Urban Landuse and Transportation Planning
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Lecture - 45
Dynamic Traffic Assignment

Welcome back in lecture 45. This is the final lecture in the traffic assignment module. In this lecture, dynamic traffic assignment will be discussed.

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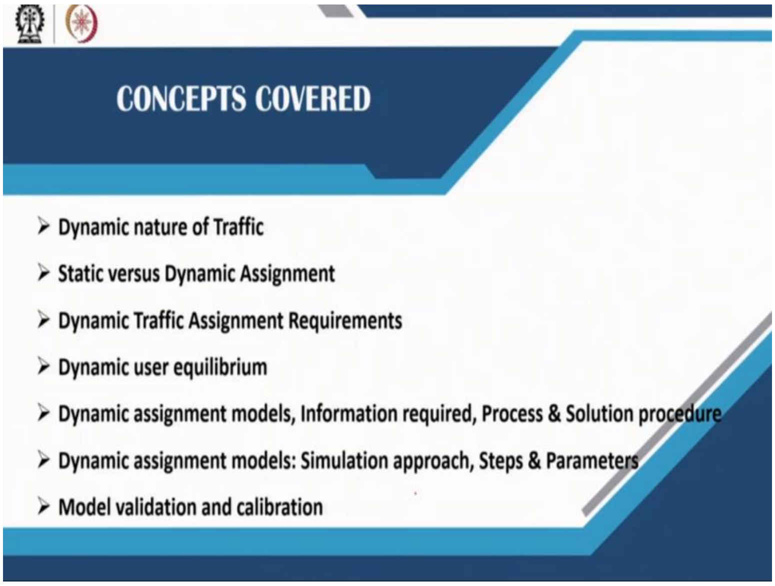

CONCEPTS COVERED

- Dynamic nature of Traffic
- Static versus Dynamic Assignment
- Dynamic Traffic Assignment Requirements
- Dynamic user equilibrium
- Dynamic assignment models, Information required, Process & Solution procedure
- Dynamic assignment models: Simulation approach, Steps & Parameters
- Model validation and calibration

This lecture will look at the dynamic nature of traffic and the differences between static and dynamic assignment. The conditions which must be satisfied to develop a dynamic traffic assignment model will also be covered. The concept of dynamic user equilibrium will be explained. Moreover, different models, the process and solution procedure to conduct dynamic traffic assignment will also be discussed. Finally, we will look into the process and the parameters involved to conduct dynamic assignment using a simulation approach. Model validation and calibration process regarding the same will also be highlighted in this lecture.

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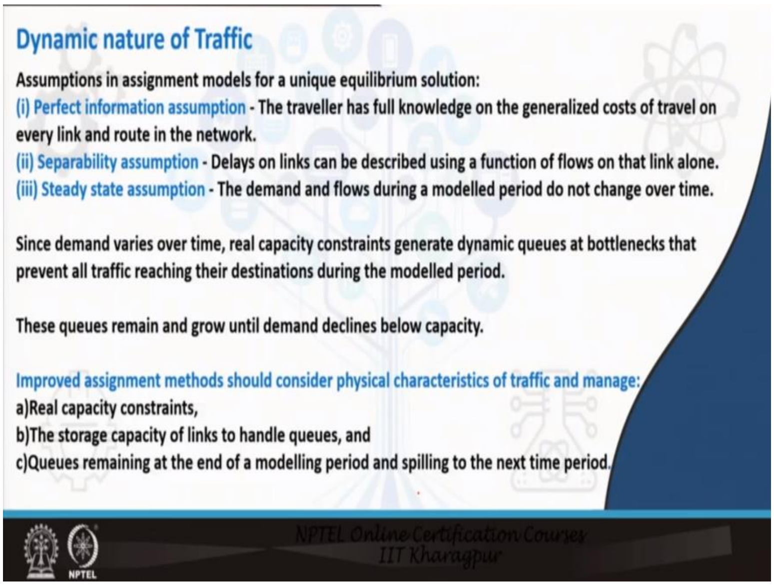

Dynamic nature of Traffic

Assumptions in assignment models for a unique equilibrium solution:

(i) Perfect information assumption - The traveller has full knowledge on the generalized costs of travel on every link and route in the network.

(ii) Separability assumption - Delays on links can be described using a function of flows on that link alone.

(iii) Steady state assumption - The demand and flows during a modelled period do not change over time.

Since demand varies over time, real capacity constraints generate dynamic queues at bottlenecks that prevent all traffic reaching their destinations during the modelled period.

These queues remain and grow until demand declines below capacity.

Improved assignment methods should consider physical characteristics of traffic and manage:

a)Real capacity constraints,

b)The storage capacity of links to handle queues, and

c)Queues remaining at the end of a modelling period and spilling to the next time period.

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Dynamic Nature of Traffic

The traffic on a real network is dynamic. But when the assignment models for unique equilibrium solutions are developed, certain assumptions are made. For example, the traveler has full knowledge of the generalized cost of travel on every link and route in the network. Such assumption can also be termed as a perfect information assumption. The delays on the links can depend on several factors like increase in traffic flow, occurrence of incidents, road maintenance etc. The delay on one link can affect other connected links as well. These factors and its effects are not considered for a separability assumption. This assumption considers that the delay on one link is a function of flows on that link alone. Finally, an assumption related to a steady state is also considered for equilibrium solution. This assumption states that the demand and flows do not change over time during the model period. But the demand varies over time. Therefore, the real capacity constraints lead to formation of dynamic queues at the bottlenecks like the intersections. Such queues prevent the entire traffic from reaching their destinations during the modeled period. As the demand increases, the queue also increases. As the demand declines below capacity, the queue is gradually cleared out. The queue formation and the dynamic nature of traffic does not align with the assumptions made for the static equilibrium. So, new improved assignment methods should consider certain physical characteristics of traffic like the real capacity constraints of a corridor (path or even a link), the capacity of links to handle queues, impact of queues at the bottlenecks, queues remaining at the end of the modeling period, queues spilling over to the next time period. While real nature of the network and traffic is usually not considered for static assignment problems, the same are considered when developing a dynamic traffic assignment model.

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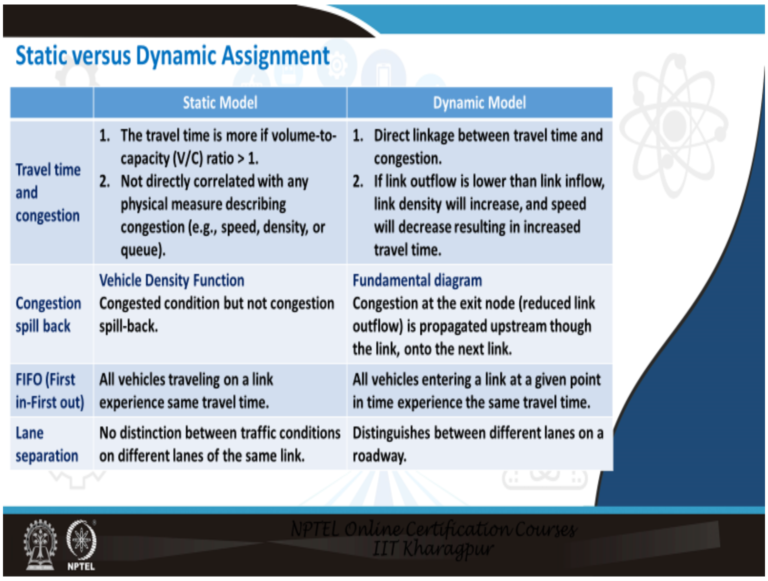

Static versus Dynamic Assignment

	Static Model	Dynamic Model
Travel time and congestion	1. The travel time is more if volume-to-capacity (V/C) ratio > 1. 2. Not directly correlated with any physical measure describing congestion (e.g., speed, density, or queue).	1. Direct linkage between travel time and congestion. 2. If link outflow is lower than link inflow, link density will increase, and speed will decrease resulting in increased travel time.
Congestion spill back	Vehicle Density Function Congested condition but not congestion spill-back.	Fundamental diagram Congestion at the exit node (reduced link outflow) is propagated upstream though the link, onto the next link.
FIFO (First in-First out)	All vehicles traveling on a link experience same travel time.	All vehicles entering a link at a given point in time experience the same travel time.
Lane separation	No distinction between traffic conditions on different lanes of the same link.	Distinguishes between different lanes on a roadway.

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<u>Static versus Dynamic Assignment</u>

Based on the above discussion, we can understand that the dynamic model differs from the static model in assumptions. Let us study the differences in detail between both the models. While travel time is linked to volume by capacity ratio for static models, travel time is directly linked to congestion for dynamic models. Physical measures describing congestion like speed, density or queue are not considered for static models. In a dynamic model, the congestion effects are expressed in terms of inflow, outflow, density and speed. If a link outflow is lower than the link inflow, then link density will increase, and speed will decrease resulting in increased travel time. In the static model, congested condition is taken into consideration through vehicle density function, but the congestion spill back is not taken care of. On the other hand, in the dynamic model, the congestion at the exit node (where there is a reduced link outflow) is propagated upstream through the link on to the next link. The first in first out (FIFO) rule holds true for both dynamic and static models. The difference is that all vehicles travelling on a link experiences the same travel time in the static model. Whereas, in the dynamic model, we assume that all vehicles entering a link at a given point of time experienced the same travel time. Therefore, the basis of dynamic equilibrium is the vehicles entering into a link within a time window is assumed to have equal travel time. In addition to the above differences, no distinction between traffic conditions on different lanes of the same link is considered for a static model. Different lanes have different characteristics based on speed and capacity. This distinction between different lanes are considered in dynamic models. So, a high occupancy vehicle lane like transit lanes will be modeled separately compared to an unrestricted lane for dynamic models.

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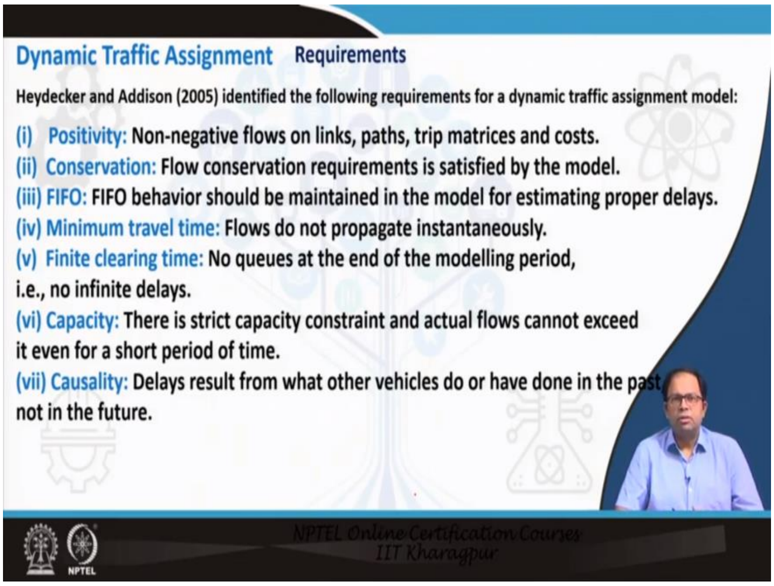

Dynamic Traffic Assignment **Requirements**

Heydecker and Addison (2005) identified the following requirements for a dynamic traffic assignment model:

(i) **Positivity:** Non-negative flows on links, paths, trip matrices and costs.
(ii) **Conservation:** Flow conservation requirements is satisfied by the model.
(iii) **FIFO:** FIFO behavior should be maintained in the model for estimating proper delays.
(iv) **Minimum travel time:** Flows do not propagate instantaneously.
(v) **Finite clearing time:** No queues at the end of the modelling period, i.e., no infinite delays.
(vi) **Capacity:** There is strict capacity constraint and actual flows cannot exceed it even for a short period of time.
(vii) **Causality:** Delays result from what other vehicles do or have done in the past, not in the future.

Heydecker and Addison identified certain requirements for developing a dynamic traffic assignment model. A dynamic assignment model must satisfy the conditions of positivity. It implies that there are non-negative flows on the links, paths, trip-matrices and cost. The models must satisfy the flow conservation requirement. Besides, the FIFO behavior, as discussed earlier, must be maintained for estimating the delays. A travel time is associated with the link flow and the flows do not propagate instantaneously. The models must satisfy the condition that there is a minimum travel time associated with the propagation of the flow. The models must also ensure a finite clearing time for the queues at the end of the modeling period. It implies that there should be no queues once the model terminates and indefinite delays are not encouraged for dynamic models. The dynamic models follow a strict capacity constraint and actual flows cannot exceed even for a short period of time. Finally, causality condition must also be met by the dynamic models. This condition defines delay as a causal effect of the actions taken by other vehicles at the past or current time period. Actions of these vehicles in the future do not matter for estimating the delay. In static equilibrium, the delays on a link is estimated based on the vehicle density function. This function considers the flow during the current time period and the flow determined in the previous time window is not taken into consideration. But in dynamic equilibrium, the link flows in both past and present time windows are considered to estimate the delay. Therefore, link flow estimated for the current time period will affect the decisions in the subsequent stages. For example, a queue formed during a specific time windows might not be cleared in the same time-window.

Therefore, the flow on that link must be estimated after considering the queue in the previous stages.

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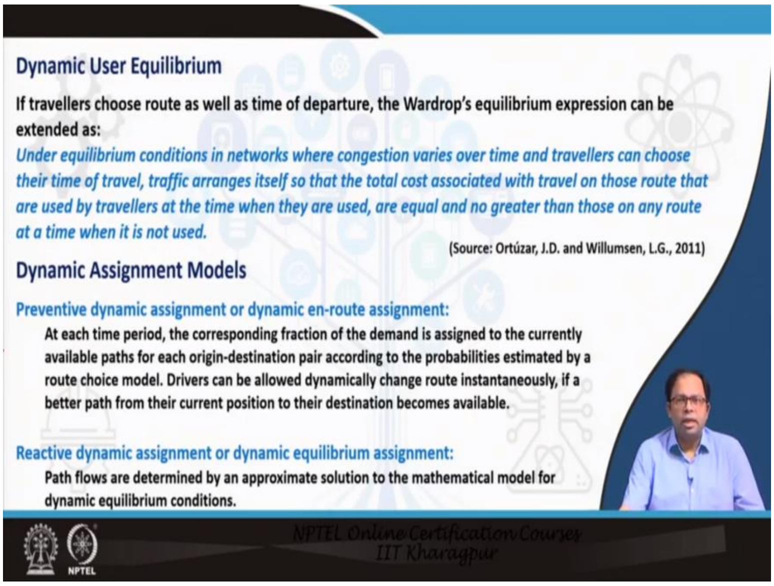

Dynamic User Equilibrium

If travellers choose route as well as time of departure, the Wardrop's equilibrium expression can be extended as:

Under equilibrium conditions in networks where congestion varies over time and travellers can choose their time of travel, traffic arranges itself so that the total cost associated with travel on those route that are used by travellers at the time when they are used, are equal and no greater than those on any route at a time when it is not used.

(Source: Ortúzar, J.D. and Willumsen, L.G., 2011)

Dynamic Assignment Models

Preventive dynamic assignment or dynamic en-route assignment:

At each time period, the corresponding fraction of the demand is assigned to the currently available paths for each origin-destination pair according to the probabilities estimated by a route choice model. Drivers can be allowed dynamically change route instantaneously, if a better path from their current position to their destination becomes available.

Reactive dynamic assignment or dynamic equilibrium assignment:

Path flows are determined by an approximate solution to the mathematical model for dynamic equilibrium conditions.

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Dynamic User Equilibrium

In dynamic equilibrium, the expression of Wardrop's equilibrium can be modified if travelers choose route as well as time of departure. The Wardrop's equilibrium can be extended as:

Under equilibrium conditions in networks where congestion varies over time and travelers can choose their time of travel, traffic arranges itself so that the total cost associated with travel on those route that are used by travelers at the time when they are used, are equal and no greater than those on any route at a time when it is not used.

Therefore, the same equilibrium concept is extended with the aspect of time. Whenever a traveler chooses a route, the traffic on that link will arrange itself based on the conditions prevailing in that time window leading to an equilibrium condition. The dynamic assignment models are of two types, a preventive dynamic assignment or dynamic en-route assignment and reactive dynamic assignment or dynamic equilibrium assignment. Preventive dynamic assignment, also known as dynamic en-route assignment can be defined as the assignment where the equilibrium is obtained during the assignment process whereas, in reactive dynamic assignment or dynamic equilibrium assignment, the equilibrium is obtained after the termination of the assignment process. In preventive dynamic assignment, the corresponding fraction of the demand is assigned to the currently available paths for each origin-destination pair according to the probabilities estimated by the route choice model during each time period. The drivers can then be allowed to dynamically change route instantaneously, if a better path from their current position to the destination becomes available. Initially, an individual i.e. a driver is assigned to a route based on the probabilities estimated for each route through the route choice model. If a new path becomes available during the assignment process, which is better than the previous path, then drivers can dynamically shift to that route as well. On the other hand, in reactive dynamic assignment or dynamic equilibrium assignment path flows are determined by an approximate solution to the mathematical model for dynamic equilibrium conditions. Here, we have not discussed the mathematical model, but it is similar to the Wardrop’s model. The model assumes that the travel time in a route chosen by the travelers will be equal to the speed in that route whereas, in the other routes the travel time will be higher, and speed will be lower for that time period. The dynamic equilibrium problem can also be solved in a similar manner as done for a static equilibrium but, the dynamic equilibrium will be considered for multiple time segments. So, the dynamic assignment can be conducted using either of the two approaches. But the first approach is commonly used, because it follows the simulation approach and drivers are also able to adjust the routes dynamically during the process. In the dynamic assignment, a probabilistic solution is preferred to a deterministic solution.

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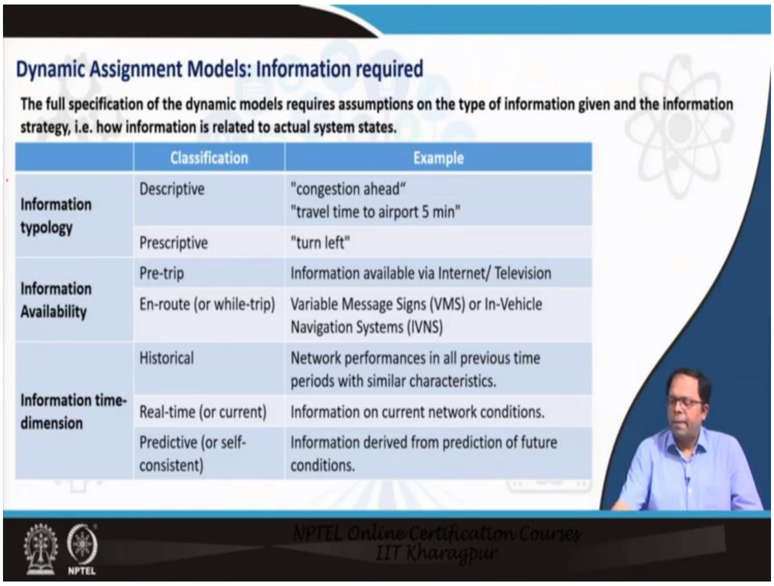

Dynamic Assignment Models: Information required

The full specification of the dynamic models requires assumptions on the type of information given and the information strategy, i.e. how information is related to actual system states.

	Classification	Example
Information typology	Descriptive	"congestion ahead" "travel time to airport 5 min"
	Prescriptive	"turn left"
Information Availability	Pre-trip	Information available via Internet/ Television
	En-route (or while-trip)	Variable Message Signs (VMS) or In-Vehicle Navigation Systems (IVNS)
Information time-dimension	Historical	Network performances in all previous time periods with similar characteristics.
	Real-time (or current)	Information on current network conditions.
	Predictive (or self-consistent)	Information derived from prediction of future conditions.

Information required in Dynamic Assignment Models

To run a dynamic assignment model, different types of information are required. The information conveyed to the driver can change his decisions related to the trip, mode and route. For example, if he gets the information of a better path, then he can choose that path to reach his destination conveniently. The information can be provided in three categories, type of information, availability of information and time-dimensions of information. The type of information can be descriptive or prescriptive. Descriptive information refers to the information based on description related to time or incidents. Congestion ahead or travel time to airport is 5 minutes are examples of descriptive information. Prescriptive information refers to information which are prescribed to the individuals (or the information which provided instructions). For example, a virtual navigation assistant can provide directions to a destination to turn left or right. Availability of information can also enable the individuals to make better decisions related to their trips. The information can be available either before conducting a trip (pre-trip) or while traveling to a destination (en-route). Pre-trip information are usually available via internet or electronic media. For example, an announcement is made over television regarding an incident along a corridor. En-route information can be conveyed in different ways. It can be provided by a VMS board or an in-vehicle navigation system. For example, the in-vehicle navigation system continuously updates the route as per the real-time conditions of certain links. Therefore, the navigation system is providing the information after the driver has already determined the route. The driver can travel on a cheaper route based on this information. Information is also available for three different time dimensions; historical, real-time and predictive. The historical data can be estimated based on the network performance in all previous time periods with similar characteristics. For example, if Google traffic or navigation is utilized to know the travel time between two zones, then it will provide the travel time based on the estimates conducted on the previous travel times along a route between those two zones. Therefore, a predictive algorithm is used to predict a probable travel time. Based on this information, the individual can take a decision. The real time data or current information like en-route information is the information based on current network conditions. Even if an individual has initiated the trip along a route, the conditions prevailing on that route between the origin and destination can change. Although a prediction is obtained from Google traffic, a different prediction might be obtained along the journey. The predictive or self-consistent information is the information derived from prediction of future conditions. Here, future possibilities across the network are predicted since everything cannot be known with certainty. Some conjectures can be deduced based on these predictions. For instance, there is a roadblock, and based on the prediction, the possible condition of the links can be presumed. Therefore, a decision related to diversion can be taken based on the information related to possibilities. So, these are the some of the different information required to understand the various states of the entire system, i.e. the traffic system or the network system. The dynamic models can work efficiently if the above information about the network can be provided.

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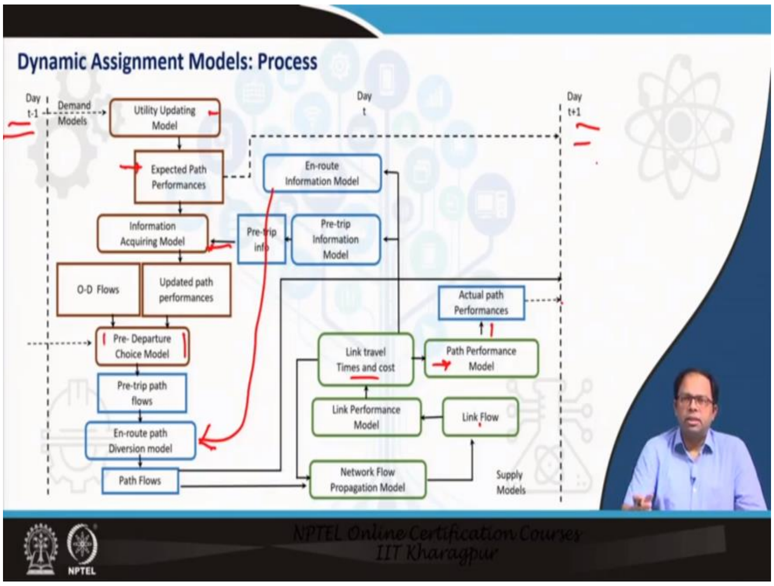

Dynamic Assignment Models: Process

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Process of Dynamic Assignment

In the image given above, the dynamic assignment model is explained for *t* th day. The data that is obtained from the previous day, i.e. *t-1* day is taken as an input to the model developed for *t* th day and the information obtained from the current day is used as the initial information for the next day, i.e. *t+1*. Therefore, based on the demand models, the OD matrix can be predicted for the current day. The trip volumes on the links can be decided based on the costs of different links in the network. These costs will determine the utility of each path between different OD pairs. The expected path performances during that time period can be determined based on their utilities. Therefore, these performances can be explained based on information obtained from the previous day, i.e. *t-1*. The information related to the performance of each path can be stored using an information acquiring model. The information on the O-D flows and updated path performances are used to build a pre-departure choice model to decide on the available attractive routes. The path flows before the initiation of trip can be determined based on the pre-trip departure choice model. This model will provide information before the journey. Once a trip has been initiated, the en-route path diversion model can determine other route alternatives between the origin and the destination based on current network conditions. The routes taken by the individuals are re-evaluated and the flows on each link are re-estimated. Now, the path flows ensure flow propagation across the network leading to the network flow propagation model which updates the link flows. The performance of each link can be derived based on the flows in each link determined through a link performance model based on the fundamental equation or any link cost function. Therefore, we can determine the travel time and cost of the new link which will again affect the network flow or propagation. So, the updated travel time and costs for the links can provide feedback to the network propagation model. Based on the costs of each link, performances of each path can be estimated through path performance model and the data for actual path performances are taken as an input for the next day. The updated link travel times and costs can provide en-route as well as pre-trip information. The pre-trip information can be used by other individuals who initiate their trips in the latter part of the day. The en-route information can enable the en-route diversion model to work efficiently. Therefore, an individual is getting continuous information before initiation of his trip as well as during the trip. Based on this information, routes are determined. The paths are re-computed continuously, and the trip volumes are assigned to specific paths based on updated travel times and costs. When all the vehicle-trips have been assigned, the network flow can be determined. The network flow leads to link flows which will again lead to different link costs. These costs determine the new path performance of a path. The change in path performances can provide the en-route information for some existing vehicles in the network. The same information can act as a pre-trip information for new vehicles joining into the system. Expected path performances is the output of the dynamic assignment model developed for the present day which is used as an input to the model for the next day. Therefore, the travel time estimates for different links for the next day can be obtained.

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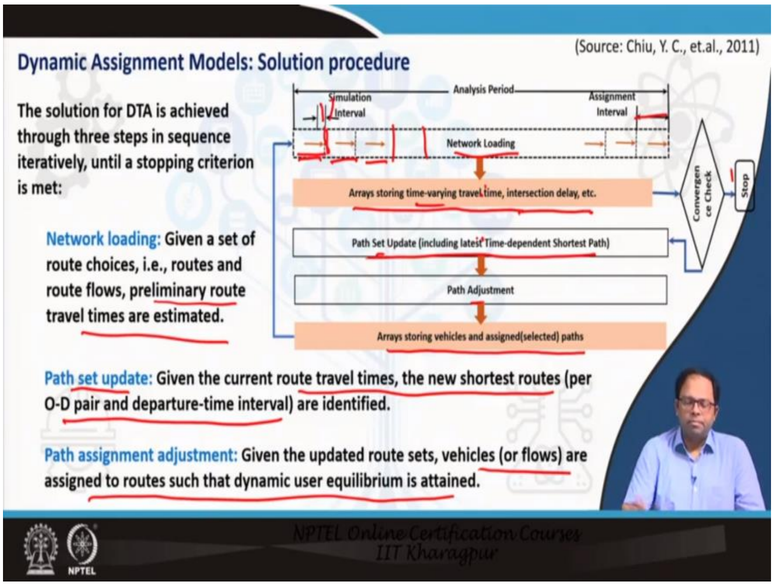

Dynamic Assignment Models: Solution procedure

(Source: Chiu, Y. C., et.al., 2011)

The solution for DTA is achieved through three steps in sequence iteratively, until a stopping criterion is met:

Analysis Period

Simulation Interval

Assignment Interval

Network Loading

Arrays storing time-varying travel time, intersection delay, etc.

Path Set Update (including latest Time-dependent Shortest Path)

Path Adjustment

Arrays storing vehicles and assigned(selected) paths

Convergence Check

Stop

Network loading: Given a set of route choices, i.e., routes and route flows, preliminary route travel times are estimated.

Path set update: Given the current route travel times, the new shortest routes (per O-D pair and departure-time interval) are identified.

Path assignment adjustment: Given the updated route sets, vehicles (or flows) are assigned to routes such that dynamic user equilibrium is attained.

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Solution Procedure of Dynamic Assignment

A dynamic assignment problem is usually solved in three steps. The iterations of these steps are continued till the stopping criteria is met. The stopping criterion is based on convergence of the solution. The convergence leads to the dynamic equilibrium. Firstly, the network loading is conducted using the OD matrices. Given a set of route choices (routes and route flows), preliminary route travel times are estimated. The travel times as well as intersection delays are stored in the arrays. The next step is conducted to update the path sets. Given the current route travel times, the new shortest routes (per O-D pair and departure-time interval) are identified. Therefore, the shortest routes between the O-D pairs can change for each time interval. It depends on the travel times on the links for that route. Finally, the flows are adjusted on each path based on updated travel costs on each path. Given the updated route sets, vehicles or flows are assigned to a route such that dynamic equilibrium is attained. Based on the updated path values, the flows and assigned path sets are stored in the arrays which are updated based on the outputs available in each iteration. These are the basic steps involved in a dynamic traffic assignment process. Therefore, based on the principles of dynamic assignment the route choices are determined for shorter time periods while checking the travel time convergence between all the time intervals. For example, there is a given simulation interval and assignment interval. For every assignment interval, there is an update on the total travel time for all the routes in the network. For a given simulation interval, δt a portion of the entire flow is assigned to the suitable route segments. Based on the path information, the cost of different paths for all the intervals can be determined. Based on such information, the route choice probabilities for each route during that time intervals can be estimated. The simulation time intervals are smaller because the flows during each of these time periods are assigned to the network. The assignment intervals are longer because the total network times as well as the paths are updated during these time intervals. In the image shown above, the process is conducted iteratively for different groups of vehicles and till the convergence is attained based on equilibrium of travel time (i.e. the travel time becomes same for different routes in that assignment period). Once the equilibrium is attained for an assignment interval, the next interval can be taken into consideration. The simulation is conducted till all the assignment intervals have been covered.

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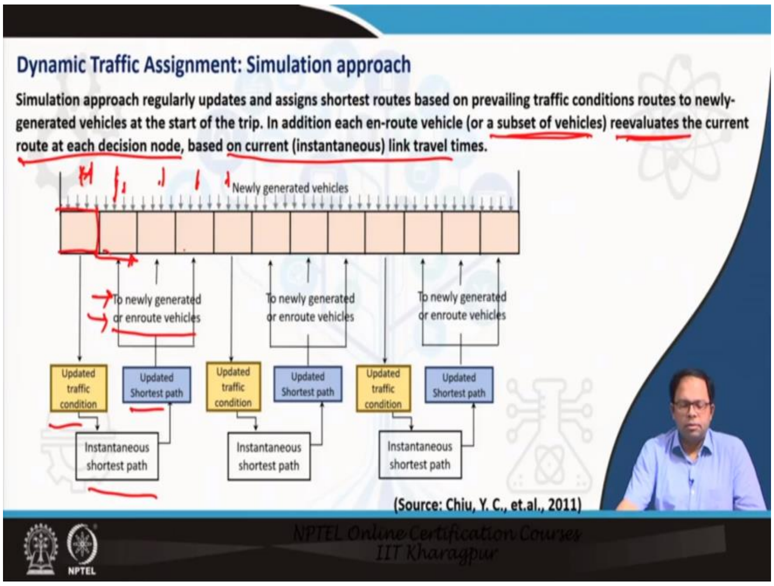

Dynamic Traffic Assignment: Simulation approach

Simulation approach regularly updates and assigns shortest routes based on prevailing traffic conditions routes to newly-generated vehicles at the start of the trip. In addition each en-route vehicle (or a subset of vehicles) reevaluates the current route at each decision node, based on current (instantaneous) link travel times.

(Source: Chiu, Y. C., et.al., 2011)

Simulation Approach in Dynamic Traffic Assignment

The dynamic assignment through simulation can be elaborated further. In this process, the vehicles arriving in the network are newly generated at different time periods. These time intervals are the assignment periods. Once these new groups of vehicles join the system, they receive updated traffic information based on current conditions. Based on the instantaneous shortest path information, the shortest paths along their journey can be updated. The updated shortest paths can help the new drivers joining or the old drivers driving along the paths in the next time period. For example, if the information about shortest paths obtained during the current assignment period, *t* is sent to newly generated vehicles during *t+1* time period and this information will serve as their pre-trip information. The en-route vehicles will use the same information to update their routes or the choice of routes. Therefore, in simulation approach, the shortest routes are updated, and the flows are assigned based on prevailing traffic conditions for every step in the simulation. Moreover, at every step the updated information is passed onto the newly generated vehicles at the start of the trip. In addition, each en-route vehicle (or a subset of vehicles) reevaluates the current route at each decision node, based on current (instantaneous) link travel times. Therefore, at each decision node, the group of vehicles considered for the simulation time interval update their route choice. The process is repeated for each assignment time period. The next assignment period is considered once the dynamic equilibrium is attained for the current assignment period. Therefore, the simulation approach assigns the vehicles and updates the shortest path information dynamically for each time period.

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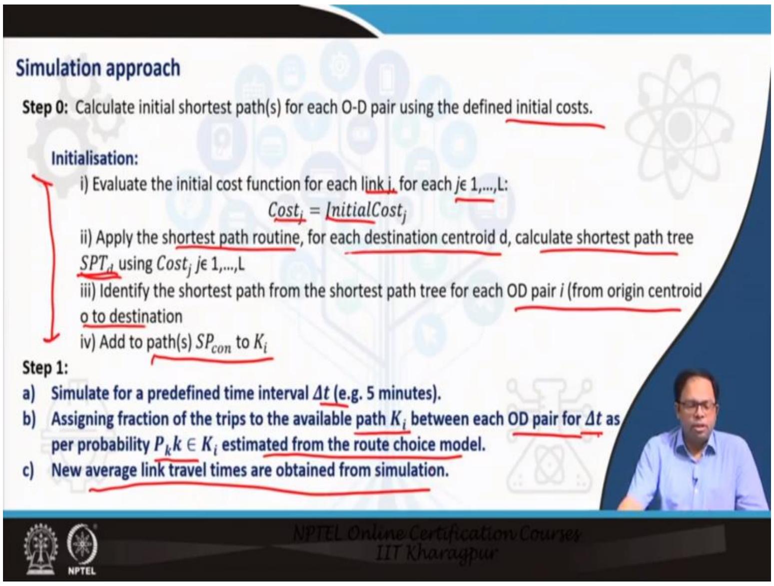

Simulation approach

Step 0: Calculate initial shortest path(s) for each O-D pair using the defined initial costs.

Initialisation:

i) Evaluate the initial cost function for each link j, for each $j \epsilon 1,\ldots,L$:

$$Cost_j = InitialCost_j$$

ii) Apply the shortest path routine, for each destination centroid d, calculate shortest path tree SPT_d using $Cost_j$ $j \epsilon 1,\ldots,L$

iii) Identify the shortest path from the shortest path tree for each OD pair *i* (from origin centroid o to destination

iv) Add to path(s) SP_{con} to K_i

Step 1:

a) **Simulate for a predefined time interval Δt (e.g. 5 minutes).**

b) **Assigning fraction of the trips to the available path K_i between each OD pair for Δt as per probability $P_k k \in K_i$ estimated from the route choice model.**

c) **New average link travel times are obtained from simulation.**

There are different steps involved in a simulation. Let us discuss those steps in detail. Firstly, the initial shortest path for each O-D pair must be calculated using the defined initial cost. The initial cost function for each link j must be evaluated, and for each link *j*, the cost is,

$$Cost_j = InitialCost_j$$

The shortest path routine must be applied for each destination centroid *d*, (i.e. for reaching every point *d*), and the shortest path tree, SPT_d from every other origin must be calculated. The shortest path from the shortest path tree for each origin centroid *o* to destination *d* must be identified. The path so identified, SP_{con} should be added to the list of available paths, K_i. Therefore, the simulation is initialized with the identification of the shortest paths. Once the shortest paths are determined, the simulation is carried out for a predefined time interval Δt, *i.e.* a smaller time interval as discussed earlier. A fraction of the trips is assigned to the available path list K_i between each O-D pair for Δt as per probability, $P_k k \epsilon K_i$, which is estimated from the route choice model. For example, there are three shortest paths for a given OD pair, *k* and these are measured. Now, the probability for assigning vehicle to each of these shortest paths can be determined based on the route choice model. Based on such estimation, vehicle fraction available during Δt time period, will be assigned to each path using the probability of choosing each of the shortest path. Once the assignment has been conducted, the updated average link travel time can be estimated. The new link travel times obtained during the simulation process will be used in the following steps.

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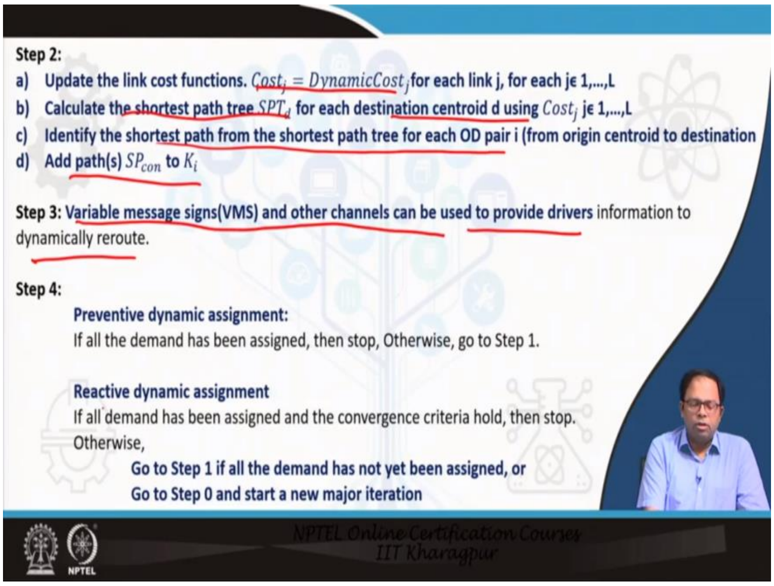

Step 2:

a) Update the link cost functions. $Cost_j = DynamicCost_j$ for each link j, for each jϵ 1,...,L

b) Calculate the shortest path tree SPT_d for each destination centroid d using $Cost_j$ jϵ 1,...,L

c) Identify the shortest path from the shortest path tree for each OD pair i (from origin centroid to destination

d) Add path(s) SP_{con} to K_i

Step 3: Variable message signs(VMS) and other channels can be used to provide drivers information to dynamically reroute.

Step 4:

Preventive dynamic assignment:

If all the demand has been assigned, then stop, Otherwise, go to Step 1.

Reactive dynamic assignment

If all demand has been assigned and the convergence criteria hold, then stop. Otherwise,

Go to Step 1 if all the demand has not yet been assigned, or

Go to Step 0 and start a new major iteration

Based on the travel times estimated in the previous step, the link cost functions are updated, and the cost for each link *j* is,

$$Cost_j = DynamicCost_j$$

The cost is considered to be dynamic since it changes in every step. Based on the determined costs, the shortest path tree SPT_d for each destination centroid *d* are estimated again. The previous process of identification of the shortest path for the shortest path tree for each O-D pair *i* is also repeated. The updated shortest paths SP_{con} are added to the path list K_i. Therefore, based on pre-trip information, the vehicles are assigned initially during the Δt time period. The vehicles assigned are a fraction of entire traffic. Once the paths are assigned with flows, the travel time is updated. The updated travel times will generate new shortest paths. The information related to updated shortest paths are provided using variable message sign (VMS) and other channels like internet or navigation system to the drivers. Based on such information, they can dynamically change their route. Once the route choice decisions are adopted, decision related to type of assignment can be made. If preventive dynamic assignment is conducted, then the simulation is continued till the entire demand has been assigned to the network. If the assignment is based on reactive dynamic assignment, the simulation must meet two criteria for termination, the entire demand must be assigned, and the equilibrium is attained, or the assignment converges to a solution.

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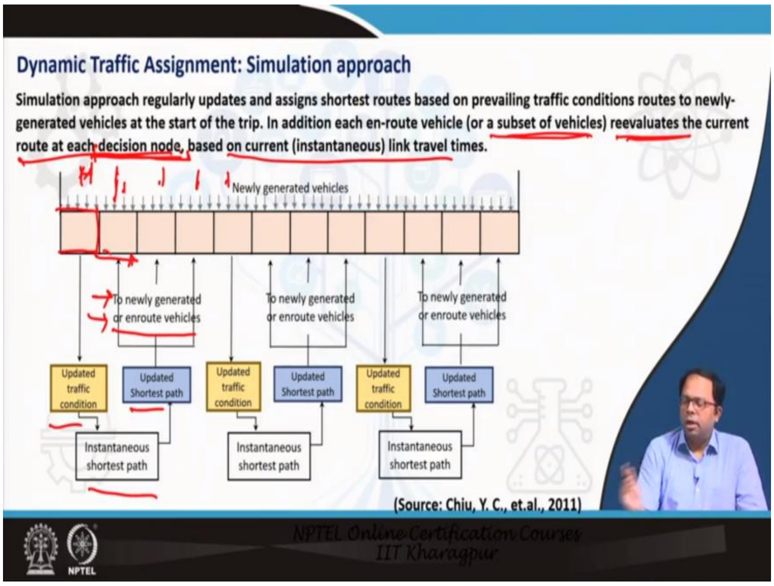

Dynamic Traffic Assignment: Simulation approach

Simulation approach regularly updates and assigns shortest routes based on prevailing traffic conditions routes to newly-generated vehicles at the start of the trip. In addition each en-route vehicle (or a subset of vehicles) reevaluates the current route at each decision node, based on current (instantaneous) link travel times.

(Source: Chiu, Y. C., et.al., 2011)

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The decision node in the network plays an important part in deciding the type of information. Each driver reevaluates the current route after he receives the en-route information at each decision node. This decision node could be an intersection or crossroads from where he has the option to divert. Therefore, at each decision node, he can take the decision of taking the diversion.

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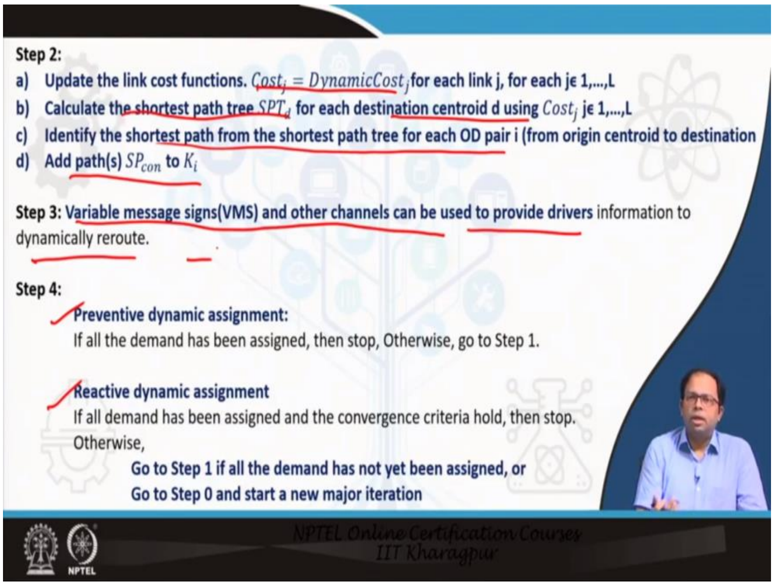

Step 2:

a) Update the link cost functions. $Cost_j = DynamicCost_j$ for each link j, for each j∊ 1,...,L

b) Calculate the shortest path tree SPT_d for each destination centroid d using $Cost_j$ j∊ 1,...,L

c) Identify the shortest path from the shortest path tree for each OD pair i (from origin centroid to destination

d) Add path(s) SP_{con} to K_i

Step 3: Variable message signs(VMS) and other channels can be used to provide drivers information to dynamically reroute.

Step 4:

Preventive dynamic assignment:
If all the demand has been assigned, then stop, Otherwise, go to Step 1.

Reactive dynamic assignment
If all demand has been assigned and the convergence criteria hold, then stop.
Otherwise,
Go to Step 1 if all the demand has not yet been assigned, or
Go to Step 0 and start a new major iteration

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Once the en-route information is received, a decision is made at a decision node and the driver may divert to a different road. So, once the route choice is done, i.e. a new route is adopted from a decision node, either preventive or reactive dynamic assignment can be conducted. In Reactive dynamic assignment, the convergent solution can be attained through a model based on different travel time functions for different group of vehicles. Once the model is developed, it can be solved like an equilibrium solution as discussed earlier. If the entire demand is not assigned, the iteration must be carried out after the estimation of new travel times which will enable the drivers to take decisions on the diversions at the decision nodes. If the entire demand has been assigned but convergent solution is not achieved, then a major iteration involving the initial identification of the shortest path must be carried out for a reactive dynamic assignment. Such iterations in reactive assignment are repeated till the equilibrium solution is attained.

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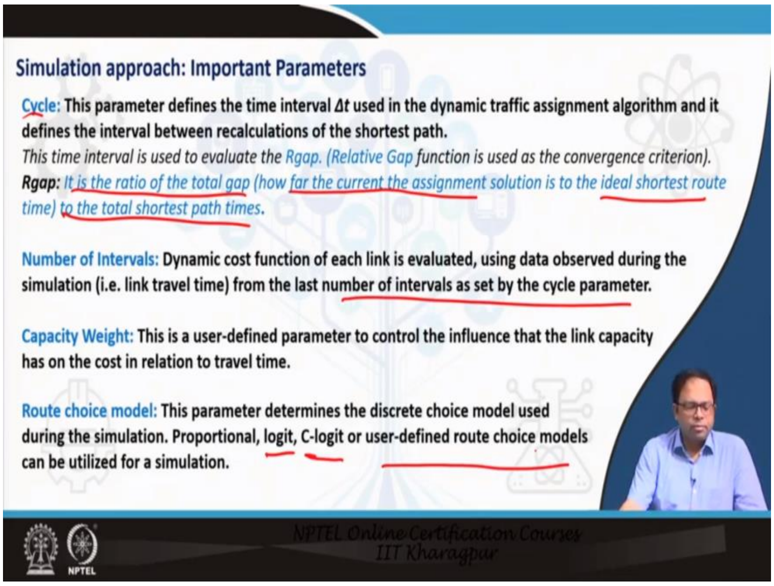

Simulation approach: Important Parameters

Cycle: This parameter defines the time interval Δt used in the dynamic traffic assignment algorithm and it defines the interval between recalculations of the shortest path.

This time interval is used to evaluate the Rgap. (Relative Gap function is used as the convergence criterion).

Rgap: *It is the ratio of the total gap (how far the current the assignment solution is to the ideal shortest route time) to the total shortest path times.*

Number of Intervals: Dynamic cost function of each link is evaluated, using data observed during the simulation (i.e. link travel time) from the last number of intervals as set by the cycle parameter.

Capacity Weight: This is a user-defined parameter to control the influence that the link capacity has on the cost in relation to travel time.

Route choice model: This parameter determines the discrete choice model used during the simulation. Proportional, logit, C-logit or user-defined route choice models can be utilized for a simulation.

There are certain important parameters which are used in the simulation. One of the important parameters is the cycle of the simulation which defines the time interval Δt used in the dynamic traffic assignment algorithm. This parameter defines the interval between recalculations of the shortest path. So, after each interval Δt, the shortest path will be recalculated. This time interval is also used to evaluate R_{gap} function. The R_{gap} function, also known as relative gap function, is the one used to check the convergence criteria. R_{gap} function is the ratio of the total gap (how far the current assignment solution is to the ideal shortest route time) to the total shortest path time. When this ratio is closer to zero and it does not improve with further iterations, the solution is said to attain equilibrium, i.e. the dynamic equilibrium is reached. Another important parameter for the simulation is the number of intervals considered based on the cycle of the simulation. The simulation is terminated once all the time intervals specified in the simulation are covered. The dynamic cost function of each link is evaluated using the data observed during the simulation (i.e. link travel times) from the all the previous intervals. So, this parameter determines the number of intervals to be considered for the simulation. This parameter can also influence the cycle parameter because Δt is dependent on number of intervals. The capacity weight is a user-defined parameter to control the influence that the link capacity has on the cost in relation to travel time. This parameter defines the weightage of the links. The route choice model parameter determines the discrete choice model used during the simulation. The trips can either be divided proportionally to different routes or based on a logit model or on a conditional logit model. A user-defined route choice model can also be used in the simulation. Such route choice models are based on the strategies that the user undertakes.

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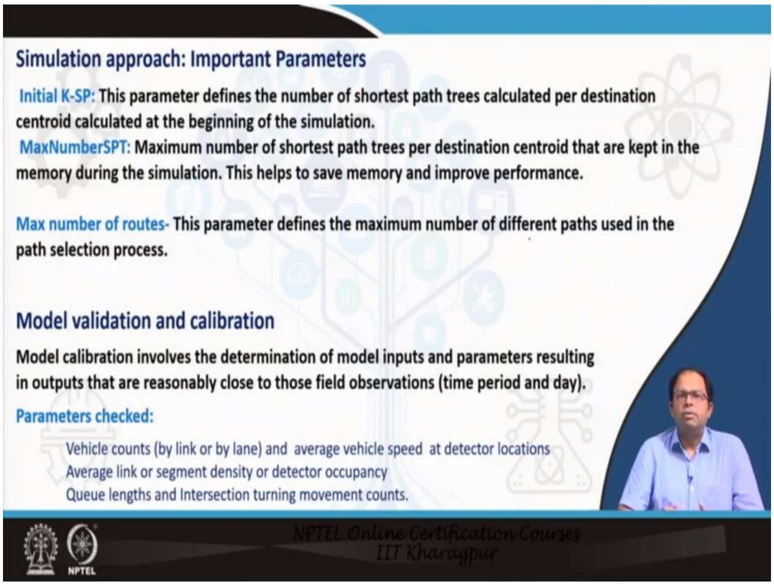

Simulation approach: Important Parameters

Initial K-SP: This parameter defines the number of shortest path trees calculated per destination centroid calculated at the beginning of the simulation.

MaxNumberSPT: Maximum number of shortest path trees per destination centroid that are kept in the memory during the simulation. This helps to save memory and improve performance.

Max number of routes- This parameter defines the maximum number of different paths used in the path selection process.

Model validation and calibration

Model calibration involves the determination of model inputs and parameters resulting in outputs that are reasonably close to those field observations (time period and day).

Parameters checked:

Vehicle counts (by link or by lane) and average vehicle speed at detector locations
Average link or segment density or detector occupancy
Queue lengths and Intersection turning movement counts.

We also need to determine the number of shortest paths which are going to be stored. The initial K-SP parameter defines the number of shortest path trees calculated per destination centroid calculated at the beginning of a simulation. Once initial K-SP is determined, MaxNumberSPT specifies the maximum number of shortest path trees per destination kept in the memory during the simulation. This helps to save memory and improves the performance because only the shortest paths are included. The maximum number of routes defines the maximum number of different paths used in the path selection process. This parameter is different for each path. For each destination pair, there is a shortest path which have different links which are stored in the memory. Once the simulation is conducted, the model must be calibrated and validated. Model calibration involves the determination of model inputs and parameters resulting in outputs that are reasonably close to those field observations (time period and day). Now, certain parameters are checked to calibrate a simulation model based on the existing data. These parameters include vehicle counts (by link or by lane) and average vehicle speed which can be estimated at detector locations using inductive-loop traffic detectors. The average link or segment density or detector occupancy can also be measured at that detector locations. The queue lengths and intersection turning movement counts can also be estimated based on the traffic loops installed at various locations. Therefore, the data for the above parameters is collected over a certain time period and the model parameters are adjusted to match these parameters to replicate the real-time network in the simulation model.

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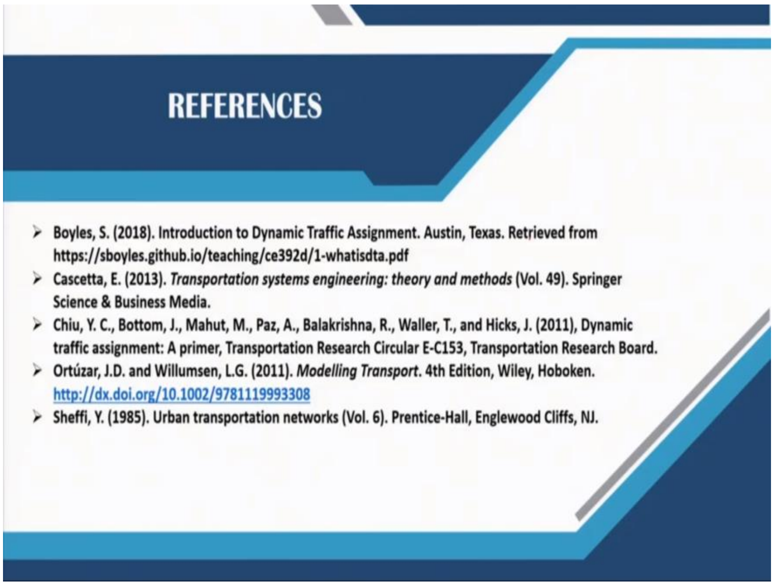

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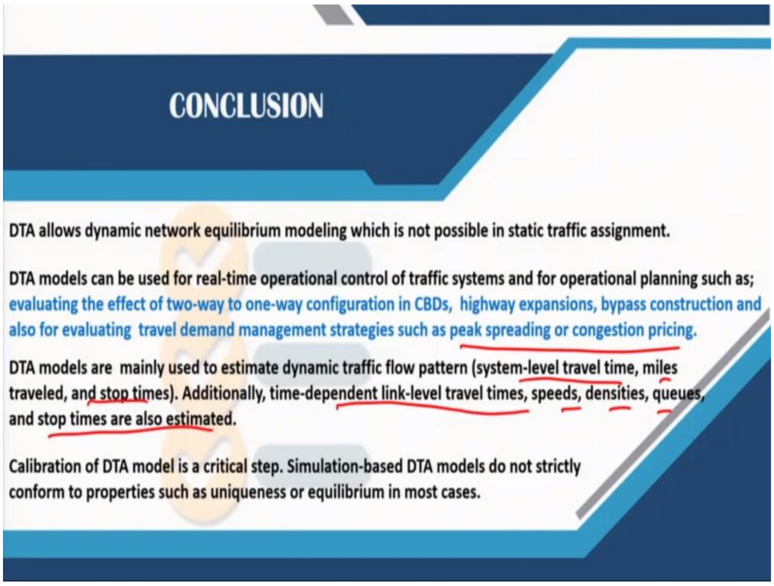

CONCLUSION

DTA allows dynamic network equilibrium modeling which is not possible in static traffic assignment.

DTA models can be used for real-time operational control of traffic systems and for operational planning such as; evaluating the effect of two-way to one-way configuration in CBDs, highway expansions, bypass construction and also for evaluating travel demand management strategies such as peak spreading or congestion pricing.

DTA models are mainly used to estimate dynamic traffic flow pattern (system-level travel time, miles traveled, and stop times). Additionally, time-dependent link-level travel times, speeds, densities, queues, and stop times are also estimated.

Calibration of DTA model is a critical step. Simulation-based DTA models do not strictly conform to properties such as uniqueness or equilibrium in most cases.

Conclusion

Dynamic Traffic Assignment (DTA) allows dynamic network equilibrium modeling which is not possible in static traffic assignment. Besides, DTA models can be used for real-time operational control of traffic systems and for operational planning such as, evaluating the effect of two-way to one-way configuration in CBDs, highway expansions, bypass construction. The dynamic assignment also helps in the evaluation travel demand management strategies such as peak spreading or congestion pricing. This is because it helps us to determine the impact of travel plan variations across individuals on network conditions and pricing. This enables us to understand the travel demand variations eventually. DTA models are mainly used to estimate dynamic traffic flow patterns like system-level travel time, miles travelled and stop times. Additionally, time-dependent link-level travel time, speed, densities, queues and stop times can also be estimated using this kind of model. The calibration of the DTA model is the most critical step. Simulation-based DTA models do not strictly conform to properties such as uniqueness or equilibrium in most cases, i.e. the equilibrium cannot be achieved perfectly. Therefore, the dynamic traffic assignment helps us in getting real-time information of different links and such information can be modeled using this assignment. The idea behind replacing the static equilibrium process with DTA models is to increase the efficiency and accuracy of the models. These are data-intensive models and require high computational efficiency. Although the systems with higher configuration can solve such models, the data collection and analysis of a complex network can be challenging for DTA models. Thank you!