**Urban Landuse and Transportation Planning**
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**Lecture-06**
**Theoretical Foundations, Part-1**

Welcome back. This module will cover land use transportation models and frameworks and the first 2 lectures, lecture 6 and lecture 7 will cover the theoretical foundations.

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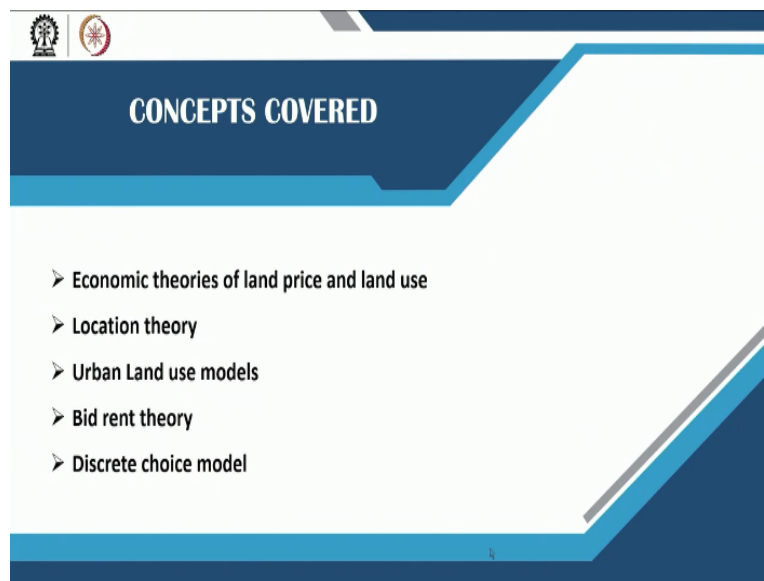


The different concepts that will be covered in this particular lecture are economic theories of land price and land use, location theory, urban land use models, bid rent theory and discrete choice model. While location theory, bid rent theory, discrete choice models are all part of economic theories, the resulting urban land use models arising out of these theories will be also covered in this lecture to some extent.

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The term land use in urban land use transportation models represents many different aspects of human activity and in some cases the physical use of the land is not implied.

The foundation of economic theories of land-price and land-use was laid by Ricardo and by Von Thünen. Ricardo (1817) explained land prices in terms of land quality whereas, Von Thünen (1826) explained land-use patterns and land prices in terms of distance and transportation costs.

Central place theory by Christaller (1933, 1966) explained the hierarchical structure of cities in terms of size, location and number as per the services they provide and their demand from surroundings.

This was linked to industrial location theory by Losch (1943, 1954) where market areas were represented by hexagons based on spatial competition between firms.

Classical mechanics (Newton's Laws of Motion) have also been used to explain the relationships between people/jobs and their spatial movement and allocation.

## Introduction

The term land use in urban land use transportation models does not mean only land, it covers different aspects of human activities and also considers land price, the number of jobs in a particular area or the number of residences or even the total built square footage in an area.

The basic foundation of economic theories of land price and land use was laid by Ricardo and Von Thunen. Ricardo proposed that land prices vary as per land(agricultural) quality whereas, Von Thunen explained that, land use patterns and land prices vary as per distances and transportation cost. He proposed that, land price would be less if transportation cost is high and vice versa. Next, in the Central Place theory, Christaller explained that, the hierarchy or structure in terms of size, location and number for cities depends on the services the cities provide and the demand from the surrounding hinterland. This was linked to the Industrial Location theory by Losch who proposed that, different industries serve different market areas and these markets can be represented by hexagons which also depends on the spatial competition between these particular industries. So these two theories were developed by extending the theories by Ricardo and Von Thunen.

The relationship between people or jobs and their spatial movement and allocation in an urban area was also explored from other perspectives. Newton's Laws of Motion were also considered to establish relationships between land use and transportation.

These theories can be broadly summarized into; economic theories, spatial interaction theory, accessibility based location model/theories and social theories. Economic theories talks about the different reasons behind the evolution of land use patterns and their dynamics and can be broadly classified into location theory and discrete choice theory. The spatial interaction theory also explains the change in land use and is based on geography. Accessibility based location theories combines the economic theory particularly the discrete choice theory and the spatial interaction theory and finally comes the social theories.

## Economic theory

In economic theory, the fundamental concept is that, land is an economic asset with fixed supply and thus this results in demand and supply mismatch which leads to increase and decrease in the land price. Additionally, land parcels have certain characteristics such as accessibility, altitude, gradient, soil quality, use(land use) and so on which also results in different land prices.

Land use of a land parcel not only influences itself, but also surrounding land uses. For example, a nice park in a particular area also benefits the surrounding lands.

Land use is also influenced by certain constraints like government regulations which can be also considered as an externality. For example, government may encourage or prevent a certain land use even though it has a legitimate right to be there. For example, we take an example of a transport nagar or freight transport hub in an Indian city. Urban dwellers usually feel unsafe in the presence of large trucks and accordingly, government may bring in legislation preventing residential land use near transport hubs or alternatively transport hubs should be relocated to the outskirts of the city. Similarly, government can also encourage agricultural activities or small plantation areas inside an urban area to increase greenery. So, that is how government can also play a role in determining the location and the dynamics of land.

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## Location theory

Location theory explains the economic rationale for a firm to locate at a specific point in space. This choice is guided by the location of its production resources i.e., resources used to produce something and also by the location of the final markets where it sells its products. Thus, the classical models of location choice look into minimizing transportation costs both at the production side and during the final distribution of goods. The division of the spatial market among different producers, and also distribution of different activities in space is also based on this transportation cost. This means it is not only how one firm locates itself, but also how a particular area could be divided among different firms for distribution. Or alternatively, we can consider the people working in that firm and how they are distributed in an urban area. On the other hand, transportation costs not only refer to the actual cost of time, but also look into the opportunity cost. Opportunity cost includes the losses from not doing other things which could have been done during this time.

In addition to minimizing transportation cost, the concept of agglomeration economies i.e., economic advantages resulting from agglomeration of firms is also part of the location theory. Agglomeration economies lead to reduction in production costs since firms can economize on equipment and other production resources. It also results in more number of labors, workers and services which lead to further reduction in production cost. This also leads to distribution benefits due to presence of a readymade goods market particularly for new firms. However, this is not directly related with transportation and whenever a firm is choosing to locate with other firms, it may not result in reduction of transportation cost.
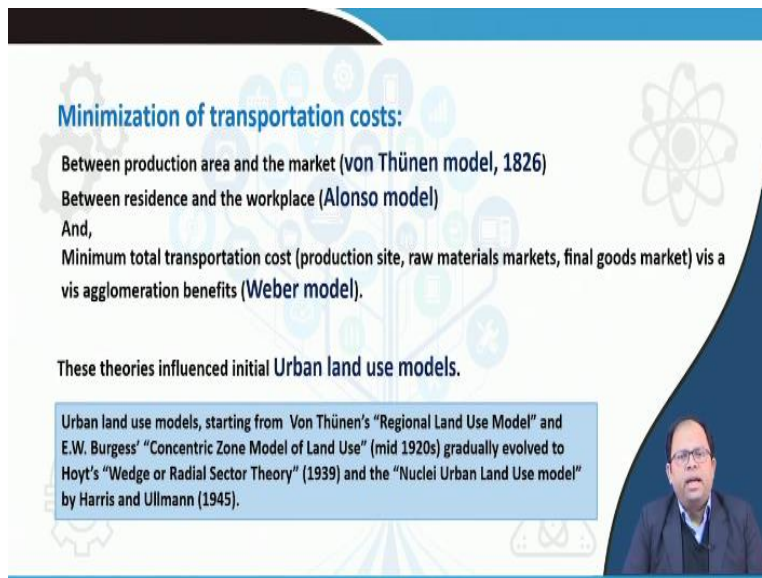
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## Urban land use models based on transportation cost

Von Thunen first talked about minimizing transportation costs between production area and the market in his regional land use model. Next, Alonso talked about minimization of transportation costs between residences and workplace. And finally, in Weber's model, minimum transportation cost was taken along with agglomeration benefits to decide on the location choice of firms. These theories of location choice were gradually incorporated into the urban land use models/theories. For example, E.W Burgess first came out with the concentric zone model of land use following the Von Thunen regional land use model. Over the time this evolved into Hoyt's Wedge or Radial Sector Theory and finally, the Nuclei Urban Land Use model by Harris and Ullmann.

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**Burgess model**

Von Thunen's model explained the spatial distribution of sites based on its rent generation capacity. Rent here refers to the cost of the land or the building and so on. The theory states that, at different distances from a market (the central business district), rent varies and it is higher near the particular market, and vice versa. So, this concept was taken in the Burgess model where it is assumed that, urban growth happens in concentric rings of development from a central area. As shown in the image, the central most ring is the central business district. Then, there is the zone of transition which is basically a mixed residential and commercial zone. Next, is the zone of working class homes of low salaried workers and then middle class homes which is zone of better residences and finally the commuter zone. While, this model of development is not observed in all cities but few cities show this kind of structure and in some cases the Burgess model was found to be actually suitable.

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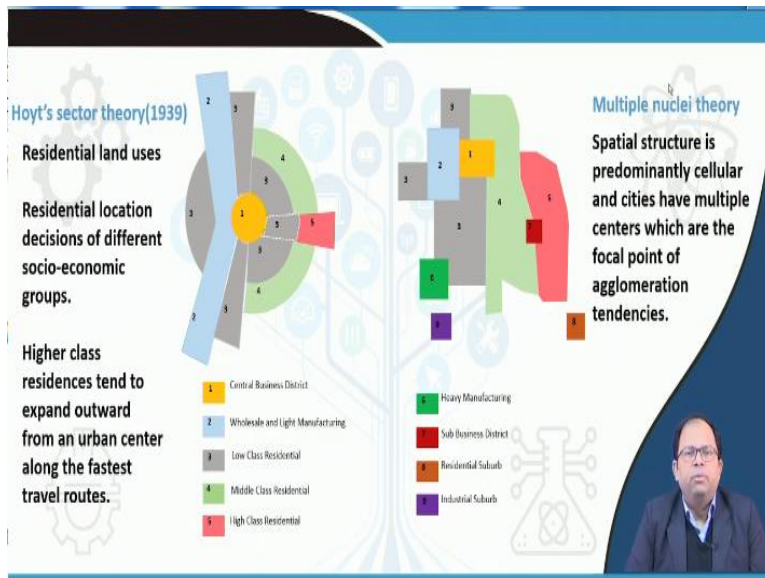
## Hoyt's sector theory

Hoyt's sector theory, more or less follows the same theory as Burgess but it concentrates more on the residential land uses. The theory explores how residential location choices vary between different socio economic groups and proposes that higher class residences tend to expand outward from an urban center and along the fastest travel routes, i.e., along the transit corridors. Like the Burgess model, the central business district (CBD) remained at the center of an urban area. Next, is the wholesale and light manufacturing areas surrounded by low class residential and then by the middle class residences. The high class residences are found to be moving outwards from the city and expanding towards the periphery of the city.
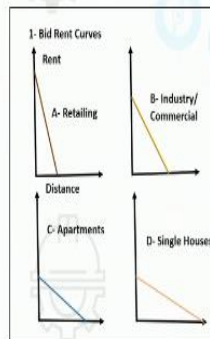
## Multiple nuclei theory

Same as the Burgess theory, Hoyt's sector theory was not able to explain many of the existing urban land uses. This led to the multiple nuclei theory where instead of a single CBD like the earlier two theories Ullmann talked about multiple CBDs. For example, as shown in the image, the CBD remained as it is, but several other sub business districts were proposed including both industrial and residential sub CBDs. Thus, in the multiple nuclei theory, spatial structure proposed is predominantly cellular and cities were proposed to have multiple centers which are the focal point of agglomeration tendencies. This led to the concept of polycentric development.

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**Bid rent theory**

Alonso proposed the bid rent theory which proposes that, firms and households choose the location at which their bid rent which is basically the bid or price they are willing to pay, matches the rent or price that is demanded by the landowners or building owners. This results in a land market clearing process which results in equilibrium or at least partial equilibrium. Equilibrium is attained when supply and demand matches. While, this usually matches (imperfectly) over a very long period, there are imbalances within shorter periods. Other considerations in regards to this theory are that, people have perfect knowledge about the cost of land, the location benefits of that land and so on. In absence of perfect knowledge which is usually the case, perfect equilibrium is not possible to be attained.

The rent a person or a firm is willing to pay for a particular piece of land or a building is based on the previous theory of minimizing transportation costs. An individual or firm will makes a tradeoff between the land price and the transportation costs while choosing a location. However, this is from the demand side i.e., how the demand is determined, whereas, from the supply side locations are rented to the highest bidder which means, the individual or firm who/which bids the highest gets that particular building or plot of land. This results in certain bid rent functions or curves.

As shown in the image, X axis shows distance and the Y axis shows the rent. With increasing distance, rent reduces and it is highest at the CBD and the slope of the function depends on the type of land use or building. For example, in case of retail, the slope is steep. This means retail is mostly concentrated at the center and as the distance from center increases rent decreases. Industry and commercial developments are rarely found in this central area since they are unable to afford that high rent. Accordingly, slope of their rent curve is also relatively flat compared to retail. Apartments and single houses show even more flat curves or bid rent curves or functions. These kinds of functions have been implemented in many land use transportation model to determine the likely location of firms and residences.
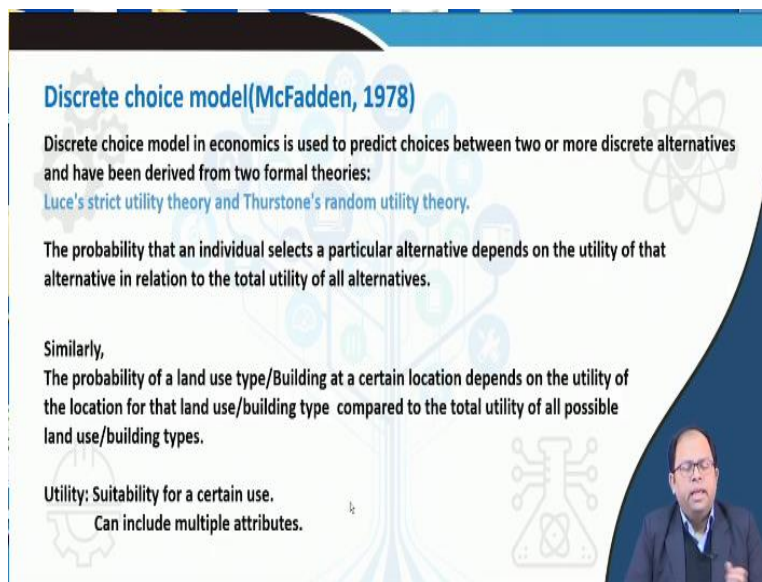
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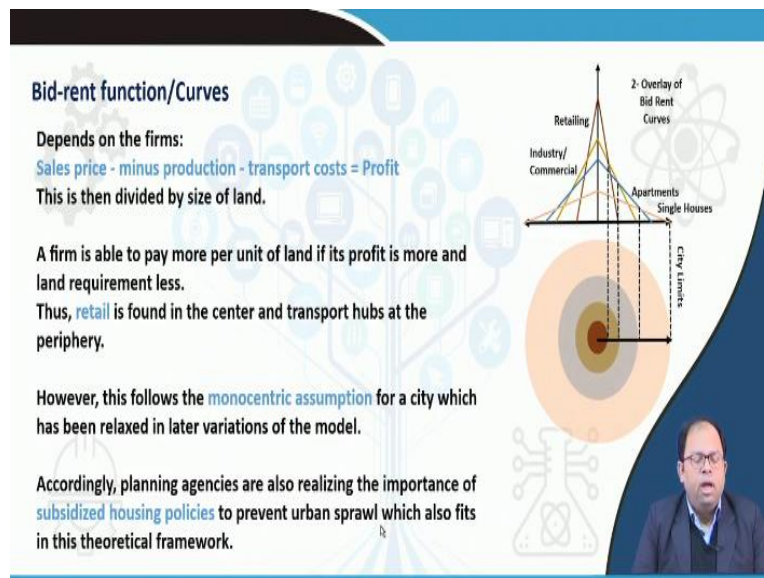


Superimposing all the different bid rent curves as shown in the image, retail is found in the central (CBD) area since they are able to pay higher rent. Next, are the industrial and commercial areas, and finally the apartments and single houses. This matches with the Burgess theory of concentric land uses.

The amount of money/profit a firm makes depends on the total amount of sale it does minus the production cost and the transport cost. Next, if this profit is divided by the amount of required land, it shows the rent amount that the firm can afford. Thus, firms making the same profit but having different land requirement are able to afford different levels of rent i.e., a firm is able to

pay more per unit of land if its profit is more and land requirement is less. So, retail is found in the center and transport hubs are found at the periphery even though both are commercial activities because transport hubs require much more land. Similarly, to reduce urban sprawl, planning agencies need to subsidize housing for lower and middle income groups so that these could be brought in the inner part of the city. This also fits into the overall bid rent framework.

While, the bid rent theory is based on the mono centric assumption of a city, it has been extended to poly centric cities as well in the latest models.

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## Discrete choice models

The theoretical basis of discrete choice model was developed by McFadden in 1978. Choices between two or more discrete alternatives can be considered following two theories; one is Luce's Strict Utility Theory or Thurston's Random Utility Theory. The term utility basically means suitability for a certain use which also mean that utility varies from individual to individual or from a firm to firm and also signifies how much the choice is suitable for this particular firm or this particular individual. Thus, for each individual the same land or same building can have different utilities or similarly different land can have different utilities for the same individual. The probability that an individual selects a particular alternative depends on the utility of that alternative in relation to the total utility of all alternatives as per Luce's strict utility

theory. In other words, probability of selection is determined by estimating the utility of a particular alternative divided by the utility of all the different alternatives that are available to choose. In terms of land use and building use, it can be stated that, the probability of a land use type or building at a certain location depends on the utility of the location which could be measured from the total utility of all possible land use and building types at that location. Discrete choice model thus brings in a probability component which was not available in the location choice theory.

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Suitability or utility depends on many factors and varies as per the physical criteria. In case of agricultural land use, soil type could be physical criteria whereas, in case of a particular firm choosing to locate inside a city, accessibility or distance to different facilities can be the main criteria along with other spatial policies. Utility can be defined by the person/firm and depends on the criteria he/it feels are important. Thus, suitability/utility is synonymous to bid price since utility of the land/building is the amount of bid price he is going to offer for that particular land.

As shown in the equation;

$$P_{Ai} = e^{\beta * U_{Ai}} / \sum_{k}^{k} e^{\beta * U_{Ak}}$$

Where:

$P_{Ai}$ is the probability of plot A being allocated or transformed to land-use type i

e is the base of the natural logarithm

$U_{Ai}$ is the utility/suitability of plot A for land-use type i

$U_{Ak}$ is the suitability of plot A for land-use types (k)

β is a parameter to adjust the sensitivity of the model.

The probability of a particular plot A being allocated or transformed to land use type i is given by $P_{Ai}$, which can be estimated by calculating the utility of that particular plot A for land use type i($U_{Ai}$) and then taking its exponential and dividing it by the summation of exponential of utilities of that particular plot A for land use types *(k)*. Beta (β) is the parameter which is also multiplied with utility. This parameter is used to adjust the sensitivity of the model. The value of beta is changed till the results match the actual data. This is also called calibration of the model.

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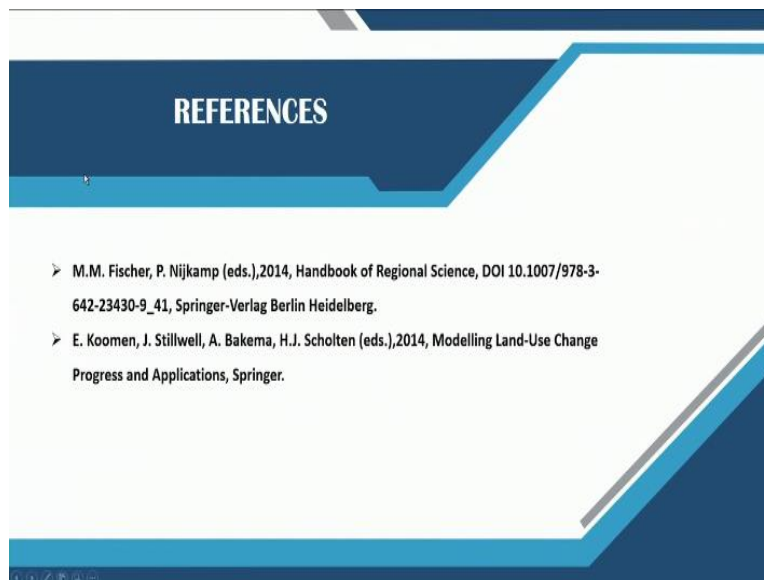


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Economic theories of land use and land price are the basis of many land use models.

The location theory states that the location choice of a firm or an individual is based on minimizing transportation costs.

Individual or firms select a location where the bid rent matches with rent or price demanded which again depends on a tradeoff between building land price and transport cost. This means, an individual or firm selects a location where it first evaluates the amount of transport cost or other costs that comes from locating in that particular area and then determines a price he/it is willing to pay for that land and when this matches with the price demanded then the land is actually sold.

Finally, discrete choice model is also used in determining probability of a land use at a certain location where different suitability criteria can be evaluated in form of a utility equation.

Thank you.