Urban Landuse and Transportation Planning
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Lecture-10
Land Use Transportation Model Components and Future Challenges

Lecture 10 is on land use transportation model components and future challenges. The different concepts covered in this lecture are components of a land use transportation model, software architecture for urban simulation systems, land use components in existing comprehensive mobility plans, and future challenges.

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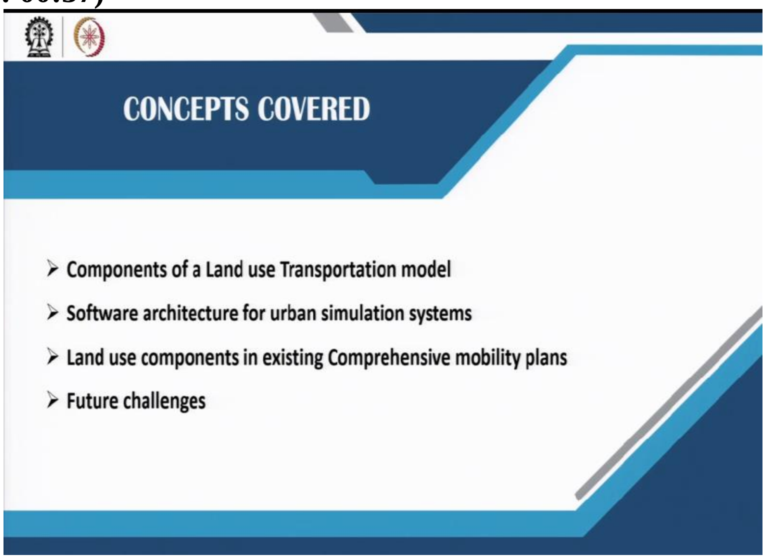

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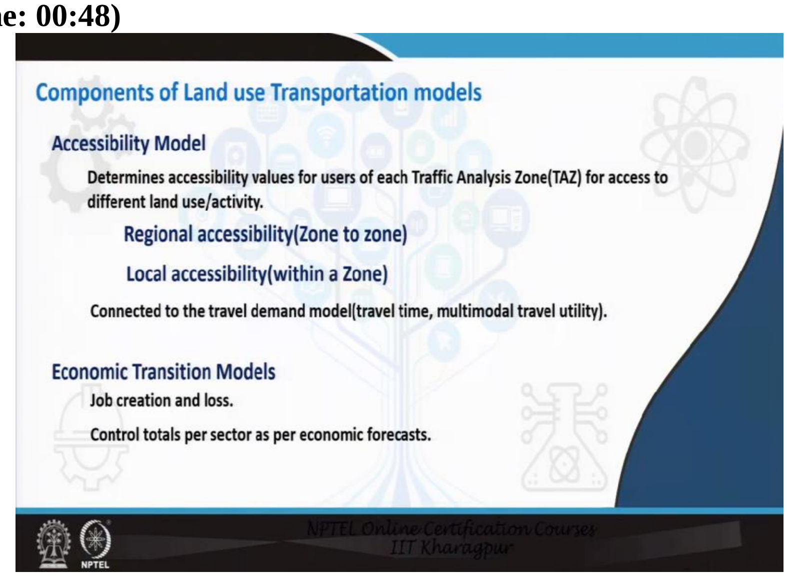

Components of land-use transportation model

Accessibility Model

The first component is the accessibility model. This model determines accessibility values for the users of each traffic analysis zone for access to different land use or activity. This model does not affect any change in land use or the transportation process directly. This is an intermediate model, values of which can be used in other models such as while determining the location choice of a household, the decision for a particular family to move or not, or even for transportation componets as well. This particular model is basically connected with a travel demand model and when the travel time estimation from that travel demand model changes automatically accessibility of a particular zone also changes.

For example, consider a route that connects Zone A and Zone B, because of congestion along this route, there is an increase in the travel time. Since the travel time increases, zonal accessibility also reduces i.e., if the trip is originating from Zone B and going to Zone A then zone B's accessibility will decrease. This model is connected to the travel demand model, travel time, and multimodal travel utility. The term utility refers to, how suitable or attractive are the different available choices of different modes in a particular area. A travel demand model can furnish the information on the availability of different modes in an area or the viability of different modes, which leads to the utility of the transportation system in that particular area. So, both these things change when there is a change in the infrastructure or change due to congestion and so on. This comes as a feedback to the accessibility model where the accessibility value also changes.

Accessibility could be of two kinds, one is regional accessibility, that is in between TAZ zones. The other is local accessibility which is within a zone and refers to how accessible the zone is probably by foot which means how easy it is to walk around inside the zone or it could be local travel or intra zone travel using rickshaws if the zone is larger. Regional accessibility could be related to infrastructure, for example, if there are many bus stops, the accessibility of that particular zone is high. Regional accessibility also talks about the number of opportunities that are available for trips for that particular zone or for the people to do a particular activity. For example, if many movie theatres are there in nearby zones to this particular zone then, it will increase accessibility for this particular zone, maybe for recreational trips.

Economic Transition Model

The Economic Transition model predicts job creation and job loss in a particular urban area during the planning period or when the model is being estimated. So, this model predicts jobs that are added and jobs which move away from that particular urban area.

The control totals per sector as per economic forecast also need to be aligned i.e. if the yearly economic forecast for jobs of each different sector is available, and the job creation and loss are modeled for different zones in an urban area, the total of all these jobs created and lost should match with the total of that with the economic forecast. Thus, it is a sort of check to see that the forecast and the actual model matches or the prediction by both models matches.

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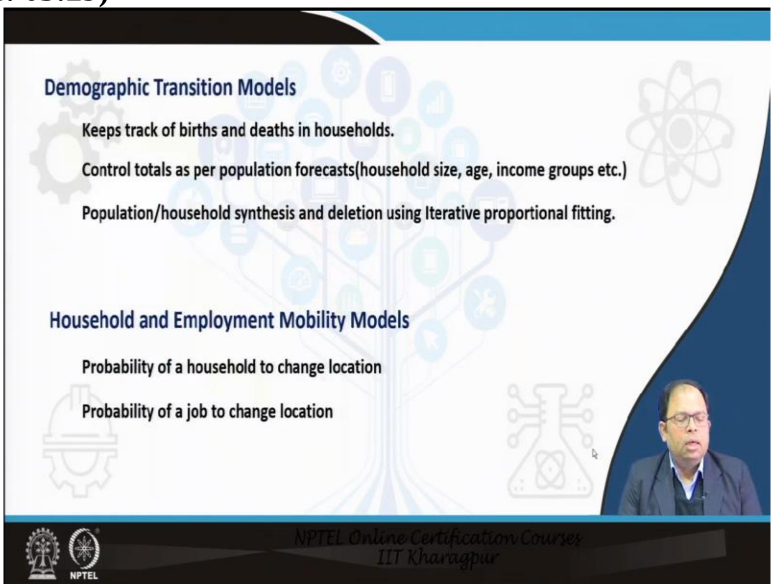

Demographic transition model

This model keeps track of births and deaths in households. This model also includes control totals as per the population forecast and also checks household size, age, or income group totals if the forecast for these particular variables are available. Once the total amount of births and deaths are computed for different zones, these are added up to match the control totals of the overall area or with the forecast for this particular area or with the forecasted household size or age and income group and so on. Thus, to do this, population or household synthesis and deletion are required.

If a survey is conducted in a particular urban area, it is not possible to survey the entire population. Only a handful of people are surveyed and they will represent the entire heterogeneous population of that particular urban area. But to apply disaggregate models which predicts different outcome for each person, the sample needs to be expanded. Therefore, a synthetic population, using these characteristics of the sample population and the proportion of different socio-economic groups in the population, is created. Again, it is important to make sure that the total average or the total number of different characteristics like household size, age groups, etc. match with the forecasted population totals for this particular area.

Household and Employment Mobility models

These are two separate models. One is the household mobility model and the other is the employment mobility model. The household mobility model predicts the probability that a household will change location. It does not predict where it will locate, it just predicts if the household will change location or not. For example, when there is a birth in the household and there is not enough space in the existing place where this household stays, they need to search for a new residence. So, that is why households may want to change the location. When somebody gets a job in the household, then also the household may wish to change location. Similar to household, the change of a job location can be predicted i.e. certain companies in an urban area can shift their location because the existing location is probably not adequate or maybe the company wants to grow, it wants to move into some other building or in a different location and so on. This probability of a job to change location also needs to be modeled. So, when this happens, the existing space where this company or the household is occupying, that becomes available in the market for a next family or a next job to occupy and this group of people are waiting to be allocated to a new area. Therefore, this happens in sequence. The allocation part is discussed in the next model.

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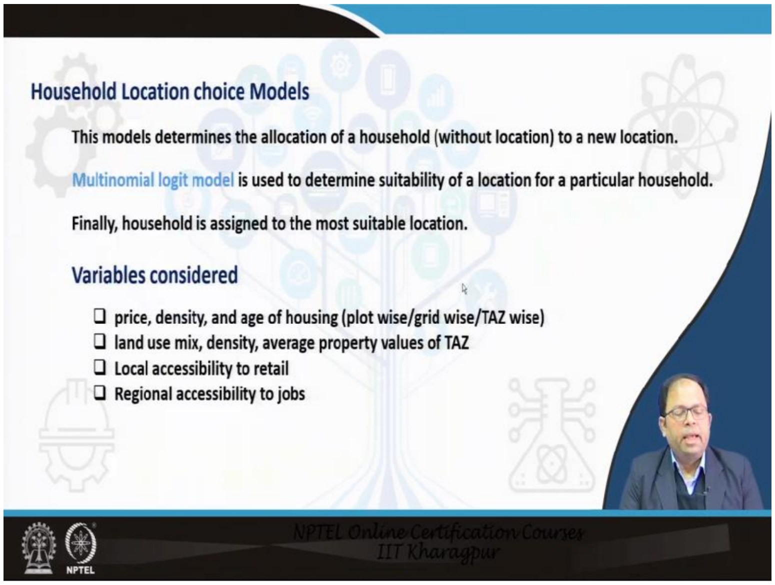

Household Location choice model

In the household location choice model, the allocation of a household without location to a new location is determined. It is important to note that, different kinds of the household will have different preferences for different locations, and that is generally determined through a utility equation. A household will move into a particular location whichever gives the highest utility. Also, a household is presented with many choices (or locations) from which they choose a location. In general, a multinomial logit model is used to determine suitability (or utility) of a location for a particular household and it also takes care of multiple-choice scenarios. Finally, the household is assigned to the most suitable location.

So, once the probability of a household to shift to a particular location is known, the one with the highest probability is the one where the household will shift. So, for this kind of model different kinds of variables are required. Some of the variables are related to the housing type, the density, or the age of the particular building in which the person is thinking of moving. These variables could be plot-wise, grid wise, or TAZ wise. That means, depending on the scale (or level) of analysis (or choice set consideration), variables are generalized. For example, if the level of analysis or choice set is considered at TAZ level, then the average density for the TAZ, or the average age of housing in the TAZ, or the average price of housing in that TAZ are considered in the model. If it is in the form of a grid, which is of a smaller scale compared to a TAZ then it is a bit more accurate. If it is plot-wise then each plot price can be considered. Also, at the plot level, the exact densities, age of that particular building in that particular plot are known. But if it is grid wise or TAZ wise then average for that particular grid or TAZ are considered respectively. Since the TAZ size is more, therefore, the accuracy reduces.

Other variables are related to the total characteristics of the surrounding neighborhood or the surrounding TAZ, or zone surrounding that particular building. For example, land use mix, density, average property values of TAZ. This is done at the TAZ level. However, in most cases, the first two becomes the same where individual plot-wise price density variation in a TAZ is not available. So, this becomes more or less like an average property value if you take TAZ as the smallest zone to be used in the model. Housing location choice models work best when a smaller classification or smaller zones or grids are considered for modeling.

Local accessibility to retail is another characteristic or variable. So, this is where the accessibility model contributes. The accessibility values are calculated through the accessibility model to determine what the accessibility to retail is. Similarly, regional accessibility to jobs could be estimated from the accessibility model.

So, accessibility, different attributes of transportation, land use characteristics, the plot, or the housing characteristics all play a role in the household's location choice to shift to a particular area.

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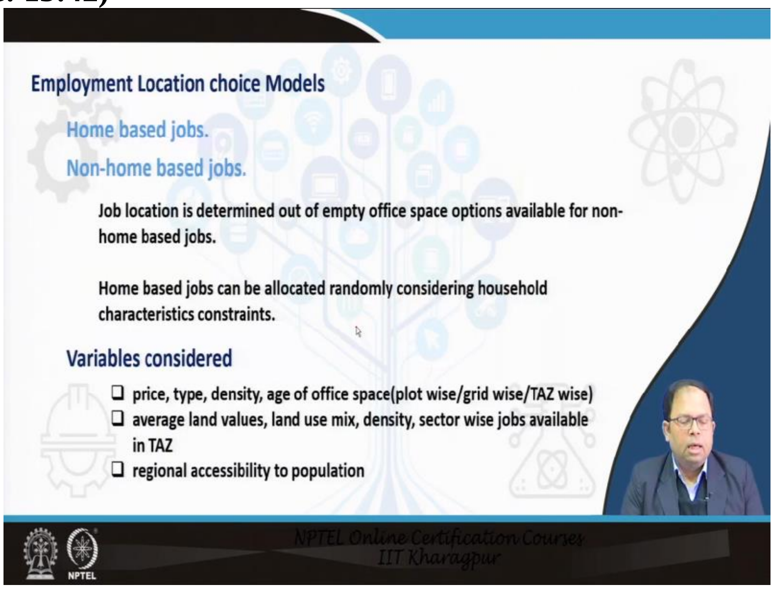

Employment Location choice model

Similar to housing location choice, the employment location choice model determines job locations. This could be done for home-based jobs and also for non-home based jobs. So, for non-home based jobs, job location is determined out of empty office space options available for non-home based jobs i.e. all new offices, new commercial buildings which have come up, empty offices for where a person can move, or empty offices vacated by other companies who want to shift their location. Home-based jobs could be allocated randomly considering household characteristics constraints. Non-home based jobs are in commercial areas, or commercial land use, whereas home-based jobs are jobs that could be carried out at home, which means that certain households are more susceptible to have a home-based job. For example, a household having only a single person and he is already employed in a non-home based job probably does not have a home-based job, but a household which has got 2 persons without any job and probably one of the persons among the houses or both the persons are engaged in a home-based job. Therefore, existing housing can be considered randomly, where these home-based jobs could be allocated, but at the same time, different household characteristics that could act as constraint in the model to determine where these home-based jobs would be allocated needs to be considered.

Similarly, if a company tries to locate itself in an empty area or an empty commercial building, it will look into certain attributes of that particular plot or that particular area. This suitability could be transformed in form of a utility for that particular area or it will be estimated as a utility for that area. Therefore, price, type, density, age of office space, and other variables will be considered. Similar to housing location choice, level of analysis could be plot-wise, grid wise, or TAZ wise. All these parameters could be estimated for that particular plot or a particular grid as well. Average land values, land use mix, density, sector-wise jobs available at the TAZ level are also considered. So all these parameters play a role in location choice.

While locating a particular job in a particular TAZ, the capacity of that particular TAZ to take in the number of jobs and type of jobs can also be considered. Similarly, regional accessibility is also considered. This parameter is again the transportation component in this particular model, which shows that with improvement in transportation infrastructure or accessibility, there is more chance for a company to move into a particular location.

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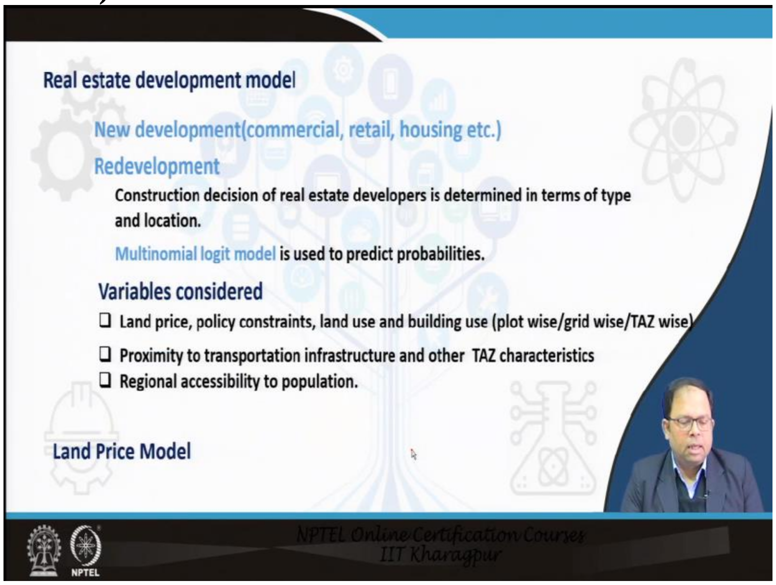

Real estate development model

This model predicts where new development or redevelopment is going to happen. A sudden amount of redevelopment happens all over the city, but new development occurs only in certain areas, which are growing areas or the areas that have been added to the urban area recently or areas where a satellite township has come.

New development could include any kind of building or categories of building such as commercial, retail, and housing. The subtypes of housing could be high-end residential, or residence for middle-income groups, or plotted housing, and so on. Similarly, retail and commercial buildings could be of a different kind as well.

In this model, the construction decision of real estate developers is determined in terms of type and location. A multinomial logit model is used to predict probabilities. The variables considered are the ones that influence a developer to choose a particular location to develop e.g., land price, policy constraints, land use, and building use etc. Similar to the household and employment location model, the scale of analysis is considered plot-wise, grid wise, or TAZ wise. The other variables include proximity to transportation, infrastructure, and other TAZ characteristics. A developer will always want to build in an area where there is adequate transportation. In case of a commercial building, it should be accessible from different parts of the city and so on. Similarly, regional accessibility of population is also estimated, which shows how accessible is an area from different surrounding regions. This model is very closely related to the land price model.

Land price model

The land price model is the final model component. This model is used to predict the land price for a particular area. Now, the land price of a particular area varies as per the infrastructure of that area, accessibility of the area, and other factors. So, when the land price changes, it does not change the land use, choice, or the transportation choices of people directly, rather land price change influences the choices of a particular business to move at a location, or the choice of a particular person to choose a housing at a particular location. So, this is how the land price model influences the overall land-use transportation interaction process.

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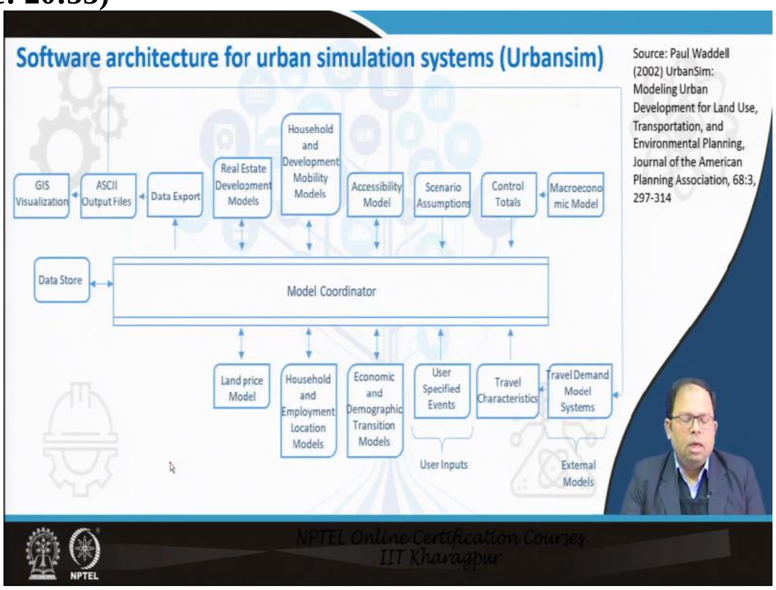

<u>**Software architecture for urban simulation system**</u>

The term urban simulation systems are used because there are several model components like real estate development model, household and employment mobility models, accessibility models, economic and demographic transition models, household and employment location models, and land price model. These models are running together and output from one is going as input to another model and so on. So, the software architecture decides how these different model components would be tied up and how the simulation will run, which model will be run in what sequence, and so on.

In any computer programming, there is the main program from where different functions are called or classes are initiated. The model coordinator in urban simulation systems works similarly to the main program. The model coordinator is the one that decides the overall flow, the sequence of the program, how one iteration will happen, how the data from one iteration gets stored, and then taking this data as input for the next iteration and so on. So, the sequence of how the entire modeling will run is determined by the model coordinator.

The illustrated software architecture is from the UrbanSim model. In UrbanSim, there are 2 external models; one is the travel demand model and the other is a macroeconomic model. The macroeconomic model along with population synthesis, job synthesis, and so on, is run at the beginning. Once this part is run, the other models are also run because initial estimates for population, jobs, are required. Thereafter, certain user-specified events and scenario assumptions can be analyzed like new infrastructure or higher density in certain areas.

All these inputs could be given before a model is run. Once it is given, the component models are run in sequence one after another, considering their relationship within this particular model. For example, the land price model computes the land price, the accessibility model computes the accessibility for a particular area, then only the household and employment mobility models can be determined. The real estate development model can also be run parallel. But as soon as the real estate development model will run, certain new areas are selected for developing, and this data is stored. This data is saved or stored because these buildings are not available immediately. Instead, these buildings become available 3 years down the line. After 3 years, automatically these buildings are made available in the market.

So, this data is saved, pulled out, and also read back and forth which happens continuously. When the results come out, the data is exported and generates ASCII files as output files, which could be used for visualizing using a GIS platform to give a nice face to the entire output of this model system. For example, the output of the residential location model can be used to visualize the location choices of people, and so on. The coordination of the model is very important and the sequence with which the model will run, how components are related, has to be followed carefully.

If a similar model system is to be developed in our context, then few model components can be modeled and the other components could be taken as exogenous input into the model system. For example, the number of jobs or new jobs in a particular area will be taken as exogenous input. Sometimes, the real estate developer does not share data where they are going to develop in the next coming years or so, then the real estate development component can be taken as exogenous input. This input can be inferred from the existing pattern of development of real estate.

Therefore, the model components could be endogenous or exogenous. So, the model coordinator has to take into consideration all these factors and then run these different components in sequence to get the output at the end of each simulation to store data and visualize it and also to keep on simulating it for a certain number of years. This is the software architecture of the simulation system. There are different variations of this simulation system in different land use transport interaction modeling systems that are used commonly.

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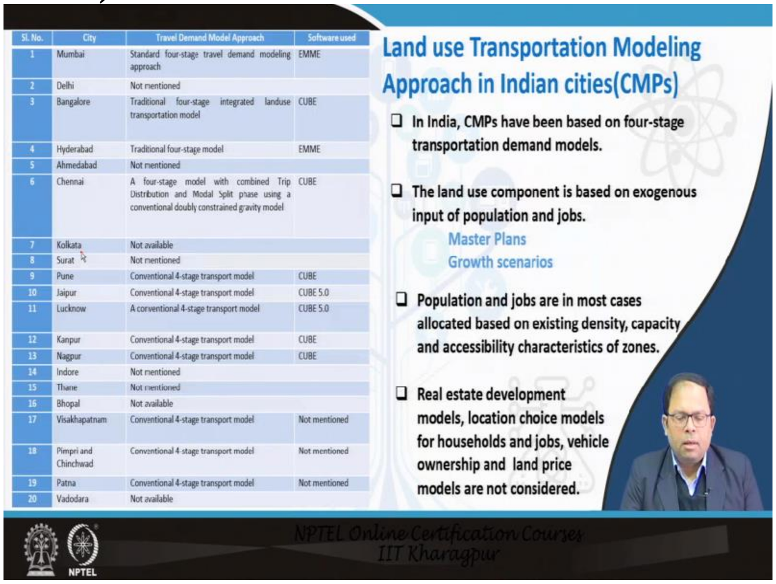

Sl. No.	City	Travel Demand Model Approach	Software used
1	Mumbai	Standard four-stage travel demand modeling approach	EMME
2	Delhi	Not mentioned	
3	Bangalore	Traditional four-stage integrated landuse transportation model	CUBE
4	Hyderabad	Traditional four-stage model	EMME
5	Ahmedabad	Not mentioned	
6	Chennai	A four-stage model with combined Trip Distribution and Modal Split phase using a conventional doubly constrained gravity model	CUBE
7	Kolkata	Not available	
8	Surat	Not mentioned	
9	Pune	Conventional 4-stage transport model	CUBE
10	Jaipur	Conventional 4-stage transport model	CUBE 5.0
11	Lucknow	A conventional 4-stage transport model	CUBE 5.0
12	Kanpur	Conventional 4-stage transport model	CUBE
13	Nagpur	Conventional 4-stage transport model	CUBE
14	Indore	Not mentioned	
15	Thane	Not mentioned	
16	Bhopal	Not available	
17	Visakhapatnam	Conventional 4-stage transport model	Not mentioned
18	Pimpri and Chinchwad	Conventional 4-stage transport model	Not mentioned
19	Patna	Conventional 4-stage transport model	Not mentioned
20	Vadodara	Not available	

<u>**Land use Transportation Modelling Approach in Indian cities**</u>

Considering, transportation modeling for Indian cities, it is seen that, the comprehensive mobility plans are the ones that require the land use transportation modeling approach. Intially, during

2013-14, many Indian cities undertook comprehensive mobility plans focusing only on the transporation part, but from 2018 an integrated land-use and transportation plan, i.e. integration of the components that are part of land use as well as transportation, has been made mandatory. Thus, new components related to land use in the land-use transportation modeling process are now required to be modeled and estimated.

Earlier CMPs have been based on the 4 stage transportation demand model, which is primarily the transportation part of the land-use transportation modeling process. So, there was not much land-use modeling involved. The land use component (population or jobs) was taken as exogenous input and a 4 stage model takes this input of jobs, population, the existing land use, etc., to predict the number of trips that are generated in different areas. So, it is a doubly constrained model of land-use transportation which is used to determine how people move from one zone to another using what mode and along which route. Also, in CMPs, trips are determined for the business as usual scenario, then based on master plan projections like proposed land use, projected population, or projected jobs, separate scenarios can be developed. In addition to master plan projections, certain growth scenarios like new areas where development can come up, or TOD in certain areas, or higher density of development in particular zones, allocation of new jobs or population in new TOD zones are also considered.

But there is no proper modeling of how the land use is transforming, only the exogenous inputs were taken on how land use is going to be in the future years and based on that, what should be the transportation requirement or if the transportation is adequate or not is determined. In most cases, the allocation process of population and jobs is based on existing density, capacity, and accessibility characteristics of particular zones.

So, in the 4 stage model, as discussed in the Hyderabad development plan, the total area has been divided into many TAZs based on the existing density, capacity, accessibility etc. Future population, and jobs are projected, but from the modeling process perspective, these are very basic models. Also, these procedures were taken up much earlier and it has got no relationship with how areas are going to grow in the future in terms of population or jobs and can be considered vaid if existing trends continue. So, in existing CMPs, there are no real estate development model, location choice models for households and jobs, vehicle ownership models, and land price models. Only certain scenarios were considered and accordingly the transportation requirements for a particular city are predicted.

Thus, CMPs in Indian urban areas mostly include the transportation planning component and ignores planning, modeling, or determination of the future land use. For example, in Mumbai, it uses a standard 4 stage travel demand model using software. In Bangalore, a traditional 4 stage integrated land use transportation model is undertaken using the CUBE software. Similarly in Vishakhapatnam a conventional 4 stage model is used.

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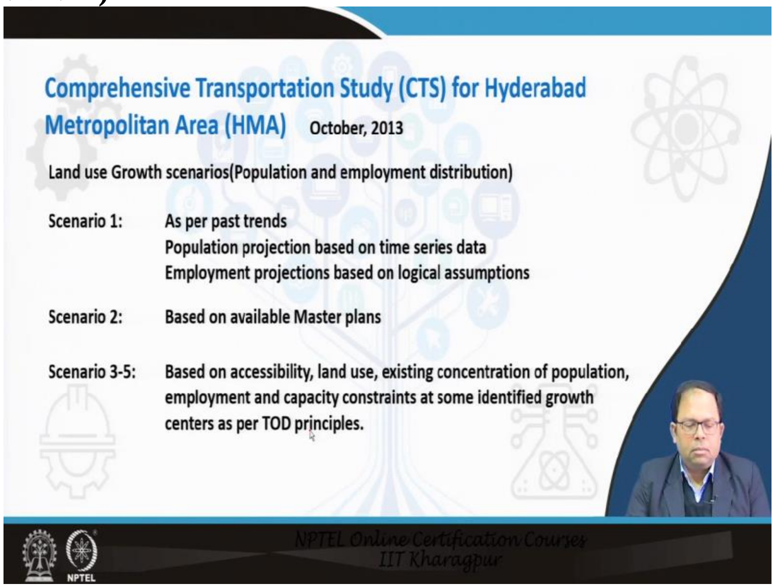

Comprehensive Transportation Study (CTS) for Hyderabad Metropolitan Area (HMA)

In the comprehensive transportation study (CTS) for Hyderabad metropolitan area (HMA) different Land use growth scenarios were estimated and population and employment distribution were undertaken as per these land use growth scenarios. As shown in the slide, scenario one is done as per past trends. Scenarios two and three was done based on the master plan and several other factors such as accessibility, existing population concentration etc. Population projection was based on time series data and employment projection was based on certain logical assumptions. In scenario 2, the existing master plans available for that particular area was considered. However, it was found that, the master plan/development plan overestimated the population and thus had to be modified. The proposed land use given in the master plan is considered as the the future land use for that particular urban area.

In scenario 3, some growth centers have been identified based on TOD principles and based on the accessibility of that growth center, the existing land use, existing concentration of population, employment and capacity constraints etc. population and jobs have been allocated considering certain assumptions. Thus, it can be concluded that in CTS for HMA there is no endogenous prediction of land use transformation.

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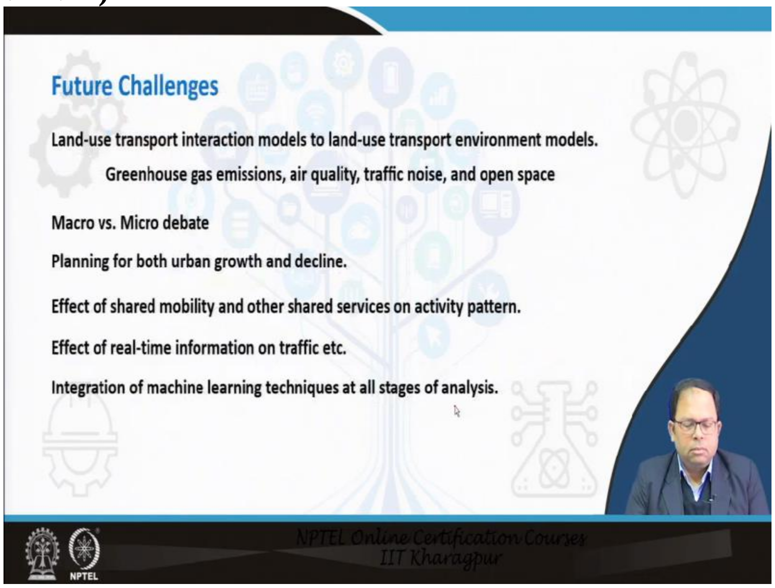

Conclusion

There is a need to introduce these land-use components inside land-use transportation modeling frameworks. This course will focus on these particular model components and how they could be integrated with the existing 4 stage modeling system.

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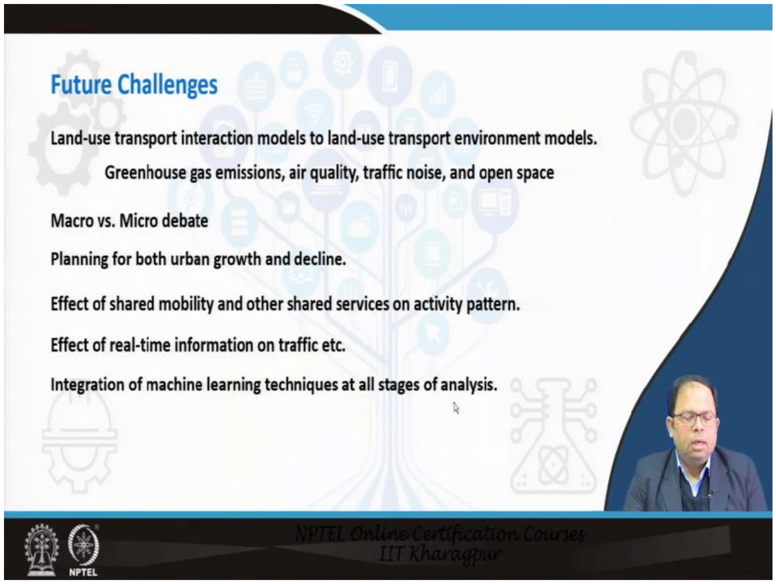

Additionally, in land use transport interaction models environment has not been taken into consideration whereas, global warming, greenhouse gas emissions, air quality, traffic noise, reduction of open spaces and green spaces are considered to be major challenges. Thus, there is a need for transformation of land use transport models into land-use transport environmental models, which means that, the different environmental parameters or characteristics should be inbuilt in the model. The change in land use has a positive or a negative impact on the environment and land use transport environmental models will be able to endogenously predict these kind of effects. It also needs to predict the effect on each individual or each group of individual who is being affected by these changes.

The macro and micro debate i.e. in micro-scale, TAZ can be further divided into grids and even into plots which will improve the accuracy of location choice models but will increase difficulty in regards to data availability. Other issues also exist like, if the number of people or jobs are less, but the location choices multiple, then the model's prediction would be different for different runs. This could be avoided at a more macro level.

Macro-level land-use transportation models look into urban growth only which means it can predict growth, but it cannot predict or rather it may not able to predict a decline. This is because the model structure is oriented towards predicting urban growth.

The entire transportation service industry is also going through a lot of changes e.g., introduction of e-mobility, shared mobility, shared services and food delivery services to households. These new services are changing the way people live which eventually changes their activity pattern for the entire day. Thus, instead of looking into only peak hour mobility, there is a need to look at the mobility for the entire day. Additionally, real-time information allows a person the freedom to choose or defer his travel to a time when there is less congestion or to choose his route to avoid congestion. Hence, future research could be focused on incorporating real-time information into the actual modeling process and integration of machine learning techniques at all stages of analysis.

The integration of machine learning techniques will improve accuracy from standard multinomial or other logit models, but at the same time, this requires a lot of data. In today's context, there is a lot of data available from various sources such as Google or from transportation authorities in an urban area. Though a lot of data is available, there is a requirement for further investigation on the analysis of these data with machine learning algorithms and integration of machine learning techniques at all stages of analysis.

These are the different future challenges that are going to be more relevant in the coming years and along with that, the land use transportation modeling processes will also gradually transform.

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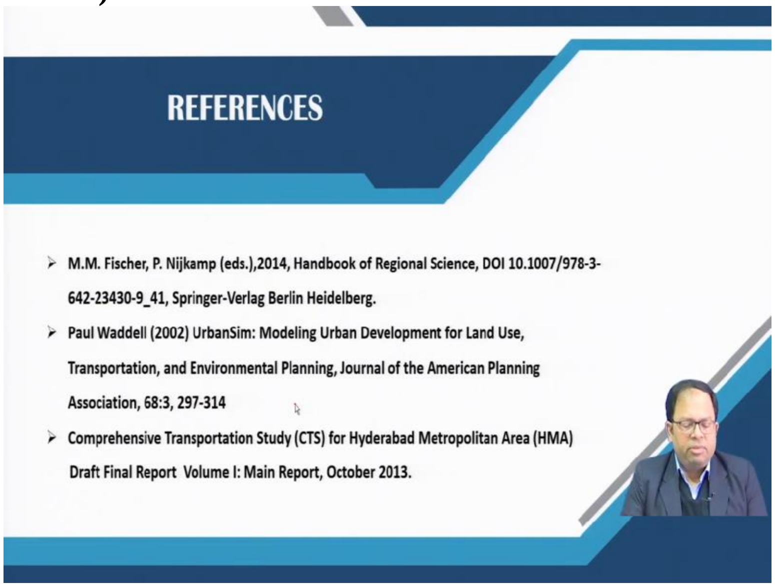

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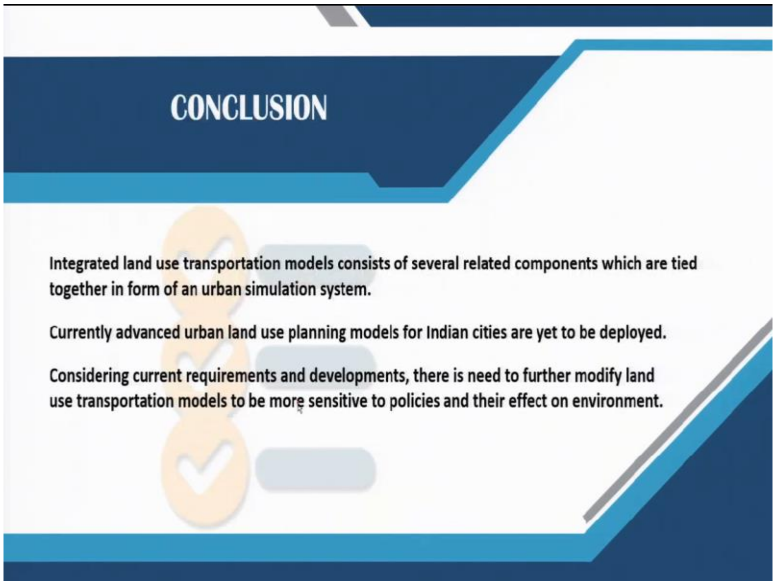

The references are mentioned in the figures.

Finally, this lecture can be summarized by stating that integrated land-use transportation models consist of several components which are tied together to form an urban simulation system. Advanced urban land use planning models for Indian cities are yet to be deployed.

Considering current requirements and developments, there is a need for further modification of land-use transportation models to make them more sensitive to policies and estimation of the effect on the environment.

Thank You.