Urban Landuse and Transportation Planning
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Lecture - 23
Accessibility - 1

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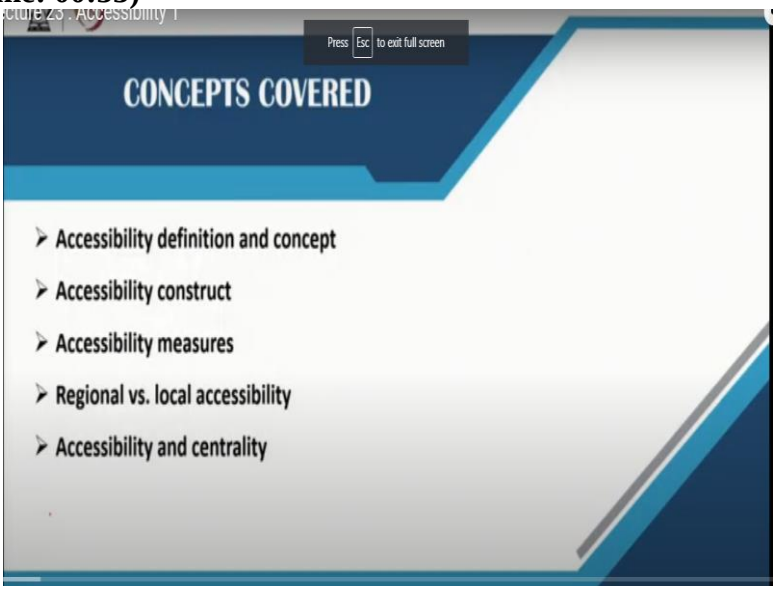

The different concepts covered in this lecture are accessibility definition and concept, accessibility construct, the different measures of accessibility, regional and local accessibility, and accessibility and centrality.

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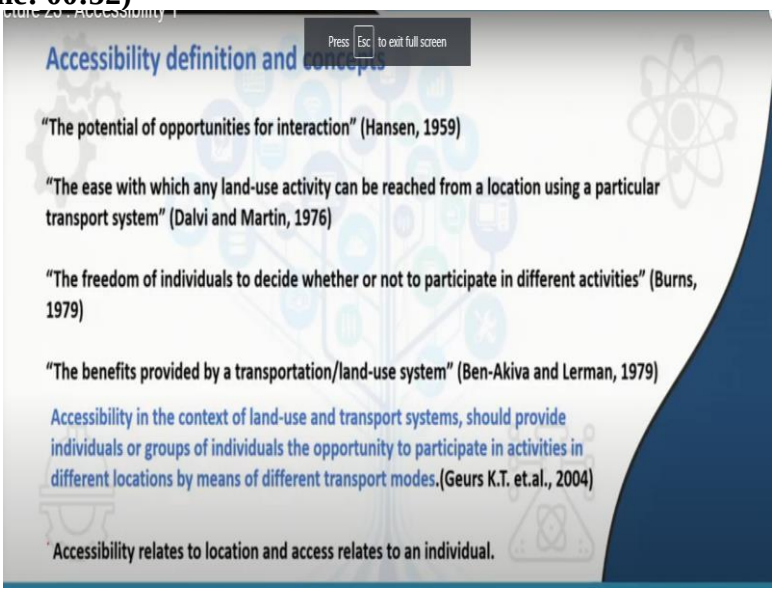

Accessibility definition and concepts

Accessibility has been defined in different ways by many scholars and authors. For example, Hansen has defined accessibility as the potential of opportunities for interaction i.e area

which offers a higher potential of opportunities for interaction has a higher accessibility. Dalvi and Martin has defined it as the ease with which any land use activity can be reached from a location using a particular transport system. It can also be defined as the freedom of individuals to decide whether or not to participate in different activities. Ben Akiva and Lerman explain accessibility as the benefits provided by the transportation/ land use system, i.e. the total benefit that a land use and transportation system provide for a particular area or a zone is the accessibility of that particular zone. So, accessibility in the context of land use and transportation systems should provide both individuals and groups of individuals, the opportunity to participate in activities in different locations through different transport modes. It is important to note that accessibility relates to location whereas access relates to the individual. So accessibility is for a zone, whereas access is for a particular individual.

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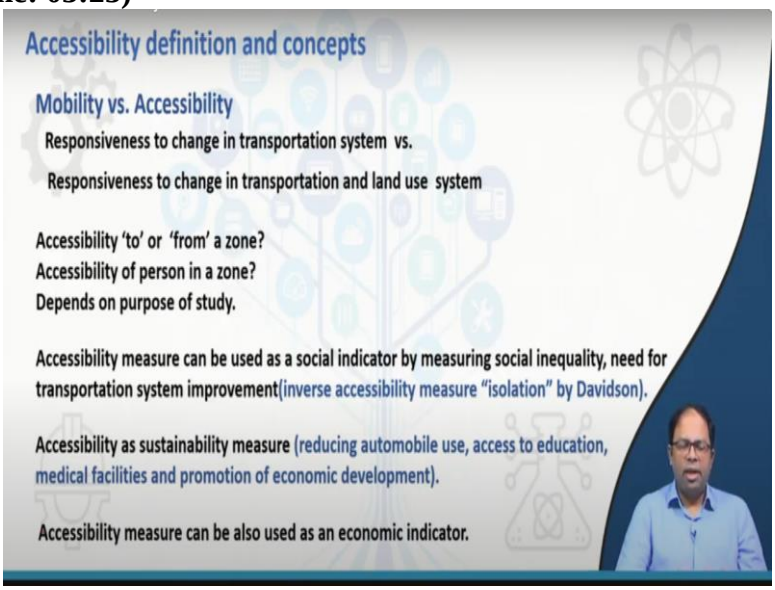

Similarly, there is a difference between mobility and accessibility. Mobility primarily refers to the transportation system or the responsiveness to change in transportation system whereas accessibility is the responsiveness to change in transportation and land use system. So accessibility relates to both transportation and land use, and mobility relates to transportation only.

While defining accessibility, it can mean accessibility to a zone or accessibility from a zone, or accessibility of a person in a zone or accessibility of that overall zone. So all these definitions would be as per the context of the study. Accessibility would be used for many other things, but primarily accessibility refers to the attractiveness and the ease of transportation systems or the availability of transportation systems for an area, or the attractiveness of that particular location in terms of how people can get access to either jobs

or to recreational facilities etc., how easily they can access those facilities. So together it creates a construct that helps in determining the importance of different urban areas, or it helps in explaining that why certain land uses are coming up in certain areas. So, a detailed understanding of accessibility is required to predict and understand the changes that happen in an urban area.

Accessibility could be used as a social indicator to measure social inequality. For example, certain areas have transportation systems, other areas may not have that much amount of transportation facilities. So there is a need for improving that particular transportation component. Researchers have also measured the inverse of accessibility and termed as isolation, which means how isolated a particular place is. Accessibility could also be used as a sustainability measure, for example reducing automobile use, access to education, medical facilities, and promotion of economic development. It can be also used as an economic indicator.

So these are different ways the accessibility could be used, but primarily it talks about the attractiveness of a particular area in terms of both access and access to opportunities and the means to access that those opportunities.

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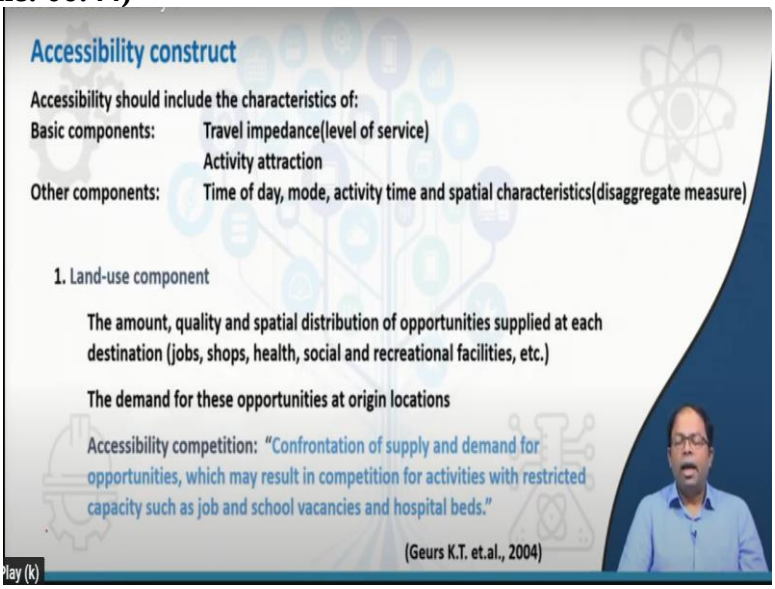

Accessibility Constructs

Accessibility construct should include certain characteristics which can be divided into two basic components. The first component is the travel impedance or level of service i.e between

any two points or between all the different opportunities that are present, what is the level of service to reach those opportunities, or what is the amount of impedance. Impedance could be costs, travel time, a combination of both, the quality of the available modes, kind of infrastructure present, or other levels of service values. The second basic component is activity attraction. So different kinds of activities and opportunities that are present surrounding a particular zone, which are available to access. These activities could be jobs, other features like schools, recreational areas, parks, and so on.

In addition to basic components, there are other components as well which could be included when considering accessibility. These are time of the day (at different times accessibility may vary), the activity time (what kind of activity, when, and for how long it is performed), and spatial characteristics of that particular area. All these components can be disaggregate measures that means, different zones can have different values, and similarly different individuals can also have different values.

Broadly, there are different parts to accessibility constructs. The first is the landuse component that includes the amount, quality, and spatial distribution of opportunities supplied at each destination. So, it not only includes the total number of jobs, recreational or healthcare facilities, etc. but also the quality of jobs or quality of recreational facilities or quality of health facilities respectively. So quality could be also brought in into this particular construct. The spatial distribution of opportunities means that how these opportunities are spread out in that particular area.

In addition to these, the demand for different types of opportunities at the origin location is also important, which means that it is not about how many activities are there in the surrounding area, but what kind of demand is there for these opportunities or activities in the origin area. For example, if a certain activity at a particular area has less demand that means it is not demanded so accessibility will be low whereas if the demand is high, then accessibility would also be higher.

Thus there is also accessibility competition that means if there is demand from different areas, for those opportunities which are in the surrounding area for a particular zone then automatically the accessibility reduces. For example, there are some good schools in the surrounding area and an individual is demanding this opportunity, but at the same time, other

individuals from other zones are also demanding the same thing. So definitely the chance of getting access to this opportunity will reduce for an individual, and this is termed as accessibility competition. So this is where the confrontation between supply and demand for opportunities takes place and this may result in competition for activities with restricted capacities, such as jobs, school vacancies, and hospital beds.

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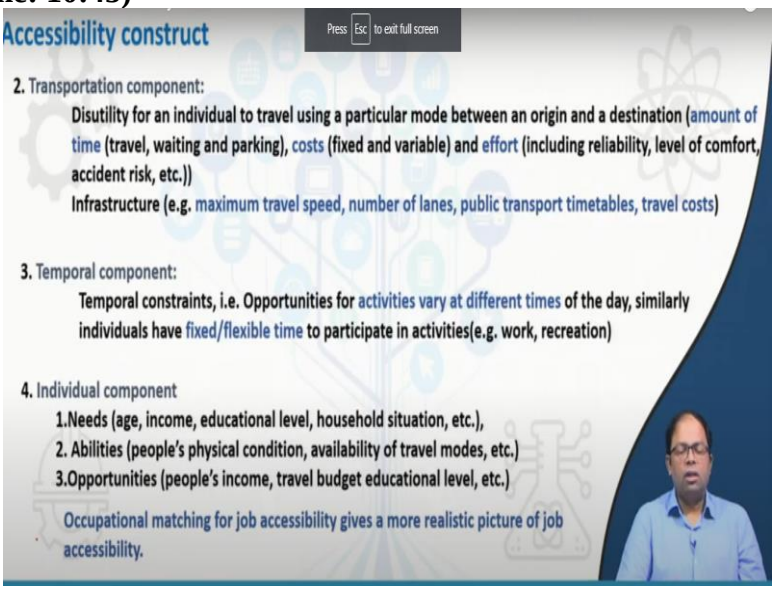

In addition to the land use part, another component is the transportation component which measures the disutility for an individual to travel, using a particular mode between an origin and destination. It measures disutility or negative utility because it is an impedance. Depending on the mode, the disutility value or the utility value will change since certain modes are better than others. Also, it has to be estimated between the origin zone and the destination zone i.e. from a particular zone to the zone where the activity is there or the opportunity is there. This utility or disutility value includes the amount of time(travel time, waiting time, parking time), cost (fixed costs, variable cost), and effort (reliability, level of comfort, accident risk along this journey). Within the transportation component, we can also have a measure for the infrastructure, for example, what kind of maximum travel speed is allowed in a particular corridor, level of service variables, the number of lanes in this particular area or a particular corridor, public transport timetables, and so on. So these are the different transportation components that play a role.

Another part is the temporal component. So, temporal constraints such as opportunities for activities vary at different times of the day, similarly, individuals have fixed or flexible times to participate in activities like work or recreation. It means that, for work activity, people

have to go for work at a particular time so it is a fixed activity, it has got a fixed time. Whereas for recreation, people may plan to vary the time period, and they may decide to go at different times based on the kind of opportunity they get in terms of travel modes and so on. So temporal components do play a role in when deciding on accessibility.

Finally, the last component is the individual component. At the individual level, needs, abilities, and opportunities vary. Individual needs may vary based on age, income, education level, housing situation, etc. These factors will play a different role in accessibility. For example, if an individual is studying in college, then he will only be looking at accessibility to colleges. If an individual is working in IT, so he will only be looking at IT job opportunities. So for each requirement, evaluation of accessibility also varies. The individual abilities refer to physical condition, or availability of travel modes etc. For example, an individual living in a particular area does not have a transit facility in that area, so he has to use a car or 2 wheeler or even a bicycle. Similarly, if a person is old, then he can only walk a certain distance, so he is restricted to certain activities. Opportunities can vary as per income, travel, budget, education level, and so on. For example, if a person does not have money, he can only travel to certain areas, or if he does not have money to purchase a car and a particular zone does not have transit facilities then he might avoid going to these areas. Therefore, the accessibility will be impacted by all these factors.

To present a more realistic picture of job accessibility, occupational matching for job accessibility should be considered that means if an individual is working in the service industry and there are no hotels in that area but other jobs are present, then the job accessibility is pretty low, because other jobs present in that area do not have any role in the person's accessibility criteria. So occupational matching is very important that has to be considered in accessibility measures.

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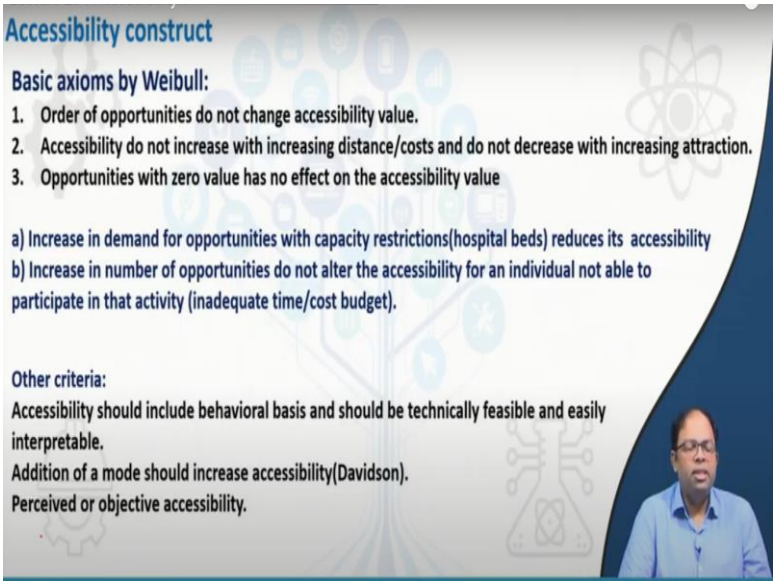

There are few basic axioms proposed by Weibull, some are primary axioms and some are derivations from the primary ones. The first axiom states that the order of opportunities does not change accessibility value. It means the order (which comes first or second) is not important, rather the total amount, quality, and the distance is important. The second axiom is that the accessibility does not increase with an increase in distance or cost, which means more the distance lower will be the accessibility. Also, it does not decrease with increasing attraction. So if attraction increases or opportunities increase then automatically accessibility will increase. The third axiom is opportunities with zero values do not affect the accessibility value. So, if a person has access to many zones, but these zones do not have jobs then it is not going to affect his accessibility.

In addition to the axioms, there are some other rules, like an increase in demand for opportunities with capacity restrictions, like hospital beds, reduces its accessibility. So, when demand increases for this kind of fixed capacity opportunity, then automatically the accessibility value decreases. Also, if there is an increase in the number of opportunities, it does not alter the accessibility for an individual who is not able to participate in that activity. These are the firm set of rules that needs to be followed.

There are some other criteria as well which need to be taken into consideration, such as accessibility should include a behavioral basis, it should be technically feasible, and easily interpretable. One can create a very complicated measure for accessibility, but it will be both difficult to measure and difficult to understand. Also, the addition of a travel mode should increase accessibility. If another mode is added in the existing transport system of a particular

zone or zones, it should reduce the travel impedance or rather increase the utility of travel. So it has to be considered in the accessibility measure otherwise, it will not have any impact on the transportation policies that might be undertaken. It is also important to understand that the actual values and perception values of accessibility are different, since people perceive different opportunities differently.

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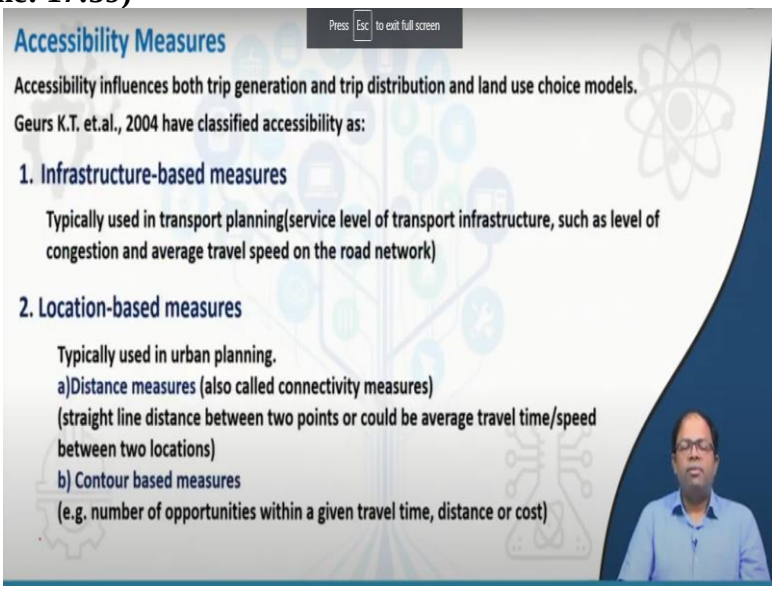

Accessibility Measures

Accessibility can be measured in different ways. Accessibility influences both trip generation and distribution, and land use choice models. It is important to understand that the different measures that are created for accessibility, or different formulas used for accessibility have got an influence on different stages of travel demand modeling i.e trip generation and trip distribution between the areas depends on accessibility. Also, accessibility will have an impact on the land use choice models. For example, people will choose areas with lower or higher accessibility to choose or buy a house, and so on.

Thus accessibility measures could be classified in different ways. The first way to measure it is infrastructure-based measures. These are primarily used in transportation planning and considers the service level of transport infrastructure such as level of congestion, average travel speed on a road network. These are measured or used to determine what sort of transport accessibility that particular area has got.

The second measure is location-based measures, these are of different types. The first type is distance measures or connectivity measures. For distance measure, the straight line distance

between 2 points i.e. the existing point and the point of opportunity where a person is supposed to go, is measured. It could also be the average travel time or speed between 2 locations.

The next type of distance measure is contour based measure. In contour based measure, the number of opportunities within a given travel time, or a distance, or a cost is measured. For example, the number of jobs available within 30 minutes of travel time. So it gives an understanding of how accessible jobs are from a particular location or how good the accessibility of a particular area considering available jobs.

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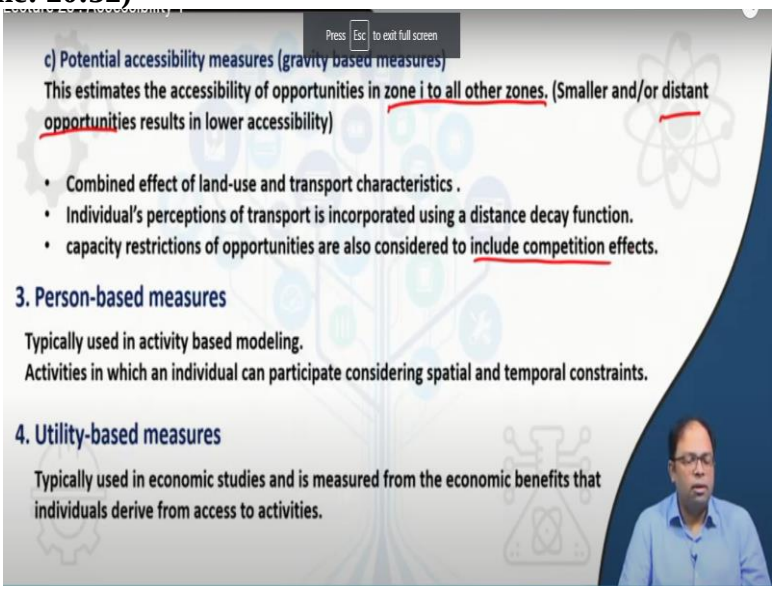

The final type of distance measures is the potential accessibility measures, or gravity based measures. In potential accessibility measures, both the opportunity as well as the transportation component are considered. This measure estimates the accessibility of opportunities in zone i to all other zones. It means that the accessibility to opportunities of a particular zone is measured based on all the other zones that are present in that particular area. Also, a smaller number of opportunities will result in lower accessibility. Similarly, distant opportunities also results in lower accessibility, because of increased impedance or travel time/cost.

Potential accessibility measures include the combined effect of land use and transport. Also, the individual's perception of transport is incorporated. For example, an individual may perceive the distance of 10 kilometers and 12 kilometers to be the same for a bigger shopping mall, whereas, a person may perceive the distance of 1 kilometer and 2 kilometers to be

different for local shops. Generally, the individual perception of transport is measured using a distance decay function. If the distance decay function is linear, then the more the distance, the more will be the impedance. But it may also follow an exponential form, or a power form, or some other mathematical relationship. To include competition effects, capacity restrictions of opportunities are also considered. So, it is not only the number of opportunities that are present, but also the demand for opportunities by individuals in other zones. These are all part of the potential accessibility measures.

In addition to distance measure, the other measure is person based measures, which are typically used in activity based modeling. In activity based modeling, individuals decide on the activities for the entire day, or the activities in which an individual can participate considering his spatial and temporal constraints.

The last accessibility measure is utility base measures. These are typically used in economic studies and measured from the economic benefit that individuals derive from access to activities. If access to activities is more/higher, more is the utility, and therefore higher is the accessibility.

These are the different types of accessibility measures that are usually considered in land use and transportation studies.

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In 2000, Bhat et al. has defined accessibility categories differently. He has used the term spatial separation, cumulative opportunity, gravity based measure, log sum or utility measure, and time-space models.

The spatial separation measure is similar to the distance based measure that has been discussed already. The cumulative opportunity measure is similar to the contour based measure. Gravity based measure is the same as potential based measure. The time-space model is similar to the person based measures. So, these are the different ways of categorizing accessibility.

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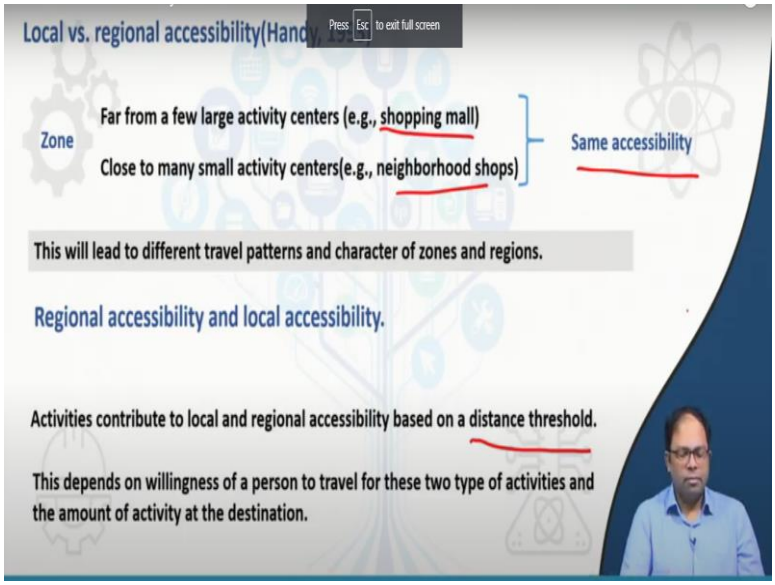

Local vs. Regional accessibility

Some researchers have looked into accessibility at different scales. One is local accessibility and another is regional accessibility. Handy has discussed both local and regional accessibility by saying that, while the accessibility may be the same for a particular zone considering both local and regional accessibility, but it has got different impacts on the land use transportation system. For example, a particular zone could be very far from a large activity center (or shopping mall), so the impedance to reach this center is high, but the attraction of this opportunity is also high, whereas the same zone could be near to small activity centers (or local shops), but the attraction of these opportunities is also less. So, mathematically the accessibility score may result in the same value for a particular zone, but actually, these have got two different dimensions altogether. It is because, both the opportunities will lead to different travel patterns and characters of zones and regions.

Activities contribute to local and regional accessibility based on a distance threshold. The distance threshold is a way to perceive the difference between local activities and regional activities. So, for evaluating different shopping malls in an area, the impedance function will be different. Whereas, the impedance function will be different for the evaluation of local shops. In this way, one will perceive the local accessibility and regional accessibility differently. Also, this accessibility depends on the willingness of a person to travel for these 2 types of activities (local or regional) and the amount of activity at the destination.

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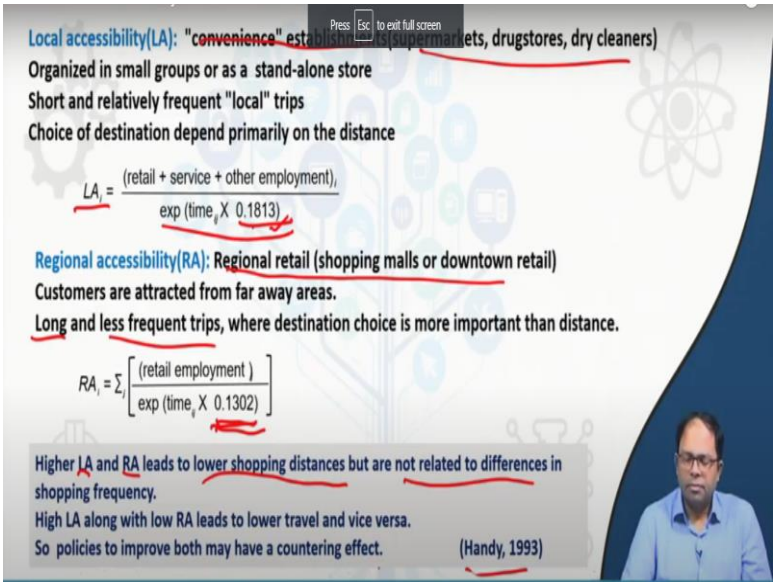

Local accessibility is determined by activities that are nearby. For example, convenience establishment (like supermarkets, drug stores, dry cleaners) which are present in any neighborhood. These are small shops that are organized in small groups or as standalone stores. The trips to these shops are relatively short and frequent, and the choice of destination depends primarily on the distance. So, an individual will choose the drug store which is near to his/her house. The reason is all the drug stores present within the zone, offer a similar kind of opportunities since all are similar types of stores.

One way of calculating the local accessibility of a particular zone is given by Handy 1993 i.e.

$$LA_i = \frac{(retail + service + other\ employment)i}{exp(time_{ij} * 0.1813)}$$

Where *i* is origin zone

Here, the local accessibility of zone i is based on retail, service and, other employment. So jobs are the criteria that have been used to understand the quantum of these particular features or the quantum of these particular opportunities. The impedance function is e^($time_{ij}$ * 0.1813), here $time_{ij}$ is time between zone i and these particular opportunities j, and a factor of 0.1813 is used in this function. This factor is particular to local accessibility.

Regional accessibility is determined by activities that are at a greater distance and have specialized goods. For example, regional retail, shopping malls, and so on. The customers are attracted to these opportunities from far away. The distances are long, and the trips are less frequent. So, people are willing to travel more distance. Handy (1993) has also introduced a formula to calculate the regional accessibility which is;

$$RA_i = \sum_j \frac{(retail\ employment\ j)}{exp(time_{ij} * 0.1302)}$$

Where *i* is the origin zone and *j* is the destination regional center.

Since the effect of distance is low, the factor used to calculate regional accessibility is lesser as compared to the local accessibility factor.

It is important to mention that, in trip distribution model, or location choice models, many authors have introduced larger values (or factor value). For example, if the distance is 10 km, it is fine. But as soon as the distance becomes 100 km, then a larger value is introduced to lessen the impact. So, if a person is going to a shopping mall, he is willing to travel more because he travels once in a week or once in a month, that is why the factor lessens the impact of this impedance.

Handy (1993) found out that, if local accessibility and regional accessibility are both high, this leads to lower shopping distances, but are not related to differences in shopping frequency. Also, high local accessibility, along with low regional accessibility leads to lower travel and vice versa.

In urban areas, certain policies are determined for future development considering some goals and objectives. For example, if the goal is to reduce the total travel distance or total vehicle kilometers, then one can focus on developing a mixed land use in the local neighborhood so

that all the different needs for shopping can be catered within the neighborhood. So, people will travel less, and they will go to a regional shopping center occasionally. In addition to higher number of local shops in the neighborhood, there would be a consideration for lowering the number of shopping malls. If both are high in number, then the total retail requirement for this particular city is met by both shopping malls and local stores, which will not give good results. Therefore, high local accessibility and low regional accessibility lead to a lower amount of travel and vice versa. So policies to improve both may have a countering effect.

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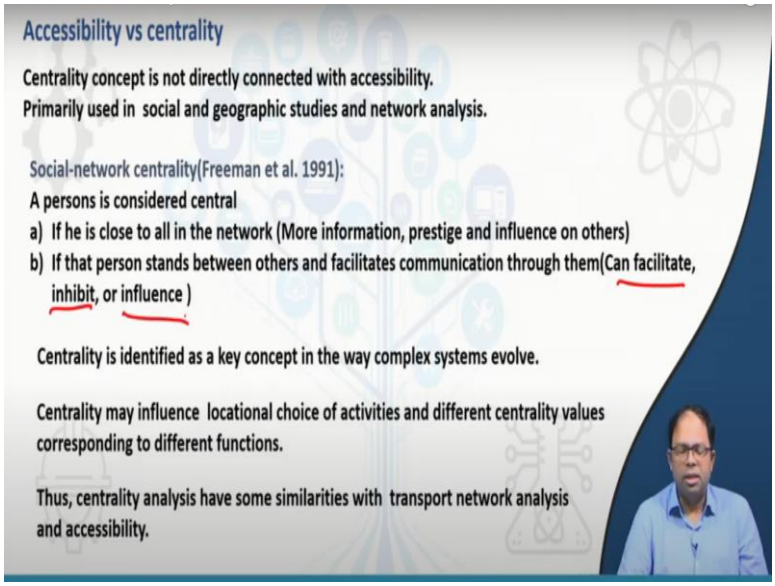

Accessibility and Centrality

In addition to the concept of local and regional accessibility, there is another concept which is called centrality. Even though it is not directly connected with accessibility, but it is linked with accessibility to some extent. It is primarily used in social and geographic studies, and network analysis. In social network centrality, a person is considered to be central if he is close to all in the network that means if he is connected to more persons in his particular social network then he is more central or he is more accessible. Therefore, he will have more information, more prestige, and influence on others. Also, if that person stands between others and facilitates communications through them then that is also good. Since he can facilitate inhibit or influence more as compared to others. It is the reason why social network influencers have gained popularity.

Centrality has also been identified with evolution of complex systems. It may influence locational choices of activities and also different centrality values corresponding to different

functions. For example, in some areas having more centrality, certain functions appear, whereas certain activities take place in certain areas which are more central. Also, centrality analysis has some similarities with transport network analysis and accessibility to some extent.

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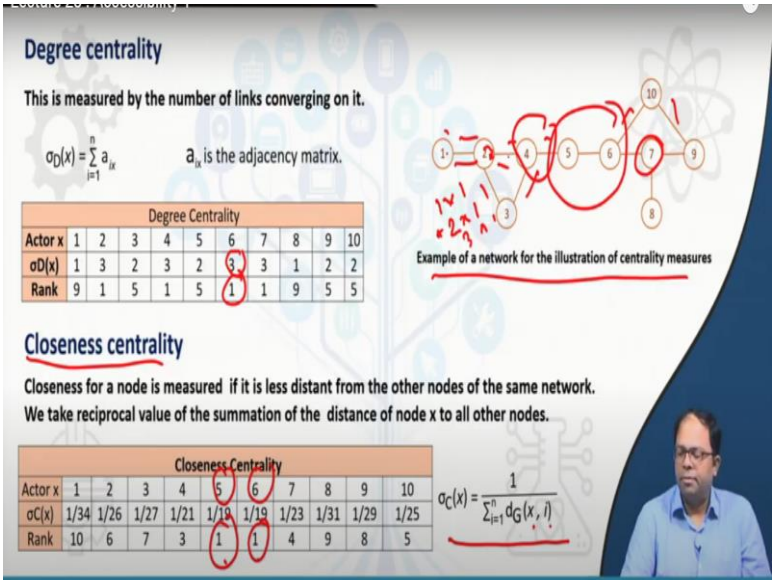

There are different measures of centrality. The most basic measure is called degree centrality, where the total number of links converging to a particular zone or rather node (since network is considered) is measured. In this particular example of a network, there are ten nodes, 1, 2, 4, 3, 5, 6, and so on. There are links between each node. So node 1 is connected with node 2, similarly, node 2 is connected with 3 links, node 10 is connected with 2 links, and so on. Accordingly, the number of links for each node has been mentioned in the given table (degree of centrality). The highest number of links a node has got is 3 and the lowest number of links is 1. Based on the number of links, ranks have been given to each node. So nodes 1, 2, 3, 4 having a rank of 1 and then 9, 10, 5, and 3 have got a rank of 5 because the first 4 places are taken up and so on.

The next measure is the closeness centrality where closeness for a node is measured if it is less distant from the other nodes of the same network, i.e. how close a person is to all other nodes in the network. It is measured by taking a reciprocal value of the summation of the distance of nodes x to all other nodes. For example, if a person is at node x, the distance to all of the nodes is being measured. The formula is given as follows:

$$\sigma C(x) = \frac{1}{\sum_{i=1}^{n} dG(x,i)}$$

Where, d_G is the distance from 'x' to 'i' i.e. the distance from 'x' to all other nodes (1 to n).

The inverse to this value is the closeness centrality. The higher the value of closeness centrality, more closer is the person to everybody.

For the given network, the closeness centrality for node 1 can be calculated as follows,

Node number	Distance from node 1
2	1
3,4	2
5	3
6	4
7,10	5
8,9	6

= 1/ (1 * 1 + 2*2 + 1*3+ 1*4+2*5+2*6) = 1/34

Similarly, the closeness centrality for all other nodes can be measured. The value for nodes 5 and 6 is the highest, therefore node 5 and node 6 are closest to all other nodes. It is true because they are most centrally located compared to the other nodes. So node 5 and node 6 has got a rank 1. The next highest value is for node 4, therefore it has got rank 3, since two places have already been taken. Similarly, the ranks have been given to other nodes. This is how closeness centrality is measured.

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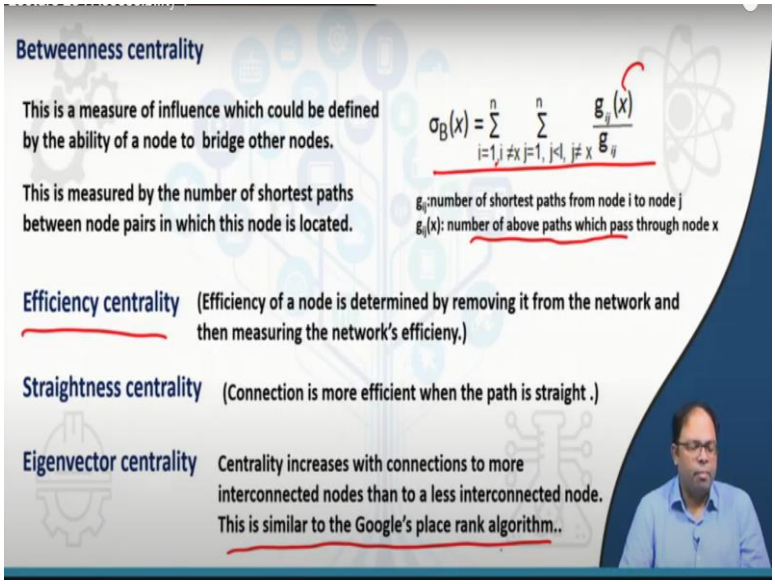

Betweeness centrality is another measure. It is a measure of influence, which could be defined by the ability of a node to bridge other nodes. It is measured by the number of shortest paths between node pairs in which this node is located. There is the shortest path from every node to every node. Considering the given network, from node 1 to node 2 there is a shortest path which is 1-2, for node 1 to node 3 there is a shortest path which is from 1-2-3. So, node 2 has got 1 shortest path going through it. If node 4 is considered, probably the shortest path between nodes 1 to 5, nodes 1 to 6, node 1 to 10 all of them go through node 4. But node 1 to node 3 this shortest path does not go through node 4. So in this way, it can be measured that how many of the shortest path goes through node 4.

More number of shortest paths between any pair goes through a particular node that node is of higher importance because it can track the total number of connections between different zones or it may be able to influence those connections or inhibit those connections.

So, betweeness centrality is given by this particular formula;

$$\sigma_B(x) = \sum_{i=1, i\neq x}^{n} \quad \sum_{j=1\ j<1, j\neq x}^{n} \frac{g_{ij}(x)}{g_{ij}}$$

where g ij is the total number of shortest paths from node i to node j and g_{ij} (x) for this particular node x is the number of the above shortest path which passed through node x. So in this way, betweenness centrality can be estimated for each node pair.

In efficiency centrality, the efficiency of a node is determined by removing it from the network and then measuring the network efficiency. So, the efficiency criteria are determined first, and then each node is removed to see how the criteria varies. The node where it changes most is of the highest centrality.

Another measure of centrality is straightness centrality. So, in this measure, it is considered that the connection is more efficient when the path is straight.

In eigenvector centrality, the centrality increases with connections to more interconnected nodes than to a less interconnected node. So that means the more one node is connected to other interconnected nodes that is better. So that means it is not only measuring how many

nodes it is connected to. It is also measuring how many nodes those nodes are connected to. This is more or less similar to the Google place rank algorithm.

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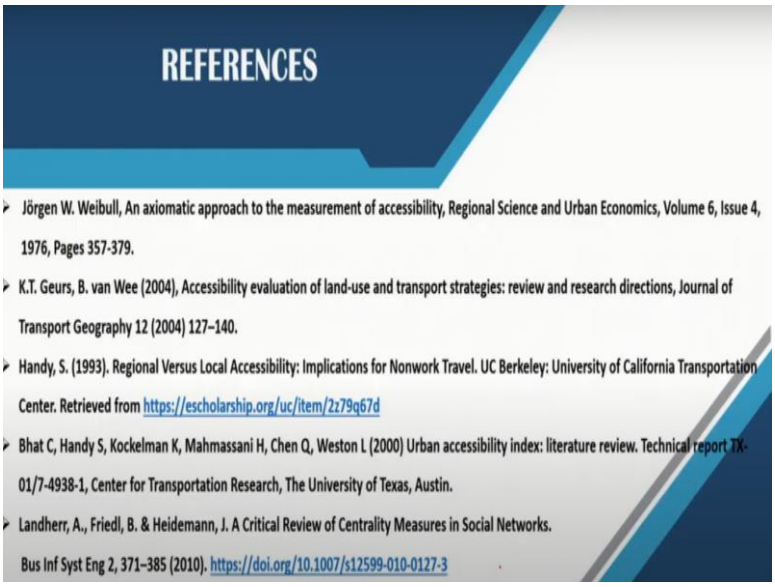

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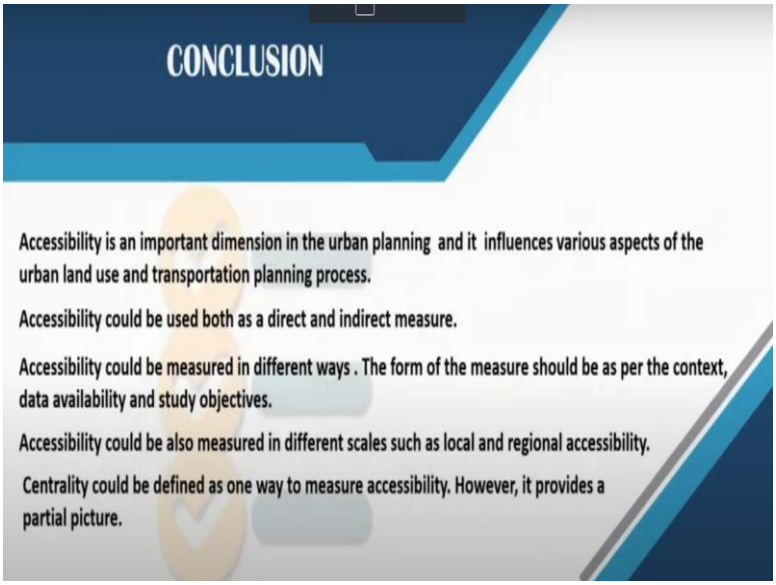

Some of the references are listed in the above slide.

Conclusion

Accessibility is an important dimension in urban planning and it influences various aspects of the urban land use and transportation planning process. In most of the models or most of the travel demand estimates, accessibility comes into play.

Accessibility could be used both as a direct and indirect measure. Since it can be used by other models to predict other things, or accessibility itself can predict certain things. Also, it

could be measured in different ways. So, the form of the measure should be as per the context, data availability, and study objectives. It can also be measured at different scales such as local and regional accessibility. Also, one of the ways to measure accessibility is centrality; however, it provides a partial picture of accessibility.