicular efficiency, because for same distance if you have a good efficient vehicle, it will emit less amount of air pollutants, if you are using very old vehicle, which is not fuel efficient, it will consume more fuel it will cost you more, as well as it will pollute environment more.

Infrastructure means transport efficiency will depend upon infrastructure. If you have very bad road, you will, it will take a lot of time to travel from one point to another. Fuel consumption will also be more and that is why, now you can see our government is investing a lot of money in developing good highways and those kinds of road facilities transportation infrastructure.

Demand means economic activity, if we have more economic activity, then demand of mobility also increases even if you do online shopping something will come to you but that will be transported from one place to another. So, mobility has to be there. Then, spatial infrastructure like transport distance this will depend of course, in total design means, how design of the urban area has been there and do you need to travel from one place to another larger distances when you go to office or you can get accommodation here to office, all these influence the total emissions and contribution or impact to the environment.

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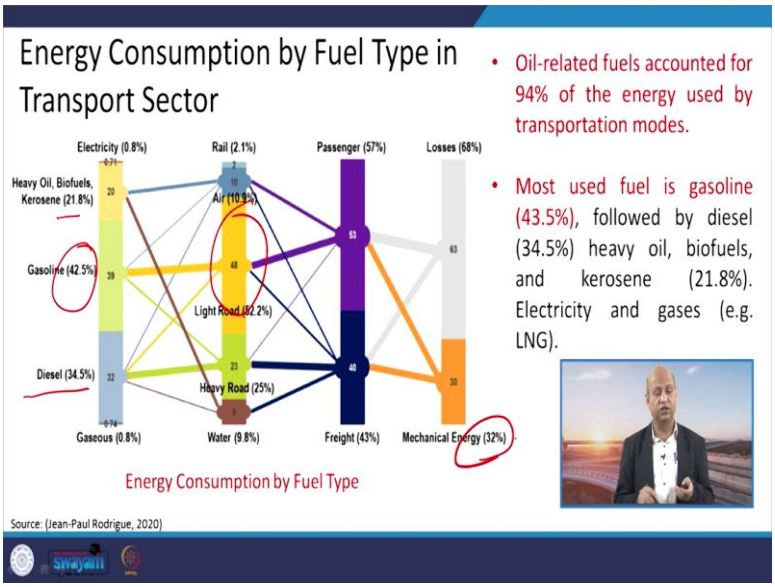

Like energy consumption, if you want to see, fuel type then there is interesting thing like diesel around 35 percent, share of the diesel, gasoline 43 percent and heavy oil, biofuels, kerosene etc. 21 or 22 percent. So, if you see this share of rail, air or light road and heavy road traffic. So, you will find that road traffic uses maximum share of this energy, consume maximum share.

If you divide it into passenger and freight, so, passenger share is more like 57 percent and so, and losses, if you want to see then mechanical energy, conversion of this chemical energy which is in terms of fossil fuel, when we convert it into mechanical energy when we are driving a vehicle then basically, we are converting the energy.

So, that is only 32 percent and losses in transfer of energy is very huge. So, there is a lot of scope that if we can have better transportation systems, where losses can be minimized that is a biggest scope to reduce energy consumption and thus reduce the emissions related to transport sector.

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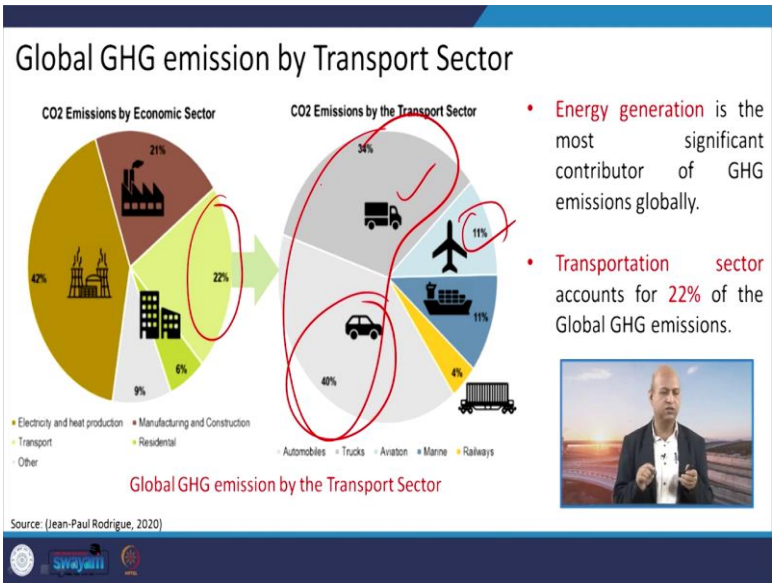

Now, if we want to see like greenhouse gas emissions, because as last time, we discussed that greenhouse gas emissions are the real culprit for climate change related aspects. So, greenhouse gas emissions if you want to see in different sectors like these 42 percent for industry and heat production etc.

And their share of transportation sector is 22 percent. Within this, if you want to divide it into you want to see the broader picture, then trucks like they have 34 percent, aviation 11 percent and these road transport automobiles related is around 40 percent and in total truck and this automobiles, they becomes around 70 percent.

So, huge scope is there for reduction of greenhouse gas emissions from road transportation sector and that is the reason why world over electric vehicles is being discussed that, can we have electric vehicles. Because road related emissions directly affect our health. The reason is the emissions are at the level where we inhale, we do all the activities. Means, of course, some people argue that when you use electricity, you are also producing electricity from coal-based power plants.

So, emissions are there, but there is a difference, because coal based thermal power plants are emitting emissions at a very, great height because of these stakes. And when it comes to the ground level, it gets diluted. So, a lot of difference is there when we are emitting emissions from the road transport sector, then we are emitting at the level of our inhalation and our respiratory system gets very badly affected. So, there is a huge scope if we go for de-carbonization of the transportation sector or electric mobility, lot of advantage may be expected.

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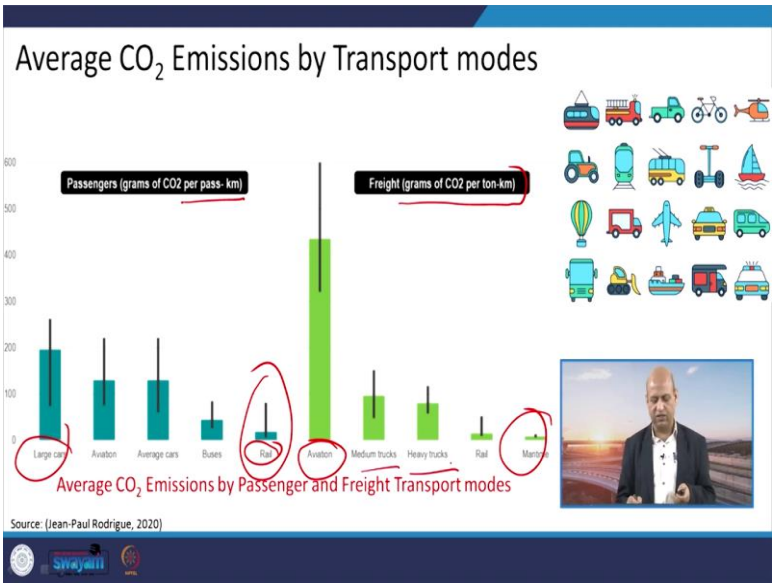

If we see like average CO2 emissions from like passenger part or freight, means these major activities which are used for transportation, means for this transportation sector is responsible. So, like large cars, rails, so rail is, when it is taking passengers So, grams of CO2 per passenger kilometer, so that means, railway is the very good transport sector, although here inland waterways has not been included, but that is more environment friendly in terms of emissions, if we can calculate.

So, average cars or aviation all these are higher ones per passenger kilometer, but railway is good, so maybe we can promote railway and we can link them with the inland waterways. Freight, if you see the freight's share, then grams of CO2 per ton per kilometer emissions means one ton transferred, transported for one kilometer, then how many tones or grams of emissions of CO2 will be there.

So, in that sense, aviation is the largest contributor means that means our most of the freight is transported by aviation from around the globe, you can see. So, can we reduce it? Because maritime is quite less, but there are other challenges, of course, so those challenges we have to keep in mind, but then medium trucks and heavy trucks they also have larger share on the road.

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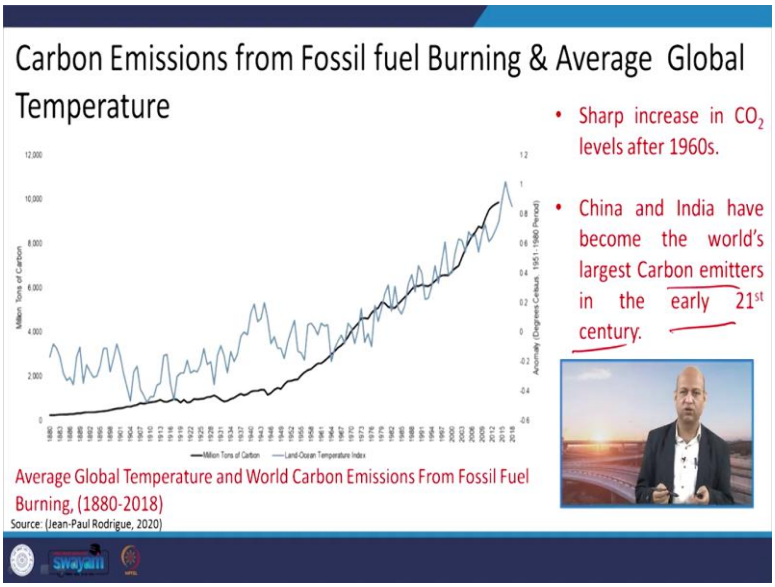

We have seen this kind of trend in last lecture that carbon emissions from fossil fuel burning and the average global temperature they have good trend or good relationship means they are increasing since last two centuries in a big way and the temperature is also increasing and China and India becomes the world's largest carbon emitters as per estimation, but US is the top one in terms of air pollution and greenhouse gases that we have seen in the last slides.

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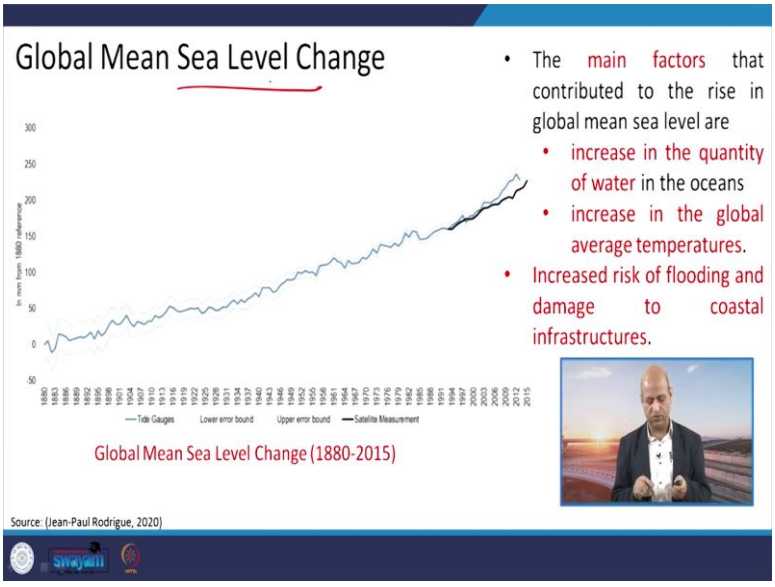

Then, global mean sea temperature is also increasing or sea level is also changing, temperature is another aspect and sea level is another aspect. So, sea level is changing that means coastal cities they are under threat. So, we have to address those issues also.

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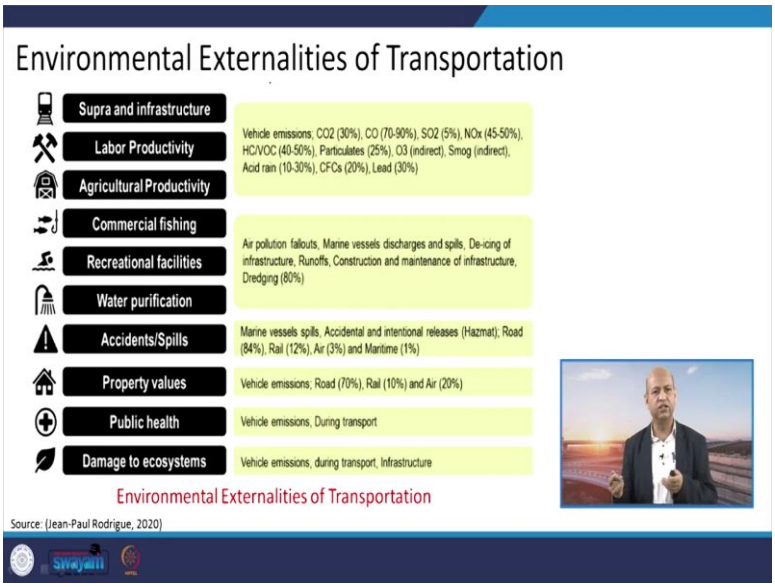

Well, when we want to see all these things in terms of environmental externalities of the transportation, so there are plus things for example, we need infrastructure and mobility related transport sector because we have to move from one place to another, it contributes to the economy, it gives job opportunities.

So, there is a lot of contribution in the wealth generation of the country or society through transportation sector, but there are, so this this is good or plus point or positive externalities you can say, there are negative externalities, which we have discussed earlier also, that these emissions or like accidents or traffic congestion, which eat up our lot of time and then health effects, environmental effects or building damage because of other issues. So, those are the negative externalities.

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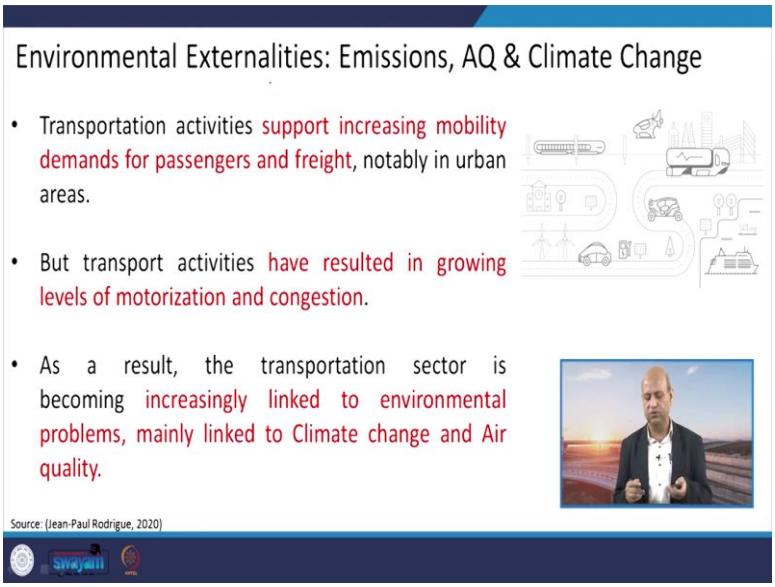

So, one part is of environmental externalities is related to emissions, air quality and climate change, emissions are there because of fossil fuel use and air quality has direct impact upon the human health as well as building material and those and climate change contribution is there due to greenhouse gas emissions and as we have seen, these are emitted a lot of by transport sector.

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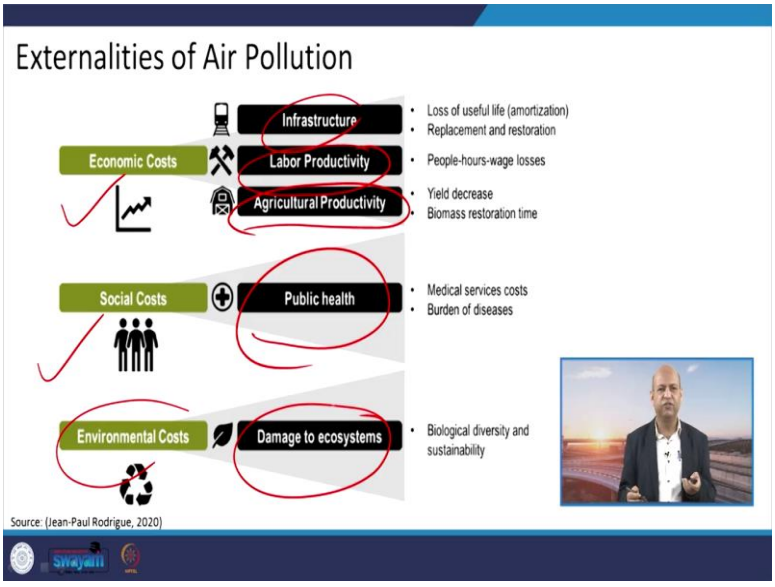

Externalities of air pollution means one part there are several externalities, if we talk about air pollution, externalities, then there are different costs, economic cost, because if we are ill, because of exposure to the air pollution, if we are having some respiratory problem, sneezing, burning eyes due to allergy and so, and if you are not good in health, so, either we will not

attend the school, college or office. So, if you are not going to office, we are not working then we are losing our salary in a one way or at least we are not contributing in the, this economic activity. So, economic losses are there.

Then social cost is there because of the public health in a cumulative sense and economic like agricultural productivity is reduced because ozone reduces this crop yield and labor productivity is reduced because people if they are not in good health then these are the economic losses, infrastructure related all these things.

Then, environmental costs, so damage of the ecosystem, whether it is air, water or soil or lakes or rivers or sea, so all those are environmental costs. Unfortunately, we do not include these environmental costs when we derive cost of any product or service and that is the reason sometimes these are neglected.

If there is cost of the environment, directly incorporated into the cost of a product, then people will think that how to reduce those impacts which are translating into cost. So, that is why like environmental economics is a big subject and they argue that we should include these environmental costs into products and services, then the principle of polluters pay will be implemented and maybe we can have better air quality and better environment.

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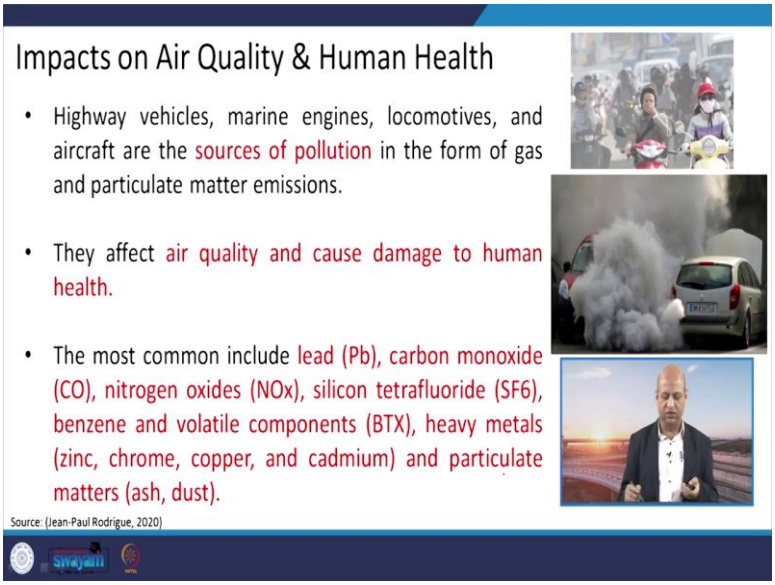

The impacts on air quality and human health, we have discussed several times like NOX or particulate matters, they have their own consequences to the health.

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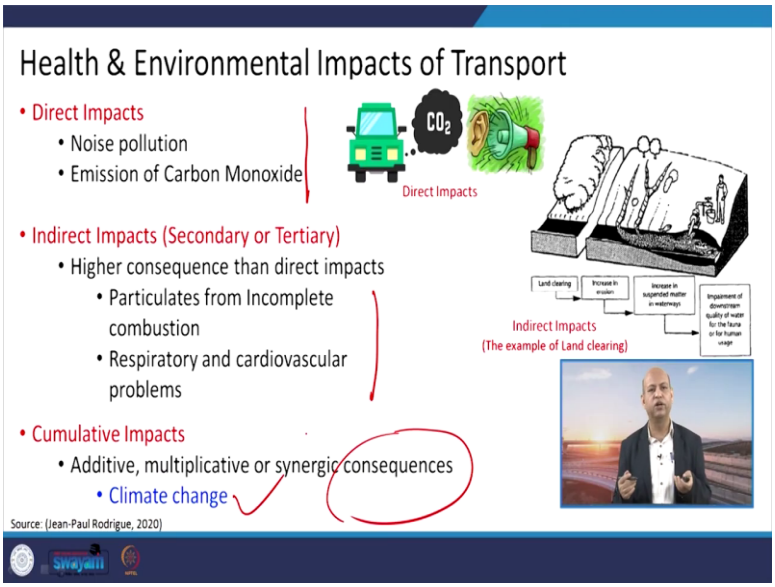

Plus, direct impacts, indirect impacts, direct impacts as noise or emissions of any air pollution, these are the direct impacts, and then indirect impacts, as we know that some kind of disease which is triggered by air pollutants or particulate matters, etc., then there are indirect effects of these transport sector, although, when we are using ambulance, that means, transport sector is saving our life.

So, means this is not just, it is only contributing to negative things, there are positive aspects, there are negative aspects, we have to enhance positive aspects, we have to reduce negative aspects. In cumulative impact, if we see, so like climate change, climate change is one of the cumulative effect of the transport sector related emissions and other things.

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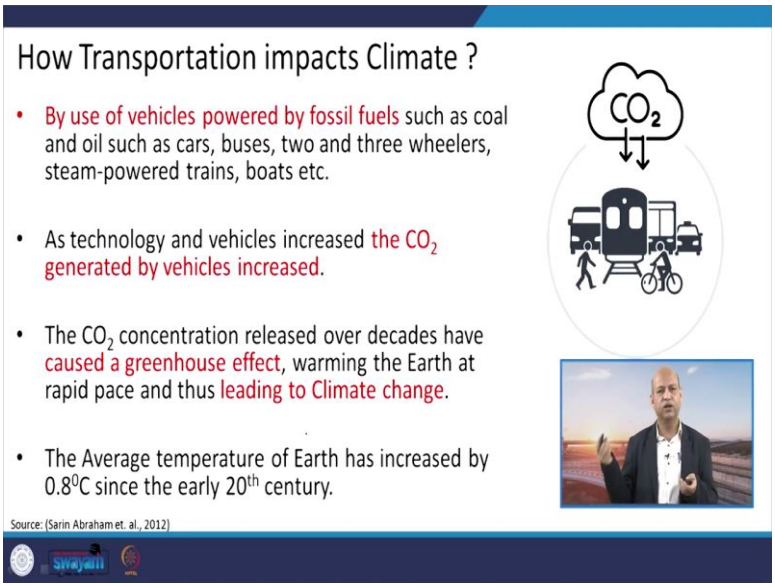

So, we see this how transportation impact the climate, very simple, because it emits greenhouse gas, CO2 and other greenhouse gases and they contribute into climate change, global warming etc. direct impact is there in that sense.

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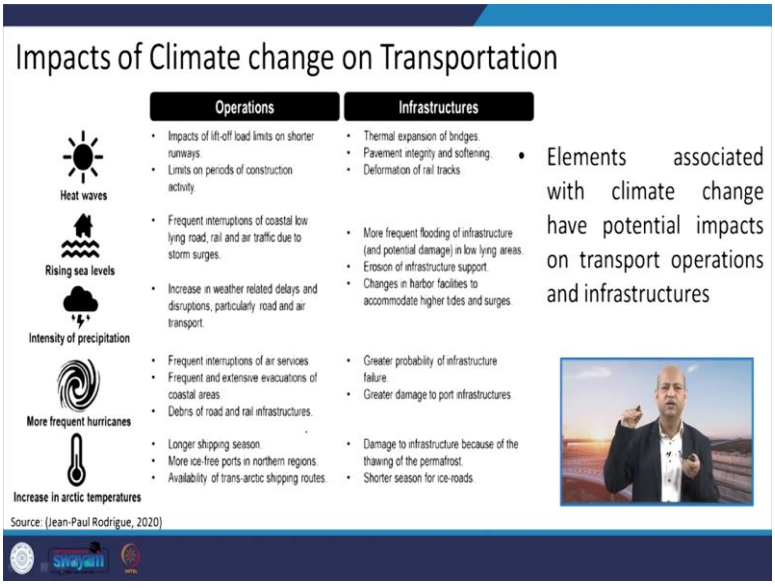

And the impact of climate change on the transportation can also be discussed. So, it is a kind of two-way process. One way transportation sector is enhancing the climate change and on other side, this climate change also influencing the transportation related infrastructure, because when we like are facing floods. So, roads are damaged. So, that is the cost to the transportation sector. We have to repair roads, there are other issues or if there is some acid rain or in coastal regions some sort of storms are there, so, the infrastructure is damaged, so,

we have to repair them. So, these are the cost or these are the influences of the climate change.

Even climate change also influence, for example, temperature of a particular place is growing where it has been a negative in the sense negative temperature not missing the higher altitudes, there may be kind of very cold regions. And if it is increasing, then some thermal related diseases may also be increased. So, those are the impacts of the climate change.

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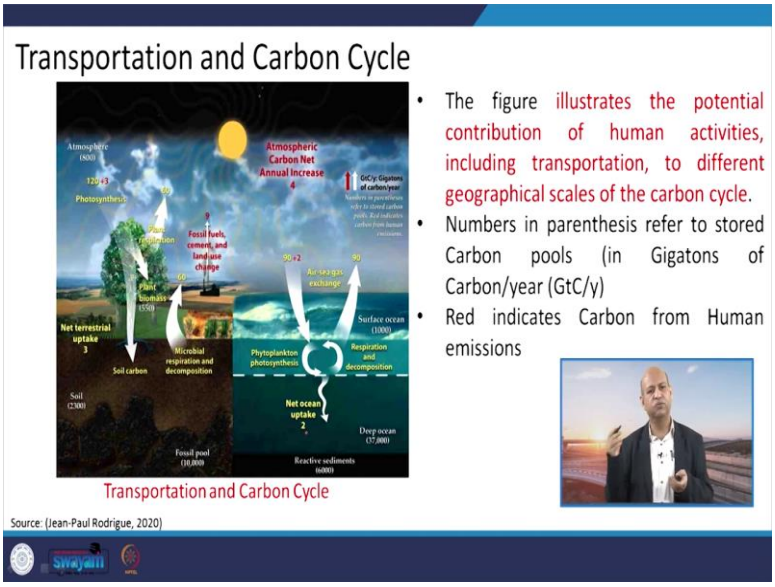

Well, if we see in the broader sense, the transportation and carbon cycle are related to each other because transportation is emitting this carbon related emissions like CO2 or hydrocarbons etc. And they are having consequences to the environment and to the health. And this carbon cycle also adding to like, sea is absorbing a lot of CO2, but at the same time heat, it is being heated up. So, its capacity also getting reduce, then if acid rain is there, so, forests are being damaged, and its sinking capacity of the CO2 is being reduced. So, it is a complex phenomenon, but transportation and carbon cycle can be linked in that way.

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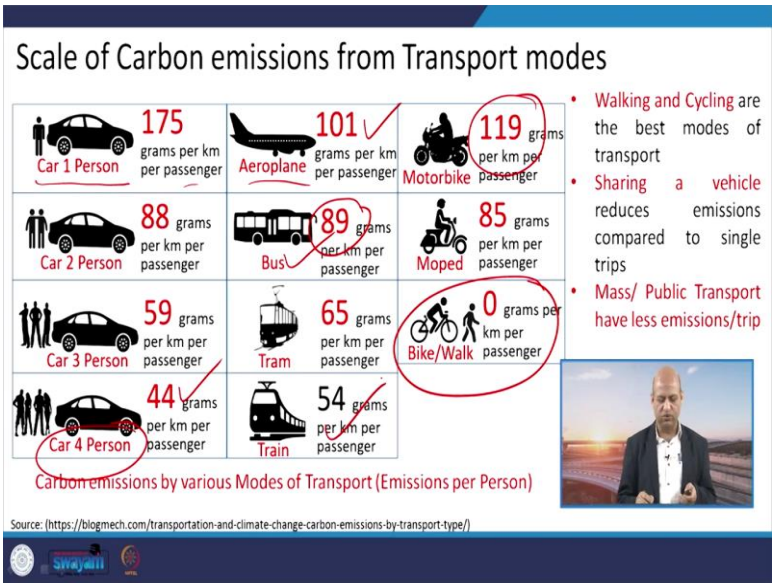

If we see the scale of carbon emissions from different transport modes, very interesting thing is emerging here like if we are using one person, one car, if it is using then 175 grams per kilometer per passenger is the outcome of this traveling and airplane is contributing around 101, and motorcycle is also contributing a lot 119, best is like walking or bicycle. So, they are contributing zero emissions to travel means of course, emissions are there when we are producing bicycles, but when we are using it there are no emissions.

So, this picture gives us that this kind of transportation sector we can increase or enhance or promote. Like, when car is being used by four people, so around 44 grams per kilometer per passenger is there. So, that means, carpooling is a good thing. And or buses when we are using then it is 89. So, that means per passenger per kilometer travel emissions should be very less only those kind of transport sectors we should promote, railways also good in that sense.

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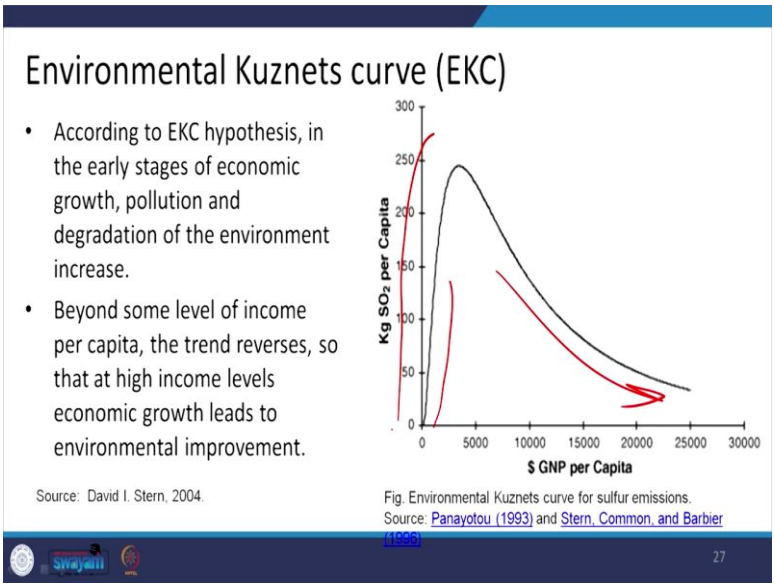

This is very interesting relationship of economic growth and environmental related impact. So, there is this very popular Environmental Kuznets curve, although there are now different research and this curve has been challenged, but it is very interesting to know that when economy grows as it is return, when in early stages, when economy growth is there, pollution also grows because we have less money to invest and we are trying to have better economy. So, environment is neglected and environmental damage is also there because of these environmental externalities of economic activities including transportation sector.

But when we have good amount of wealth at the national level or our per capita income has increased, then we are able to invest. So, that is why this per capita income is increasing and like the relationship of kilogram SO2 per capita is also increasing. After that, maybe they have applied some technology to clean the sulfur component of the fuel and, so more economic growth is there and less SO2 emissions is there. So, that curve can be seen in many ways means, like emissions of greenhouse gases or emissions of particulate matter, etc.

But now, because developing countries or who are having need for access for energy, etc. they have better options, I mean, it is not necessary that we have to go through this path only, this is only to show that sometimes it happens that environmental externalities are there and they are addressed when we have sufficient amount of money.

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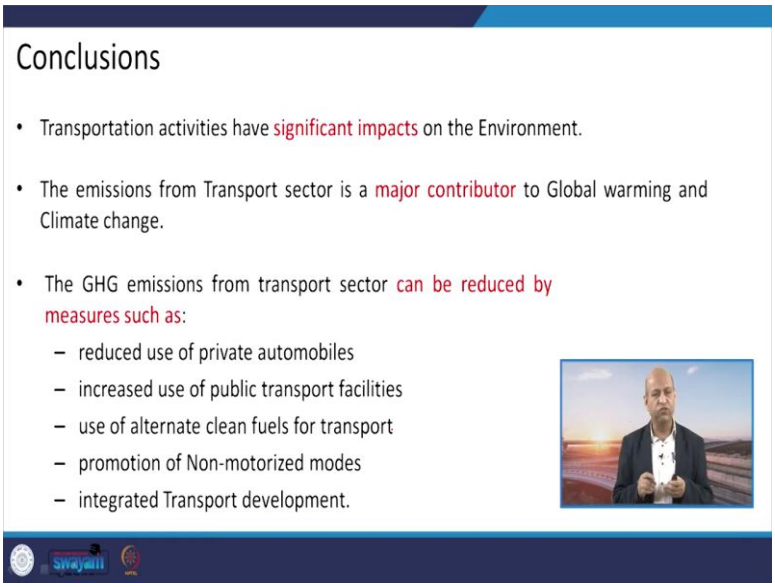

Well, in conclusion, we can say that there is a significant impact of transportation sector on the environment, it also influences human health, that we will see in detail afterwards. And if we go for integrated kind of transportation development, so that we can harness like this railways, integration of railways with the inland waterways or very less amount of emissions are coming from those kinds of sectors or vehicle categories or transportation modes. If we promote those kinds of transportation modes, then we are achieving good mobility as well as very minimum impact on the environment.

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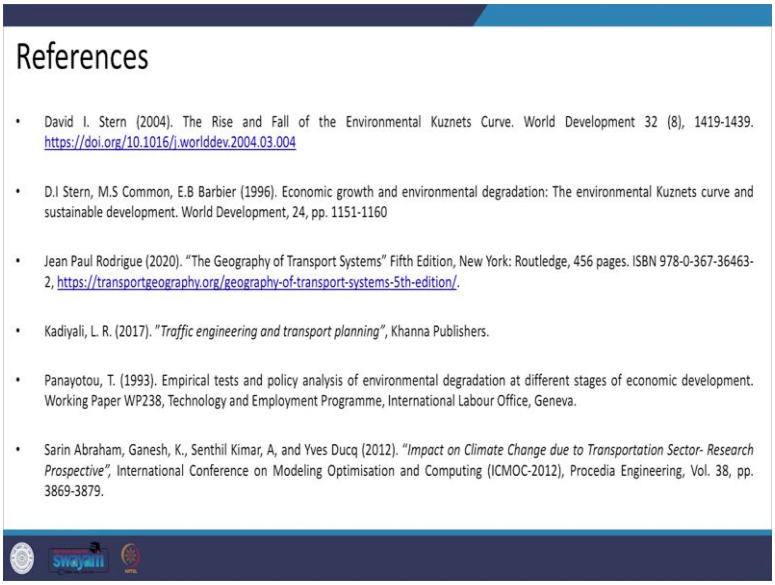

And these are the references. So, that is all for today. Thank you again for your attention, and have a nice time. Thanks.