Urban Landuse and Transportation Planning
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Lecture-07
Theoretical Foundations, Part-2

Welcome back. In lecture 7, we will complete the theoretical foundations that we started in the previous lecture.

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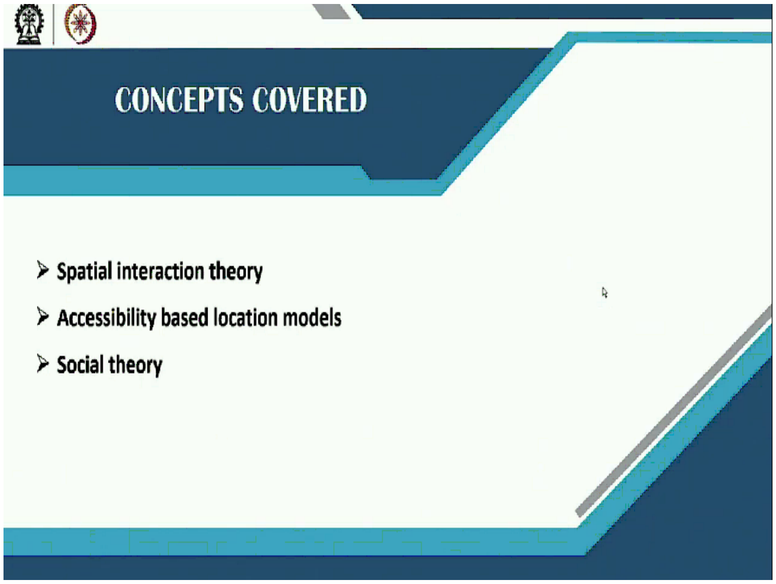

The different concepts that will be covered in this lecture are; spatial interaction theory, accessibility based location models and social theory.

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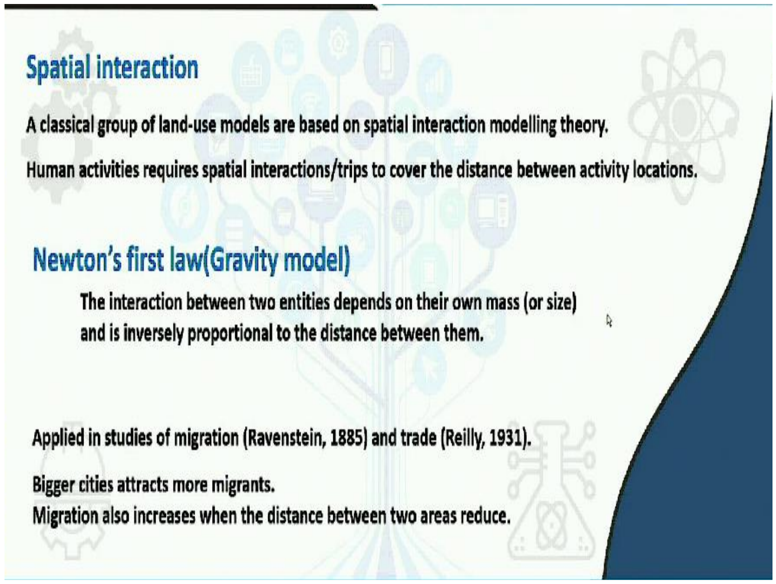

Spatial interaction theory

The spatial interaction theory refers to spatial interaction or movement amongst human beings. Many classical land use models are based on this particular theory. The theory proposes that, human activities require spatial interactions or trips to cover the distance between the different activity locations and this could be explained using Newton's first law or the gravity model which says that, the interaction between 2 entities depend on their own mass and is inversely proportional to the distance between them. This is a departure from the location theory which was only focused on determining transportation cost and also from the bid rent theory which centers around rent whose value depends on the distance from the center. On the other hand, Newton's gravity model, states that the amount of interaction between two entities not only depends on the distance which is inversely related, but, also on their own mass i.e., the size of those two particular entities. This concept has been applied in studies of migration by Ravenstein and trade by Reilly long before. In case of migration, bigger cities attract more migrants as per the law of the gravity since it depends on the mass and also migration increases when the distance between two areas reduce.

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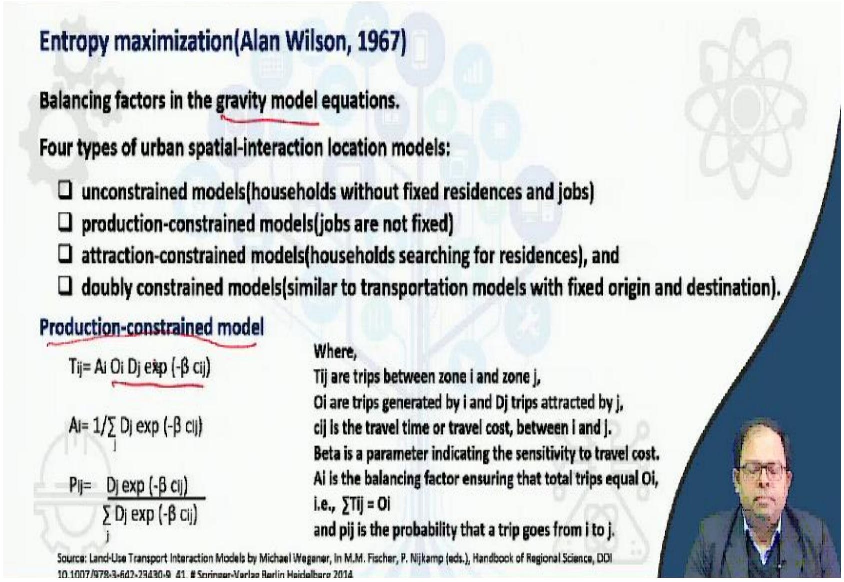

Entropy maximization model

The gravity model was the first spatial interaction model. This spatial interaction model can also be transformed into a location model. Alan Wilson in his Entropy Maximization model, transformed the gravity model formulation into a location model when he proposed four types of urban spatial interactions or models.

The first one is an unconstrained model where households are without any fixed residences and jobs. Next, is a production constrained model where jobs are not fixed. Then, an attraction constrained models, where households with fixed jobs are searching for residences, and finally, a doubly constrained model, which is similar to transportation models with fixed origin and destination.

In the entropy maximization model, Wilson introduced a balancing factor (Ai) in addition to the normal gravity model equation as shown in the slide. In a standard gravity model, the size of the origin, the size of the destinations and c_{ij} which is the cost or impedance for travel between these two points can be found. This distance is however, not taken directly. Instead exponential (function) of the distance is considered and the negative sign shown in the equation signifies the inverse relation. Finally, beta is a parameter indicating the sensitivity to the travel time or travel cost which can be calibrated or changed to fit the model with actual data. The balancing factor or the new part (Ai) ensures that the total trips i.e., summation of T_{ij} is equal to O_i which are trips generated by all i.

Similarly, if T_{ij} is fixed then the total number of trips originating (O_i) and number of trips going to a particular zone (D_j) can be predicted as well. Thus, location for residences and jobs can be predicted using the spatial interaction model as well.

In a doubly constrained model, where both the number of trips originating from a particular area and the number of jobs available at the destinations are known, the equation takes the form of a gravity model and the total number of trips in between the origin and destination can be predicted. But if only trip origins or residences are known and jobs at destination zones are not known, then job locations can be determined if T_{ij} values are known. This is a production constrained model where,

$T_{ij} = A_i O_i D_j \exp(-\beta c_{ij})$

$A_i = 1/\sum_j D_j \exp(-\beta c_{ij})$

$P_{ij} = D_j \exp(-\beta c_{ij}) / \sum_j D_j \exp(-\beta c_{ij})$

Where,

T_{ij} are trips between zone i and zone j,

O_i are trips generated by i and D_j trips attracted by j,

c_{ij} is the travel time or travel cost, between i and j.

Beta is a parameter indicating the sensitivity to travel cost.

A_i is the balancing factor ensuring that total trips equal O_i for all i,

i.e., $\sum T_{ij} = O_i$

and P_{ij} is the probability that a trip goes from i to j.

This equations help us to determine the total amount of trips between any two zones and using the balancing factor (A_i), the probability of a trip going from i to j can be also predicted. Thus, the location of jobs can be predicted if the number of trips from one zone to another is known. This could be achieved through iterating and checking the distribution of D_j based on known values of O_i. Thus, if O_i is known then automatically D_j can be predicted and vice versa. This is how entropy maximization actually improved the existing gravity models and also gave a new form to the equation which can be used for determining allocation of people or allocation of jobs in a particular urban area.

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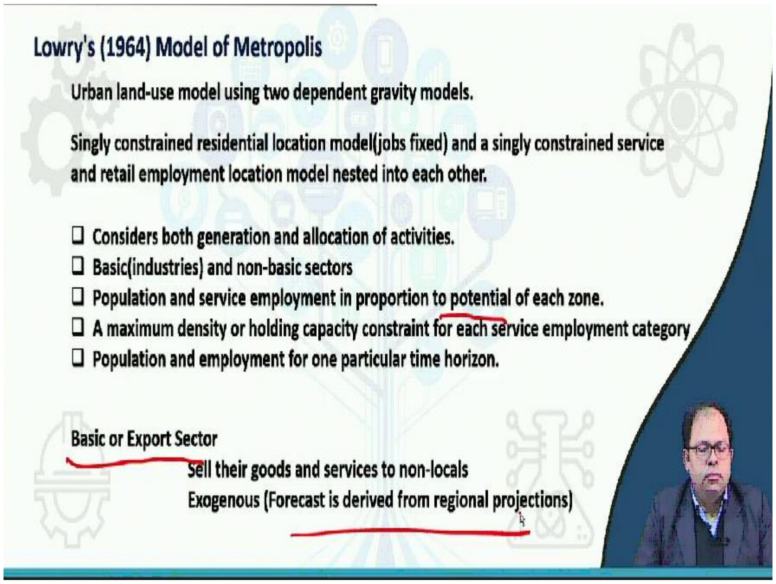

Lowry's model of Metropolis

Lowry's model of Metropolis developed during 1964 is the most famous land use transportation model. This included two dependent singly constrained gravity models. The first one is a singly constrained residential location model where jobs are fixed, and the second is a singly constrained service and retail employment location model based on fixed residences and these two models were nested into each other.

In the first model, based on fixed job locations, residences were allocated to different zones of the city and then, based on this spread of residences, the retail employment location model determined retail job locations. The basic assumption was that, residences based on their location will require retail which will lead to requirement of retail jobs. Next, new retail jobs will require new people to be employed and their residential location also needs to be determined. Considering this as the first iteration, in the next iteration again new residences needs to be distributed based on the new quantum of retail employment. This iteration is carried on till the entire system gets balanced.

Lowry's model of Metropolis considers both generation and allocation of activities. Initially the model considers primary industries which are taken as an exogenous input. This signifies that, new jobs coming to an urban area lead to growth of residences which again lead to growth of other non basic sectors like retail and service employment. This new employment generation was proposed to be proportional to the potential of each zone. However, the term potential has to be considered carefully since a maximum density or holding capacity constraint for each service employment category also needs to be considered. Additionally, this is estimated only for one particular time horizon/period which is also referred to as static equilibrium.

Looking at the sequence of this model from another perspective, it can be stated that, initially the basic or export sectors which sell their goods and services to non-locals are considered. These numbers of jobs are derived from regional projections and job forecasts are exogenous input which is not part of the model.

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This leads to growth of the non-basic or retail sector. This sector actually sells their goods and services to locals and their size and location are determined from the size and location of the existing population. Other non-retail service sectors like education (government schools) etc. can be also part of the non-basic sectors. These are endogenous to the model system.

Finally, the size of the household sector is determined by the number of employment opportunities which includes both basic and non-basic sectors. While, the size of the household sector is determined through an iterative process as discussed earlier, their location is determined based on accessibility and particularly on accessibility to employment.

MEPLAN, TRANUS, PECAS are currently operational major land use transportation modeling systems which use this particular concept of allocation or spatial allocation theory and uses formulation similar to the Lowry's model.

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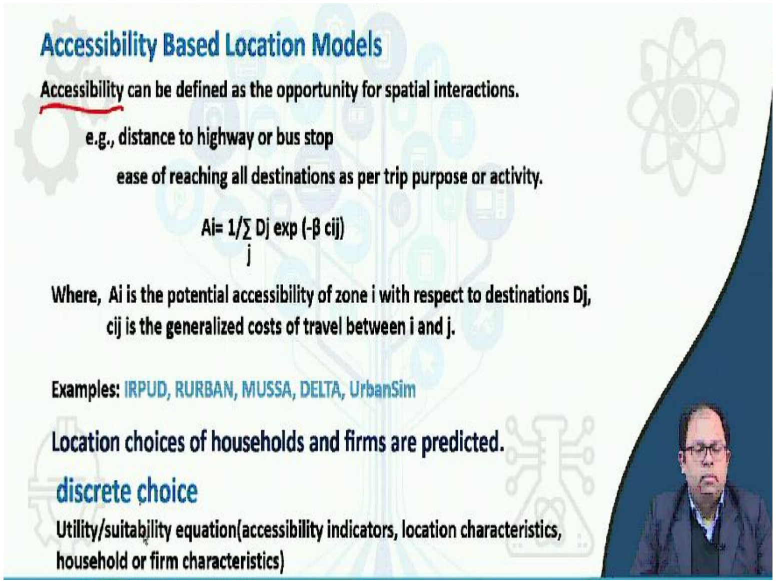

Accessibility based location model

Accessibility based location models combines the best of both the economic theory as well as the spatial interaction theory. The main focus is on the term accessibility. Accessibility can be defined as the opportunity for spatial interactions which can be estimated as the distance to a highway or a bus stop or can be estimated as the ease of reaching all destinations as per trip purpose or activity. For a person located in a particular area, the accessibility of that area depends on the different activities the person participates and what benefit this area holds in terms of his access to these different activities. For example, while going to a movie theater from a particular zone, accessibility depends on how accessible is that particular zone considering the different movie theaters in that urban area located at different zones. Thus, accessibility can be measured as the distance to all the different zones which have got a movie theater.

$$A_i = 1/\sum_j D_j \exp(-\beta c_{ij})$$

Where,
A_i is the potential accessibility of zone i with respect to destinations D_j,
c_{ij} is the generalized costs of travel between i and j.

The above equation shows one formula where, A_i is the potential accessibility of zone i with respect to destination D_j and c_{ij} is the generalized cost of travel between i and j. In this equation accessibility is measured as 1 divided by the summation of the potential of all the locations divided by the exponential of their distance. This formulation is similar to the balancing factor discussed earlier. The concept of accessibility has been incorporated in several urban land use transportation model systems, such as IRPUD, RURBAN, MUSSA, DELTA and UrbanSim.

Accessibility based location models actually predicts the location choice of households and firms. This is achieved using the concept of discrete choice which depends on the utility/suitability of a particular area compared to the utility of all other areas. One of the parameters to determine utility or suitability is accessibility in addition to parameters like location characteristics of that particular area, land use characteristics etc. Household/firm/individual characteristics of the decision making entity also plays a role in determining the utility of that particular choice for that particular entity.

Thus, a component of the location theory in form of accessibility is incorporated in the discrete choice theory in accessibility based location choice models of land use and transportation.

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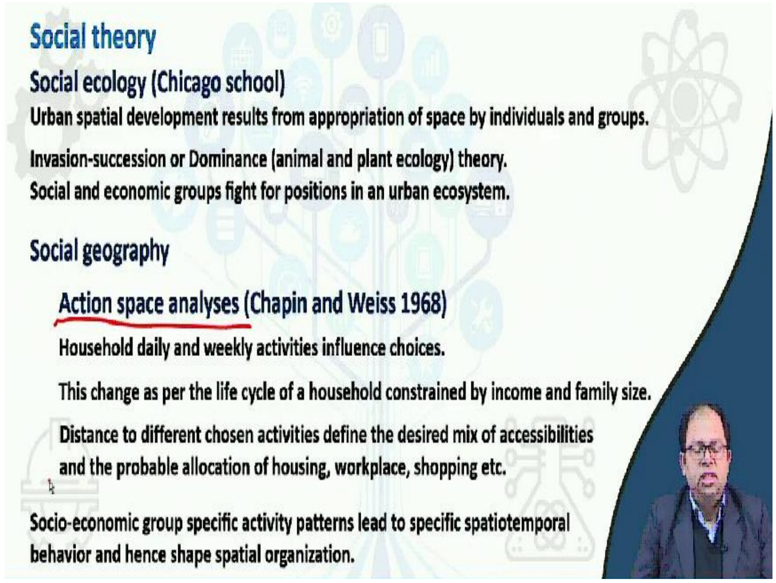

<u>Social theory</u>

Social theory includes two theories; first the social ecology theory from the Chicago school and the second, the social geography theory.

Social ecology theory

In social ecology, urban spatial development is considered to result from appropriation of space by individuals or groups. This follows the theories of invasion, succession or dominance which is based on animal and plant ecology. When a particular groups migrates to an area which may be termed as invasion and then succeeds or dominates over that particular area this is referred to as the invasion succession concept. This happens in form of social and economic growth and fight for positions in that particular urban system which eventually results in equilibrium.

Social geography theory

The social geography theory is considered to be more appropriate for urban planning. A new concept called action space analysis was introduced by Chapin and Weiss in 1968. This theory states that, household's daily and weekly activities influences the routine a household follow during a particular day or during the entire week. This includes the choice undertaken by a household to either select a location, time or to accompany someone to a particular activity like going to a movie, going to a school etc. Activities undertaken by households and individuals vary and also change as part of the life cycle of the household and are also constrained by income and family characteristics. For example, a young person does certain activities which are different from an older person or families with kids undertake activities which are different from families without kids. Thus, during different life stages, activity patterns change and it is also constrained by income and family size. A poor family conducts different activities compared to a rich family. Similarly, in case of a large family all members may not get access to the family car.

Distances to different chosen activities also define the desired mix of accessibilities and the location of housing, workplace and shopping. For example, location of workplace influences both residential location and mode choice from residence to work. Thus, desired accessibility for a particular location is dependent on choice of workplace, housing, school etc.

Socio-economic group specific activity patterns lead to specific spatiotemporal behavior and hence shape spatial organization of an urban area.

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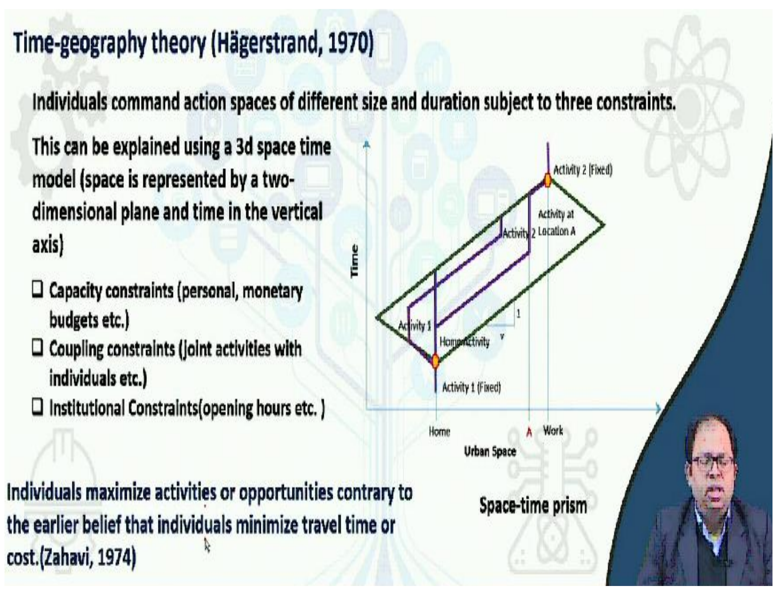

Time geography theory

The time geography theory proposed by Hagerstrand during 1970s gave the action space analysis, an operational form which could be used to determine mode choices or route choices. This theory states that, individuals command action spaces of different size and duration subject to three constraints.

Action space is basically their activity pattern, time schedule etc. and can be explained using a 3d space time model, where urban space is represented by a 2 dimensional plane and time in the vertical axis as shown in the image. This shows that, an individual has a time budget and has to perform certain activities within this limited time. The activity pattern depends on what an individual wants to perform. For example, as shown in the image, the location of activity one is home, and activity two is also fixed which maybe his job, but in between there is an alternative activity like shopping or dropping drop off his kid to a school which needs to be performed while going from activity one to two. Depending on when an individual starts from home he will be able to spend time for the intermediate activity since time for job or activity 2 is fixed. Different individuals adopt different patterns and depending on what kind of activities an individual performs, his time area diagram will vary and this is also called a space time prism. This space time prism helps in determining how a person should use his daily pattern of movement from one zone to another. This could be also used to determine the time when an individual should choose to travel for a particular activity. Thus considering the space time prism, it could be stated that individuals maximize activities or opportunities, contrary to the earlier belief that individuals minimize travel time or cost, which was the basis of location theories and spatial interaction theory.

The time geography theory also considers 3 kinds of constraints.

First, is the capacity constraint which includes personnel, monetary budget etc. While, an old person may not be capable to do certain activities, other individuals lack capital to undertake certain activities.

Next, is the coupling constraint which refers to mandatory joint activities with other individuals like taking kids to school etc. Thus, the choices of both individuals will be dependent and will be different from individual choices. For example, an individual could have taken a cycle for work but since his kid will accompany the journey is conducted using car. Thus, coupling constraints also play a role in determining activity patterns.

The final constraint is the institutional constraint like time for opening of an office or movie theatre which determines the time for the journey.

Thus, the focus of the time geography theory is not to minimize the travel time or cost, but to maximize the kind of activities or opportunities that a person can undertake in a particular day or a particular week which is a departure from the earlier models. This theory is also the basis of activity based models of land use transportation which are currently being developed.

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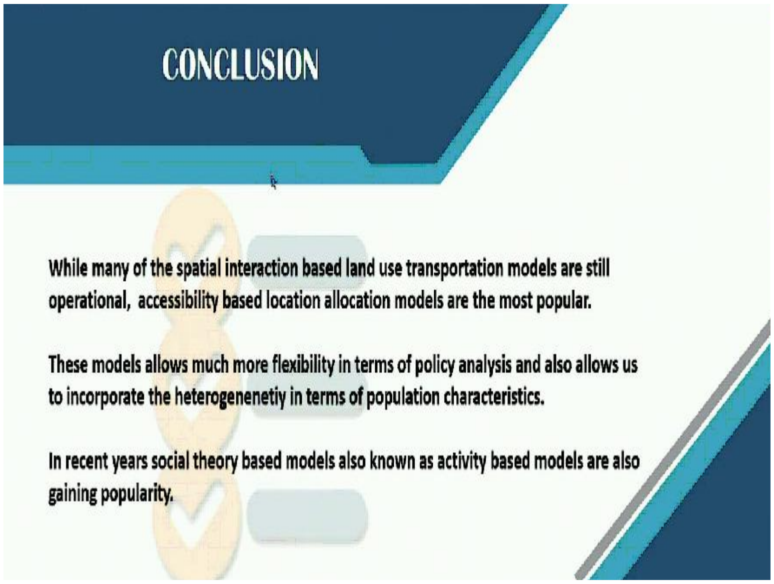

To conclude, we can say that;

While many of the spatial interaction based land use transportation models are still operational, accessibility based location allocation models are the most popular and robust.

These models also allow much more flexibility in terms of policy analysis and also allow us to incorporate the heterogeneity in terms of population characteristics.

In recent years, social theory based models also known as activity based models are also gaining popularity.

This is how these different theories actually influence different land use transportation models, or the structure of land use transportation models for urban areas.

Thank you.