Introduction to System Dynamics Modeling
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Casual Loop Diagram Part-3
Lecture - 4.1
Study Traffic Congestion using CLD-I

So, today's class most of time we will try to spend in looking over a case scenario and then followed with some practice problems problem.

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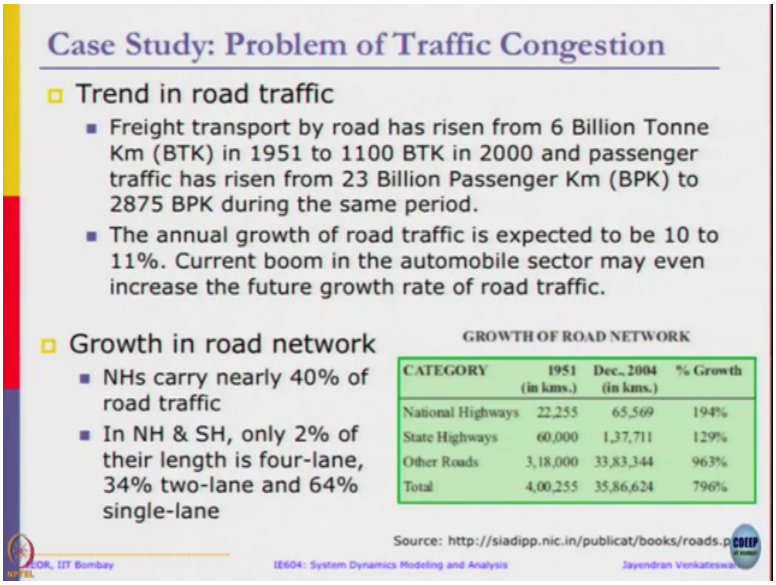

So, as a case study let us take a look at this notion of say Traffic Congestion. So, this can even illustrate what kind of policy resistance that comes up and how we can iteratively build a model, let us try to encompass at least a key aspects towards traffic congestion. First some background. So, there the freight transport by road has risen from 6 billion tonnes. This for

statistics for India in 51 to 11 million tonne per kilometer in 2000. So, for 50 years and passenger traffic has also raised from 23 billion passenger kilometer to 2875 billion passengers per kilometer during the same period.

So, the order of the growth has been tremendous. The annual growth rate of traffic expected to be 10 to 11 percent when was a boom in automobile structure sector that leads to increase in road traffic in the future. So, that is a part of the traffic, but when you look at the capacity that is a road network national highways carrying a 40 percent of traffic among national highways and state highways, only 2 percent of the lengths are four lanes, 34 percent two lanes, 64 percent single lane. This is as of 2004.

It is not that updated, but both would have increased since then. So, we can assume a parallel or similar kind of increases or increase in the cars on the road versus road network. Main area is a trend. The growth percentages that has been tremendous both in the capacity as well as the in the traffic.

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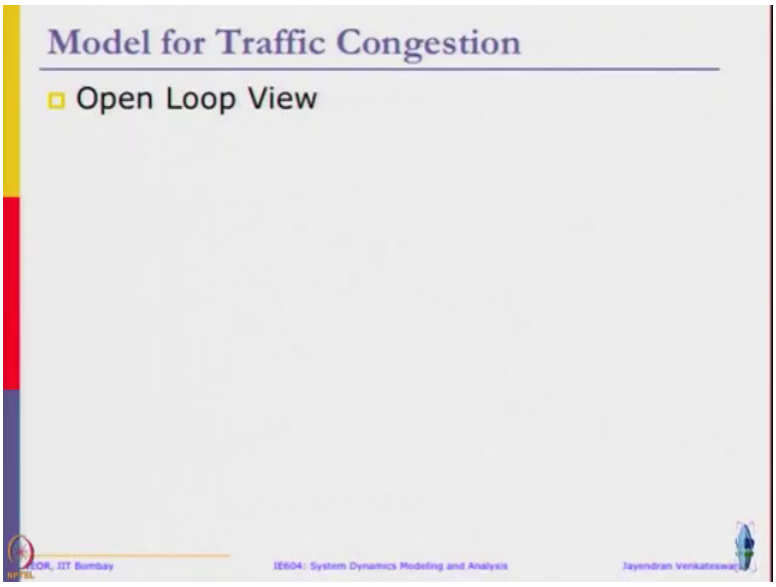

So, now this is, so we like to now model this concept of traffic congestion as well as how we are going to say increase the capacity. The simple example we saw last class as an example for delays itself captured this where you try to model traffic congestion as well as the how do you add capacity, how do you add capacity to road network increasing amount of paved roads. So, you can reach further places or widening the existing roads. Either way it is going to involve construction.

So, only we are going to increase capacity is going road construction either way. Maybe we will build better bridges, you know do some shortcuts for different locations tunnels or then expand the road network by widening the lane. Widening is very common as well as the expanding the reach of paved roads into more remote areas and new locations and things like that, ok.

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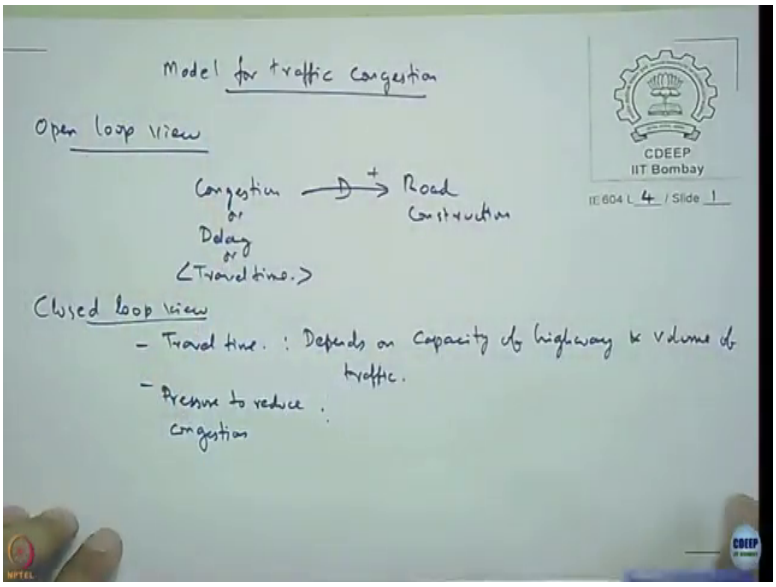

So, model for traffic congestion that is you can open loop view, but we make what we want to try is that I know there seems to be some congestion. You know when how to measure congestion? Congestion in the road after a delay we find that road construction happens most of the time it is not the other way like initially there is a lot of congestion, then government invests in expanding the road facilities there.

And as soon as road construction is finished, traffic seems you know lighter and going smoother right. So, how do you measure this congestion, how can you measure this congestion, but what do you mean by congestion. Anyone? Density of vehicles on the road what does it affect?.

Student: Speed.

Speed eventually what?.

Student: Time.

Travel time. So, what we are interested in is congestion or delay or let us make a better road called as travel time. So, we can expect that as travel time increases and we want after some delay, it will prompt action to expand the road capacity by involving road construction, right. This is what we want to do because a density in one hand can be little misleading because it I just taking it point in time or the speed can be regulated, but as long as traffic seems to be moving and you are getting from one point to other within your preferred travel time, then people are happy ok.

But this kind of open loop is not sufficient because even in my own I mean your own narration in our head what we want to do is, move now towards the let us start at the basic closed loop view. So, close loop view let us use couple of variables, let us call it travel time and ok.

What we are trying to model is this entire scenario of how traffic congestion as well as the moment in the road traffic, how it is affecting our road construction, highway capacity expansion and the interrelated system within that. So, that is a very broad scope and we will just iterate it and move ahead.

So, let us define congestion by using what we call as travel time, what affects travel time and some of the things is already given what affects travel time density or you have the number of vehicles on the road as well as the capacity of the road right or the highway capacity affects it as well as number of vehicles or the volume of traffic.

We will make it as part of the capacity, its a highway capacity. We will determine quality is bad we will just transfer it into a the. So travel time is what can I say depends on capacity of highway capacity of highway in turn depends on a number of lanes, it depends on the quality of the road, number of signals that is there, other bottlenecks that can appear at some distinct

points in time. I mean distinct point in space depend on capacity of highway and volume of traffic, right.

So, we have two variables which we say can affect our travel time, but road construction does not immediately happen, right. Suppose even if the road is narrow or there is only single or two lane roads, but as long as what can I say there is no new pressure to expand the road network, road construction is not affected or rather there is no pressure to reduce congestion.

So, let us create identify new variable called as pressure to reduce congestion. So, more the pressure we can expect that this is going to result in as more pressure reduce congestion, it will prompt the government to take up road construction activities. The road construction activities once its completed will result in increased capacity for the highways, ok.

So, this is what we kind of can expect, but this pressure to reduce congestion itself will depend on not just the travel time, it will be a function of both the travel time as well as the desired travel time. If you have to it takes 10 minutes to go somewhere and people are happy with the 10 minutes, then there is not real pressure to reduce it, but if you want to do the same thing in 5 minutes, then that is when the pressure comes right. So, we want to define those goals explicitly.

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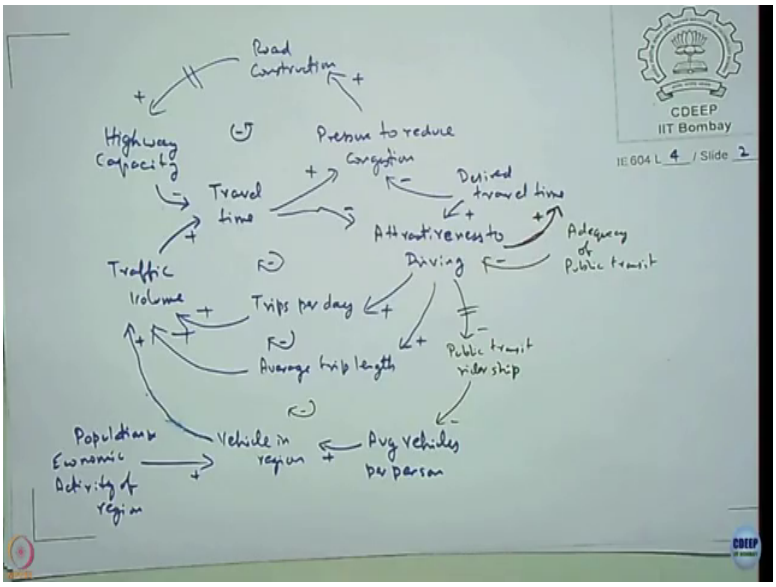

So, let us try to draw this preliminary loop right now as our first close loop. So, let us make me structure in travel time is defined by our highway capacity as well as traffic volume. Traffic volume is large. You expect the travel time to be large, highway capacity is large, you expect the traffic volume time to be lower and based on the travel time let us have a very large pressure to reduce congestion and if pressure to reduce congestion is large, you take a road construction and this road construction after a delay results in increase highway capacity, ok.

So the pressure to reduce congestion increases, the road construction activities are going to increase as a road construction activity increases after some delay the highway capacity will increase. It takes time to expand roads time to you know you have seen all that and as highway capacity is more, then a travel time goes down. Now as travel time increases the

pressure to reduce congestion is also needs to increase, but that increase is related to what we can call as desired travel time.

So, if you see here what i just did is apply some other guidelines that we gave we had. So, here if you look at this loop, it is a negative feedback loop for road construction. So, as travel time is more this pressure to reduce congestion, as pressure to reduce congestion increases road construction activities increase, as road construction increases after some delays capacity increases and as capacity increases the travel time falls. So, there is a negative feedback that is happening.

But what is the goal here? The goal will be has to be done explicitly it can keep on happening like this. So, the goal is the desired travel time. Based on that you decide whether it is to be a one lane to two lane or one to four lanes or one to six lanes depends on the desired travel time. So, this defines your goal of the system.

Another point while were actually doing this kind of modelling it is good to actually start thinking in some sort of units that we want to try because it will also help in identifying some new variables etcetera that we may want in the system later like we have say for example, these three variables travel time, traffic volume, highway capacity or desired travel time you can think of what kind of units that we can have for this. For example we have variables like let say traffic volume.

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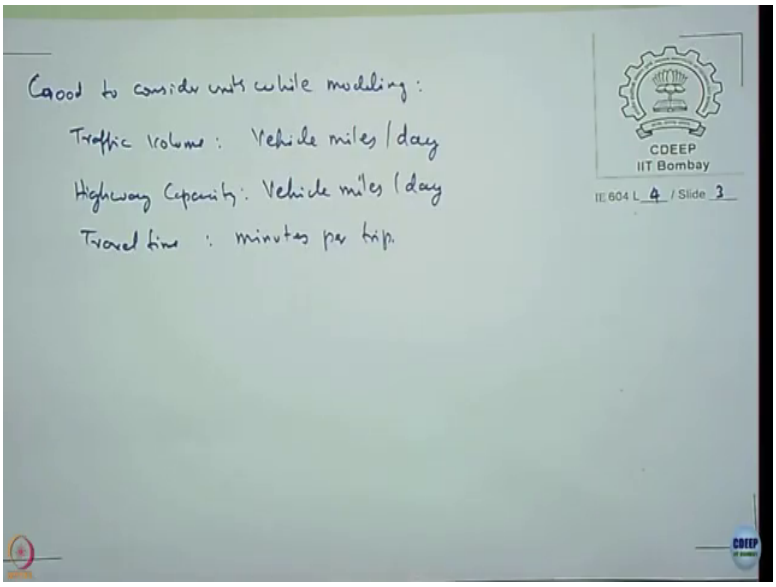

So, good to consider units while modelling a suggested units could be that if you want say traffic volume, it could be a say vehicle miles per day then highway capacity. So, eventually we want to compare highway capacity as well as our traffic volume. So, it is good to then have both in the same units. Eventually there is where the model has to come to. Highway capacity can also be defined as the vehicle miles say per time unit say per day or per minute or whatever it is the same time units can be considered. So, this means that now we can compare it.

Suppose your different highway capacity in terms of width of the road, then comparing width of the road to vehicle miles per day, then how will we compare it? We cannot subtract it or we cannot do edit or something because the units are may not necessarily match again. These

are not all the variables. I am just giving illustration traffic volume on a highway capacity, then travel time. Travel time itself could be say minutes per trip or something like that.

So, the idea here is we want to come up with some metric for what kind of unit that we are looking at, ok. This how we are going to start measuring these values and the this is how we are going to define some highway capacity and travel time it is going to minutes per trip, then we need to get some say example like average trip length or something, so that you can use it to figure out what is the how we are going to measure the measure the measure the time units and things like that ok. This is just a kind of illustrate to the idea of how we think of units.

Now, as this travel time increases as I told you are going to have congestion. So, we define that as travel time is more, then congestion is more. So, and this is a negative feedback loop and here then when you start building the model, this is kind of small steps that we can take to figure out ok. Let us draw some broad loops to close the system and then let us look at currently what are the variables that are outside the loop.

We have two variables; one is a desired travel time, other is the traffic volume. Desired travel time sounds like an exogenous variable in the outside system because it is it what people expect. Then you have traffic volume and traffic only be made endogenous. What do you think affects the traffic volume? What all affects the traffic volume?.

Student: Vehicles.

Number of vehicles and then population affects the number of vehicles, fine. Other than number of vehicles what else? Just because there is no lot of vehicles, what do they need to do? The final units we just wrote as vehicle miles per day number of cars just goes vehicles, where will I get miles in per day distance? The distance travelled quality of road affects the highway capacity. So, the traffic volume itself.

Student: Day of the week.

Excuse me it depends on the day of the week. It is fine. Let us what else? You have got two things. One is you got the number of vehicles just fine or number of cars and number of vehicle, second is we need vehicle miles per day. So, for miles we need what is the average distance or average trip distance. Average time is what you already got as travel time, right. Travel time you already got it, but what you are looking at traffic volume.

So, one is how many cars are there and what is the average distance per trip that they are making and we can also have one more variable called average number of trips per day. If for example let us say if we have a nice highway or let us say even inside campus and then there are tops right here the traffic is very low. So, even if you forget some things, we can make multiple trips to keep buying things, but if it is going to take you half an hour to reach let us say few kilometers to buy things, then you might say even if you forget something you are not going to make the second trip.

So, if there is a capacity is large, then you may be able to make more discretionary trips or more number of trips you can make that is one and two, you will make longer trips defines traffic volume as we see traffic volume can be affected by the trips per day, average trip length and vehicles in region. That means people start taking more trips, then may be traffic volume is going to be more as average trip length increases, traffic volume is going to be more.

There is more traffic congestion outside IIT is caused by people not from Powai, people not in Powai because they are all traveling large distances. People in Western suburb want to work in Eastern suburb people, in Eastern suburb want to work in Western suburb. So, it causes a traffic jam in Powai and more cars in the region we can expect higher traffic volume and as was also suggested vehicle in the region depends on the population and to some extent on the economic activity of region.

There is more the population, more vehicles can be in the region and or just that does no affect. We can also have a let us say average vehicles per person because more average

vehicle per person is there, vehicle region is going to increase which is going to contribute to traffic volume.

Now, let us try to close this loop by looking at suppose my travel time became easy. If the travel time is large and my divide my desired travel time is 15 minutes, but my current travel time is a half an hour, then it causes pressure to reduce I mean pressure to reduce congestion right. Suppose the capacity is so big that you are now able to go there really fast. So, that will attract you to driving imagine nice well lit smooth. We love to drive, we do not want to walk, we do not want to take public transport, we may just want to drive correct.

So, let us introduce that variable called attractiveness to driving. Here I am reversing the sign, right. Just observe this travel time, desired travel time your travel time is plus desired travel time minus some actual travel time is here by desired is here. So, there is huge gap, then that causes pressure to reduce congestion, but now if my travel time is only 5 minutes, but my desired travel time is like I am willing to spend a 10 minutes to go there, so that means, you are more attracted to driving because roads are free and you can go at higher speed and it is much more pleasure driving, all right.

So, and more you are attracted to drive, you will do more trips per day. You will just go out, so that you can take a spin in your motorbike, your new motorbike or new car. You will go longer distance, you will not go to the nearest shop. It was [FL]. What is this nice road? Why the hell I am stopping at the nearest shop? Let me travel little longer distance and go to the other bigger shop or some other fancy place which has you know near mall etcetera, right.

But you get the relation right like these are just opposing to each other like we may not even have two variables, but this is just to illustrate the point that the travel time is too high and it will you know for short distance itself spend long time to go. That causes pressure to reduce congestion, but your travel time is quite smooth and your then that will attract you to do more driving. You can have both ways, you can have this one also will that does make people happy because more you are attracted to driving, then your desired travel time also increases right.

But that is not the only one which attracts us to driving. We cannot consider, ok. Let us kind of finish this loop first. So, here if you see as attract as let say we are more we are more prone to say a prefer driving, then we do more trips per day which increases in traffic volume, which increases your travel time, which then reduces your attractiveness to driving. Each time you are getting caught in traffic jam, you are you do not like it. So, this becomes a negative feedback loop. Same thing goes here as more attracted to driving you do more longer trips.

But then as traffic volume increases, travel time increases, then your attractiveness driving comes down. It takes much longer time. So, we try to avoid and come up with another route things like that, so that again becomes a balancing loop attractiveness to driving by average vehicles per person is not enough. We just go through this only looking at private vehicles ownership.

Many times the attractiveness to private vehicles of course there is only just simple pleasure this also the utility of it because most of the commute is for work. So, we would like to bring in the adequacy of public transit itself on how attractive it is to try. So, let us introduce those two variables called as adequacy of public transit. As a negative relation in the sense, more adequate the public transit it is, it reduces your attractiveness to driving.

If you are really good public transit, it works either way public transit is not good enough, then attractiveness to driving increases and as more people start owning cycles or preferring their own means of transport maybe you will get a better pair of shoes that is also part of private ownership. So, that can also reduce the what can I say public transit ridership.

Now, let us look at what I have done. I have introduced a new external variable called adequacy of public transit and attractiveness driving and as attractiveness driving becomes larger, the public transit ridership falls down and it also has as it falls down the number of vehicles, average vehicle per person will also increase. It could have put a direct link also, but let us go with this diagram for now.

So, people start buying more vehicles and as they start buying more vehicles, more vehicle region will increase which will increase the traffic volume, which increase the travel time, which reduces the attractiveness to driving. So, this again I have 1 2 3 negative feedback links. So, this also becomes a larger negative feedback within the system.