Urban Landuse and Transportation Planning
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Lecture 57
Activity Based Model 1

Welcome back in lecture 57. In lecture 57 and 58, activity based models will be covered.

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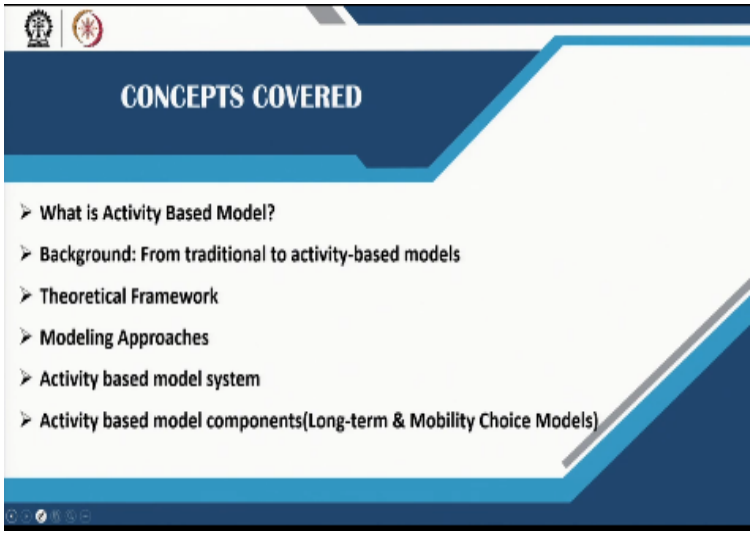

The different concepts that will be covered in this particular lecture are, what is activity based model, the background of activity based models, how it evolved from traditional 4 stage model, the theoretical framework behind activity based models, the different modelling approaches that have been adopted over time, different activity based model systems and activity based model components especially long term and mobility choice models. The other parts will be covered in the next lecture.

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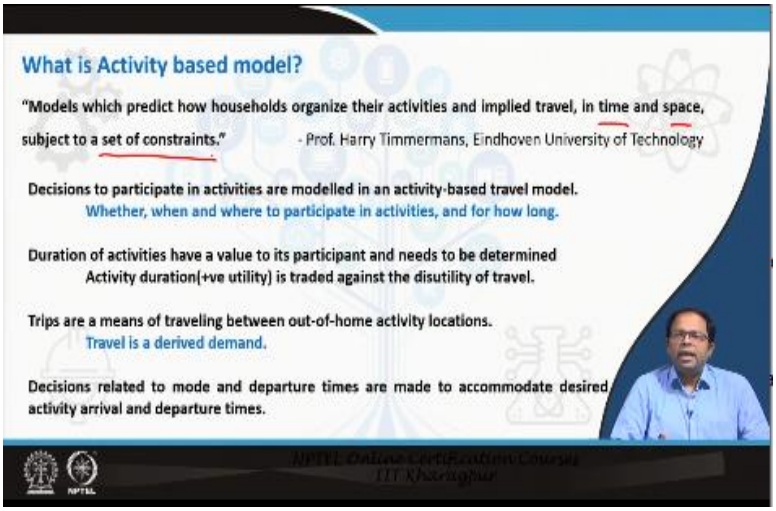

Introduction to Activity Based Model

In the words of Professor Harry Timmermans, models which predict how households organize their activities and implied travel in time and space subject to a set of constraints, are known as activity based. Travel is implied i.e. it is a result of activities and usually how households organize their activities in both time and space. Households cannot just do whatever they want to do as they are limited by a certain set of constraints. Hence, the activities performed by the individuals are organized in the household level, at a certain time, at a certain space, and subjected to a set of constraints.

Decisions to participate in activities are modelled in an activity based travel model. As the decision to participate in activities is the starting point there is a need to understand when and where to participate in activities and for how long (i.e. duration of activity).

The increase in time for the activity gives positive utility which is traded against the disutility of travel i.e. aim is to reduce travel time and to increase activity time. Hence, during activity scheduling, individuals will try to maximize the time of the activity and reduce the travel time as much as possible. So, this entire schedule has to be designed in such a way so that maximum utility can be achieved.

In the activity model travel is a derived demand, travel is not modelled directly. So, travel will be automatically generated because activities will be modelled and decisions related to mode and departure times are made to accommodate desired activity's arrival and departure time i.e. individual will choose mode and departure time to arrive at a chosen location to perform a particular activity.

In short, in activity based models the primary thing is what activity a household needs to do and accordingly household members organize their schedule and the sequence of the different activities and then they determine locations, time (i.e. when they want to do those activities). Finally based on these activities, one will decide when to travel, how to travel i.e. what mode to use etc.

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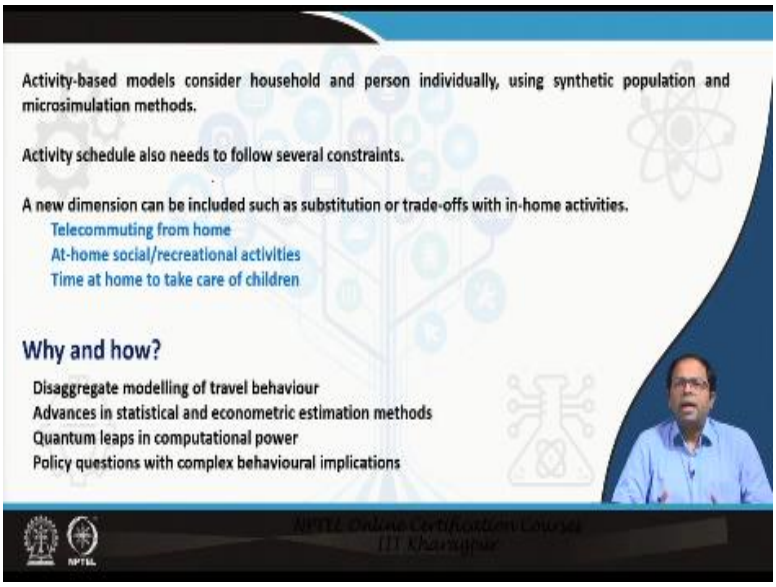

Activity based models considers both households as well as the person individually. This is done for all households and all persons in a particular urban area. Thus, based on survey data a synthetic population is needed to be created using microsimulation methods for an urban area.

Since, Activity based model is a disaggregate model i.e. these models are developed based on very small zones, individual households and individual families, detailed survey data is required compared to the traditional 4 stage model.

Activity schedule also needs to follow several constraints e.g. one person cannot be at two places at one point of time, one person needs to do certain kinds of activities on a particular day, certain activities are fixed and in certain cases, two persons need to travel together.

Some new dimensions can also be considered in activity based models such as substitution or trade-off with in-home activities i.e. activities which are performed in-home are also part of the entire modelling process e.g. sometimes people do not want to go outside and they want to eat inside their house. This kind of situation was not possible to be modelled in the 4 stage travel demand models.

Telecommuting can be also modelled i.e. what is the chance that a person will telecommute and how the telecommuters' activity pattern differs from non-telecommuting workers e.g. telecommuters may prefer at home social and recreational activities because they have to take care of children.

From activity based models, full activity profile of individuals and households can be received which can be further used to model many things beyond travel e.g. what kind of pollution these people are subjected to, as the data related to both in-home time as well as out of home time and within out of home time how much time that particular individual was in office or factory or how much time he/she was on road travelling is available which gives an exact idea about how much amount of indoor pollution or/and outdoor pollution, a particular person is exposed to.

Importance of activity based models

The activity based models give a full profile of a person's activities for a full day and these models are disaggregate models which give scope for more detailed behavioural analysis that helps to understand the variety between different individuals. Due to advances in statistical and economic estimation methods and quantum leap in computational power this kind of micro-simulation based modelling is possible. Finally, a lot of policy questions with complex behavioural implications can be answered using these modelling techniques.

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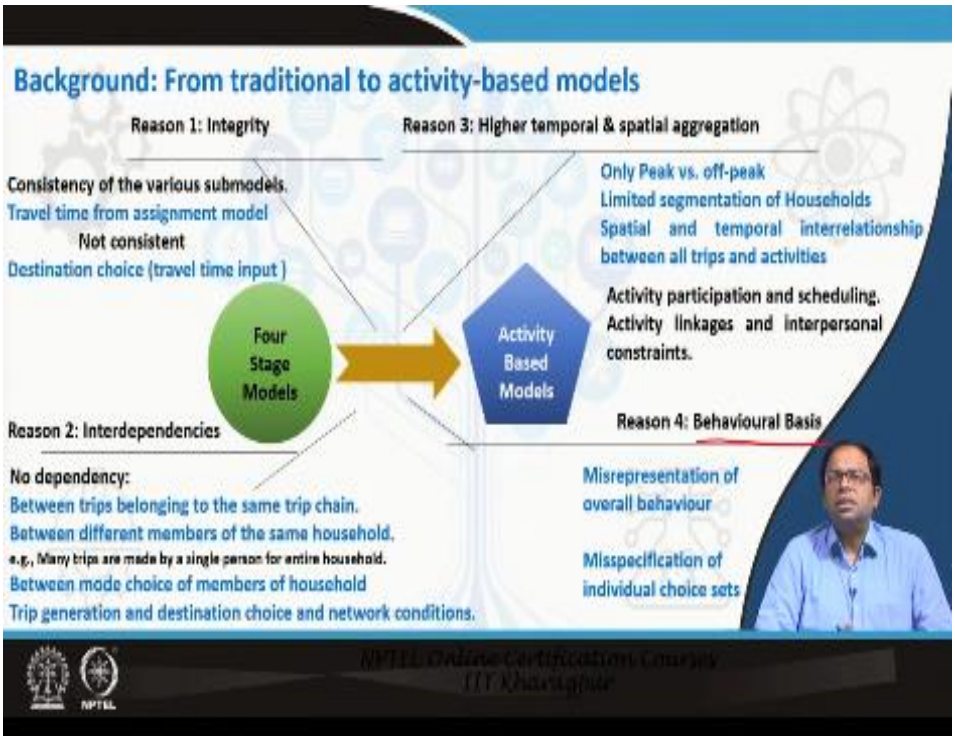

Background: from traditional to activity based models

Limitations in 4 stage addressed by activity based models

a. Integrity

Activity based models are more consistent. The 4 stage travel transportation planning model is not that consistent since mode choice and travel time from the assignment model is not used in the destination choice model i.e. destination choice(trip distribution) is first done followed by mode choice and assignment and then the feedback from assignment i.e., travel time in each links can be incorporated by creating feedback loops. But in most cases these steps are not done jointly which results in some inconsistencies in the modelling process which can be overcome in activity based models.

b. **Interdependences**

There is very little dependency in the 4 stage models in between trips belonging to the same trip chain i.e. person going to office from home and returning from office to home will be modelled separately which may result in choice of irrational options. For example, a person may have gone to his office using two-wheelers, but because of the model, he will get an option to choose two-wheeler while coming back which is not possible because he has not taken his two-wheelers from home. Thus, the second trip has to be dependent on the first trip. This kind of inconsistency may arise since interdependencies are not there in the 4 stage model.

Interdependencies between trips belonging to the same trip chain (i.e. a tour), between different members of the same household e.g., many trips are made by a single person for the entire household are not considered. Additionally, it can be said that trip generation, destination choice and network conditions are not dependent on one another.

c. Higher temporal and spatial aggregation

The main reason for preferences of activity based models over 4-stage model is higher temporal and spatial aggregation. In activity based model instead of peak and off-peak hours continuous modelling can be done i.e. mode choices could be done at a minute level as well as trip choices could be done at a minute level. So, the time of the day can be any minute of the day.

Activity based model gives spatial and temporal interrelationship between all trips and activities, activity participation and scheduling, linkages between activity and dependencies on personal interpersonal constraints.

d. Behavioural basis

In 4 stage models, there is a misspecification of individual mode choice sets since constraints are focused on what are the available modes in a particular locality whereas, one may not be able to use some of those modes because of other constraints. So, this kind of misspecification of individual choice sets or misrepresentation of overall behaviour can be taken care of in activity based models.

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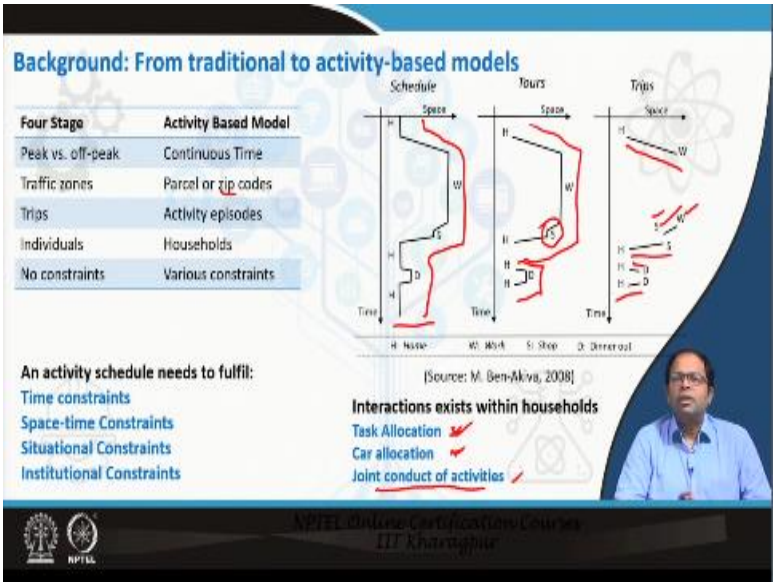

Comparison between 4 stage and activity based model

a. Traditional four stage model is generally done for peak and off peak hours whereas, an activity based model can be developed for continuous time periods.

b. The 4 stage models are usually based on traffic analysis zones whereas activity based model can be done at a personal level or even at a plot level or even based on zip codes (for US) or pin code level (that will be pretty large in the Indian context).

c. The 4 stage models predict trips whereas activity based model predicts activity episodes, which also contains that tour and the trip within each tour including the time of a tour, mode choice, and destination choice.

d. Individuals are considered in a trip based 4 stage model whereas households are considered in an activity based model, but household means the entire household including all individuals.

e. In 4 stage model, no constraints are considered, but in activity based model many constraints are considered. Whenever a decision is being taken or a choice is being made, these constraints decide on what would be the limited alternatives that are available for a person to choose i.e. it gives us a more realistic idea about the alternatives that are available to a particular person.

Types of constraints

Time constraints

There are time constraints which signify that, certain activities are not possible beyond a certain time i.e. a tour is not possible beyond a certain time.

Space time constraint

Certain activities in certain locations are not possible at certain time periods.

Situational constraints

One person cannot be there at two places at the same time.

Institutional constraints

Certain rules and laws play a role in decision making process.

In trip based models, individual trips are modeled like, home to work, work to shopping, shopping to home then again after coming back to home, home to dining and dining to home (in the above right-hand side figure). In tours, when one goes to the office (home to work) and then come back from work to home, including a small stopover at a shopping center, all decisions are linked i.e. one cannot go to the shopping center until unless leaving the workplace. When tours start at home and end at home, it is called home-based tours. In this example, there are two tours. In the case of two tours, one cannot perform the second tour unless one returns from the first tour.

The schedule for the entire day is prepared in an activity based model. The entire day's schedule is actually prepared for a week and fits multiple tours. Schedules are also rearranged and adjusted depending on what kind of trips are possible and other issues. Once the schedule is prepared automatically everything is linked and everything is dependent on one another and it is a joint decision for the entire day i.e. entire day's schedule is decided and everything else is the outcome of that.

At first, the major activities for the day are decided considering the time constraints. The next focus is on what else can be done on that day. The choices are decided based on observations from the sample considering the socio-economic background of that person (individual level and household level) and algorithms like decision trees or certain rules are used to determine the same.

Interactions that exists between households members like task allocation, car allocation (when there is only one car in the household and who will use that car), joint conduct of activities (activities are performed by 2 individuals of a household together) are taken at the household level. Tasks are (e.g., who will go to buy something from the market) directly allocated to somebody which makes the model more consistent i.e. based on constraints and based on everybody's schedule who can undertake that particular task or if it will be conducted together by two household members. This is possible if both members are free at that point of time (e.g., both members have completed office and have a free slot where they can conduct that task). There is no scope for this kind of joint activity decision in a tour-based and trip-based models.

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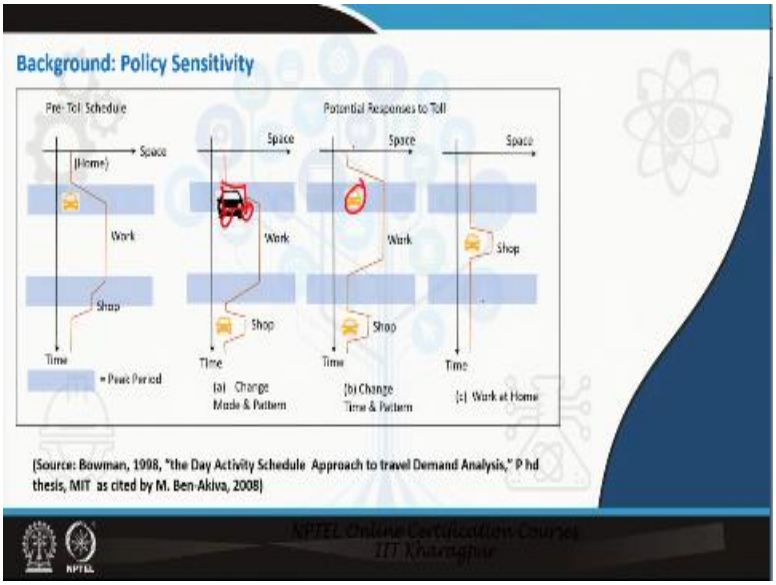

The above figure is from the PhD thesis by Bowman (Bowman, 1998, "the Day Activity Schedule Approach to travel Demand Analysis," as cited by M. Ben-Akiva, 2008). This figure shows why a activity based model is required especially from a policy perspective. In the left-most diagram, one started from home and travelled to work using own car during peak hour and came back from office at peak hour. He also stopped at a shopping centre and spend some time there and then he again travelled to home.

The rest of the three diagrams shows the change in activity-travel pattern if a toll is introduced. This toll is basically congestion pricing during peak hour to reduce the number of people using cars. Accordingly, one can change the mode i.e, instead of choosing car one may choose bus to avoid paying the toll and can travel during the same time. After returning home, he can use his own car for the shopping tour. So, one tour becomes 2 tours and choice of mode has also changed.

The other change that can happen is that this person was so prone to use his car that he changes his travel time and starts early for office and from office to avoid peak hour toll charges. After coming back to home from office, he goes for shopping after some time.

The third option is that, he may decide to work from home i.e. telecommute and he will not go to the office at all. During the middle of the day, he instead chooses to go to the shopping centre when it would be comparatively empty.

These are 3 alternatives that can happen when these kinds of policies are taken. This is not possible to be modelled using a 4 stage trip generation model. This kind of response can be determined only when activities are scheduled for the day.

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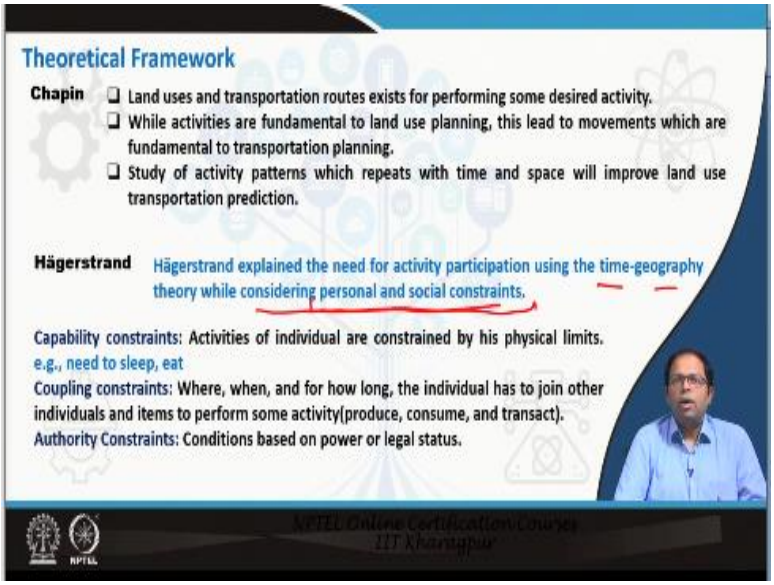

Theoretical Framework

Activity based modelling started with Chapin's work where he proposed that, landuse and transportation routes exist for performing some desired activity and while activities are fundamental to landuse planning, this lead to movements which are fundamental to transportation planning and study of activity patterns which repeats with time and space will improve landuse transportation prediction.

He was the first to suggest that activities are connected with landuse and then activities lead to travel which is connected with transportation planning and if these activity patterns could be studied in detail and the patterns of repetitions can be determined, then, future landuse and transportation for a particular area can be predicted with more accuracy.

Similarly, Hagerstrand also explained the need for activity participation using the time geography theory while considering personal and social constraints. He introduced 2 things i.e., there is a need for activity participation and this involves time and space (location). Activity schedule is thus determined considering the time and location for activities while taking into account a lot of personal and social constraints.

Constraints introduced by Hagerstrand

a. capability constraints

Activities of an individual are constrained by physical limits as one cannot do certain things beyond his physical capability like he needs to sleep for a certain amount of time and he needs to eat. Thus, he cannot do continuous work throughout the day.

b. Coupling constraint

This constraint is related to where, when and for how long the individual has to join. As individuals and items have to perform some activity like produce, consume, transact, it is important to decide which are the things that have to be done jointly and where and when these are done.

c. Authority constraint

This constraint is related to conditions based on power or legal status, certain rules etc.

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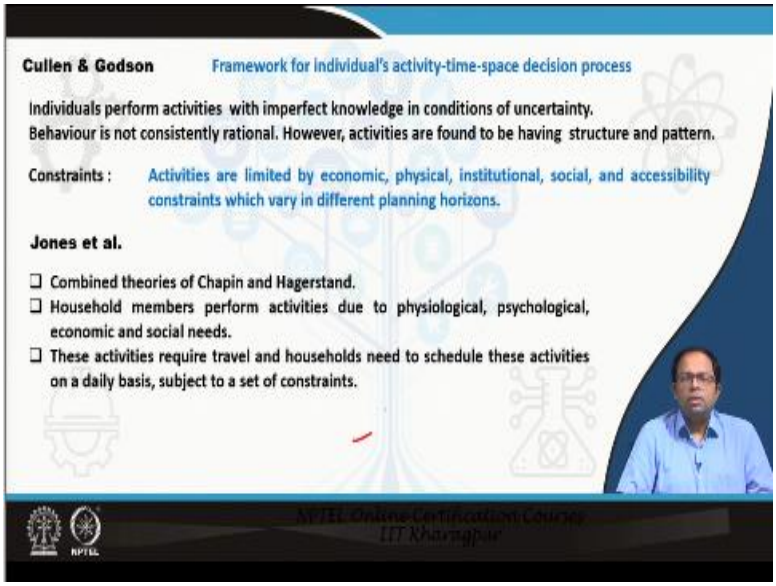

Cullen and Godson were the first to give a framework to individuals' activity time-space decision process. They proposed that, individuals perform activities with imperfect knowledge in conditions of uncertainty i.e. people do not know all the things and they perform their activities with imperfect knowledge. The behaviour is not consistently rational and people do not do the exact same thing every day.

But at the same time, activities are found to have a certain structure and pattern. So, even though there are variability, uncertainty, and imperfect knowledge, there are still certain

structures and patterns in a way a person does his/her activities and that actually can be determined and this is also limited by certain constraints such as economic constraints, physical constraints, institutional constraints, social constraints and accessibility constraints. This also varies during different planning horizons. This is more or less an advancement of Hagerstrand's work where the constraint remains and at the same time, there is a need to determine the structure and pattern of activities that was first proposed by Cullen and Godson.

Finally, Jones combined theories introduced by Chapin and Hagerstrand and he suggested that household members perform activities due to physiological, psychological, economical and social needs. The household becomes the key for activities and these activities require travel and households need to schedule these activities daily subject to a set of constraints. This is the starting point of activity based modelling.

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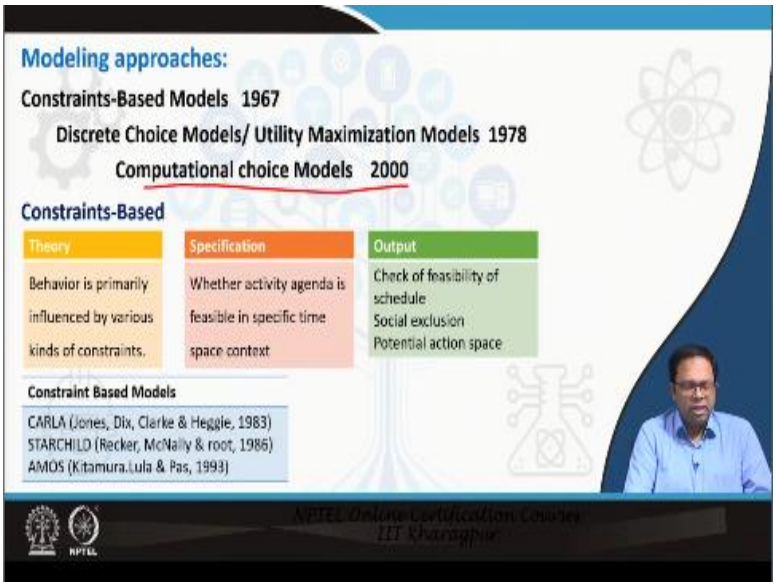

Modelling approaches

Initially, during 1967 the models were constraint-based like Hagerstrand's model and the time-space prisms. Then during 1978 discrete choice and utility maximization models were gradually adopted and several models were developed based on these principles. These models were based on the utility maximization theory. Both, single decisions or joint decisions are considered in these models. Interdependencies are also well considered in these models. A lot of nested models have been developed to solve these joint decisions. Around the year 2000, computational choice models were initiated. The increase in the number of proposed activities and further segregation (time periods etc.) resulted in huge computing

load and also made it difficult to solve these models using utility maximization principles without simplifying the model. Computational choice models address this issue through introducing certain machine learning approaches such as decision tree algorithims etc. Most of the current models use utility maximization as well as a computational process, but the most famous model in the activity based modelling space is ALBATROSS is based on the computational choice process.

Summary of the different models

In Constraint-based models, the behaviour is primarily influenced by various kinds of constraints and whether the activity agenda is feasible in a specific time and space is checked. Finally, the output is the based on the feasibility of schedule, social exclusion and potential action space. Some of the early models in this regard were Carla (Jones, Dix, Clarke & Heggie, 1983), Starchild (Recker, McNally & root, 1986) and Amos (Kitamura.Lula & Pas, 1993).

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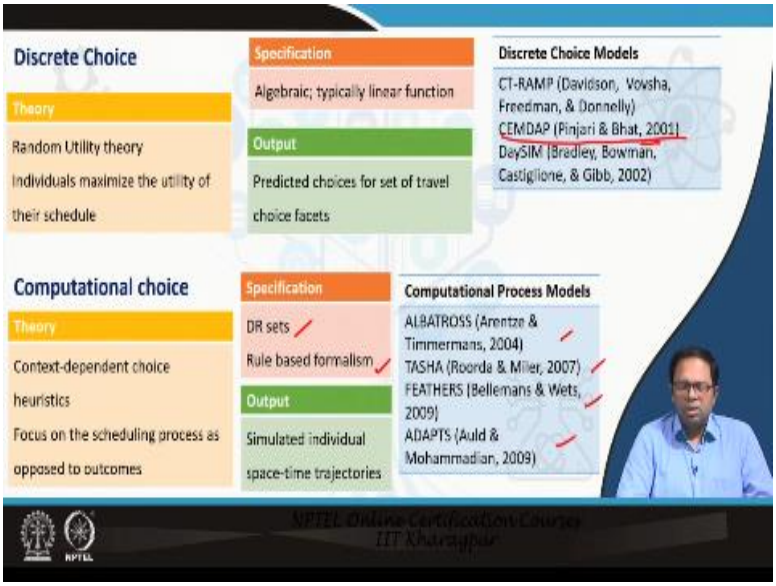

In the discrete choice model, random utility theory is used to maximize the utility of the individuals' schedule instead of maximizing the utility of a mode choice or destination choice or location choice. It is based on a linear function like any logistic regression model and predicts choices for a set of travel choices facets. Some of the important discreet choice models are CT-RAMP (Davidson, Vovsha, Freedman, & Donnelly), CEMDAP (Pinjari & Bhat), DaySIM (Bradley, Bowman, Castiglione, & Gibb).

Computational choice process models are based on context-dependent choice heuristics i.e. based on constraints, certain choices are available and one needs to choose out of those choices. Heuristics are being utilized and the focus is on the scheduling process as opposed to outcomes i.e. at first the schedule is determined and automatically outcome is a result of that. A lot of decision trees, decision rule(DR) sets and rule-based formalism are used.

These rules are like, 'if this is yes then do this' which results in decision-making and individual space-time trajectories. Space-time trajectories are determined for the synthetic population throughout the day i.e. at what time and at what location activities are conducted. Famous computational choice process models are Albatross(Arentze & Timmermans, 2004), Tasha(Roorda & Miler, 2007) and most of these models are currently also under development like Feathers(Bellemans & Wets, 2009) and Adapts(Auld & Mohammadian, 2009).

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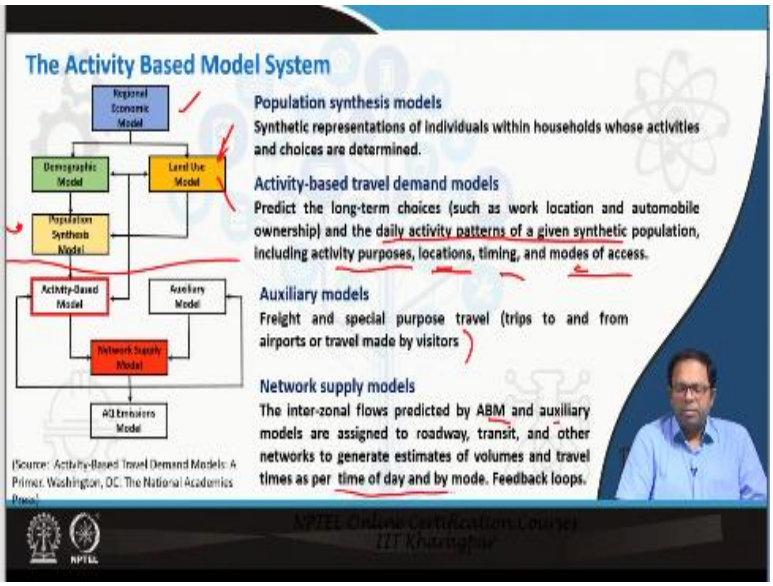

Activity based model systems

Activity based models are not standalone models and these are part of a landuse transport interaction system. Hence there is a regional economic model, which predicts the socio-economic characteristics and the macroeconomic parameters for a particular area. A demographic model takes care of the demographic projections. Along with this is a landuse model and a population synthesis model. The landuse model includes real estate development and location choice models. Similarly, the demographic model can have several sub-models based on the division of socio-economic groups and based on that population synthesis model can be developed for an entire urban area.

Next, the activity based model can be developed. Activity based model includes long term choice models such as work location, automobile ownership and then based on those long term choices, lifestyle choices, mobility choices and the daily activity pattern of the given synthetic population can be also determined which includes commuters' activities, locations, timing and modes of access.

Individuals' daily activity profile is determined based on long term choices, household or individual socio-economic characteristics, certain constraints, certain responsibilities, certain tours, or certain kinds of mandatory activities that the individual needs to do. So, the entire gamut of activities, the locations where they take place, the time of the activities and what modes are used to access those activities are determined.

As the destination and choice of mode are determined this can be input into the network model i.e. traffic assignment model which is the 4^{th} stage of 4 stage travel demand model. This part remains the same.

There are certain other auxiliary models like freight and special purpose travel like trips to and from airports, travel made by visitors. These also give their inputs to the network model. The network loads also give feedback to the activity models as well as to the auxiliary model.

Finally, outdoor emissions models can be developed based on these network models. Inter-zonal flows predicted by activity based models and auxiliary models are assigned to roadways, transit and other networks to estimates the volumes and travel time as per the time of the day and mode. There are feedback loops also to the previous models as well.

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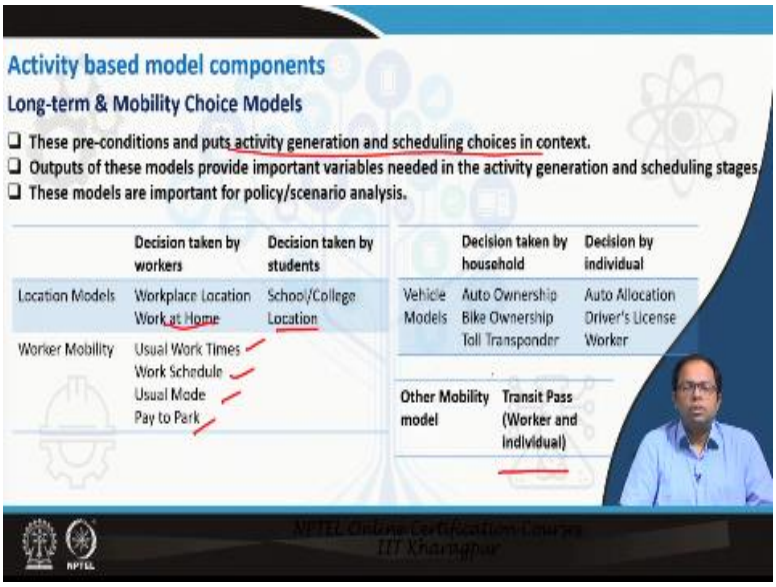

Activity based nodel Components

Long term and mobility choice models

The two major components of activity based model are long term choice and daily activity schedule. The long term and mobility choice models have been discussed earlier during the discussion of landuse transport interaction frameworks. These models are precondition and put activity generation and scheduling choices in context i.e. the daily activity schedule is generated based on these preconditions like what cars that the household has, what kind of transit pass the household owns, What is his workplace location? What is his school location? Does he work at home? When he goes to work? What is the schedule for work? What is his usual mode for work? Does he get paid to park over there?

This kind of basic decisions are long term decisions and which is not influenced by daily activity pattern, but daily activity pattern depends on this kind of decisions. So, if individuals already have a particular work time and have a particular workplace location, then daily activity pattern would be based on that.

Long term choices are first determined. Once that is determined based on those choices, all lifestyle choices, location choices, time of the day choices and activity schedule for a particular day is decided.

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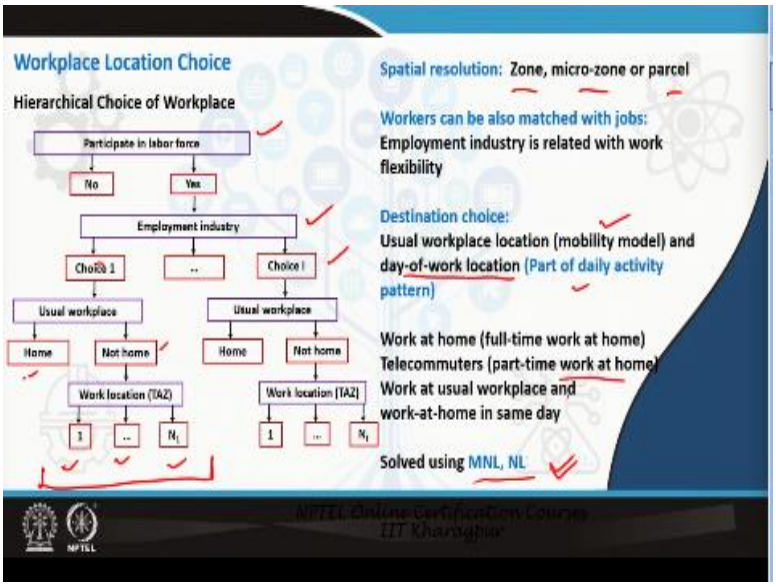

Workplace Location Choice

The above figure shows an example of workplace location choice and the hierarchy of choice of workplace. These are decision rules like whether this particular individual participates in a labor force or not. If yes then which industry is implied? Then there are choices of different industries. Once these are all determined by probabilities of the sample population and based on these choices the next question could be what his usual work involves. It could be either at home or at a factory or at an office somewhere. Then, if it is not home, his work location is one among location choice 1, location choice 2, location choice 3 and so on which is again based on a particular industry.

The data set related to the location of a particular industry has to be present earlier. This should be there in landuse data set. The data related to industrial employment patterns in different zones gives an idea of where these kinds of jobs are located and which locations could become alternatives location choices for this particular individual. In the case of more than one choice, there has to be a decision on location choice. The spatial resolution can be zone, micro-zone, or parcel level. Workers can be also matched with the jobs like employment industry then the next decision choice would be workplace location choice.

Destination of work may be determined from the mobility model or from the daily activity pattern where it can be based on day-of-work-location i.e. workplace may be changed as per the day. There could be different choices like work at home, full-time work at home, telecommute, part-time work at home, work at usual workplace, and work at home on the same day. Work at the usual workplace and work at home on the same day is also possible. In

the above example, it has been asked whether an individual works at home or not at home. This could be solved by a multinomial logit or nested logit. This kind of choice hierarchy, which could be solved using utility maximization has been discussed earlier.

But at the same time in the computational process model, decision trees are used to determine these kinds of decisions.

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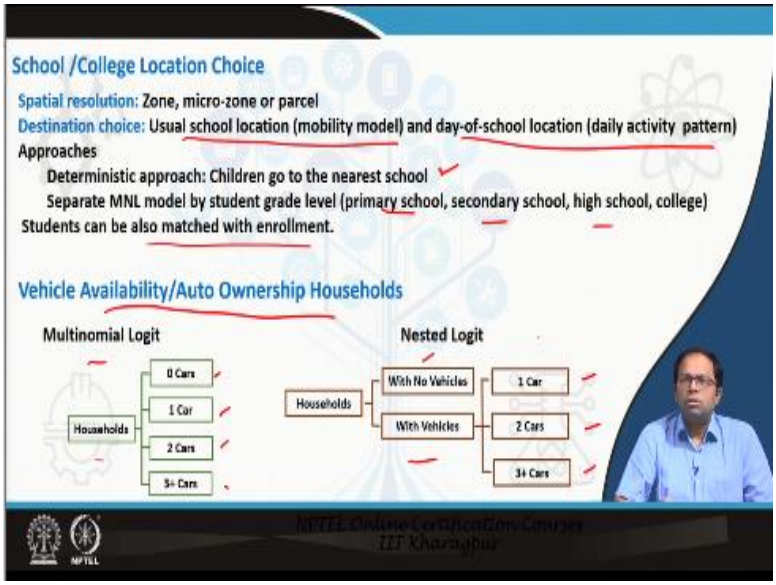

School/College Location Choice

In school, college location choice model spatial resolution could be same like zone, micro-zone or parcel. Destination choices would be two types like usual school location which is a mobility model or day-of-school location which is based on daily activity patterns. It could be based on a deterministic approach i.e., children go to the nearest school from their house which is in case children are studying in government schools. But, if they are going to a private school, which is far away then it is not possible to be determined. A location choice model is required to address this issue. Separate MNL model by students of different grade levels like primary school, secondary school, high school, college can be developed and student can also be matched with enrolment, like based on each zone, how many students are enrolled that could be matched with the total number of students that wants to go to a particular zone. These kinds of competition effects can also be considered. Similarly, vehicle availability/auto ownership per household can be also modelled. It can be a multinomial logit structure like a household with zero cars, 1 car, 2 car, 3 car or it could be a nested logit structure with a household with no vehicles, household with vehicles and then within sub-nest 1 car, 2 car, 3 car choices. So, nested logit approaches can be also used to determine these

long-term choice for auto ownership, location choice for school, location choice for employment etc.

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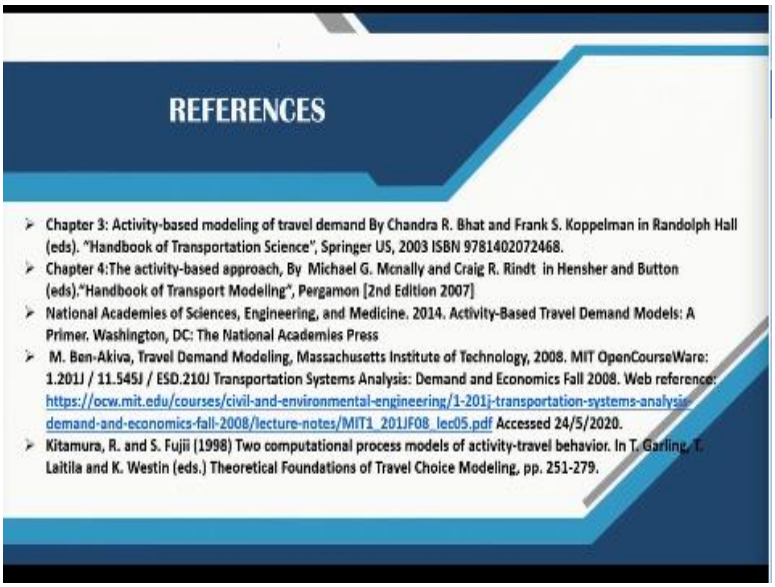

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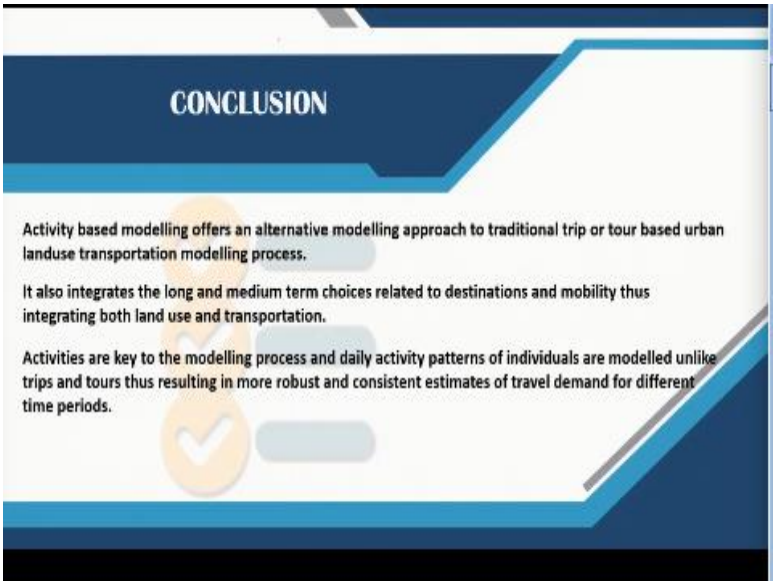

Conclusion

Activity based modelling offers an alternative modelling approach to traditional trip or tour based urban landuse transportation modelling process.

This also integrates long and medium-term charges related to destinations and mobility thus s integrating both landuse and transportation.

Finally, activities are keys to the modelling process and daily activity patterns of individuals are modelled unlike trips and tours, thus resulting in more robust and consistent estimates of travel demand for different time periods.

Thank you.