Sustainable Transportation Systems
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Lecture 37
Material Flow Analysis - Case Study

Hello friends, so soon after the theory of Material Flow Analysis, today we will discuss a case study so that this, the methodology of material flow analysis becomes clear to you, how it is implemented because you have seen the difference between MFA that is material flow analysis or EIA that is environment impact assessment or LCA that is life-cycle assessment. We have touched it briefly in the last lecture.

So, the implementation of MFA or application of MFA tool or technique to look after or to look at the infrastructure related to transportation system we have a case study which is based in Vienna.

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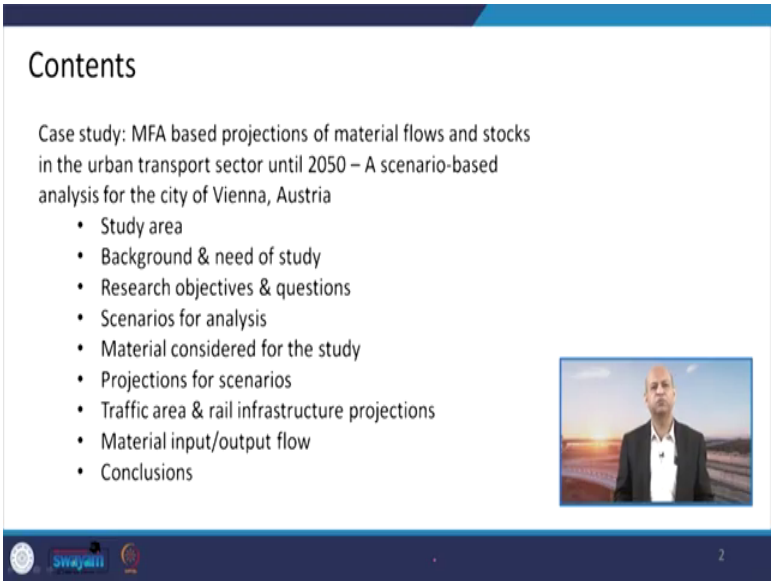

So basically, this case study is MFA based projections of material flows and stocks in the urban transport sector from 2016 to 2050 and this is a scenario-based analysis for the city of Vienna, which is in Austria. So, first of all, we will discuss briefly about the study area, then we will look at background and need of the study and then the research objectives and questions which have been problem statement, something like that and then the scenarios for analysis.

Different kind of scenarios like business as usual or some difference in motorized or non-motorized vehicles. So, different scenario for analysis we will discuss and then the material considered for the study, which particular material is to be analyzed with this technique, because there are some limitations. So, we will not go for every kind of material but certain material only which is more impactful or like that.

Then we will do the projections for different scenarios like how much material would be used or discarded or there will be decrease or increase in the material flow, in the stocks and flows, those kind of thing. Then traffic area and the rail infrastructure projections because those are the, rail infrastructure is basically part of the public transportation system.

Otherwise, traffic area also gives one insight that if area is reduced that means need of mobility in a particular, like privately owned vehicles is reducing and maybe public transportation system is taking care of, to meet the mobility related demand. And then material input and output flow we will see and at last we will conclude on the basis of this study, what are the lessons to learn from this study, how those projections help us to analyze the material flow.

And on the basis of that we can say whether this kind of scenario is better from this perspective of material utilization and reduction in the material used or this is not so good depending upon the increase in the material flow and something like that, because material flow is directly related to the resource utilization and whenever we are increasing the resource utilization basically it is increasing the impact on the environmental components whether air, water, soil and so.

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So, the study area is Vienna, in Austria and that is basically in Europe, because Austria is one country in Europe and Vienna is the capital city of Austria and it is the most populous city if we compare other cities of the Austria and with population of 2 million. So, please do not consider like Delhi or Mumbai which are 10 times more populated or something like that.

Means it is a small city in that sense but in European perspective or in Austrian perspective it is most populated. Well, this is robust public transportation system which is well connected with the regional economic activities so that kind of transportation system is there in Vienna and on the basis of that transportation system this study has been carried out.

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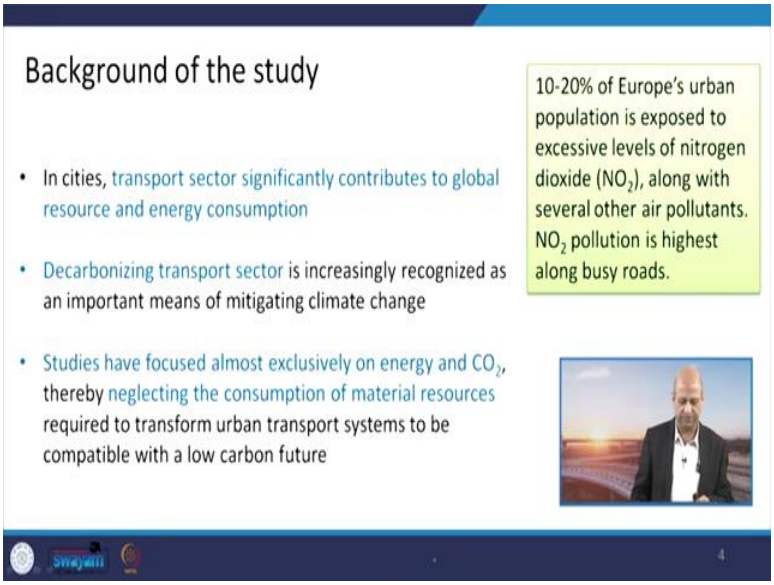

So, when we talk about the background of the study, basically this transportation sector contributes in significant way to the global resource and energy consumption that is why cities are known for highly active urban centers.

So, that is why we are choosing a city for this case study particularly, because in city, economic activities are more, need of the mobility is also more and that is why as you know that cities are known as engines of economic growth, because so many people are there, they are doing variety of activities so exchange of efforts and services and products, manufacturing of products then transportation of products and passengers.

So, many things are going on, that is why the huge resources and energy consumption are in cities and as per one estimation basically 10 % to 20 % of Europe's urban population is going to be exposed to high levels of nitrogen dioxides and as you know that NOX emissions are more from transportation sector. So, in parallel to these highways or those kind of roads, this increase of exposure of NOX emissions will be there.

But there is also one trend, which is like decarbonizing transport so that the emissions of hydrocarbons or fossil fuel-based emissions are reduced, so that means some changes are to be needed to do in, to be done in transportation sector.

So, this is one important means that if we can decarbonize it, then we can really mitigate the climate change related issues, because a lot of share is there from the emissions of transportation sector. Well, this study is basically focused on, like many studies are focused on energy and CO2, that is why this material flow is more important from the resource consumption point of view, material point of view, not the energy or emissions, but that also, that should also be taken into account so that the total picture emerges.

If we are concentrating only on emissions and we are ignoring the consumption of material resource then half picture is there, so if we want to have the total scenario then we should go for this material based or resources-based consumption and their trends and all those kind of figures should emerge.

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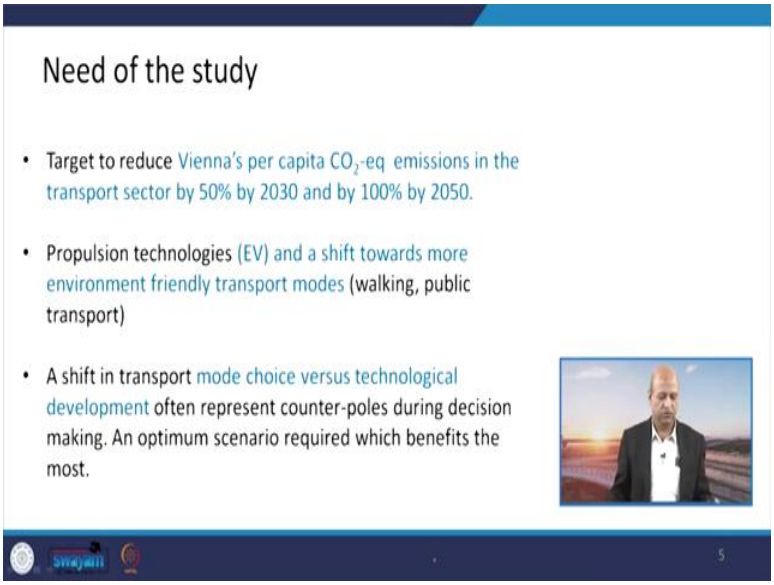

So, that is why this need of the study that the target is basically to reduce the per capita CO2 equivalent emissions in the transport sector of Vienna and like 50 % reduction by 2030 and 100 % reduction by 2050, that means by 2050, fossil fuel-based transportation sector should be abolished and some other system should be put in place. That is kind of assumption for this study.

And then these electric vehicles, these propulsion-based technologies should be promoted and the shifting towards environment friendly technologies or transportation mode should be there

like walking or public transportation. So, that the per capita emissions reduces and per kilometer distance traveled emissions should also get reduced.

So, the shift of the transportation mode, choices like technological developments, as well as different kind of decision-making tools in that sense, all these things are to be considered when we want to optimize the scenario, because sometimes you are reducing the material flow or utilization but the energy content is increasing, then that is also not good. So, a balance kind of condition is needed.

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So, the objectives of this study basically, the purpose is to see the effects of transforming urban transport systems for future material stocks or flows from material flow, using the city Vienna as a case study, that means the city boundary is there and what is material flow, that should be considered, not the regional one. That may be another study, but out this particular study is focused only in this boundary condition of the city.

Then the material flow analysis is only for the infrastructure and vehicles required until 2050, taking different kind of scenarios. And scenarios are mainly, these different model splits and time span for this particular investigation is 2016 to 2050. So, different kind of milestones are there in timeline and different kind of scenarios are also there. So, we will look at these immediately after this particular slide.

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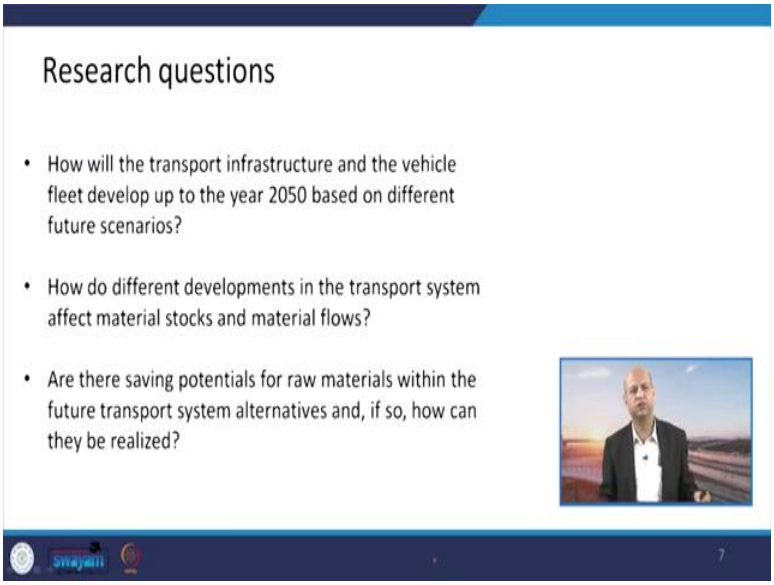

The questions for research are basically like how will this transport infrastructure and vehicle fleet develop in the future like in 2050, based on different future scenarios, like business as usual or emphasis on public transportation system, emphasis on electric vehicles something like that. These scenarios we will discuss soon after and then how do different developments in transportation system affects the materials, utilization and materials flow and stocks?

So, the total quantity, means different scenarios will give us different quantities, different share. And like saving potential of raw material for different scenarios, how much saving potential is there and in what way they will be utilized or applied in the real-world application.

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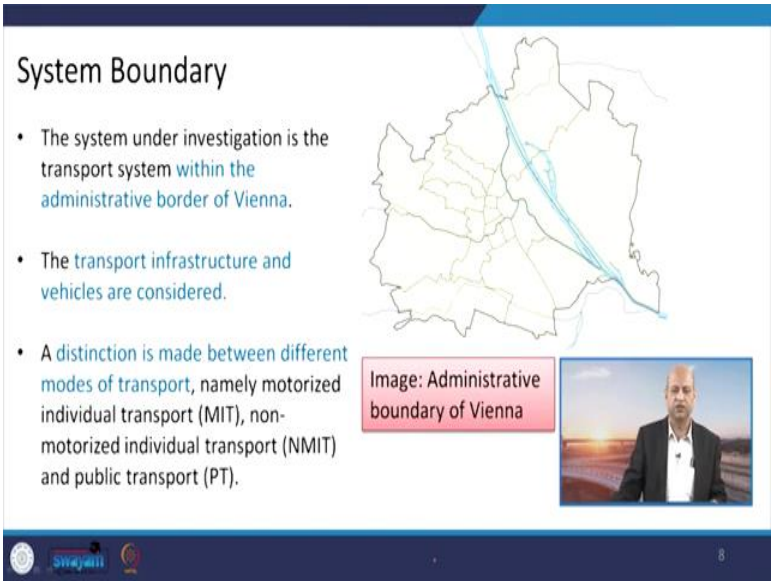

The system boundary as I said that we will focus only the Vienna city. So, the system under this investigation is the transport system within the administrative border of the Vienna, otherwise in suburban areas may also be there or some other counties or municipalities are there, but for only the administrative part of the Vienna which is the geographical area which is managed by only the Vienna administration, that will be considered for this study.

So, periphery related areas will be excluded you can assume like that, and this transportation infrastructure and vehicles are considered, and distinction like between different modes of the transport like motorized individual transport like MIT and then non-motorized individual transport NMIT or NMT, and the public transportation so these kind of distinction has to be made, so that what can learn that which kind of mode is increasing or which kind of mode is decreasing and their impacts on the material utilization. So, that clear picture emerges when we categorize in this fashion.

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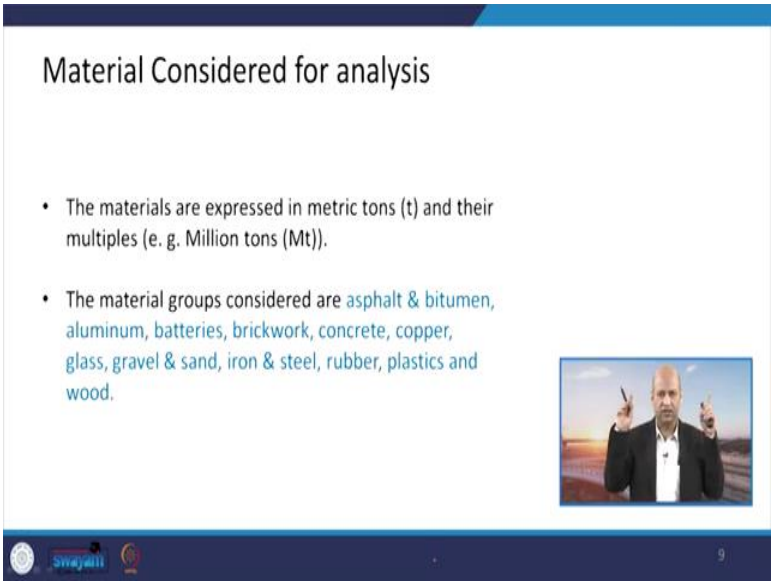

The material considered for the analysis is also to be known, so that we can go only for those selected one, so basically like the quantification has to be in certain units and that is metric tonnes or million tonnes, something like that, and the materials which has to be quantified are restricted on asphalt and bitumen or some aluminum or batteries and then the brick work or concrete, then copper glass gravel and sand, iron and steel, rubber, plastic and wood, these kind of materials have been included in this particular study. So, other material may also be there but they may be in very minimum quantity and for the sake of study that may not be so important. So, it has been excluded.

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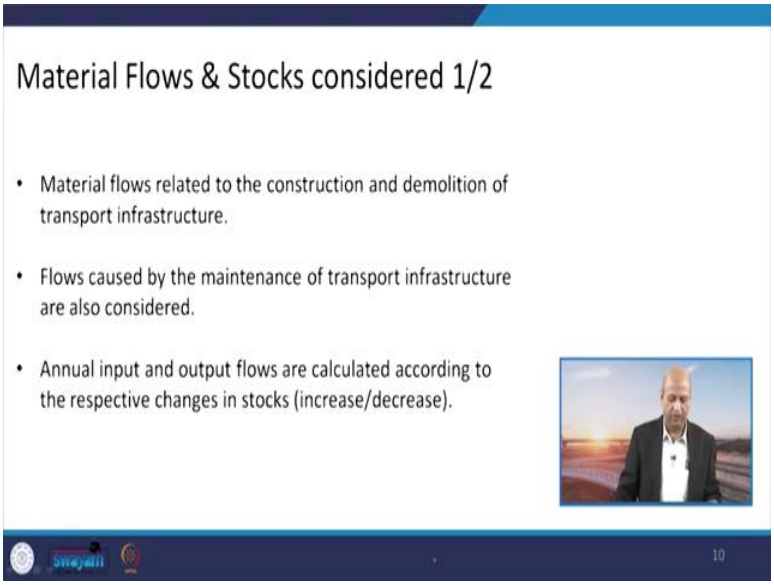

Well, when we talk about material flows and stocks, what kind of material flows and stocks we consider? Then basically construction related and demolition related transport infrastructure, so that flows has to be considered, means if you are, for a particular mode like if you are laying the track of the railways then construction activity will be there, some material will be utilized like gravels or land and then some filling in soil and then these steels all those kind of flow will be there.

If we are shifting from one kind of mode to another, so may be some roads are not needed, maybe some alternate routes you are giving in terms of railways or some other means so then this demolition will be there. So, those kind of, what kind of material will be extracted from that demolition road, so that will also be considered.

Then flows like for maintenance also, for maintaining the transport infrastructure up to the quality so that will also be considered, means construction, demolition and then maintenance and then annual input and output flows, which are calculated according to respective changes in the stocks, increase or decrease.

So, in annual quantification has to be there, so that comparison becomes easy to compare from one mode to another, how much material is extract, how much is used for maintenance, et cetera. So, comparison becomes easier.

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Then, as you can see like this railway network infrastructure in Vienna, so the materiel flow is necessary for maintenance, are based on the renewable rates and useful lives of the infrastructure and infrastructural components, so that means some components which are more robust so that will give a good inventory and utilization will be for more span of the time.

Then material flows associated with vehicle maintenance and the operation are not part of the investigation. This has to be taken in to account very clearly, because only in this particular mode only the material maintenance and construction that has been used, but for vehicle maintenance, whatever material, like if tyre is burst you are changing the tyre, so that is not taken in to account. Only for infrastructure has been taken.

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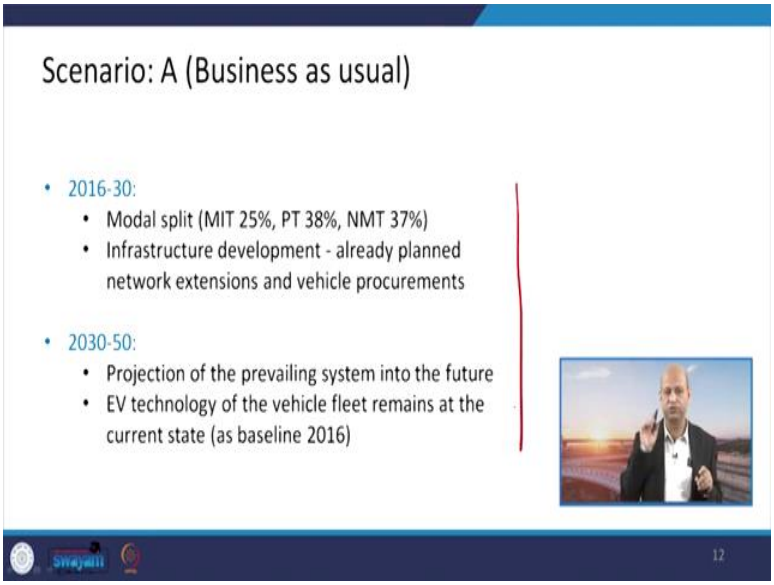

So, if you talk about this scenario A, that is the business as usual or BAU scenario, so this is, these are the values which we need to keep in mind. Like 2016 to '30, the model split has been considered like MIT 25 %, PT 38 %, NMT 37 %, total 100 %.

MIT here means motorized individual transport, and PT is public transport, NMT is non-motorized transport. So, you can see 30 % NMT, that is non-motorized transport like walking or something like that, and PT is public transport, railways, trams or buses. MIT is motorized individual transport that is privately owned cars or privately owned two-wheeler something like that.

Then infrastructure development, already which has been planned for the network extension or vehicle procurement so 2016 to '30, that particular scenario has to be taken into account. When we talk about 2030 to '50, then projections are basically, we are assuming that this, whatever we have seen that will continue but little bit EV technology will be there, like vehicle fleet remains, the current state as baseline date of the 2016. So, you can say that beyond 2030 to '50 also that the same thing will prevail. Those kind of values.

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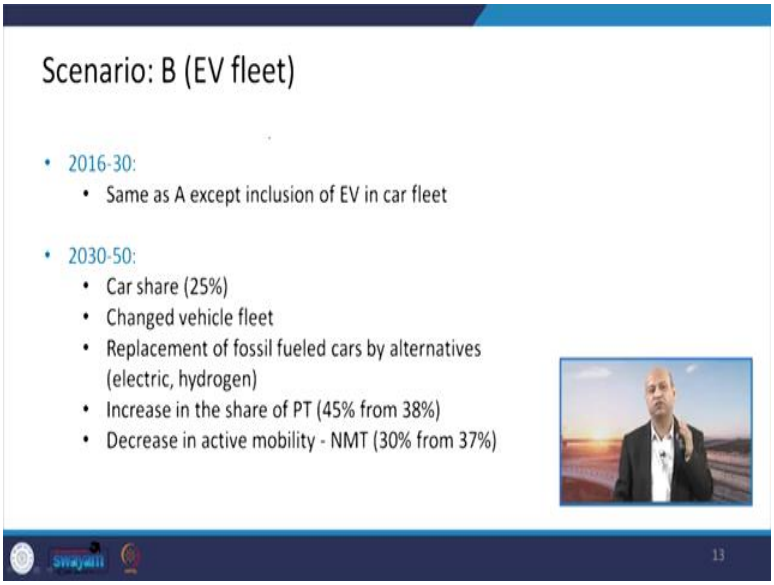

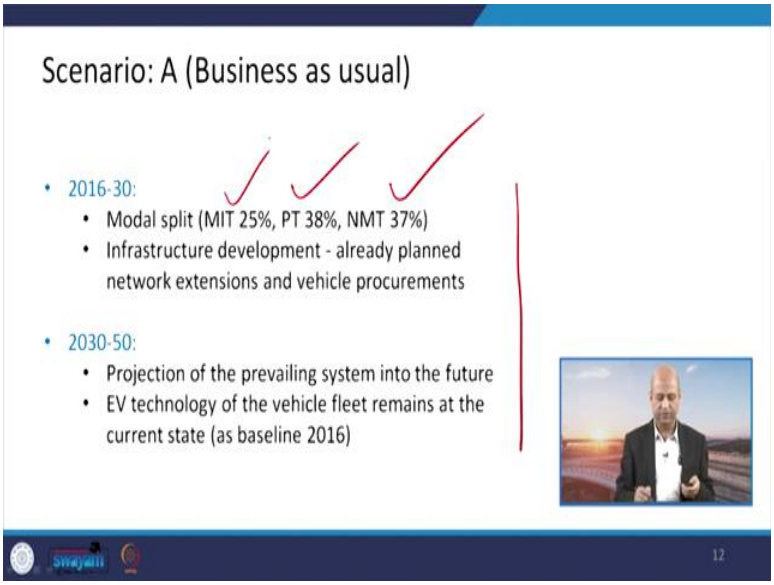

When we talk about scenario B, that is the EV fleet or electric vehicle fleet then 2016 to '30, same as BAU scenario, except that inclusion of EV in car fleet, so that is the thing which we should consider and 2030 to '50 basically the car share is 25 % and the changed vehicle fleet is there in terms of different modes and the replacement of fossil fuel cars by alternate, like electric or hydrogen fuel cell, something like that, that is also be considered. In BAU scenario that has not been considered.

Increase in the share of public transport 45 %, from 38 % like you can see 38 % here and it has been considered as 45 % in this scenario B. And decrease in active mobility that is non-motorized

transport, 30 %, from 37 %. You can see here it was 37 %, so now it is 30 %. So, those kind of changes have been considered in this scenario B.

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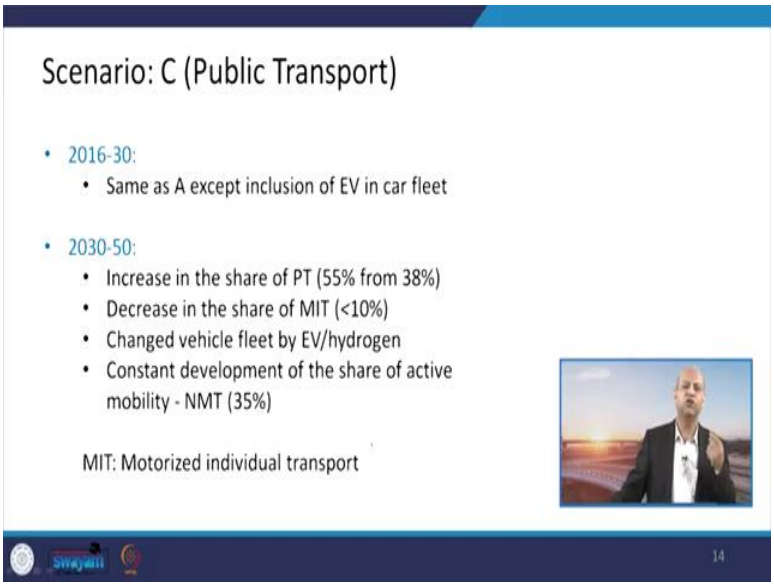

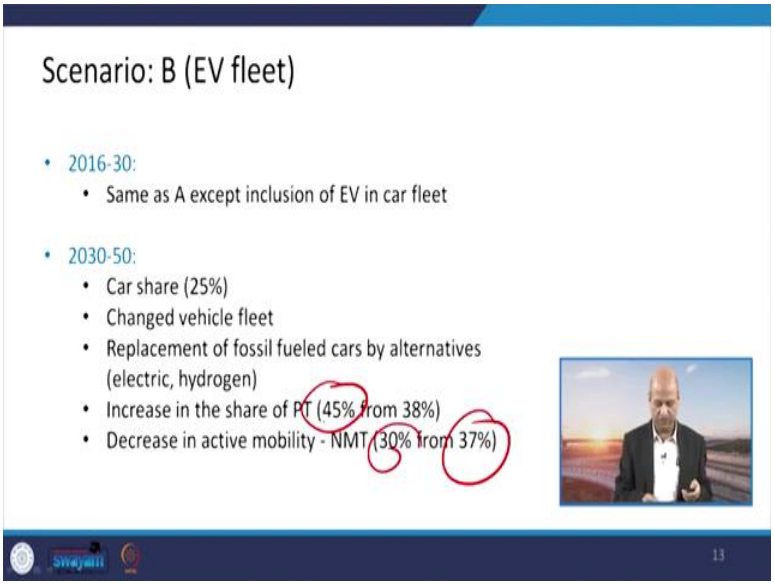

Then if you talk about the scenario C, which has emphasis, more emphasis on public transport so 2016 to '30 same as the A, business as usual scenario, except inclusion of EV in the car fleet, the same it was in the B also. From 2030 to '50 a lot of changes are there, like increase in the share of public transport 55 % from 38 % and in B it was only 45 % if you see.

Here it will be increased drastically to 55 % and decrease in the share of motorized individual transport that is less than 10 % only. So, the lot of shifting is there from privately owned vehicle to public transportation system. And changed in the vehicle fleet of the electric vehicles and hydrogen-based fuel cell and the constant development of share of the active mobility that is around 35 % or so. And as you know MIT is motorized individual transport.

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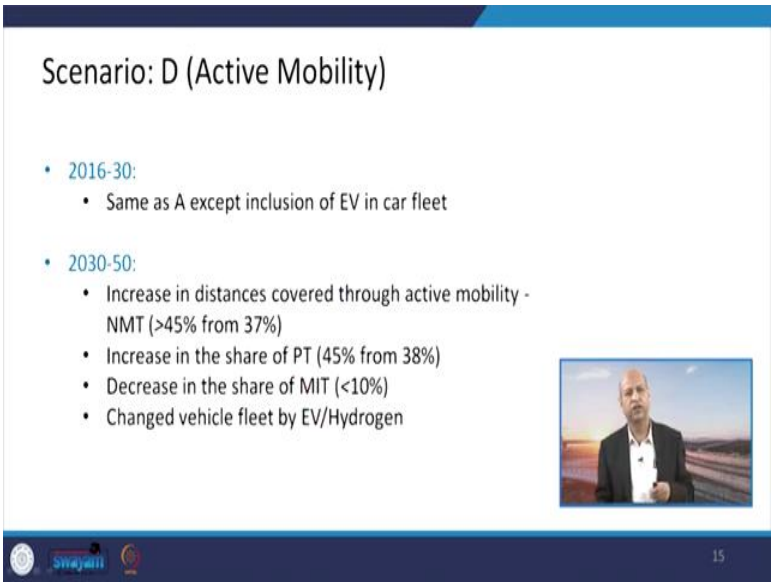

Scenario D, that is the active mobility. So, active mobility means you can see again 2016 to '30 it is same as B, C, in D also. 2030 to '50 then different kind of scenario is there, here increase in distance is covered through the active mobility that is non-motorized transport like walking, cycling, those kind of things.

It has been more than 45 %, that is very significant number and increase in the share of public transport, 45 %, again like B, not the C, in C it was 55 %. Decrease in the share of MIT less than 10 % motorized individual that is again similar to C and the change in the fleet like EV and hydrogen related fleet is also there.

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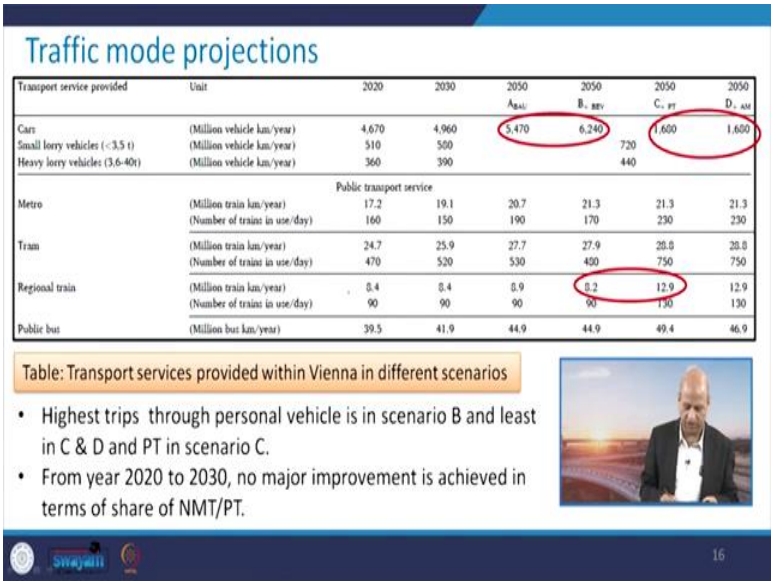

Now, there are interesting projections you can see, the traffic mode projections in these tables so there are values like 2050 and this public transport and this is active mode of transportation, it is there. Similarly, like regional train changes are there, but we are mostly focused on Vienna based related values.

So, the highest trips through personal vehicles is in scenario B, and least in C and D and public transport in scenario C, and from year 2020 to 2030 no major improvement is achieved in terms of share of non-motorized transport or public transport. So, those kind of values are reflected in this table.

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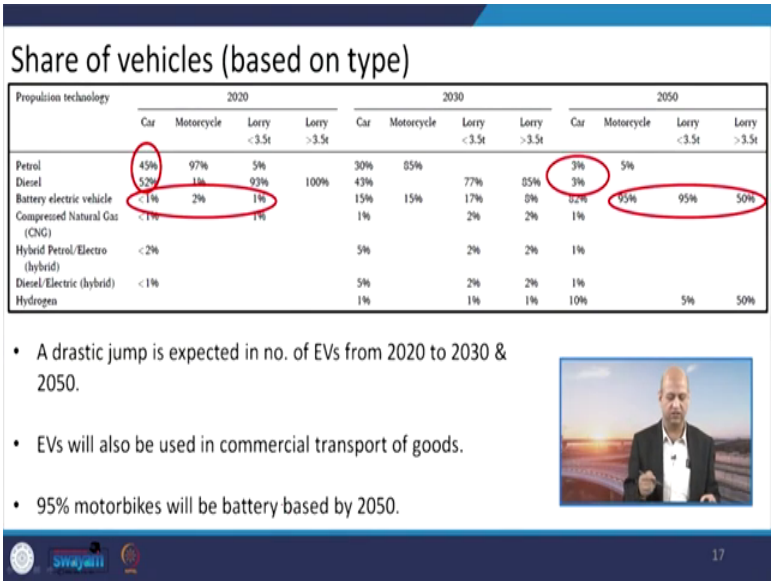

When we see this share of different vehicles so a lot of values are there, you can see this battery-operated vehicles, battery, electric vehicles, in 2050 like 95 % motorcycles, lorry 95 %. So, those kind of values are, means drastic jump is there, quantum jump is there. So, EVs in 2020 to 2030 and 2050 more number. And the commercial transport of the goods is also operated by electric vehicles. That is also one very interesting aspect. And as we have seen 95 % motorbikes operated by batteries.

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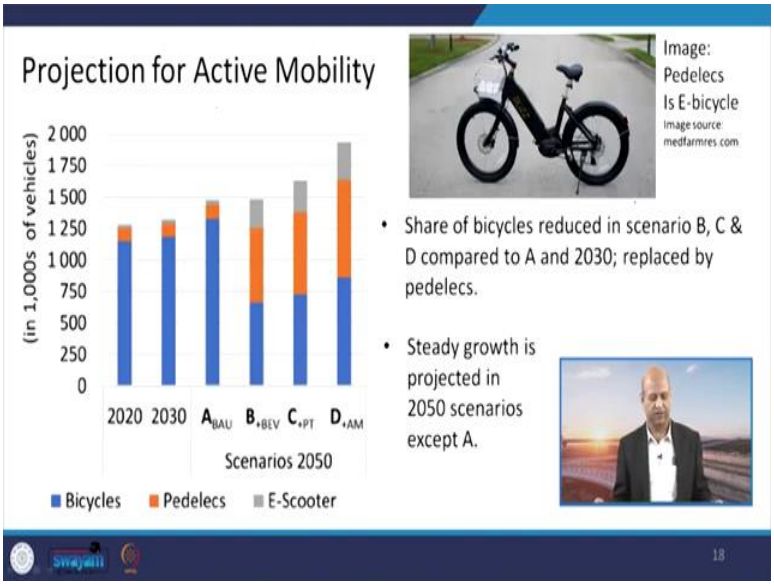

If we talk about active mobility that is cycling, bicycling or walking, those kind of scenario, so the bicycles you can see 2020, 2030, quite significant number is there and then this pedelecs like which has battery also so you can peddle as well as some power from the battery can be received so that will be, this pedelecs will increase in 2050, in all B, C, D, scenarios. Whereas in BAU scenario the bicycling is more. E-scooter is also increasing in 2050, so more battery-operated bicycles kind of things are assumed or estimated in this particular scenario.

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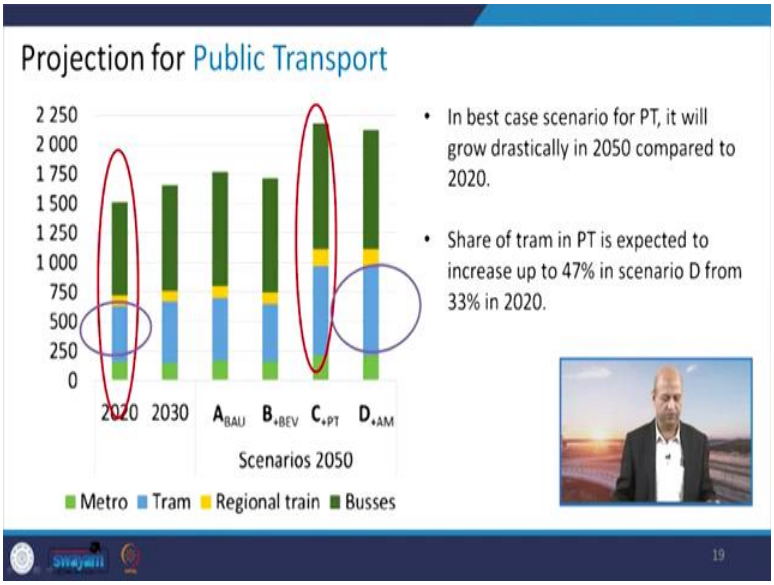

When we talk about public transportation system then metro, then tram and the regional trains and buses if you see, so in 2050 you can see these buses are more, the role of the buses is more, so public transportation increases and the tram's role is also increasing in comparison to this 2020, so the public transportation has to be like 46 % in scenario D, 33 % in 2020, so those kind of different values are there.

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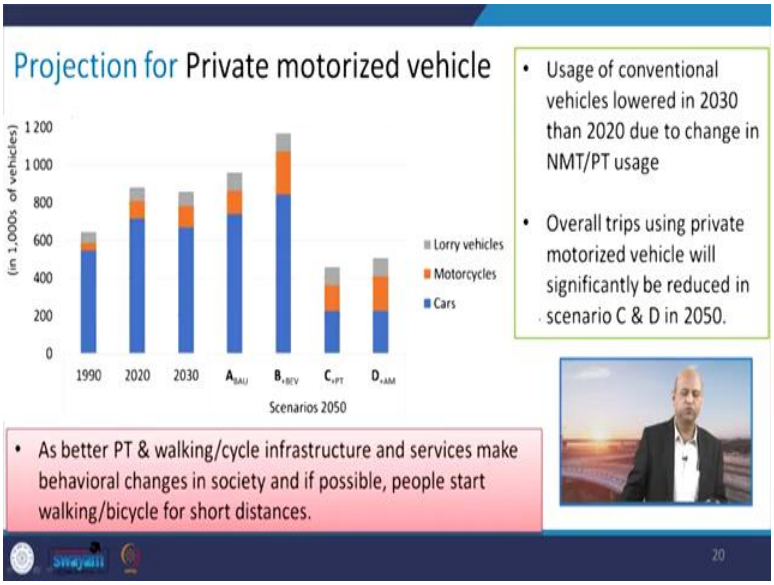

If you see the projections of private motorized vehicles, so when we talk about motorcycles or cars so they will be very less in these C and D scenarios, because more emphasis on public transportation system. So, that is why these kind of shifting is there from privately owned vehicle to public transportation system.

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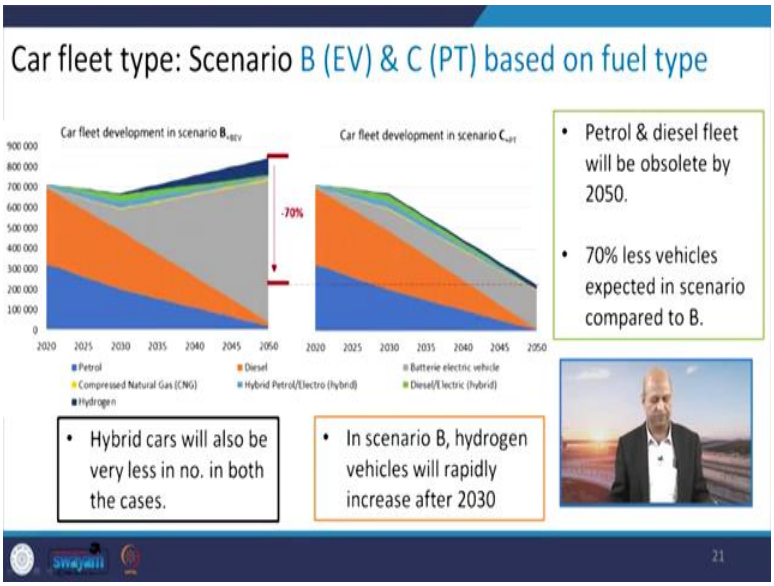

Well, car fleet scenario be that is the electric vehicle and public transportation fuel type so you can see in 2050, it is just drastically reducing and in scenario B hydrogen vehicles will rapidly increase, and also you can see the petrol and diesel fleet will be obsolete by 2050. That is the

scenario where the complete shift is assumed to electric vehicles basically. 70 percent less vehicles expected in scenario, compared to B. The reason is more public transportation system and more electric vehicles.

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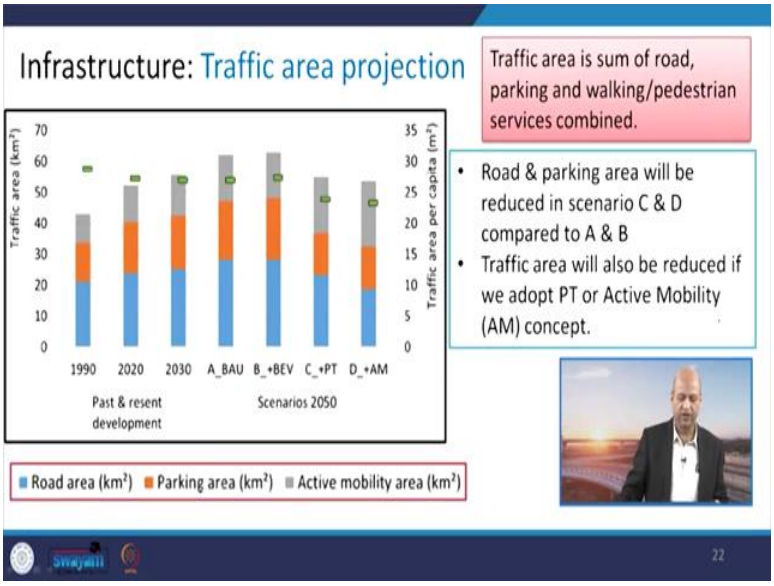

When we talk about the infrastructure that story was related to vehicles, but when we talk about the infrastructure so in traffic area projections like how much roads, area is, their land use is there for transportation system, so this is square kilometers you can see from 1990 to 2020, 2030 that is the increasing and then parking areas are also considered, road areas, these are the road area, this is the parking are and then the active mobility area, this gray.

So, you can see active mobility area is increasing in 2050, in C and D, and this road is decreasing. So, that means shifting towards public transportation system is really helping to have less kind of road network.

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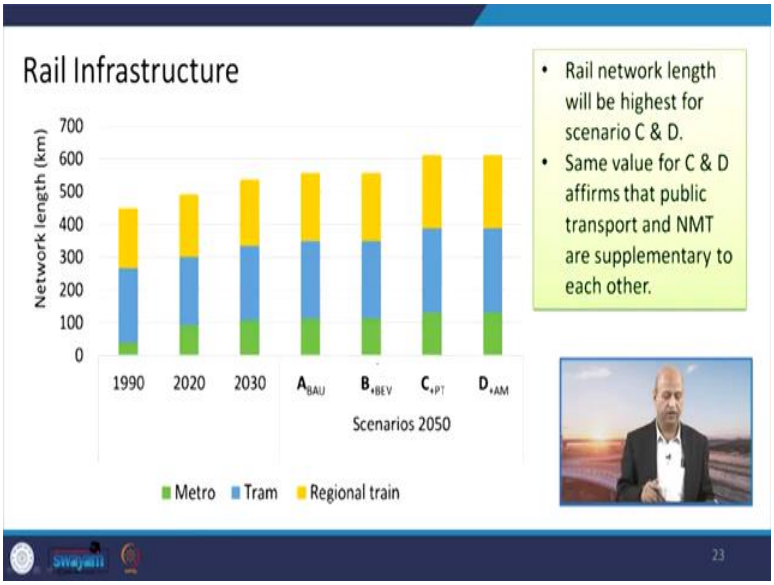

When we talk about the railway infrastructure then you can see in C and D, the railway infrastructure is increasing, whether it is regional train, tram or metro. So, metro is little bit increased, not much, but tram is increasing and the regional network, so total railway infrastructure is increasing.

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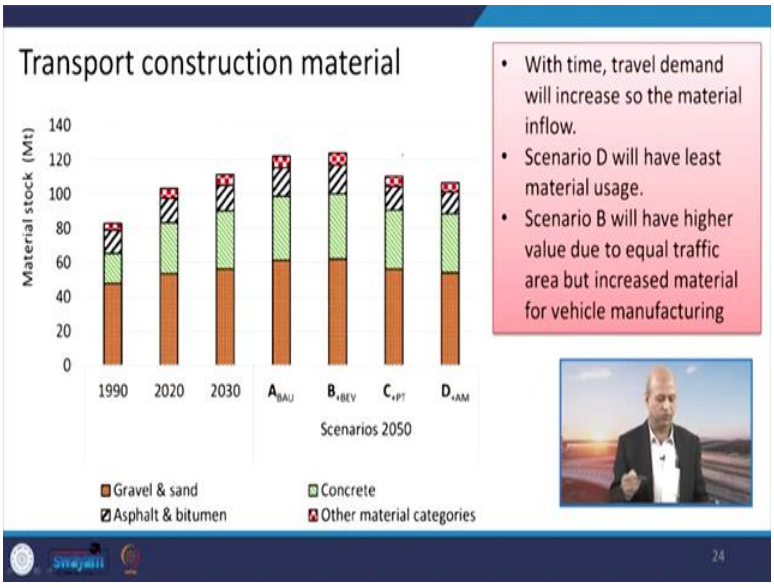

When we talk about the construction material like inflow and so, material stocks in million tonnes, so you can see like gravels and asphalt between scenario C and D, the total is reducing. So, that means the efficient system in terms of material utilization, because when road network is

reducing, we are rather getting material and out of deconstruction kind of a thing or demolition and the utilization of material is less required. This will be looked at another figure after sometime.

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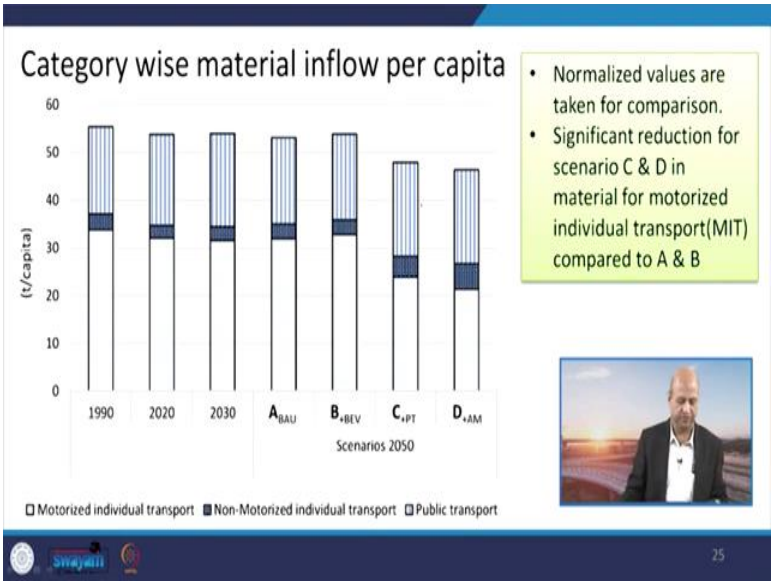

When we talk about category wise material inflow per capita, tonnes per capita so motorized individual, that is again decreasing you can see. Non-motorized it is increasing, so it is a good sign, non-motorized, public transportation also kind of significant, not changed but because this motorized individual transport is decreasing, so naturally the public transportation and NMT, non-motorized transport is increasing in that way.

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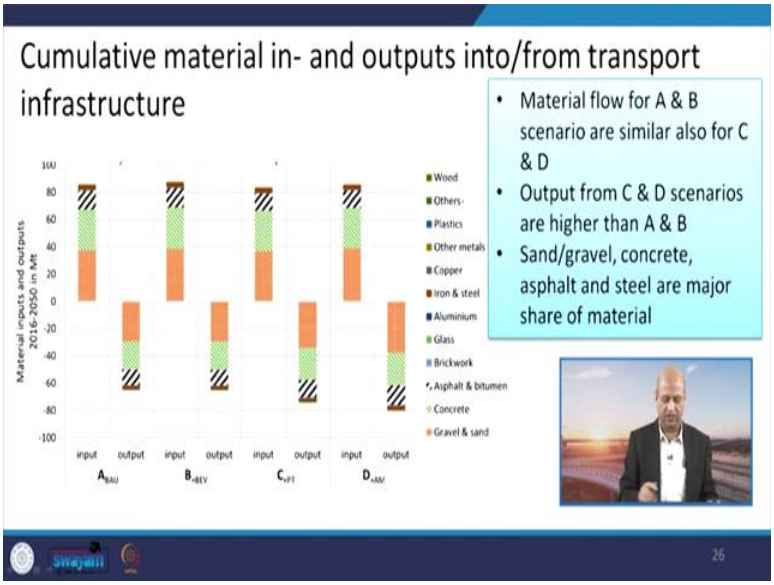

This is the picture I was talking about one slide before, that you can see this demolition related output. It is increasing. Because when you are demolishing something, you are mining and that is a term, urban mining or city mining, so when some old infrastructure is demolished, you get some raw material for another activity. So, this is increasing in this C and D scenario and otherwise the total input material is also less in comparison to the business as usual scenario.

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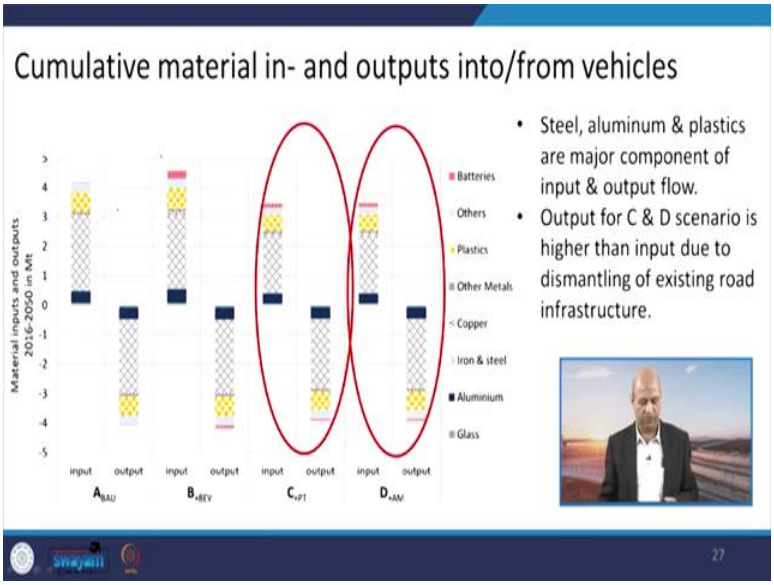

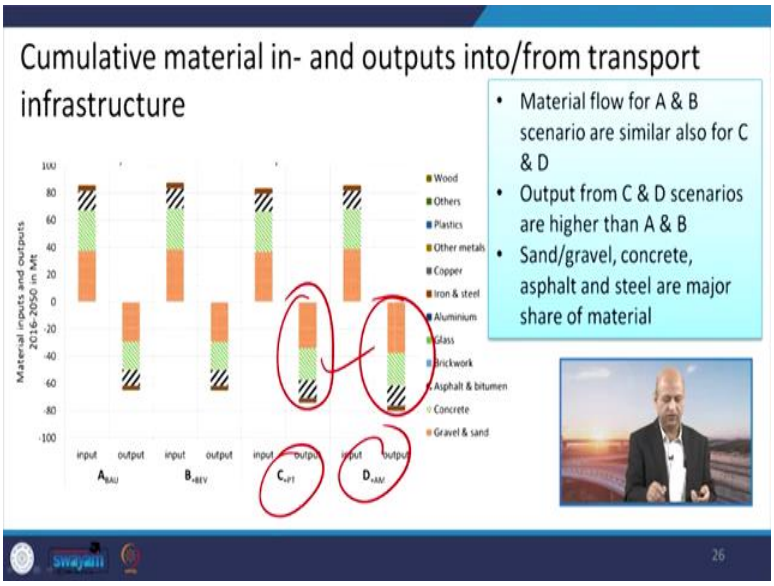

The similar thing is happening here also. The cumulative material input and output, into and from vehicles that was infrastructure related, this one infrastructure related and this is related to vehicles, so this is also the same thing, you can see. Off course it is not exactly same thing, but I mean to say there is a lot of reduction in this input. The reason is shifting towards public transportation and not on the motorized vehicles. And a lot of, because motorized privately owned vehicles are being discarded so that is why this output of material is shown here.

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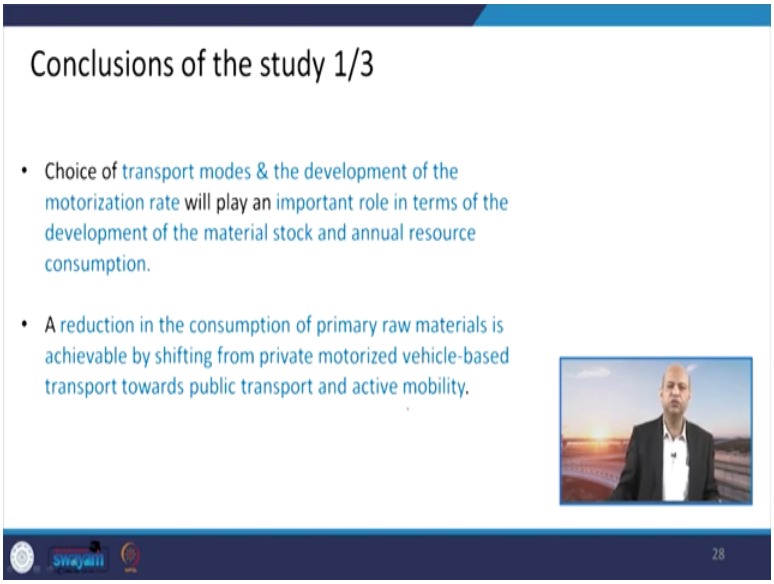

So, in conclusion if you want to say that material flow analysis, how does it really help us to get a better picture, so you can say that this transportation modes and development of the

motorization rate and then important role in terms of the material stocks and annual resource consumption, this MFA can give a better picture.

Because it is not only the emissions, but material flow is also important. Resource consumption is also very important. So, when we talk about reduction in consumption of primary raw material. That is seen by this MFA. You could see easily that utilization is decreasing as well as, because of some roads are discarded so demolition is happening so output is increasing in that sense.

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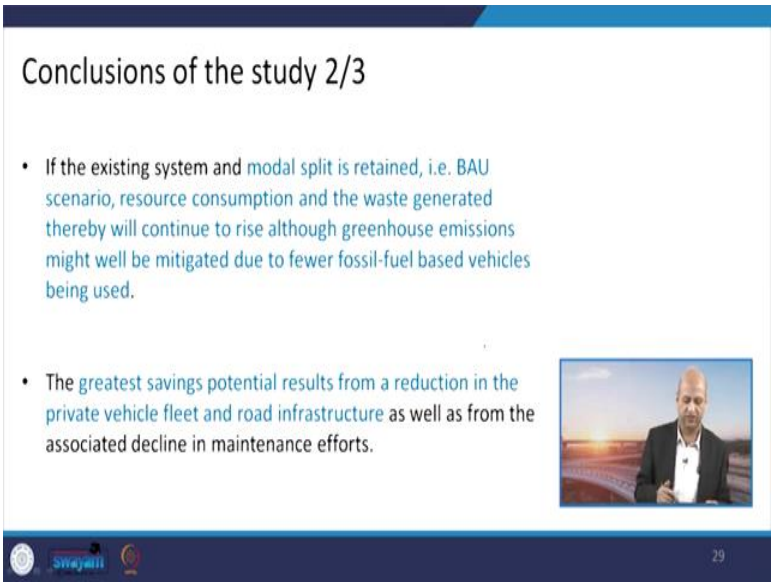

Then existing systems and modal split and BAU scenario, the comparison can give us a better picture, whether the hybrid system or the electric vehicles and the public transport, it is beneficial or not, in terms of material consumption. The greatest savings potential in reduction of private vehicle fleet and increasing of the public transportation system is clearly visible, because of this.

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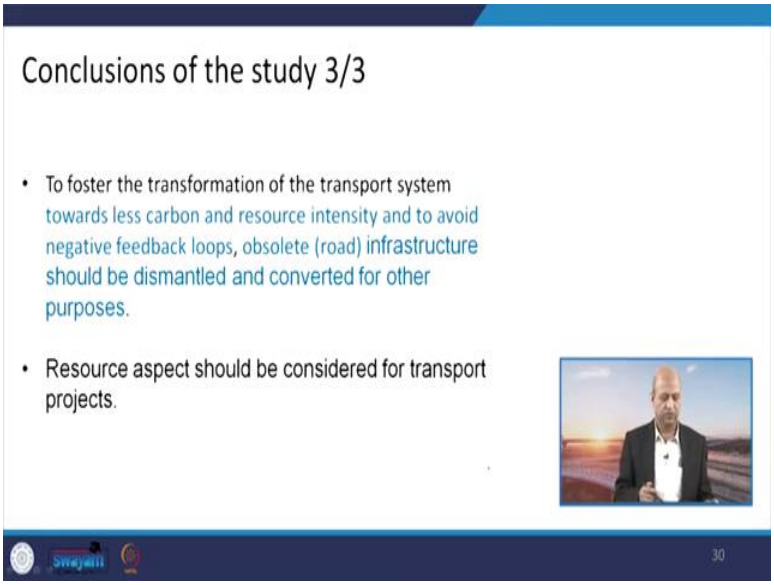

So, you can see that this transformation of the transport system towards less carbon and less resource intensity is basically when we go towards more public fleet and the obsolete roads are demolished and then we can get for better purpose those kind of resource material. And this resource aspect is to be considered for transport projects not only the energy and emissions. Because this study gives us insight that material consumption, resource consumption is equally important and we should consider them and this MFA can give us better insight.

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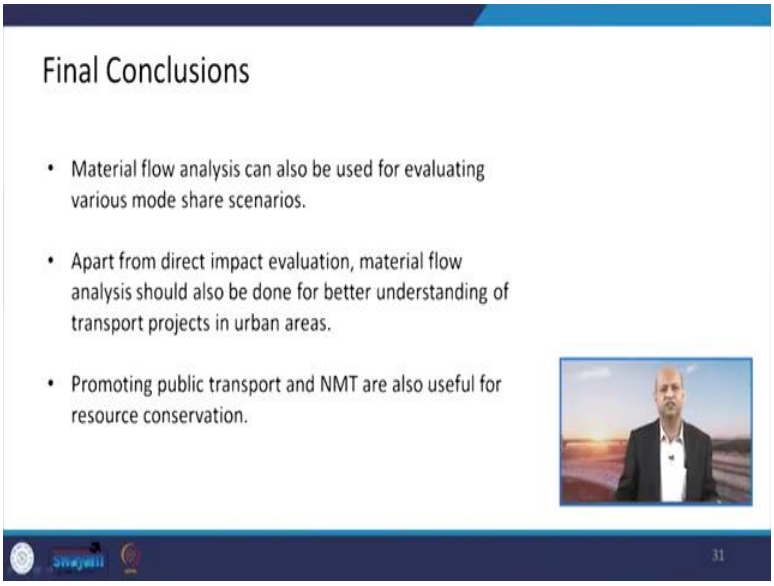

So, finally we can say that by using this MFA or material flow analysis we can evaluate various modes of the transportation and their share as per different scenarios, and the direct impact evaluation may be there but the indirect impact is also there in terms of material flow and stocks, because when some mode is being discarded like private fleet and we are shifting towards public transportation or battery driven vehicles and no fossil fuel related infrastructure is required then a lot of benefits can be seen in terms of infrastructure usage.

Promoting public transportation and non-motorized transportation it is also useful for resource conservation, because otherwise if we have more personal motorized individual transport vehicles then the tendency is that we have to use more material inflow in terms of vehicles as well as in terms of the infrastructure related to running those vehicles.

Because then you will need more garages and petrol pumps and transportation of the petrol or fuel, etc., all those things are related to that. So, if you can shift towards battery then scenario becomes much better in terms of, like less resource consumption, less material flow, less material stock.

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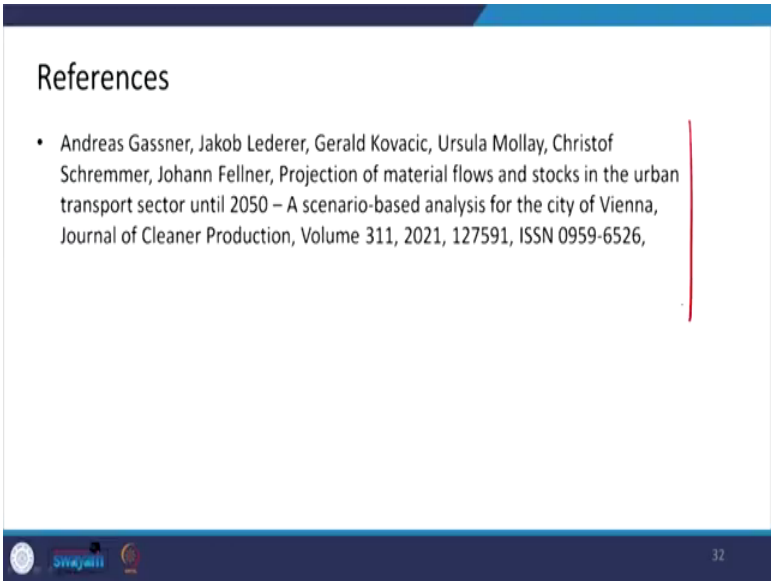

This is all for today and this is the basic report where from we have taken this information for you. So, if you are interested you can go through in detail, you can learn more about this MFA analysis. So, this is all for today. Thank you for your attention and see you again in another topic. Thanks.