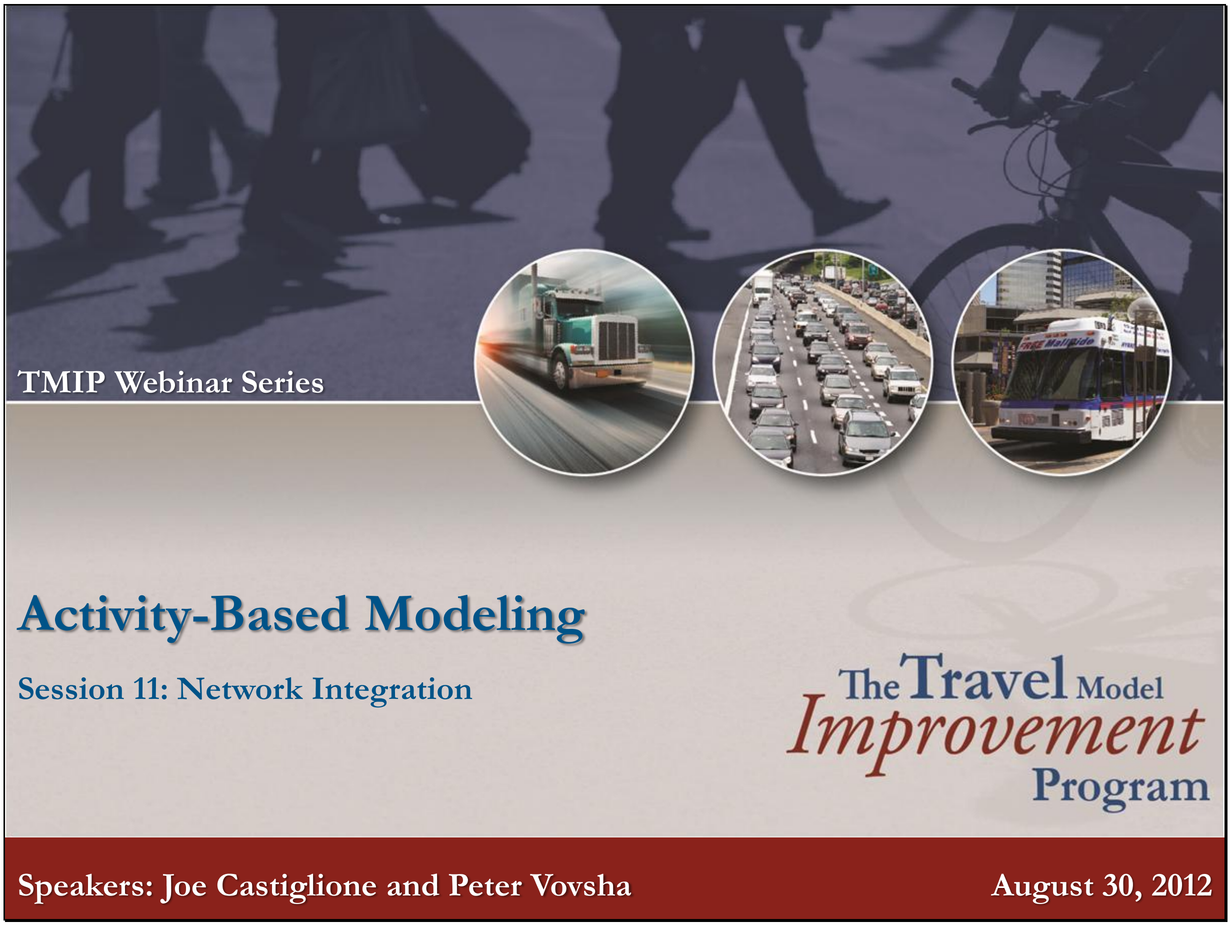
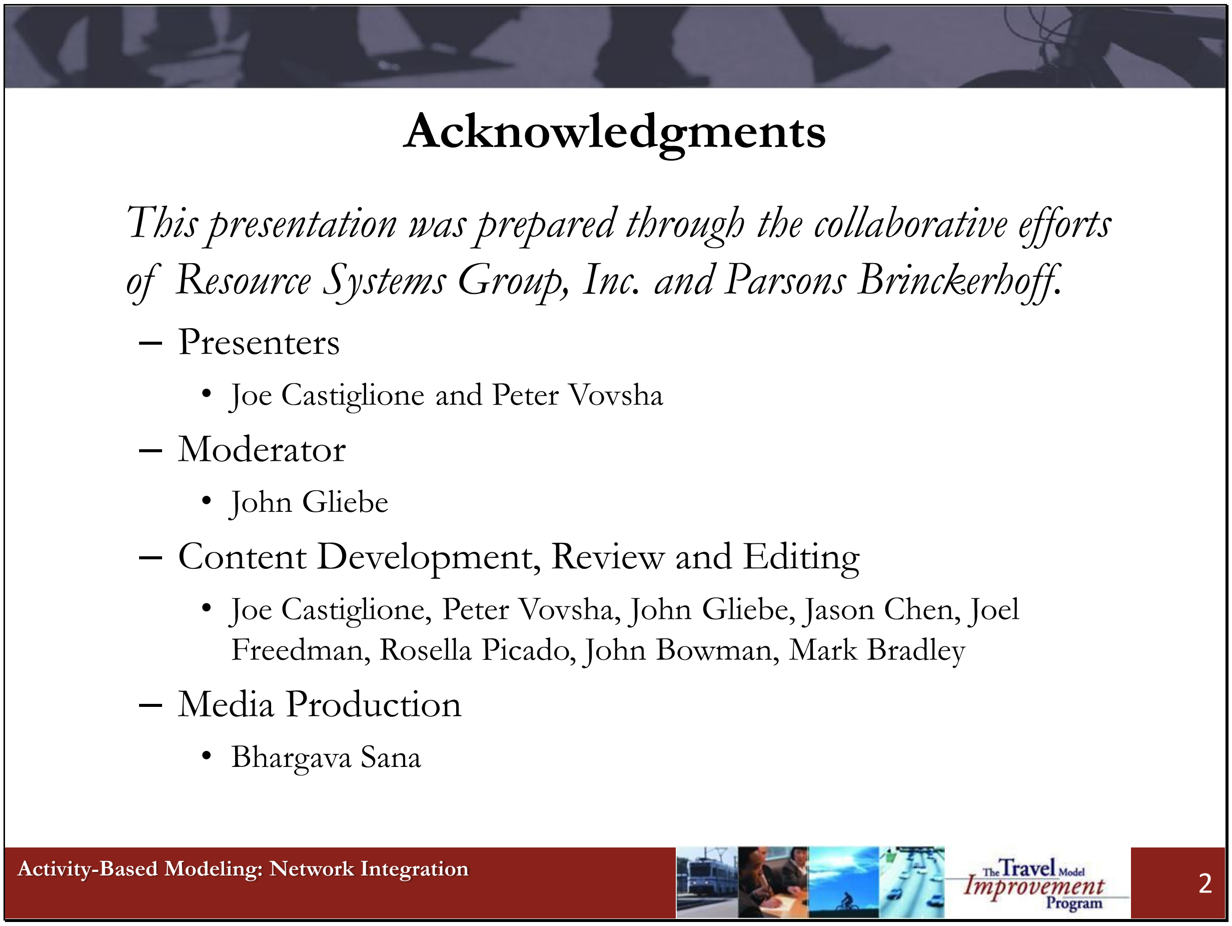

TMIP Webinar Series
Activity-Based Modeling
Session 11: Network Integration
The Travel Model Improvement Program
Speakers: Joe Castiglione and Peter Vovsha
August 30, 2012



Resource Systems Group and Parsons Brinckerhoff have developed these webinars collaboratively, and we will be presenting each webinar together. Here is a list of the persons involved in producing today's session.

- Joe Castiglione and Peter Vovsha are co-presenters. They were also primarily responsible for preparing the material presented in this session.
- John Gliebe is the session moderator.
- Content development was also provided by John Gliebe, Jason Chen, Joel Freedman, and Rosella Picado. John Bowman and Mark Bradley provided review.
- Bhargava Sana was responsible for media production, including setting up and managing the webinar presentation

2012 Activity-Based Modeling Webinar Series

Executive and Management Sessions	
Executive Perspective	February 2
Institutional Topics for Managers	February 23
Technical Issues for Managers	March 15
Technical Sessions	
Activity-Based Model Framework	April 5
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Activity-Based Modeling: Network Integration

The Travel Model Improvement Program

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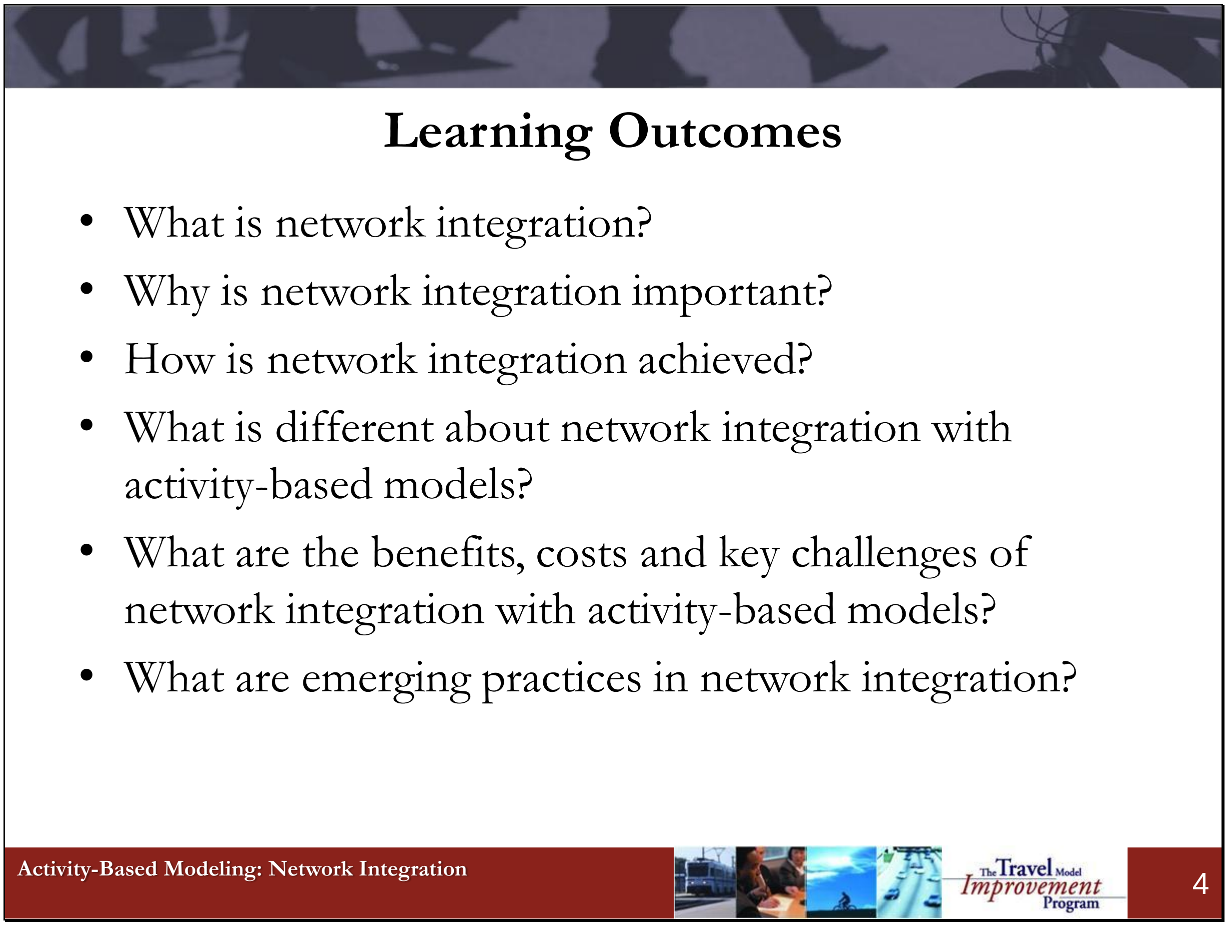
For your reference, here is a list of all of the webinars topics and dates that have been planned. As you can see, we are presenting a different webinar every three weeks. Three weeks ago, we covered the tenth topic in the series—Tour and Trip Mode, Intermediate Stop Location. This session covered some of the key mode and destination choice components of the activity-based model system.

Today's session is the eighth of nine technical webinars, where we will cover the details of activity-based model design and implementation. In today's session, we will describe how different activity-based model systems are integrated with network or supply models, and key considerations of this linkage.



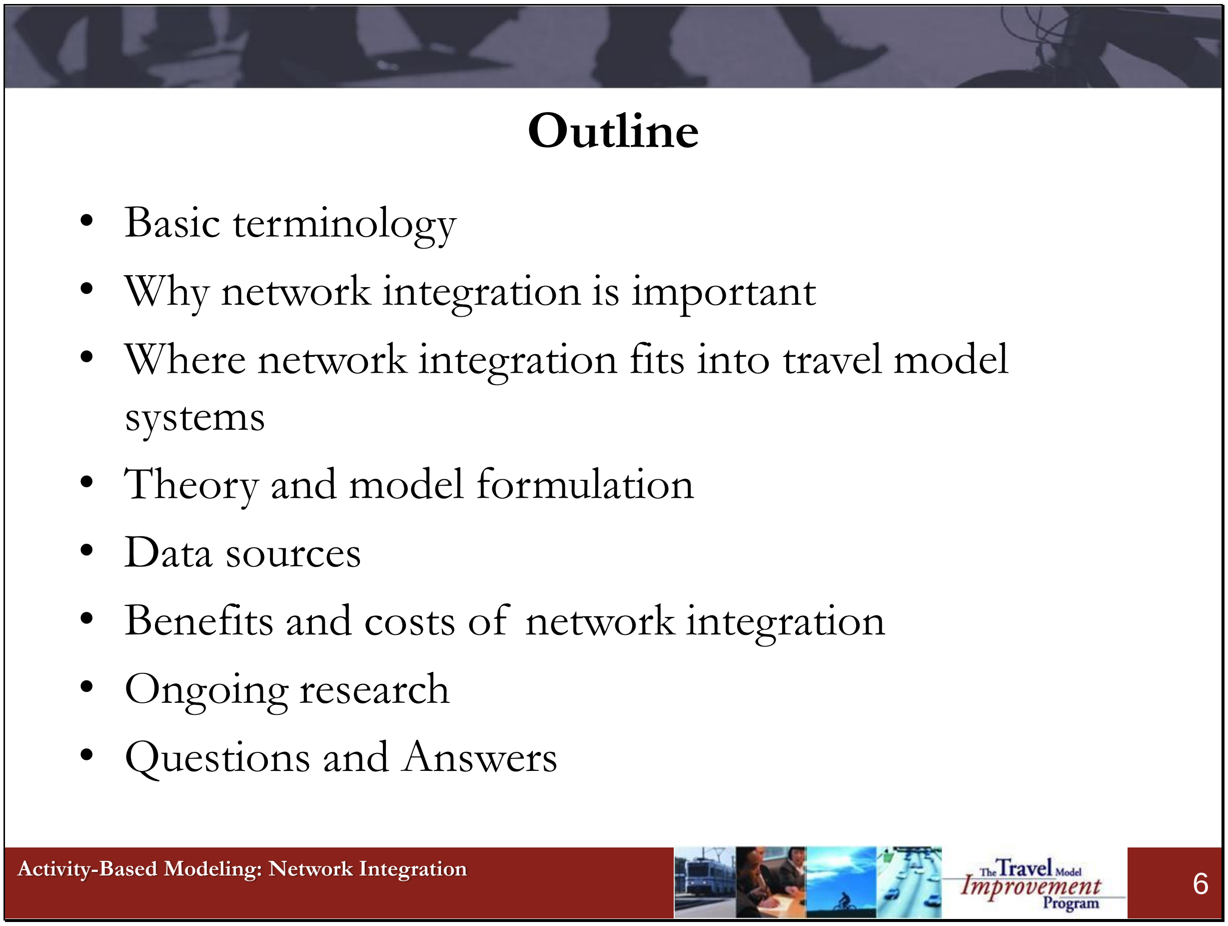
In today’s session, we will be covering different means of integrating activity-based demand models with network supply models. At the end of this session, participants should be able to answer the following questions about network integration:

- What is network integration?
- Why is network integration important?
- How is network integration achieved?
- What is different about network integration with activity-based models?
- What are the benefits, costs and key challenges of network integration with activity-based models?
- What are emerging practices in network integration?

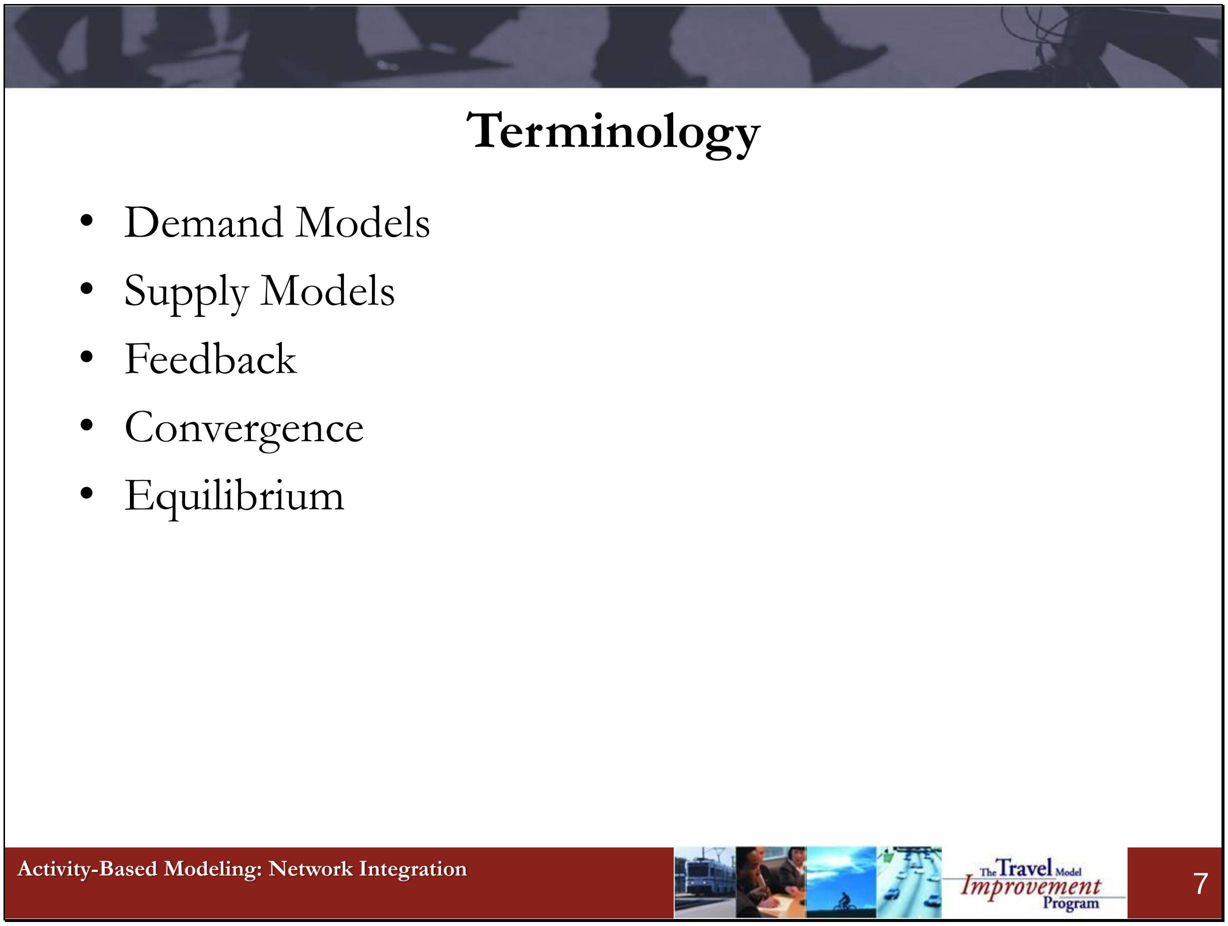
What do we mean by network integration?

- A desired outcome:
  - Network-derived level of service variables used to predict destination, mode, and trip timing decisions are consistent with the level of service predicted by the network assignment
- A system of program structures carefully designed to achieve this outcome
  - Decision modules, variable specifications, data structures, procedures

There are two senses in which we can use the term “network integration” First, the term can refer to a condition or an outcome that is achieved when the network-derived level of service variables used to predict activity generation, destination, mode, and trip timing decisions are consistent with the level of service that results when these trips are loaded onto networks during the network assignment steps. Second, the term can refer to the data structures and procedures that are used to achieve this outcome.



In this webinar, we will consider why network integration is important, and how it functions within the overall travel model system. Some basic theories and formulations and associated data requirements for implementing different types of network integration will be discussed, and consider the tradeoffs associated with different approaches. Finally, we will cover ongoing research into network integration and leave time for questions and answers.

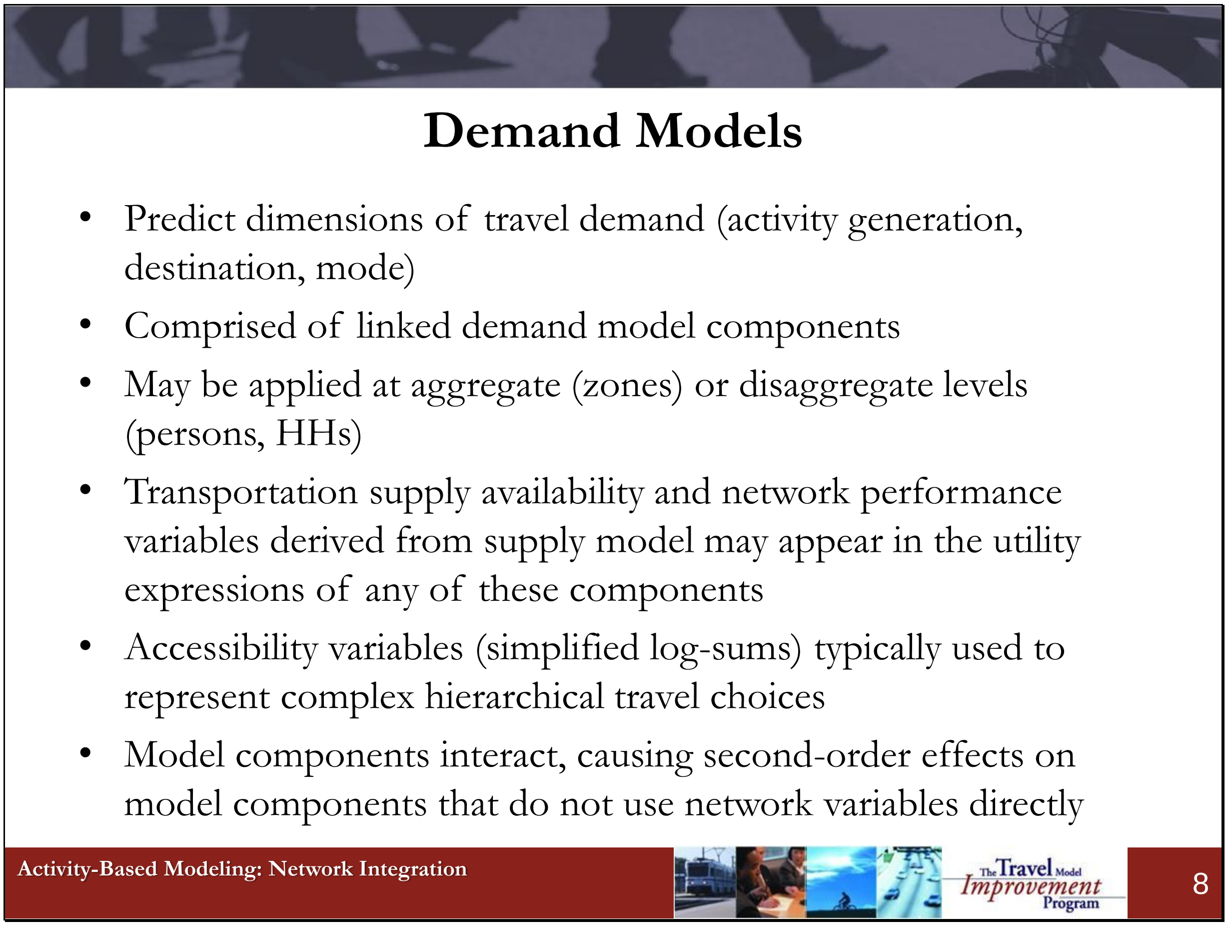


This slide shows basic terminology for that will be used in this session and other sessions.

- **Demand Models:** Tools used to generate estimates of the type, amount, locations, mode and timing of the demand for travel. Typically, this refers to the dimensions of travel that are predicted by the first three steps of a traditional 4-step model (as distinct from the final assignment step) or that predicted by an activity-based demand model. Demand models can be basic or extremely complex.
- **Supply Models:** Tools used to generate estimates network performance measures (such as link flows and congested travel times) which are used as key inputs to demand models. Like demand models, supply models can be quite basic in their formulation or significantly more complex.
- **Feedback:** Refers to the process through which information generated “lower” in the model system (such as congested travel times from network assignment) is used as direct or indirect input the models “higher” in the model system (such as activity generation).

The purpose of feedback is to ensure that the final model outputs are consistent with the model system inputs and assumptions.

- **Convergence:** The condition when the impedances or level-of-service measurements used as the basis for accessibility measures and as key inputs to the destination and mode choice models are approximately equal to the travel times and costs produced by the final network assignment process. Convergence is necessary in order to ensure the behavioral integrity of the model system, as is considered both with the context of the network assignment process, as well the overall model system.
- **Equilibrium:** Equilibrium typically refers to the condition where during the network assignment no traveler can decrease travel effort by shifting to a new path. This is known as user equilibrium, although other conditions such as system optimum can also be pursued.



Demand models are tools used to generate estimates of the type, amount, locations, mode and timing of the demand for travel. Typically, this refers to the dimensions of travel that are predicted by the first three steps of a traditional 4-step model (as distinct from the final assignment step) or that predicted by an activity-based demand model. Demand models can be extremely basic (such a simple cross-classification trip generation model) or extremely complex (such as an intra-household activity generation/coordination model). There are usually a series of individual model sub-components that we refer to collectively as a single demand model – for example, the trip or activity generation model component is distinct from the destination choice or distribution model component, which is distinct from the mode choice model component. These and other components are executed in sequence.

Demand models can be applied at an aggregate level, such as zones, as is in most traditional trip-based models, or may be applied at the level of individual persons or households, as is the case in activity-based models. Critical inputs to demand models are measures of transportation supply availability and transportation system performance that are derived from the supply model. In some cases, these measures are used directly in the demand model components, while in other cases the measures may be incorporated into accessibility measures and used indirectly in demand model components.

Network / Supply Models

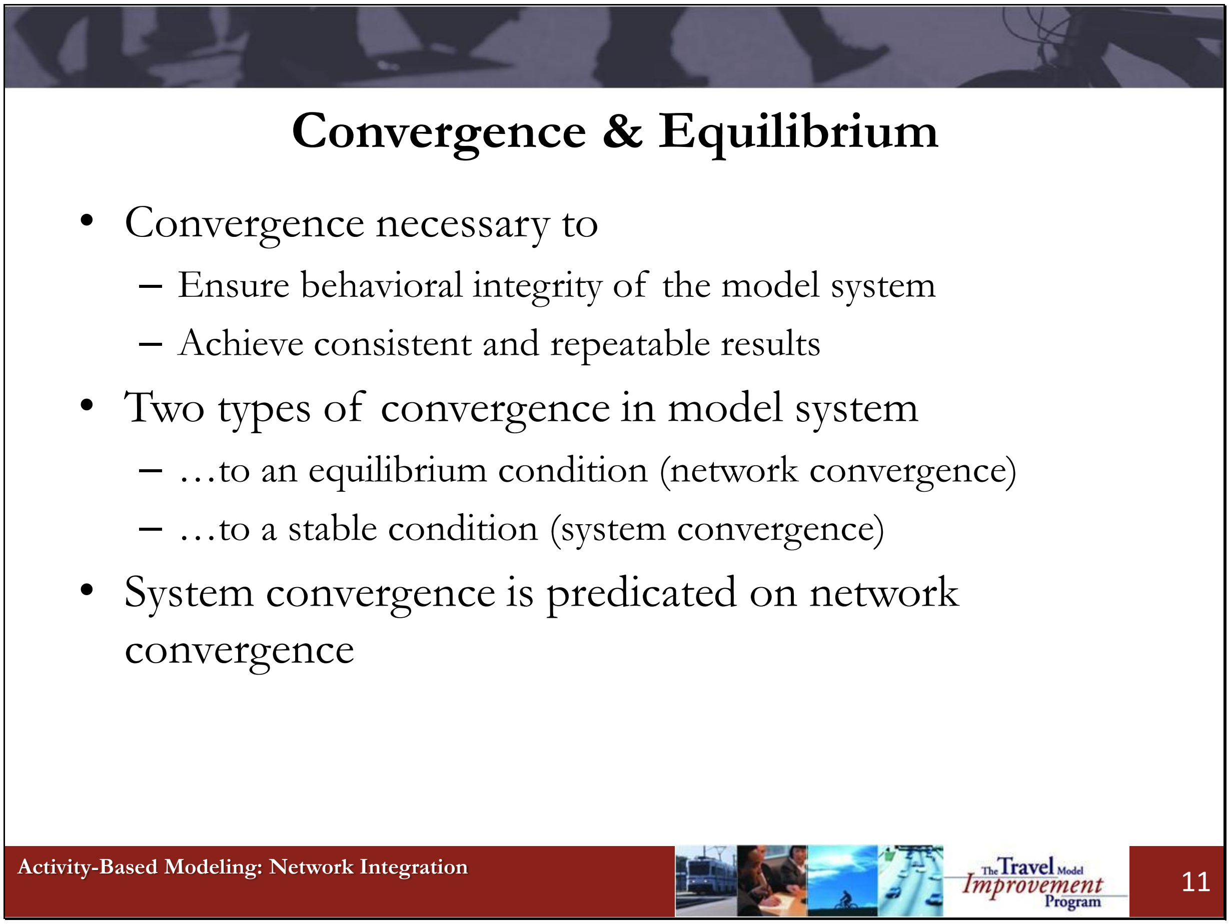
- Represent system capacity and level of service under different levels of congestion
- Require details of demand (location, timing, mode) from demand model
- Network structures composed of links and nodes, with demand loading points
- Link performance functions estimate congested travel times
- Tolls – convert monetary cost to travel time using value of time estimates and add to link travel times

Tools used to generate estimates network performance (such as link flows and congested travel times), which are used as key inputs to demand models. Supply models can be basic (such a simple aggregate static equilibrium model) or more complex (such as a DTA or traffic micro-simulation model that incorporates detailed operation attributes such as signal timing). Supply models require as input information about travel demand, such as the locations, timing, and modes used for travel. These estimates of demand are applied to representations of network structures comprised at minimum of links and nodes but sometimes incorporating additional network attributes which are used to predict the paths through the network that will be used to satisfy this demand. In traditional static assignment supply models, mathematical functions are used to estimate congested travel times given supply and demand inputs, although more recent supply modeling techniques rely less on these “volume delay functions.” Because travelers’ choices are influenced not only by travel times but also by monetary costs, supply models should be configured to convert these costs into travel times so that they can be incorporated into the path-building procedure.

Feedback

- Use of outputs from a later ("lower") model component as input into an earlier ("higher") model component
- Intended to ensure that the final model outputs are consistent with the model system inputs and assumptions
- Extent of feedback and equilibration rules relate to structure of model
- Necessary in both traditional trip-based models as well as activity-based models

Feedback refers to the process through which information generated "lower" in the model system (such as congested travel times from network assignment) is used as direct or indirect input the models "higher" in the model system (such as activity generation). Feedback is important in both traditional trip-based models as well as activity-based models in order to ensure that the final model outputs are consistent with the model system inputs and assumptions. The exact nature of this feedback is related to the structure of the model. For example, if in an activity-based model system the activity generation component uses accessibility measures that reflect network performance then the supply model outputs should be fed back to update these accessibility measures before running any subsequent model components. However, if a traditional trip-based model system incorporates no network performance measures or network-based accessibility measures in trip generation or trip distribution, then it may only be necessary to feed-back network performance information through the mode choice step.



Model convergence is necessary to ensure the behavioral integrity of the model system, and to ensure that the results will be useful in a policy context. The network performance or level-of-service measurements used as the basis for accessibility measures and as key inputs to demand model components must be approximately equal to the travel times and costs produced by the final network assignment process. In a travel model system, there are at least two types of convergence that we need to consider: network convergence and system convergence. When we talk about convergence, we are implicitly talking about convergence “to” something. Typically this means for networks that we are converging to an equilibrium condition (usually a deterministic user equilibrium where, for each time period-origin-destination combination all used routes have equal travel times, and no unused route has a lower travel time). For the overall model system, this usually means that we are converging to a stable solution (rather than an optimal solution as in the network context). It should be noted that in the context of an integrated demand and network simulation model system, an essential precondition for pursuing overall model system convergence is establishing network assignment convergence.

Importance of Network Integration

- Behavioral
  - Demand patterns produce supply cost
  - Supply costs influence demand patterns
- Structural
  - Demand models results are input to supply model
  - Supply model results are input to demand model
- Practical
  - Policy/investment choices must be informed by stable, repeatable results
  - Exchange of consistent information required to produce stable, repeatable results

Proper network integration is critical in trip-based model systems as well as in activity-based model systems because in both types of model systems the “demand models” and the “supply models” are mutually dependent. The demand model generates information about the origins, destinations, modes, and timing of travel based, in part, on transportation network performance indicators as such as travel times and costs and provides this travel information to the supply model. The supply model assigns travel to transportation model networks and generates information on network performance, which is then in turn fed back to the demand model.

This consistency and feedback between the demand and the supply components of the model system is essential to ensuring that the model system is useful as a policy and investment analysis tool. For example, attempts to assess the impacts of road-pricing strategies for congestion relief will be misleading if the model system doesn’t accurately represent the location, timing and intensity of delays – these delays arise both from the individual travel choices predicted by the demand model as well as from the network performance predicted by the supply model.

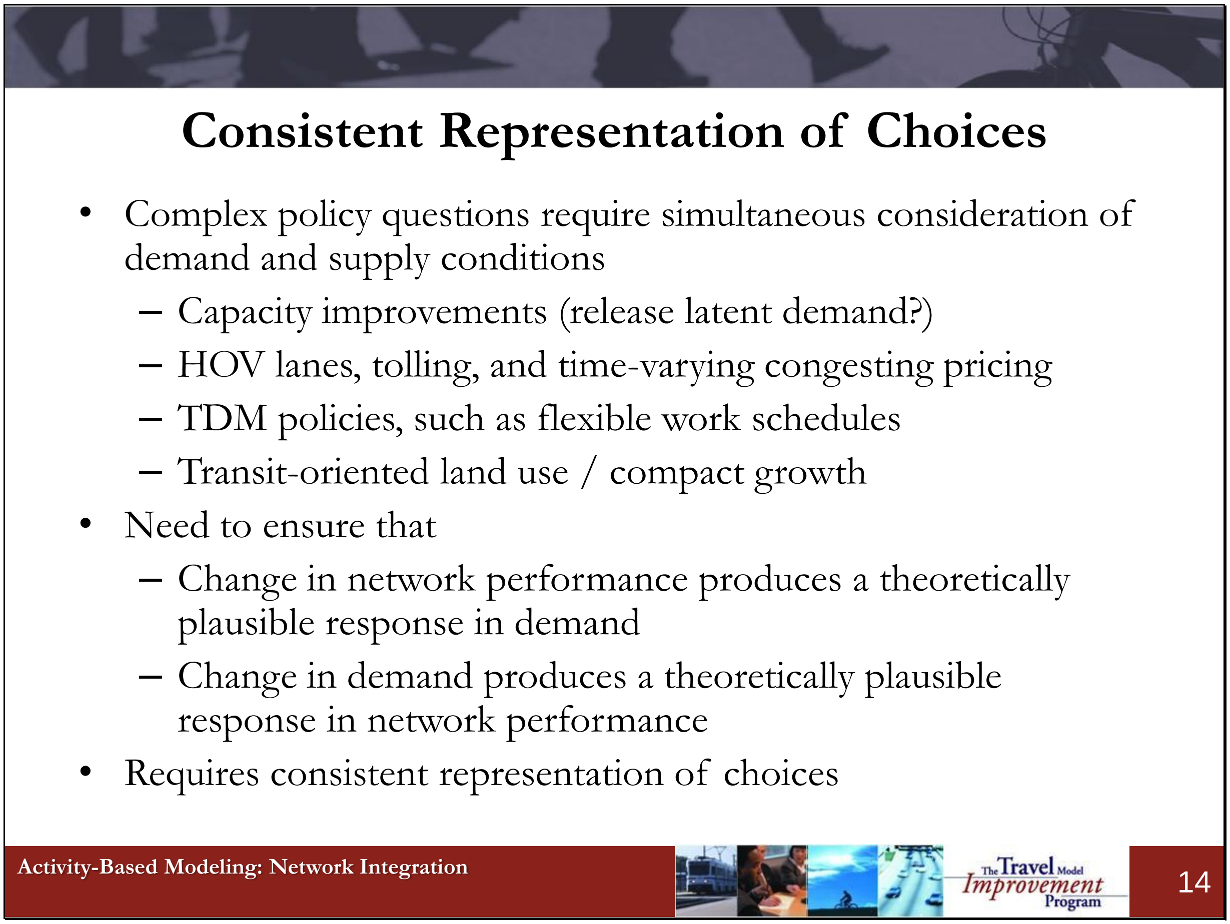
Repeatable & Stable Results

- Repeated application of the same model and inputs results in same outcomes, within an acceptable range
- Results **SHOULD**:
  - Reflect meaningful differences in input assumptions
- Results **SHOULD NOT**:
  - Depend on network starting conditions
  - Oscillate between multiple outcomes with decision-making consequences
  - Reflect model errors or other sources of randomness pertinent to microsimulation
- Influenced by
  - Demand model methods
  - Supply model methods
  - Model integration methods

Travel demand forecasting model systems are tools with which we try to measure the impacts (on travel choices, on network performance) of different policy and investments. It is essential that they generate the same outputs when fed the same inputs, within some acceptable range. The tool would be useless if it could not generate reproducible results. Activity-based model systems, which are typically implemented using Monte Carlo simulation techniques may produce slight variations in outcomes because their probabilistic nature, although as prior webinars have described most activity-based models incorporate features that significantly attenuate these stochastic effects. Ultimately, we want to avoid using a model system that generates multiple outputs that are sufficiently different that they may lead to different decisions.

Not only is it important that models produce repeatable, stable and dependable results, but also that when models are used to compare alternative scenarios the differences in the model outputs reflect difference in the input assumptions or parameters, and are not attributable to model error. If model output differences reflect issues with the model implementation rather than difference in the scenarios, the tool will not be useful. In addition, we want to avoid using a model system that is dependent on the specifics of the network starting conditions, as this may thwart efforts to produce repeatable results. For example, we want to our model system to produce similar final results regardless of the “seed” impedances that we may use in the model systems initial iteration. We also want to avoid using a model system where the results oscillate between multiple outcomes in ways that may be consequential to decision making.

Our ability to produce repeatable and stable results is influenced by the resolution of the methods used within both the demand and supply models, but is perhaps most crucially affected by the methods we use to integrate our demand and supply models.

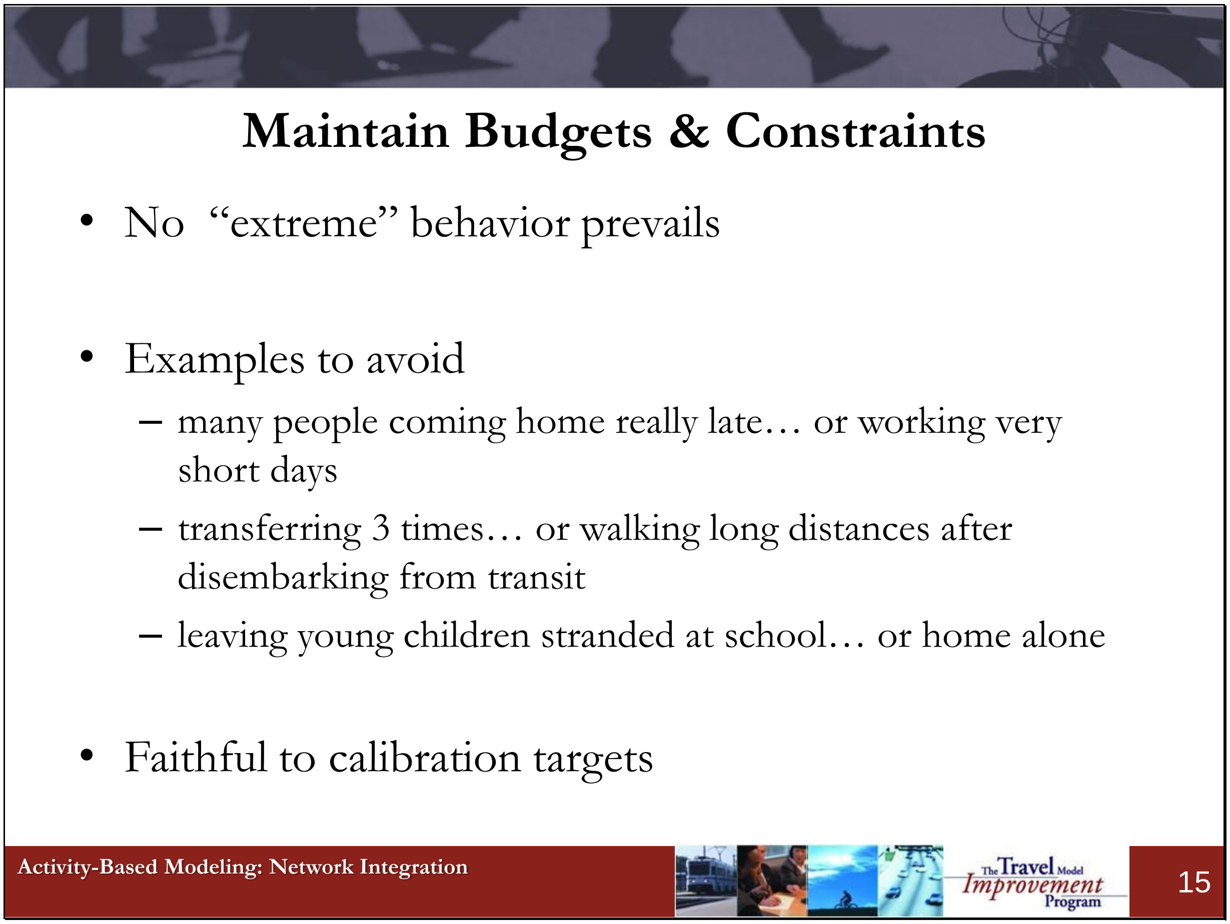


When travel demand forecasting first emerged, the questions that practitioners asked of travel models were simpler, such as how to size a given facility given the expected locations of future populations and jobs. These days, decision-makers rely on travel demand models for answers to more complex policy questions, and expect that these models are appropriately sensitive to the complex behavioral responses.

For example, adding capacity to a roadway segment may not only result in diversion of traffic as people seek reduced travel times, but might release latent demand that was suppressed due to exiting congestion. Similarly, a pricing scenario might influence not only the use of specific routes, but also timing and mode choices, destination choices, and even the generation of activities.

And the complex policy questions are not strictly limited to transportation investments. Decision-makers want travel models that are appropriately sensitive to the effects of compact, mixed use, and transit-oriented land use. They want models that can help inform travel demand management strategies such as flexible work schedules. And (ideally) they want models that can tell them who is impacted by these transportation and land use policy and investment decisions.

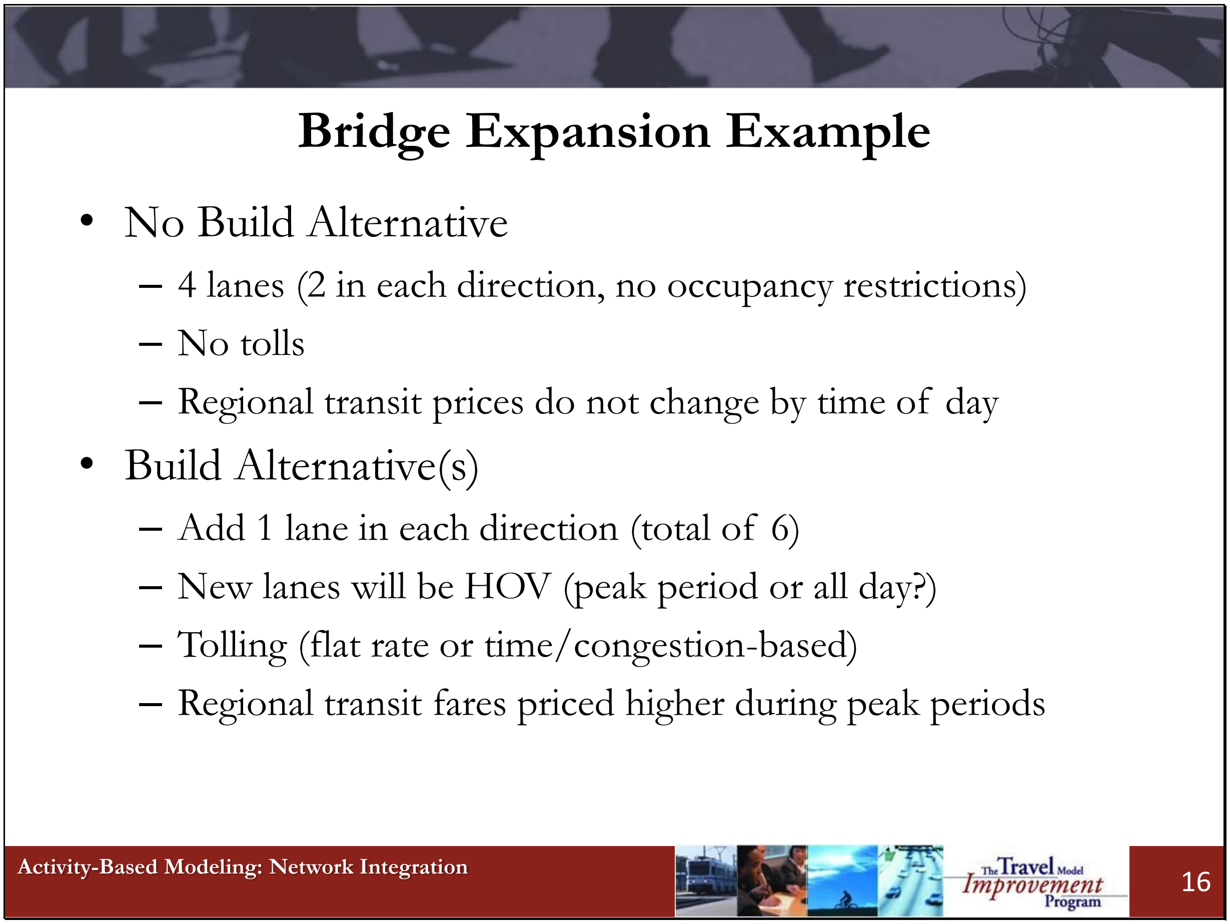
The complex questions necessitate models that appropriately and consistently capture the relationship between travel demand and supply. If network pricing is to change by time-of-day, then ideally network information (times, costs) at a time resolution consistent with this pricing scenario can be fed back from supply model to demand model. Similarly, if value-of-time distribution information is used when predicting demand, then ideally this segmentation would be reflected in the configuration of the supply model.



Related to the notion maintaining a consistent representation of choices between the demand and network supply components of the model system is the issue of respecting temporal and spatial constraints. Activity-based models contain intrinsic logic that already constrains individual travel choices. For example, members of household that don't own cars typically aren't allowed to use "drive alone" modes. People don't drive home from work alone if they haven't driven to their work location. Travelers aren't allowed to depart from a location that wasn't the destination of the prior trip.

Ideally, the supply component of the model system can reflect these constraints. For example, transit skims should have sufficient temporal detail that they can reflect the fact that after a certain time transit service is significantly less frequent, and thus shouldn't be considered as an alternative. The transit network processing should discourage extreme behavior such as making three or more transfers, or assuming long-walk egress.

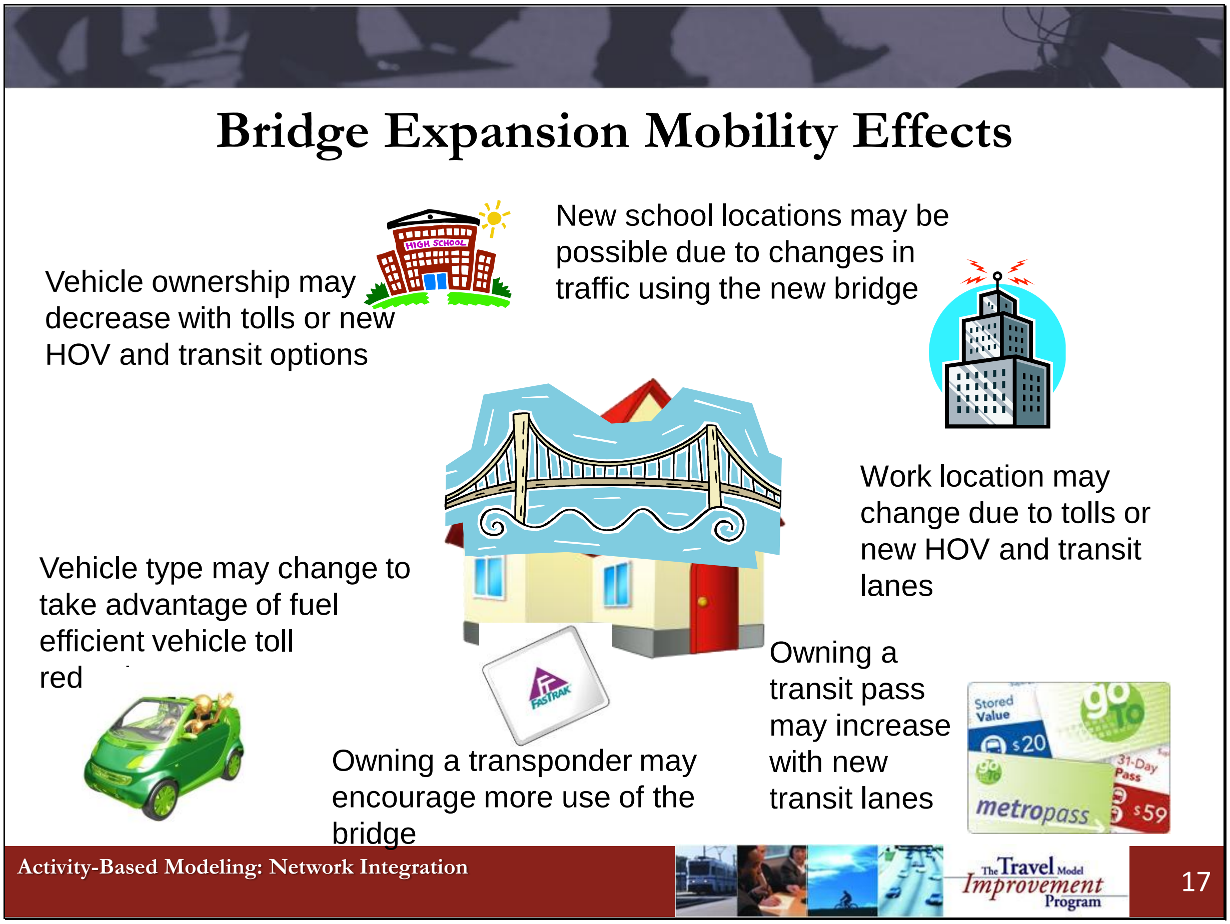
Maintaining budgets and constraints is not usually considered one of the primary challenges in integrating activity-based demand models with current network supply models. However, as network supply models incorporate ever increasing levels of temporal, spatial and behavioral detail (such as the linked nature of trips on a tour), these issues may become more pronounced.



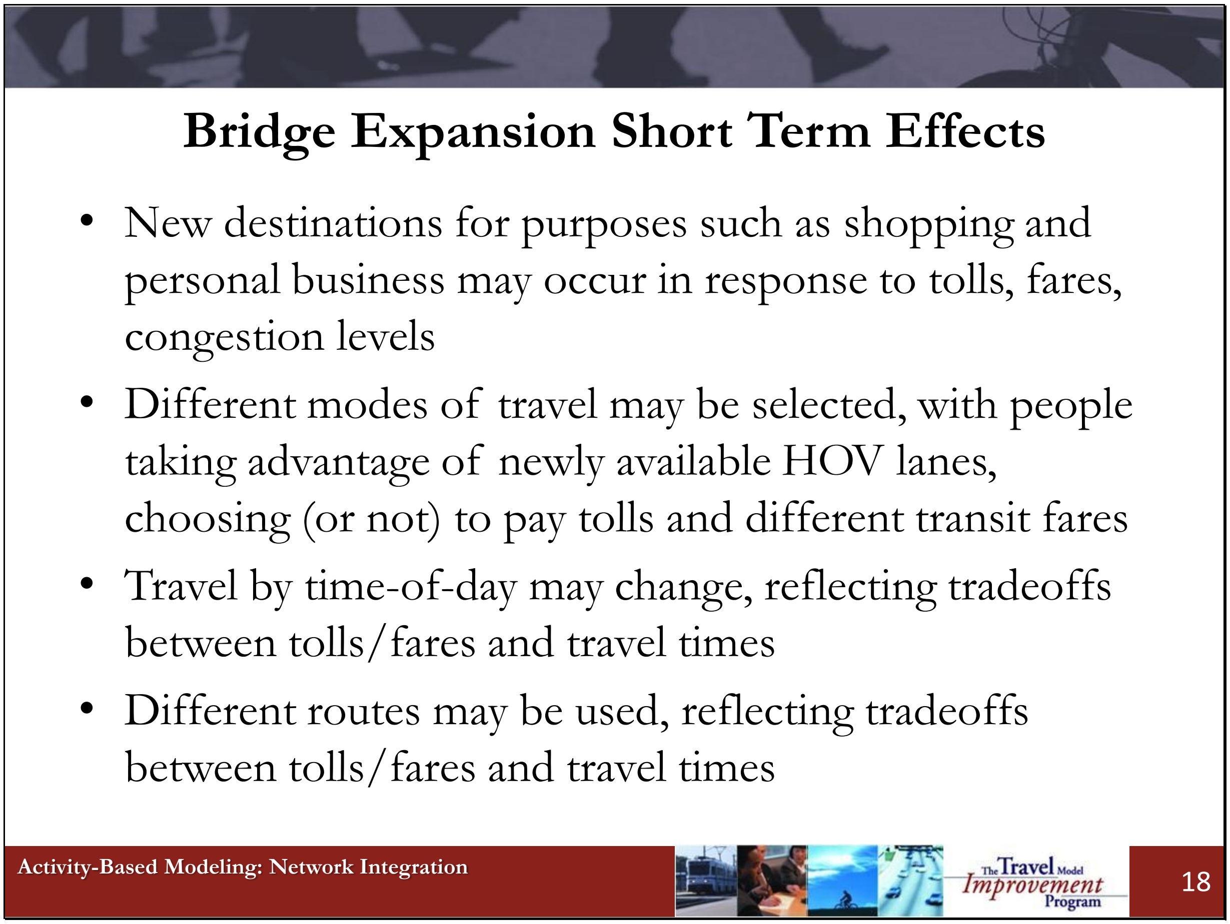
To understand the impacts of network integration, let's revisit the example bridge expansion transportation planning and policy project.

For this scenario analysis, we will be considering a number of alternatives: a no-build alternative and a various configurations of the build alternative. In the no-build alternative the bridge has 4 lanes (2 in each direction), there are no tolls, and the transit fare stays the same all day. In the various build alternatives, there are 6 lanes on the bridge. In some alternatives the two additional lanes will be HOV lanes all day, while in other alternatives the two additional lanes will be HOV lanes only during peak periods. In addition, in some build alternatives there will be a new toll that is the same across the entire day, while in other build alternatives there will be a toll that will be only applied during peak periods, or when certain levels of congestion occur. Finally, in the build alternatives regional transit fares will be higher during peak periods.

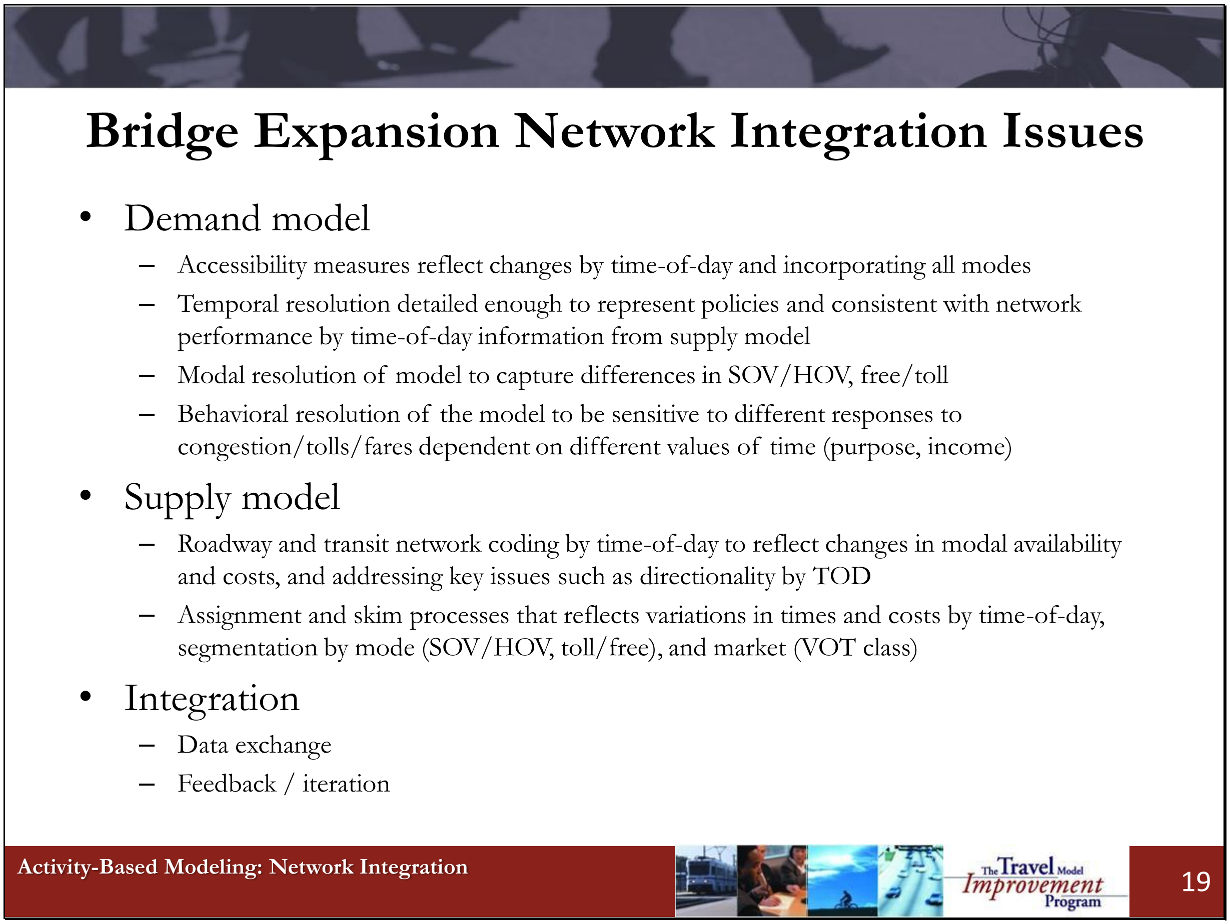
How would the analysis of these alternatives be impacted by different network integration schemes?



Previous presentations have described the potential long-term and medium-term effects of the bridge expansion, such as changes in the usual work and school locations, changes in levels of vehicle ownership, and the types of vehicles owned, and changes in the transit pass or toll transponder adoption.



In addition to changes in these medium and long term "mobility" choices, travelers may also have "short term" responses to the bridge alternatives. For example, in response to the different levels of congestion and costs associated with the different alternatives, travelers may choose new locations for discretionary purposes such as shopping or personal business potentially avoiding bridge crossings if subject to an additional toll or conversely choosing to make a bridge crossing to take advantage of congestion relief associated with using HOV lanes or provided by congestion-based tolling. If tolls, transit fares, or the availability of HOV lanes varies by time-of-day, then travelers may choose to change the timing of their travel to either take advantage of or to avoid differences in travel time and costs by time-of-day. Similarly, these differences in travel times and costs may induce some travelers to choose new routes – in some cases this may mean new travelers using the bridge, while in other cases it may mean existing bridge travelers selecting alternative routes. The ability of the model system to be sensitive to these potential traveler responses depends upon the how the network supply components of the model system are integrated with the demand components.

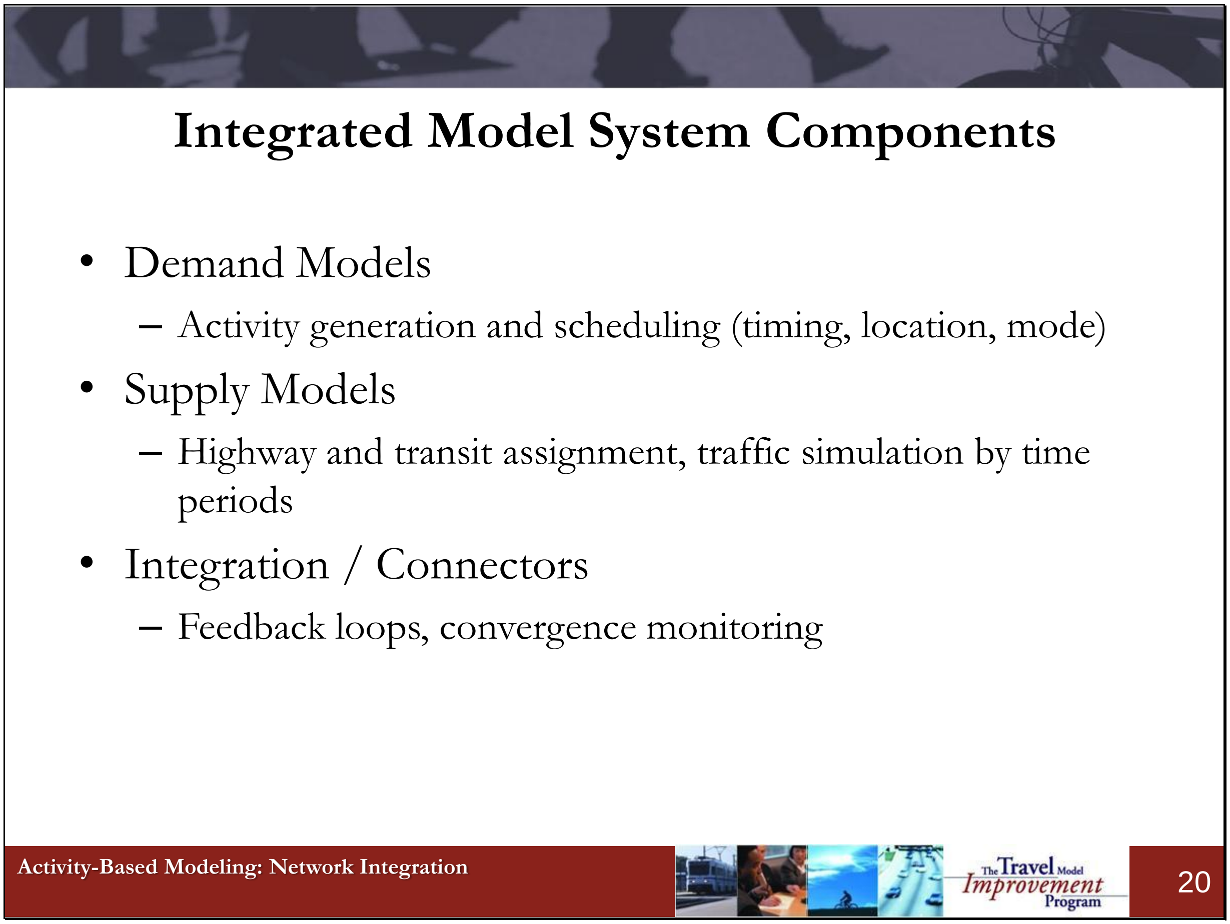


In order to ensure that the model is appropriately sensitive to the various alternative configurations, careful consideration must be given to the design of the demand model components, the supply/network model components, and the integration between the two.

On the demand side, ideally the model incorporates accessibility measures which influence longand medium-term choices as well as activity generation and these measures are sensitive to changes in accessibility by time-of-day and reflective of all modes. Given that a fundamental aspect of the project involves variations in mode availability, tolls, and fares by time-of-day, the demand model should incorporate a temporal resolution that is fine-grained enough to represent the policies as well as the changes in network performance by time-of-day provided by the network supply model. The demand model must also be able to distinguish between SOV and HOV alternatives given the different networks (and by extension, different network performance measures) associated with these alternatives, and might optionally include toll and notoll alternatives. It is also critical that the demand model incorporate a behavioral resolution that can reflect different sensitivities to congestion, tolls and fares depending on the traveler, travel purpose and other travel attributes.

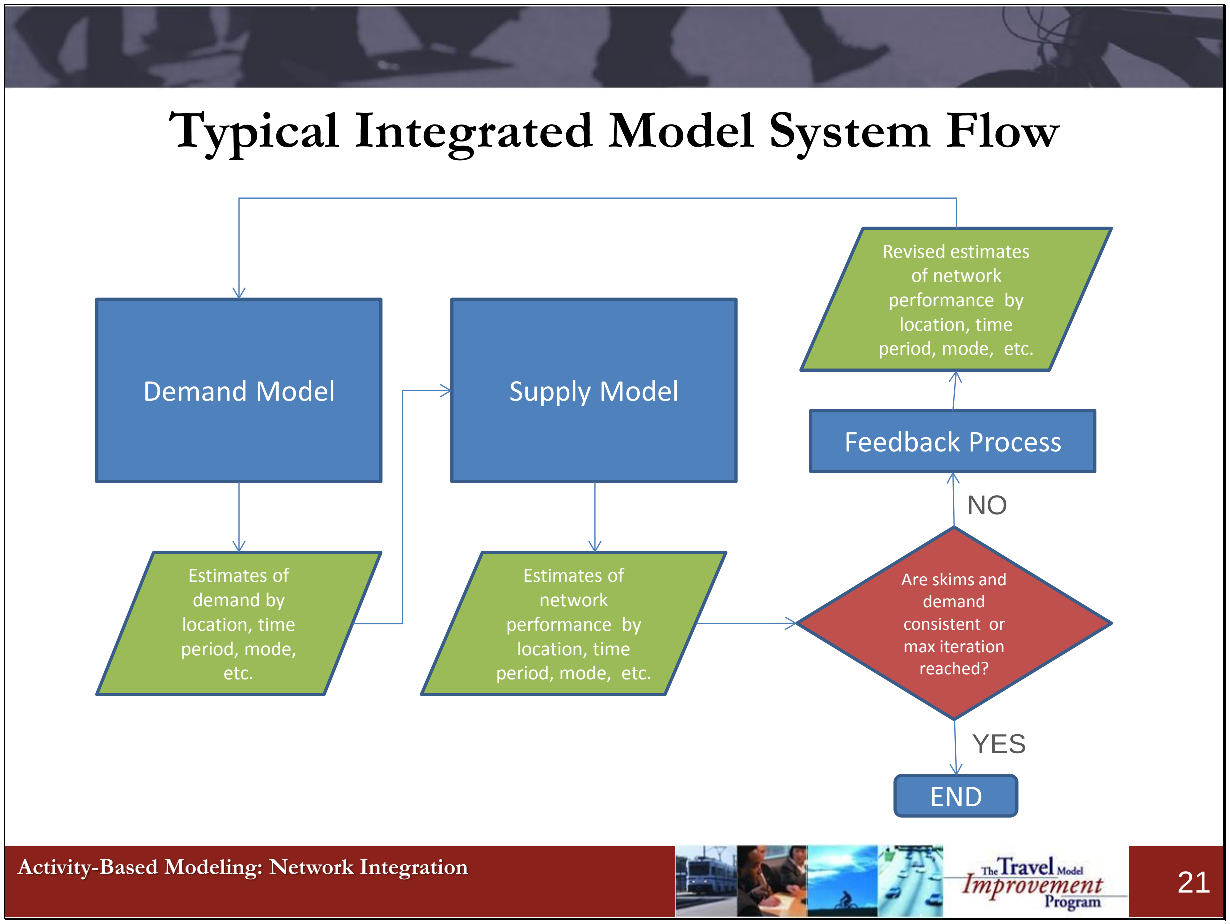
On the supply side, the roadway and transit networks should incorporate information about modal availability (such as HOV lanes) as well as about how the network configurations and costs change by time of day, consistent with the policies to be evaluated – will tolls or fares vary only by broad multi-hour time period, or will they vary by finer time periods such as individual hours? A key aspect of this is directionality, especially for transit transit networks need to be coded to reflect the true level of service provided by direction. In order to exploit the modal and time period information coded in the networks and provide relevant information to the demand model, it is also critical to ensure that the network assignment and network skim methods reflect the variations in times and costs by time-of-day, mode and potentially other dimensions such as value of time.

Finally, the core issues of integration also need to be considered – what information is being exchanged between the demand and supply components, and how are the demand and supply components interacting in an iterative feedback framework in order to ensure consistent and reasonable results? The demand model must provide information about travel demand that is sufficiently segmented by mode, time-of-day, traveler class and other attributes, while the supply model must provide information about network performance that is similarly segmented.



As the bridge scenario discussion illustrated, when considering how to achieve network integration, we need to consider three elements of the model system:

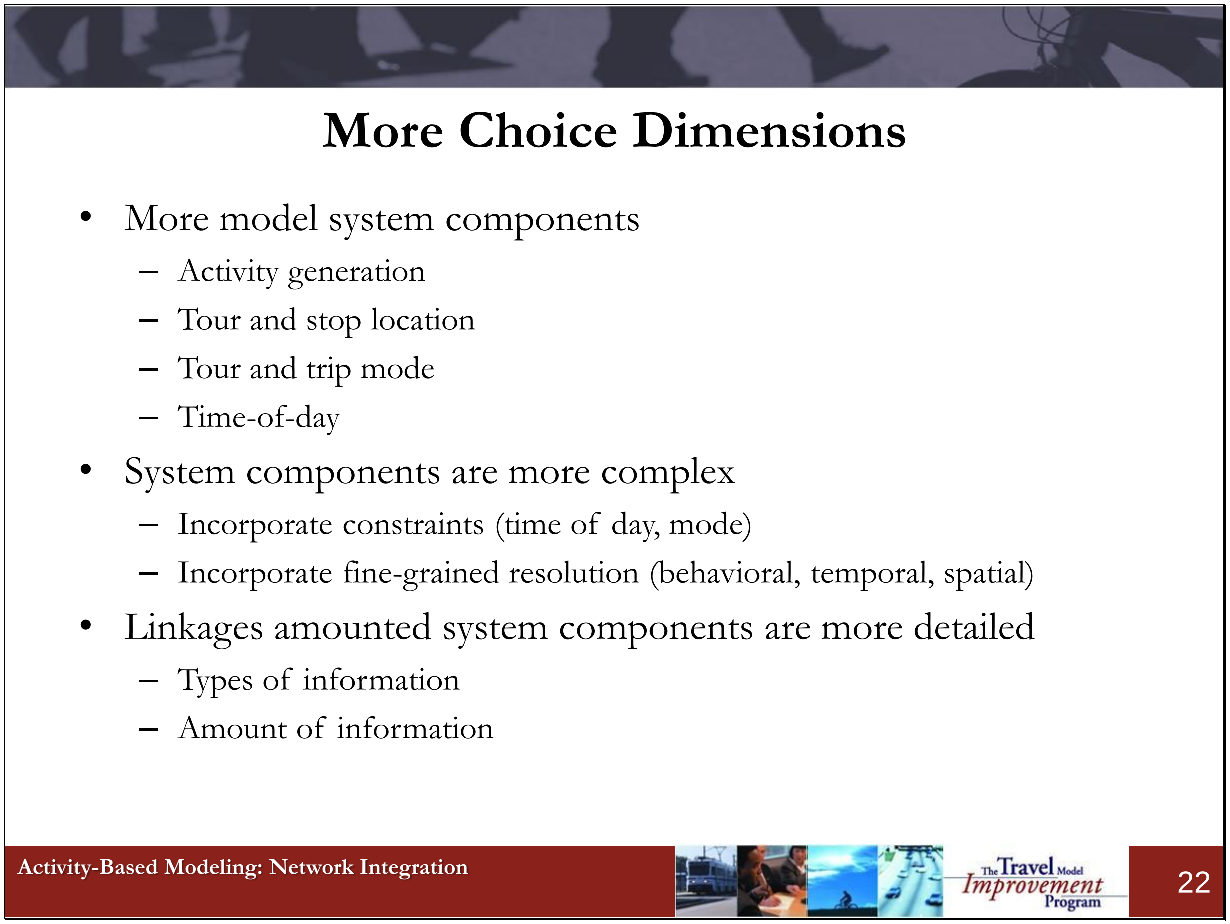
- The demand model which generates activities and predicts the location and timing of these activities as well as the mode of transport and which provides the required information to the supply model
- The supply model which assigns the demand generated by the activity-based demand model to roadway and transit networks using either static of dynamic assignment methods and which generates measures of transportation system performance or impedance for input to the activity-based demand model system; and
- The connectors which enable the feedback loops and "handshake" between the demand and supply components, and which may also assess convergence.



This figure illustrates the relationships amongst the three types of components in the integrated model system. Note that this figure is relevant regardless of whether the demand model is a more typical aggregate, trip-based model or a disaggregate activity based model. It illustrates that the demand model uses travel time and cost information in the form of skims, in addition to other attributes associated with travelers (such as income) and locations (such as the amount of employment) to predict activity-travel events.

The network supply models then apply this demand to roadway and transit networks to estimate volumes and associated times and costs. This new time and cost information is then used to develop updated skims. These new skims are then used to rerun the demand model to predict a revised set of activity-travel events and again this demand is assigned to roadway and transit networks to develop revised estimates of volumes, times and costs. The convergence of the model system to a stable solution is assessed, typically using measures that consider changes in the demand flows by geography or by changes in the skims, and if a pre-specified threshold is met, the process terminates.

If the threshold is not met, then the demand and network supply models are run again, convergence is checked, and the process repeats until either the threshold is met or the system reaches a maximum number of iterations.

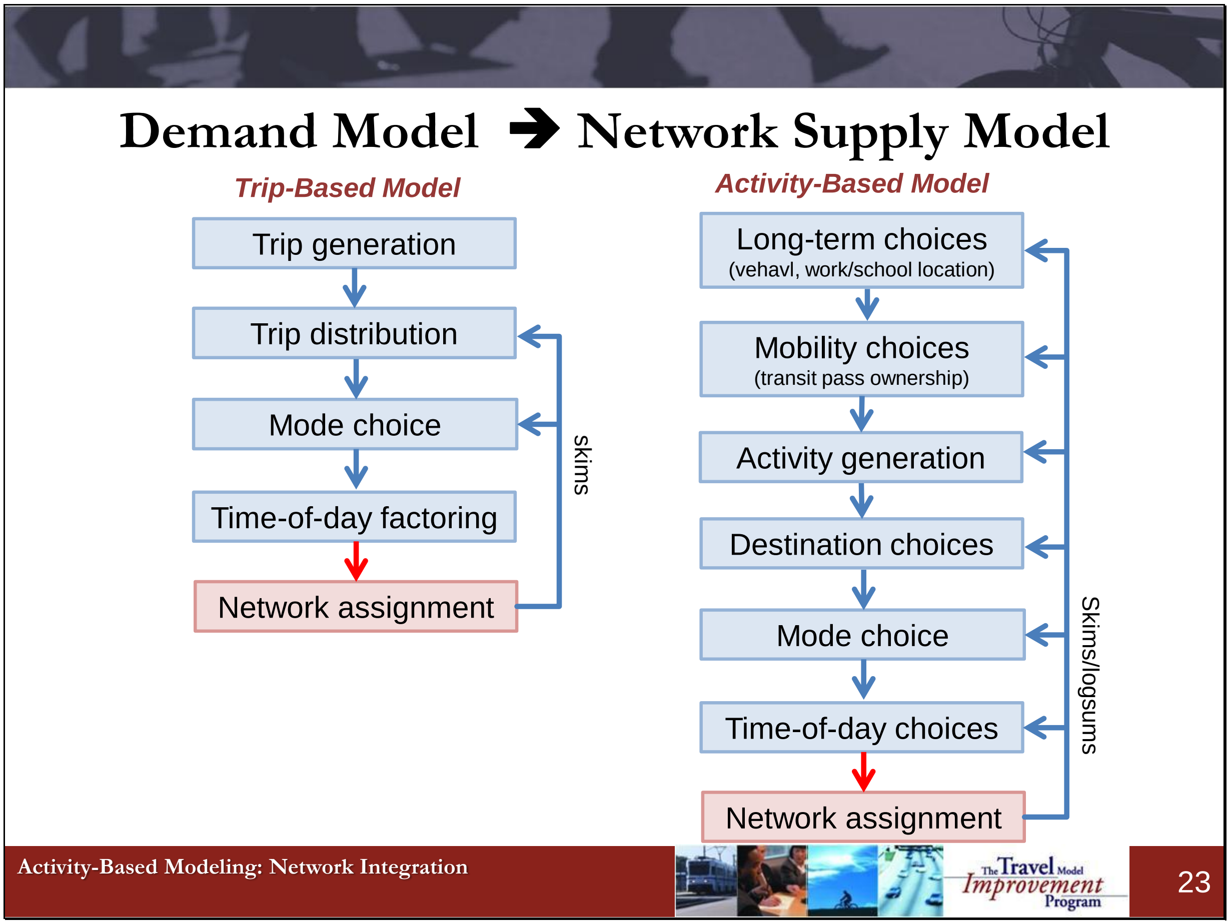


Activity-based model systems incorporate significantly more choice dimensions than traditional 4-step models. These additional dimensions are reflected both in the number of components that comprise the model system, the complexity of these components, and the type and amount of detailed information that is exchanged via the model linkages between the demand and supply components

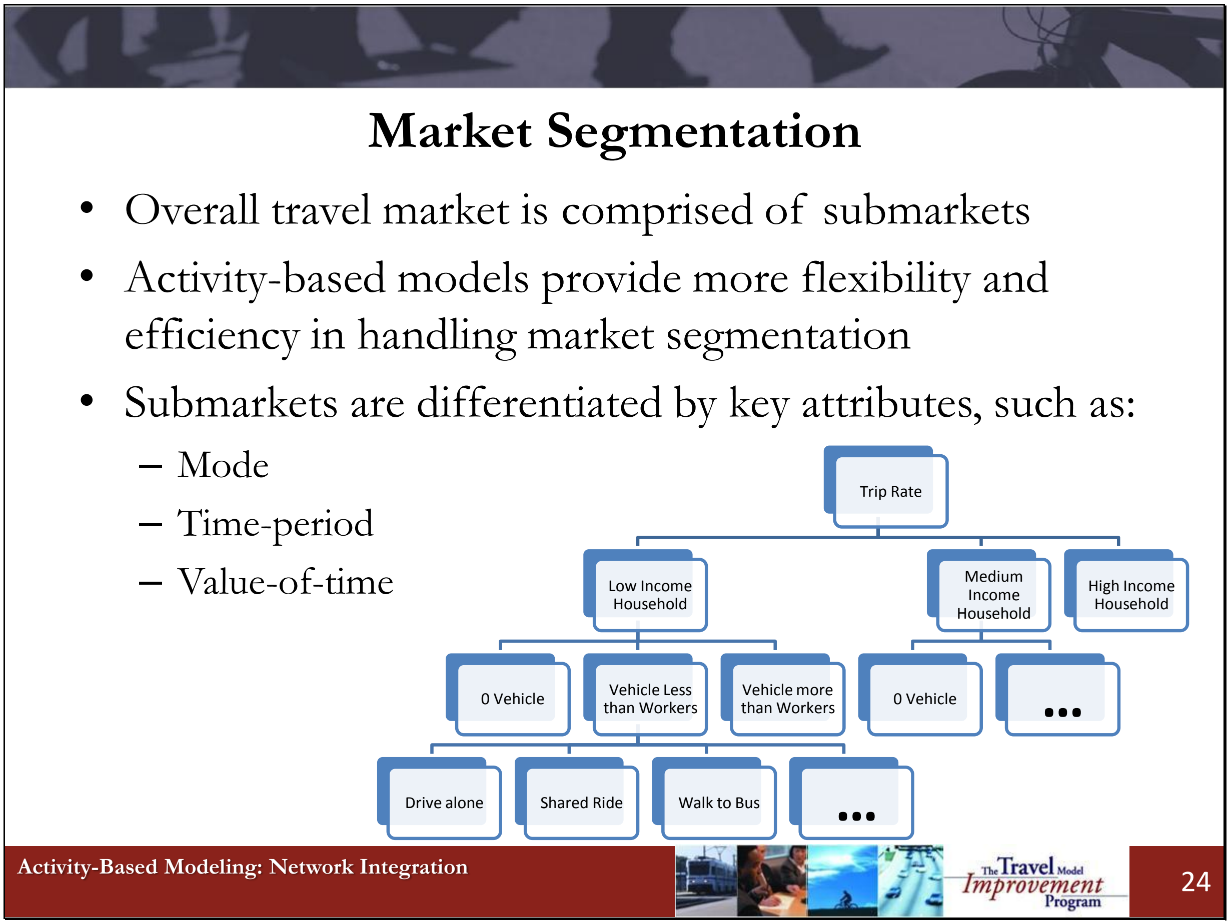
While there are a number of similarities between trip-based and activity-based models systems (for example, both types of models include mode choice components), activity-based model systems typically incorporate more model system components. As prior webinars have illustrated, some of these additional components provide more detailed sensitivity to choice dimensions, such incorporating distinct models for predicting the primary destinations for tours as well as for predicting the likely locations for intermediate stops on these tours. Other components provide sensitivities to choice dimensions that are often not embedded within a traditional trip-based model system, such as explicit models of time-of-day.

Activity-based model components are also typically more complex than traditional trip-based model systems. For example, AB model components may explicitly incorporate information about constraints, such as the time windows available to individuals to participate in activities, or the maximum distance than can be travelled within an available time window. And of course, activity-based models systems employ higher levels of behavioral, temporal and even spatial detail, using individual persons and householders as decision-makers, representing time in small time slices such as one-hour, half-hour, or even continuously.

The fine-grained behavioral, temporal, and spatial resolution of activity-based demand models and the complexity of the models that exploit this detail require that significant consideration be given to the coding the linkages between demand model system components. There are two primary linkages in an activity-based model system: from the demand model to the network supply model, and from the network supply model to the demand model.



This slide shows parallel structures of trip-based and activity-based demand-supply linkages. The primary components of a traditional trip-based model system – generation, distribution, mode choice – have analogs in the activity-based model system. The first of the two primary linkages in the model system that we will consider is the linkage from the demand model to the network supply model. As in a trip-based model system, the primary information that is being conveyed are estimates of travel demand. Careful consideration needs to be given to the type and format of how this travel demand information is conveyed.

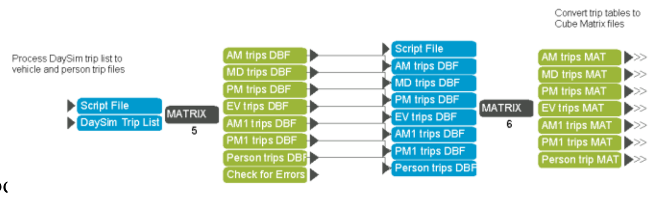


Let us first consider the issue of market segmentation. Market segmentation refers to the treatment of the overall travel market as comprised of a series of smaller markets that are differentiated by some key attributes. For example, referring back to our bridge expansion example, we can consider the transit segment (those travelers who chose to use transit) as distinct from the auto segment (those travelers who chose to drive alone or share rides). In our network supply model we want to treat these two different market segments separately – we allow transit users to find the best transit path available to them and also prevent them from driving. Conversely, we want to make sure that travelers who chose to drive alone or share rides don't end up using transit instead. Note that we have assumed in this example that our demand model determines the mode (or sub-mode) that a traveler chooses.

Market segmentation applies not only to modal choices, however, but may also extend to other choice dimensions as well, such as time-of-day, value-of-time, or purpose. From a network integration perspective, one of the key advantages of an activity-based model framework is that it allows tremendous flexibility in how we define market segments – both within the demand model, within the network supply model, and in the linkages between these two components. In a trip-based model system we have less flexibility to define market segments, primarily due to the fact that as we increase the number of market segments there is a combinatorial effect that may lead to the proliferation of a huge number of segments, each of which may require the maintenance of multiple matrices regardless of how "big" the market segment truly is.

Activity Trip Lists & Segmentation

- Trip tables not produced until assignment step, more flexibly specified
- Trip lists may be converted to trip tables by aggregating over multiple dimensions
  - Time of day
  - Activity types
  - Person types
  - occupancy class
  - Transit submode /access moc
  - Other… EZ pass, transit and parking pass holders, etc.



id	tour_id	hhno	pno	day	tour	half	tseg	tsvid	opurp	dpurp	oadtyp	dadtyp	opcl	otaz	dpcl	dtaz	mode	pathtype	dorp	deptm
1	1	1	1	1	1	1	1	0	0	5	1	4	2	101	4349	513	4	1	2	787
2	1	1	1	1	1	2	1	0	5	5	4	4	4349	513	3258	434	4	1	2	886
3	1	1	1	1	1	2	2	0	5	0	4	1	3258	434	2	101	4	1	2	979
4	2	2	1	1	1	1	1	0	0	1	1	4	2	101	37564	4352	3	1	1	399
5	2	2	1	1	1	2	1	0	1	0	4	1	37564	4352	2	101	3	1	1	1037
6	3	3	1	1	1	1	1	0	0	1	1	2	13	101	203	110	3	1	1	488

In contrast to the proliferation of matrices and all the associated computation and storage challenges that results from increased market segmentation in a traditional matrix-based and trip-based model system, activity-based model systems support much more flexible market segmentation due to the "list-based" nature of the activity-based demand model simulation. One of the outputs from the activity-based demand model is a list of trips that contains all the detailed spatial, temporal, behavioral, and socio-demographic information associated with the trip and traveler.

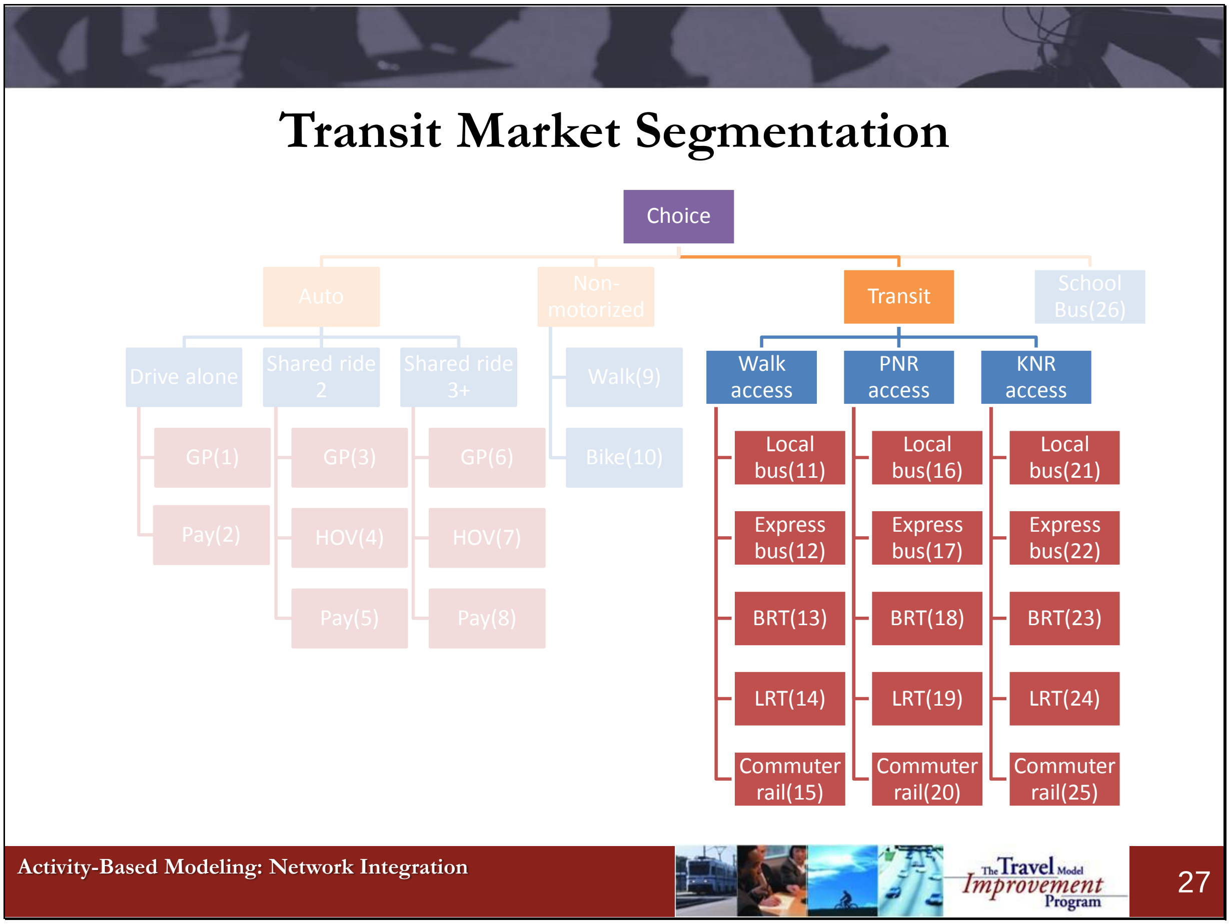
When assigning travel, most network supply models require as input a set of origin-destination matrices segmented by mode and time-of-day. The detailed information contained in the list-based activity-based demand model can be aggregated to virtually any market segmentation. For example, if a user wanted to transition from using a three hour peak period assignment to 3 separate 1-hour peak hour assignments or to assign by value of time class, they only need to revise the aggregation process and make associated changes to the network supply model assignment and skim scripts.

This figure provides an example of the segmentation of the auto market. In this scheme, the auto travel market is subdivided into a total of 8 market segments that correspond to distinct alternatives:

- 1) Represents drive alone travelers using general purpose lanes or facilities
- 2) Represents drive alone travelers using toll or pay lanes or facilities
- 3) And 6) represent shared ride travelers using general purpose lanes or facilities
- 4) And 7) represent shared ride travelers using HOV lanes or facilities and
- 5) And 8) represent shared ride travelers using toll or pay lanes or facilities

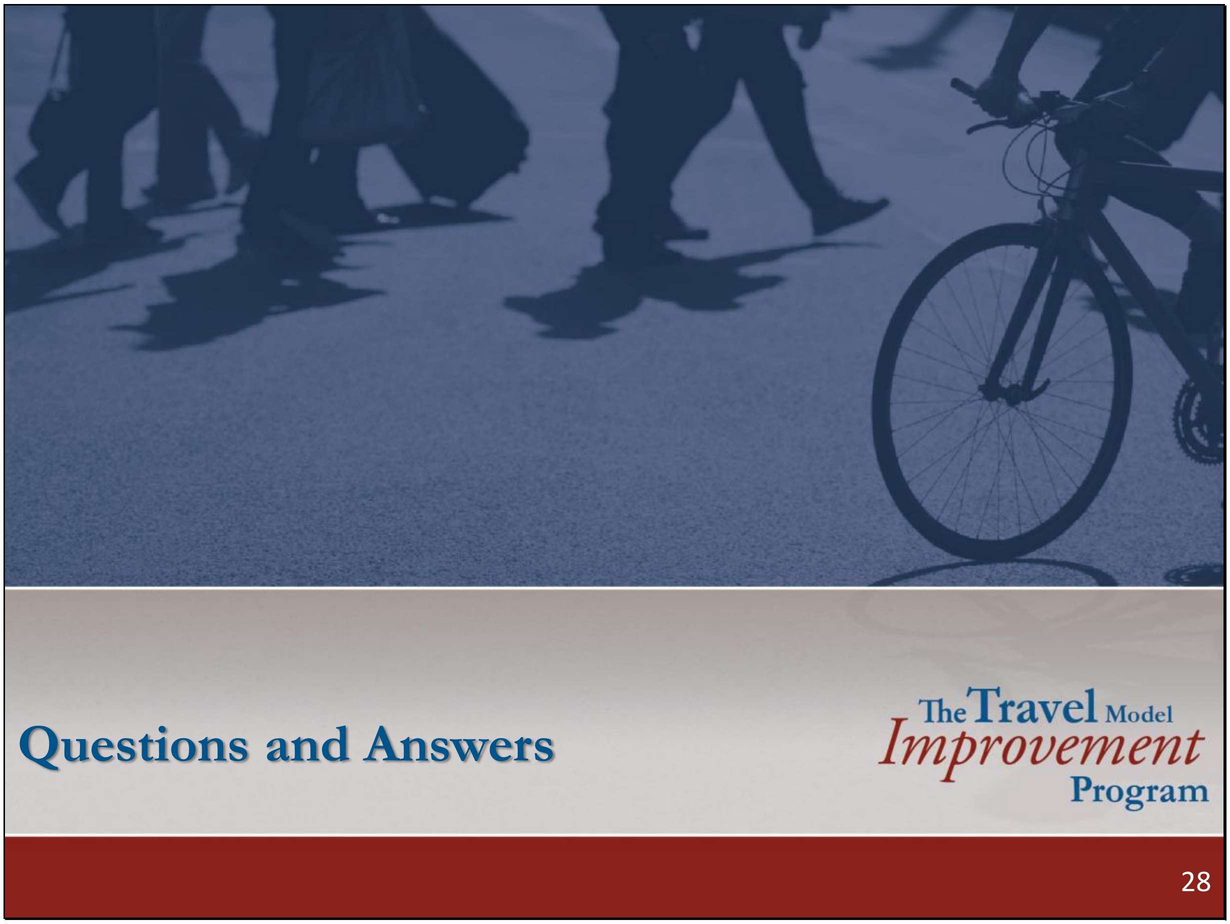
We treat these as separate choices in the demand model because they are associated with different time and cost measures. The drive alone pay alternative may have a higher monetary costs associated with it, but may have lower travel times. Depending on the individual traveler and decision making context, a travel may choose to select of these modes.

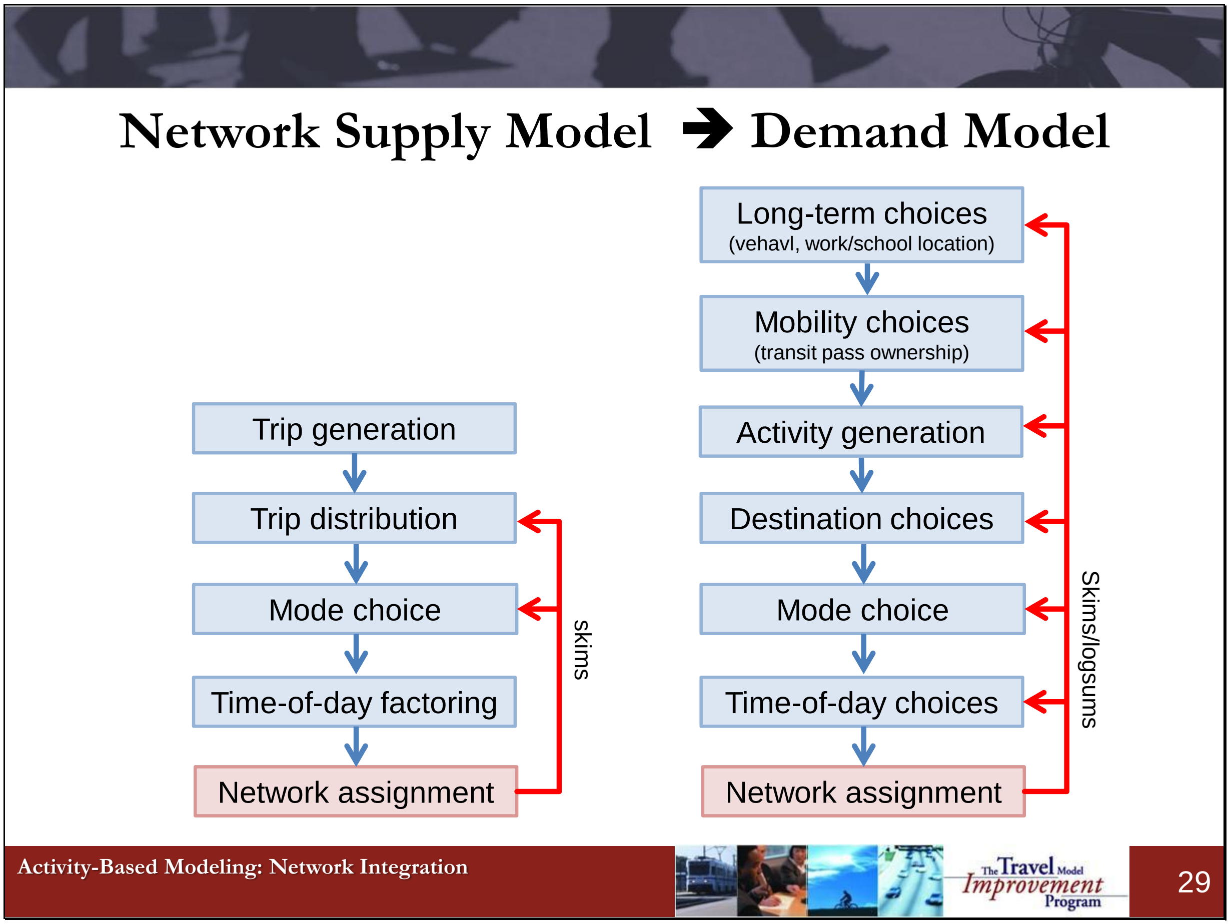
In establishing the integration with the network supply model, we want to consider this as a separate market segment because each choice may be subject to different opportunities or constraints. For example, if the mode chose for a given trip is “drive alone-pay” then when we assign this using the network supply model we can allow the trip to use pay/toll facilities as well as general purpose lanes. However, we also want to restrict this trip from using HOV lanes.



This figure provides an example of the segmentation of the transit market. In this scheme, the transit travel market is subdivided into a total of 15 market segments or alternatives. These 15 market segments represent the combination of 5 primary transit modes (local bus, express bus, BRT, LRT, and commuter rail) and 3 transit access modes (walk, park-and-ride, and kiss-and-ride). Again we treat these as separate choices in the demand model because they are associated with different time and cost measures, and potentially availability.

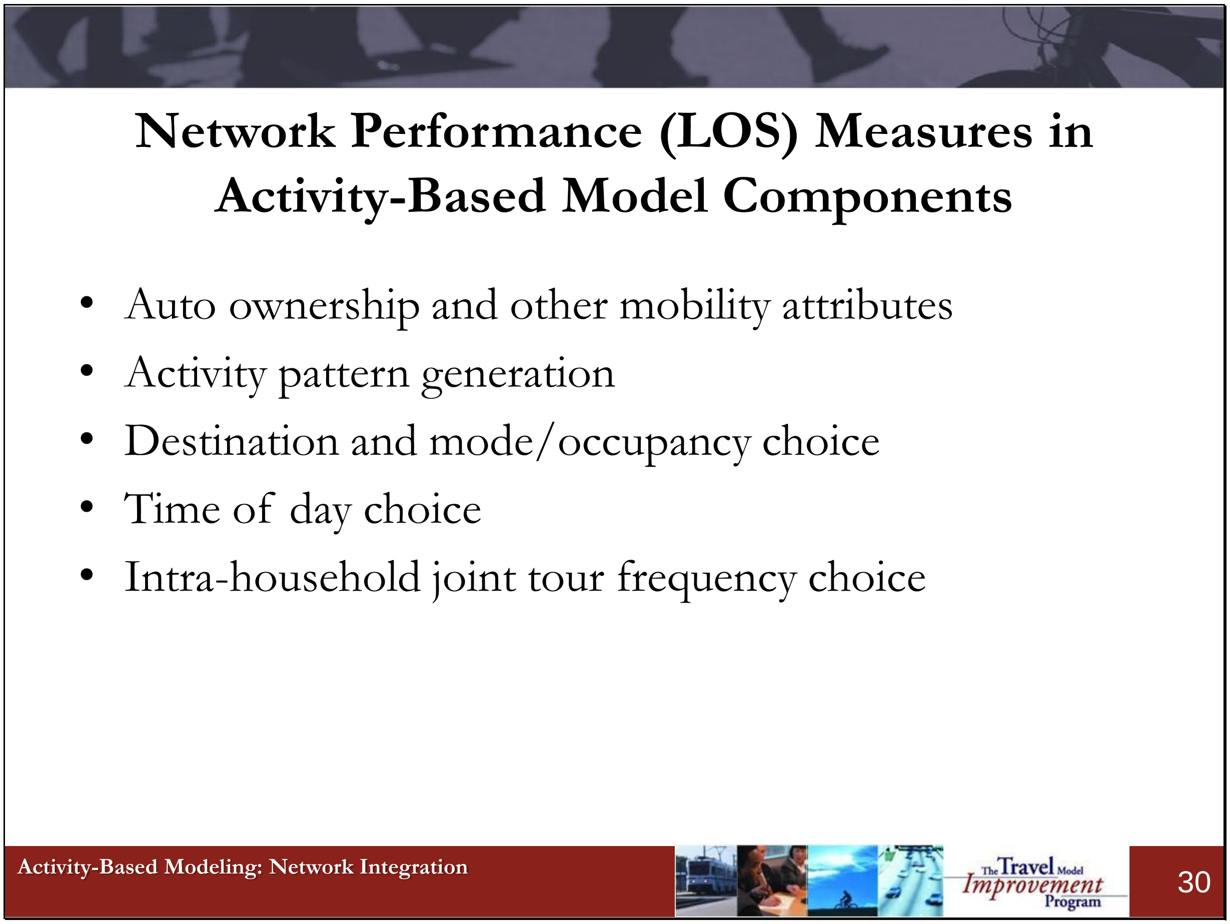
In establishing the integration with the network supply model, we want to consider each of these as a separate market segment when assigning demand and generating skims because each choice may be subject to different availability or constraints. For example, if the mode chosen for a given trip is "walk access-LRT" then when we assign this using the network supply model we can allow the trip to use LRT routes, and potentially other routes that are used to access LRT, such as local bus; however, we probably also want to restrict this trip from using commuter rail to reflect the hierarchy of transit sub-modes typically employed in representing transit services.


Questions and Answers
The Travel Model Improvement Program
28



This slide shows parallel structures of trip-based and activity-based supply-demand linkages. The second key linkage in the activity-based model system that we will consider is the linkage from the network supply model back to the demand model.

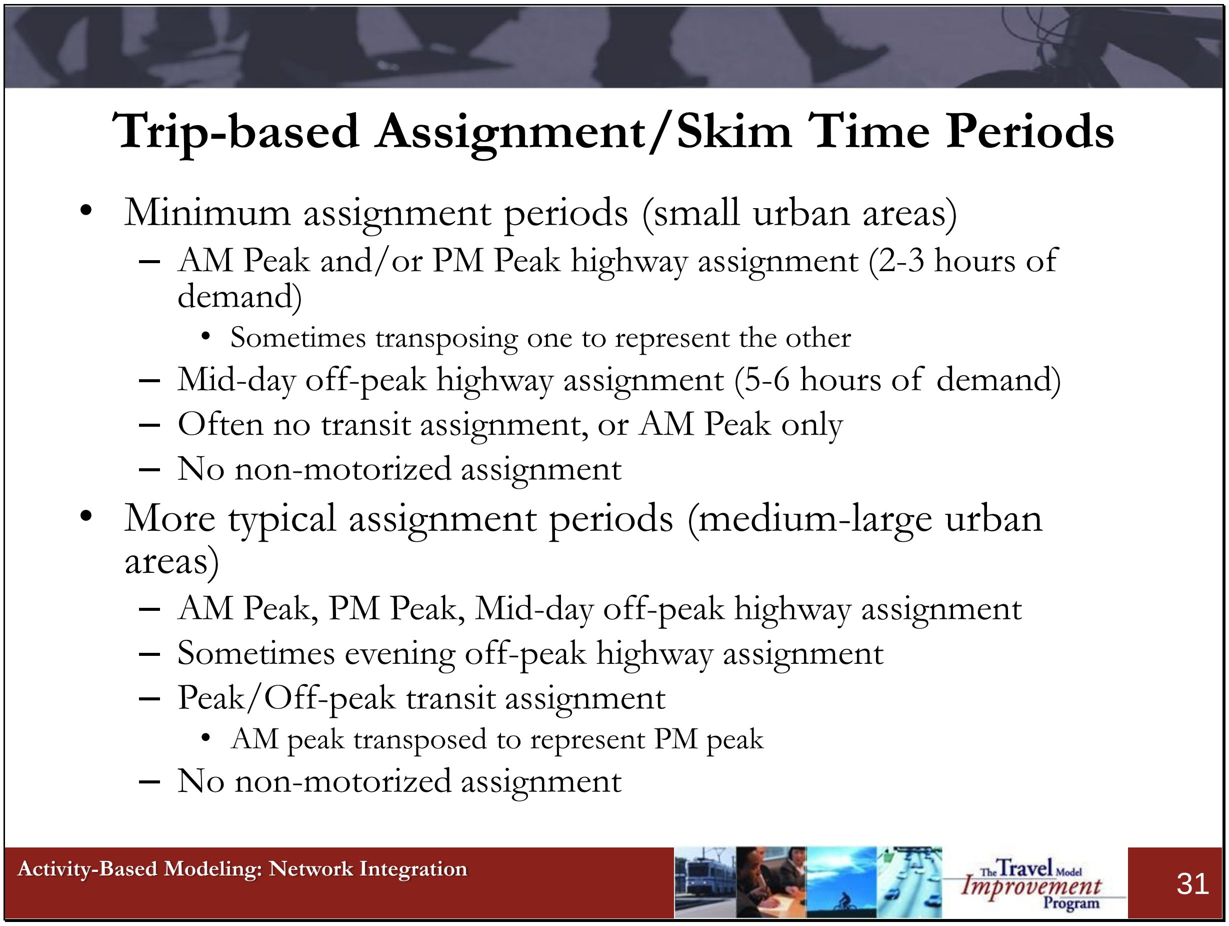
As in a trip-based model system, the primary information that is being conveyed are estimates of network performance such as travel times and costs, often referred to as network “skims”. This feedback of skims is critical to achieving the converged or stable model results that are necessary for the model to be useful as an analytic tool. As with the demand model to network supply model linkage, careful consideration needs to be given to how this network performance information is fed back and incorporated into the activity-based demand model component.



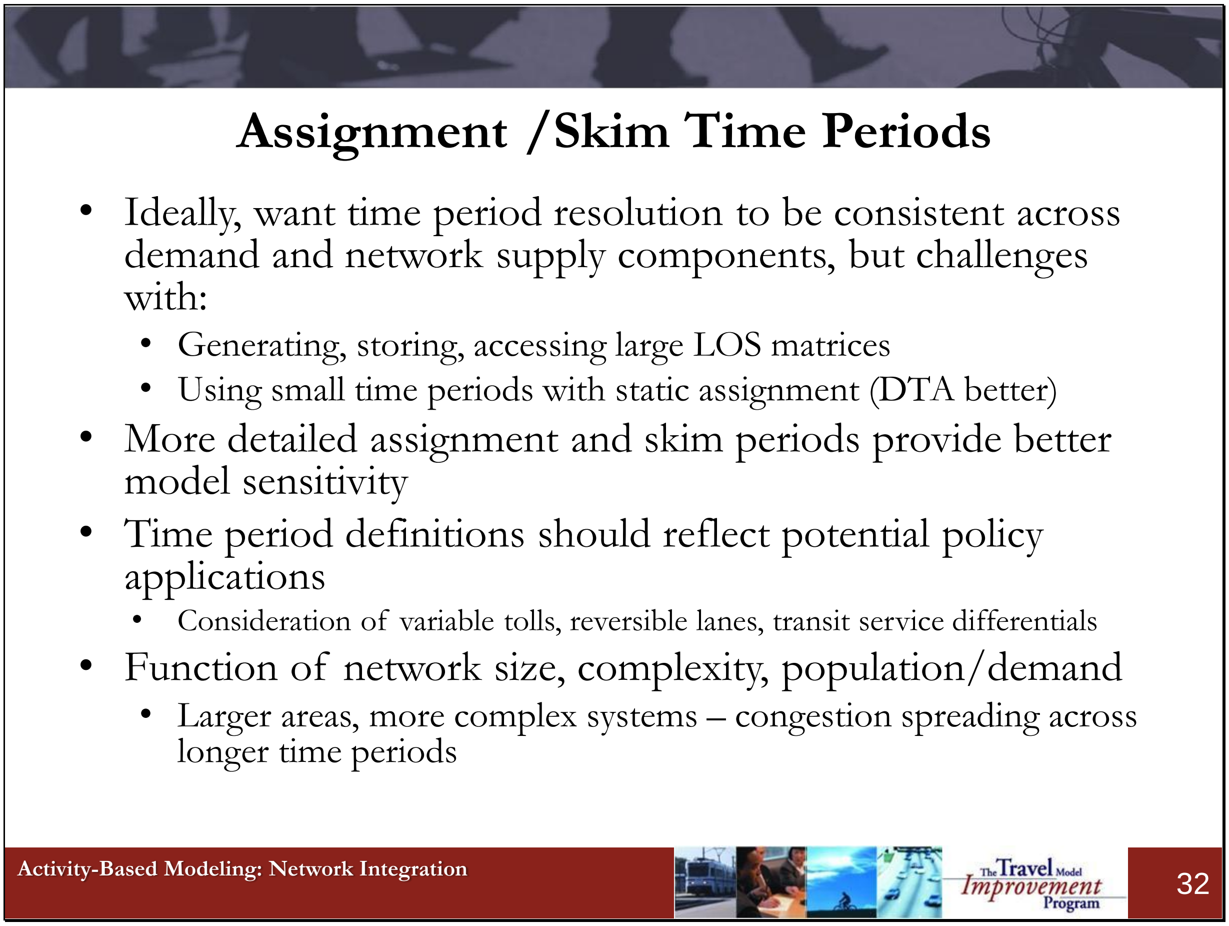
Network performance measures (or "level of service" variables) as well as accessibility variables that are calculated using these measures in combination with land use attributes, appear in virtually all subcomponents of activity-based travel demand models. For example:

- Auto ownership models incorporate information on travel times to workers' primary work destinations by different modes, and may also incorporate either work-based or home-based accessibility measures;
- Activity pattern generation models incorporate home based accessibility measures, potentially reflecting differences in accessibility by time of day to key destinations such as retail employment locations;
- Destination choice models include simple distance measures, as well as more comprehensive log-sum measures which capture the accessibility between two zones across all modes serving the zone pair. These measures are often used in combination with other attributes, such as travelers' household income;
- Tour departure time models reflect round trip travel times; and

- Intra-household joint tour frequency models have incorporated retail accessibility measures.



Trip-based models often employ a much coarser representation of network performance by time of day. For example, in smaller urban areas it is not uncommon to perform a single peak period and a single off-peak period assignment for highway, to perform only limited transit assignments (such as the AM peak only), and to provide no non-motorized assignment. In larger urban areas, trip-based models may incorporate more a few, such as both and AM and PM peak period assignment, distinct midday and evening assignments, and to perform transit assignments using these same resolutions.



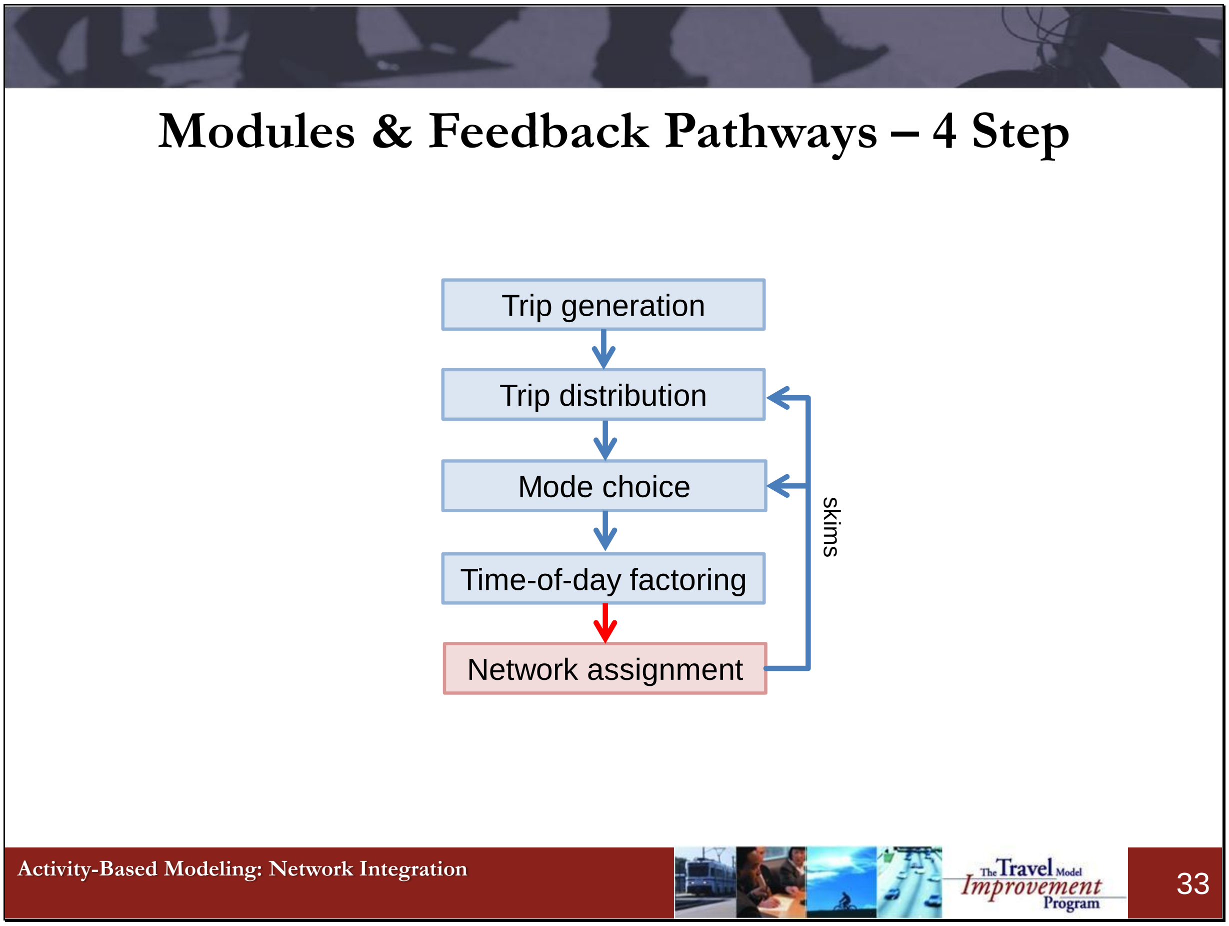
Market segmentation does not simply apply to the grouping of demand by modes of travel. One of the primary other types of market segmentation used in both traditional trip-based models as well as within activity-based models is segmentation by time-of-day. And this market segmentation affects the design not only of how demand information is transmitted to the network assignment and skimming models, but also how network skim information is transmitted back to the activity-based demand model.

Note that this discussion considers segmentation by time-of-day in the context of the demand model-network supply model integration. Specifically, what time periods are used when demand is assigned using the network supply model, and what time periods are used when skimming network performance measures for input to the demand model? This segmentation is distinct from, but related to, the temporal resolution of the demand models themselves – that is, most activity-based demand models function using a temporal resolution that is much finer grained (hours, half hours, or even finer) than the temporal resolution of the network performance indicators input to the models. Achieving consistency in temporal resolution across demand and supply models is a key current research topic.

Ideally, in order to have the greatest sensitivity in the integrated demand-network supply model system, we would input to the demand model information about network performance generated by the supply model that is consistent with the temporal resolution of the demand model, and we would assign this demand to model networks using this same temporal resolution. However, theoretical and practical concerns necessitate simplification – the runtimes and hardware requirements associated with generating, storing, and accessing network skims for detailed time periods quickly become onerous, and the using static assignment methods for short time periods may be problematic. Some of these issues may be addressed by using DTA, which we will discuss later in this presentation.

Practically, we need to consider a few issues:

- Our assignment time periods and assignment skim periods should be consistent;
- More detailed assignment and skim periods provide better model system sensitivity, particularly to changes by time of day and mode;
- Time period definitions should reflect potential policy applications – it won't be possible to test the impacts of hourly changes in tolls, fares, reversible lanes unless information at this level of temporal detail can be generated by the network supply model for input to the demand model; and
- Time period definitions should reflect the regional context – larger regions with more complex transportation systems may be more subject to phenomena such as peak spreading, or may have more diverse modal alternatives with service differential by detailed time of day.

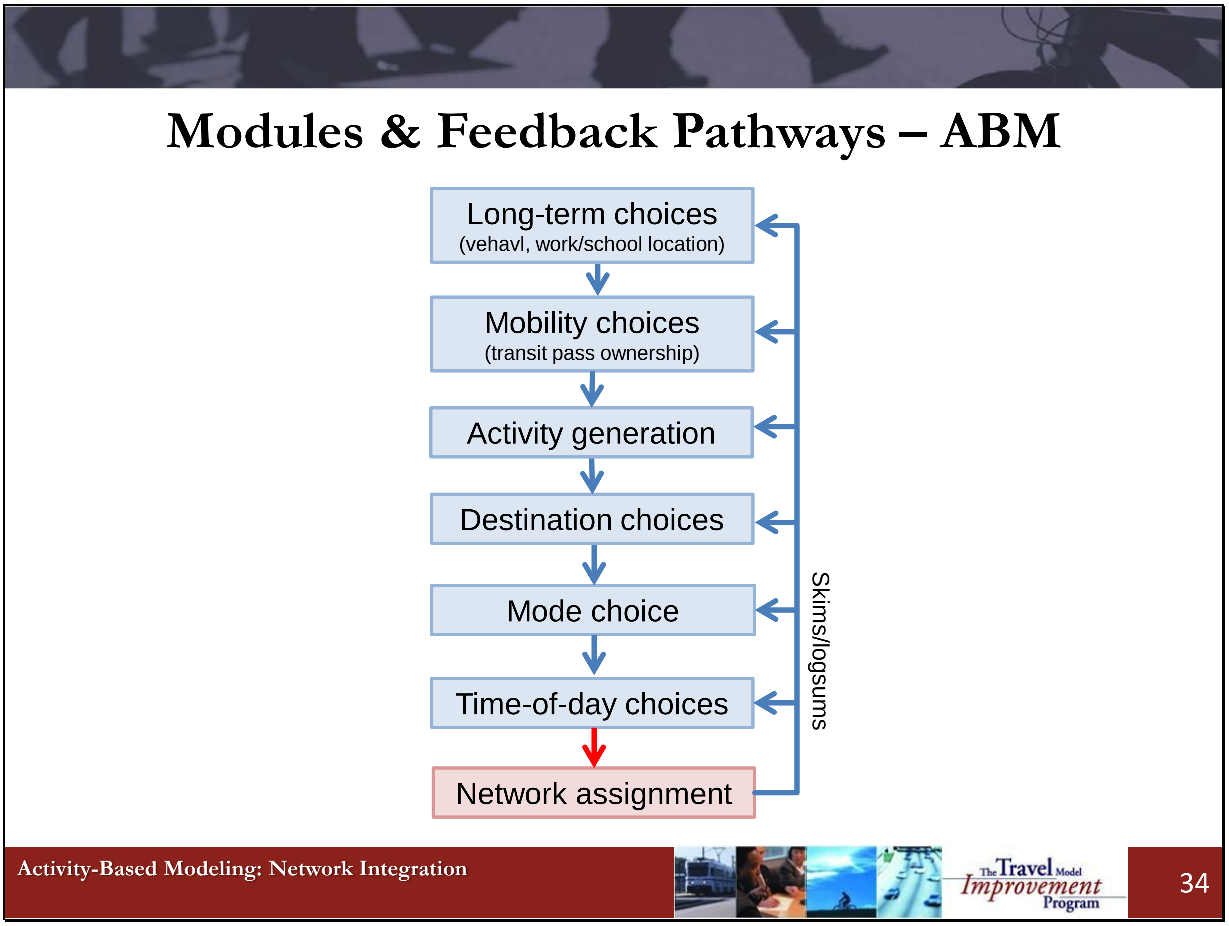


Most typical 4-step travel model systems do not incorporate explicit time-of-day models. Rather, a set of fixed factors (potentially segmented by purpose and mode) are applied post-mode choice that transform daily production-attraction format trip matrices into origin-destination trip matrices by time period.

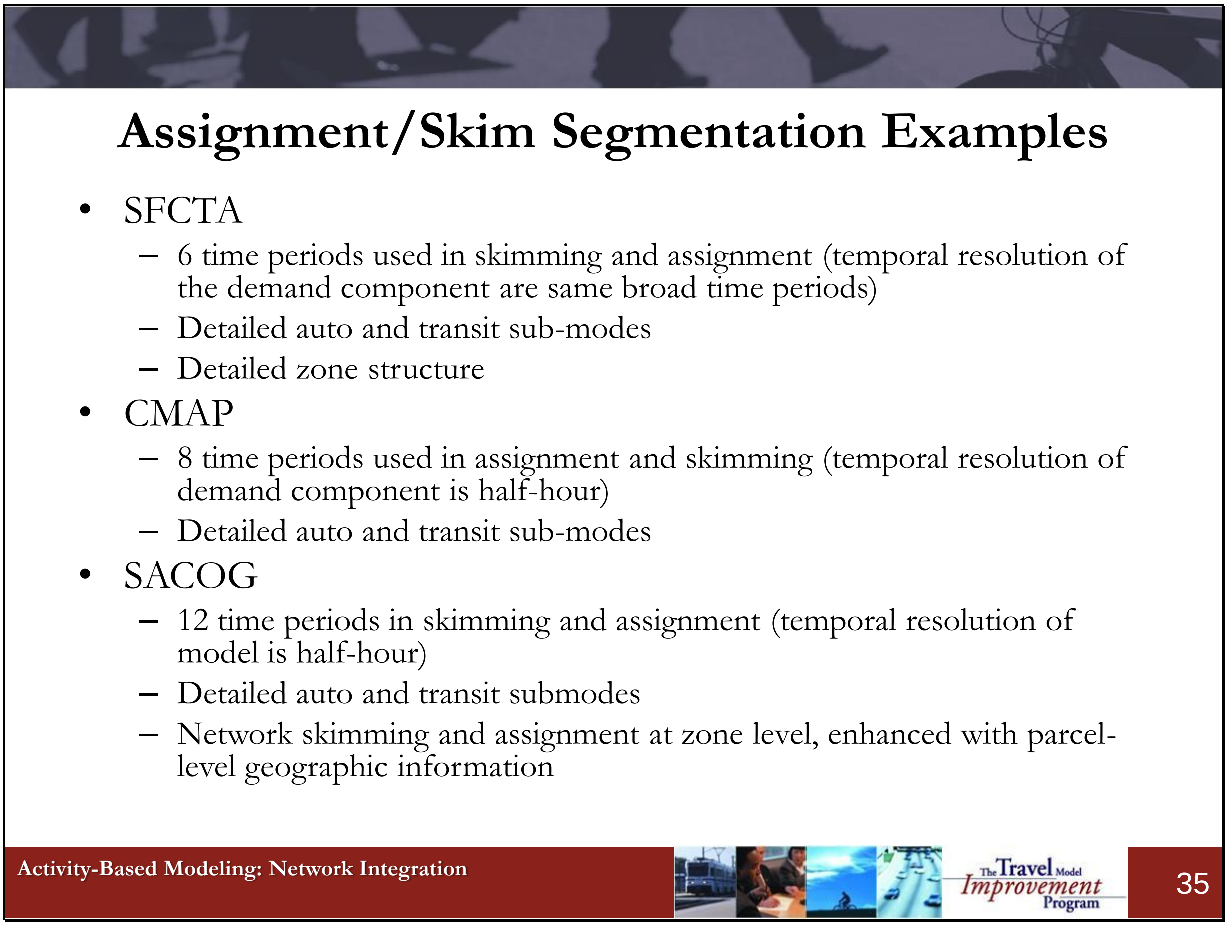
Applying time-of-day factors to the trip tables at this point in the model system is a simplification that makes it possible to generate assignment results by time-of-day, but without requiring the proliferation of matrices that would result from incorporating time of day choice models, or even from applying fixed time of day factors earlier in the model stream.

However, the use of time-of-day factors represents a significant compromise in the sensitivity of the model system. For example, the model would be unable to respond to the time-of-day changes that might result from the expansion or reduction of capacity in a congested corridor. The model would also not be sensitive to the fact that as congesting increases, travelers start to use the "shoulders" of the peak – known as peak spreading. And perhaps most significantly, there is no information on how these factors should change in the future given more demand. In this last example, the use of fixed base year factors in the future year might significantly over-estimate the amount of congestion encountered by travelers, and thus lead to unrealistic responses by other model system components.

Some trip-based models do incorporate peak spreading models that begin to capture some of the sensitivity of travelers to changing the timing of their trips. However, such features are not "typical" components of 4-step trip-based model.



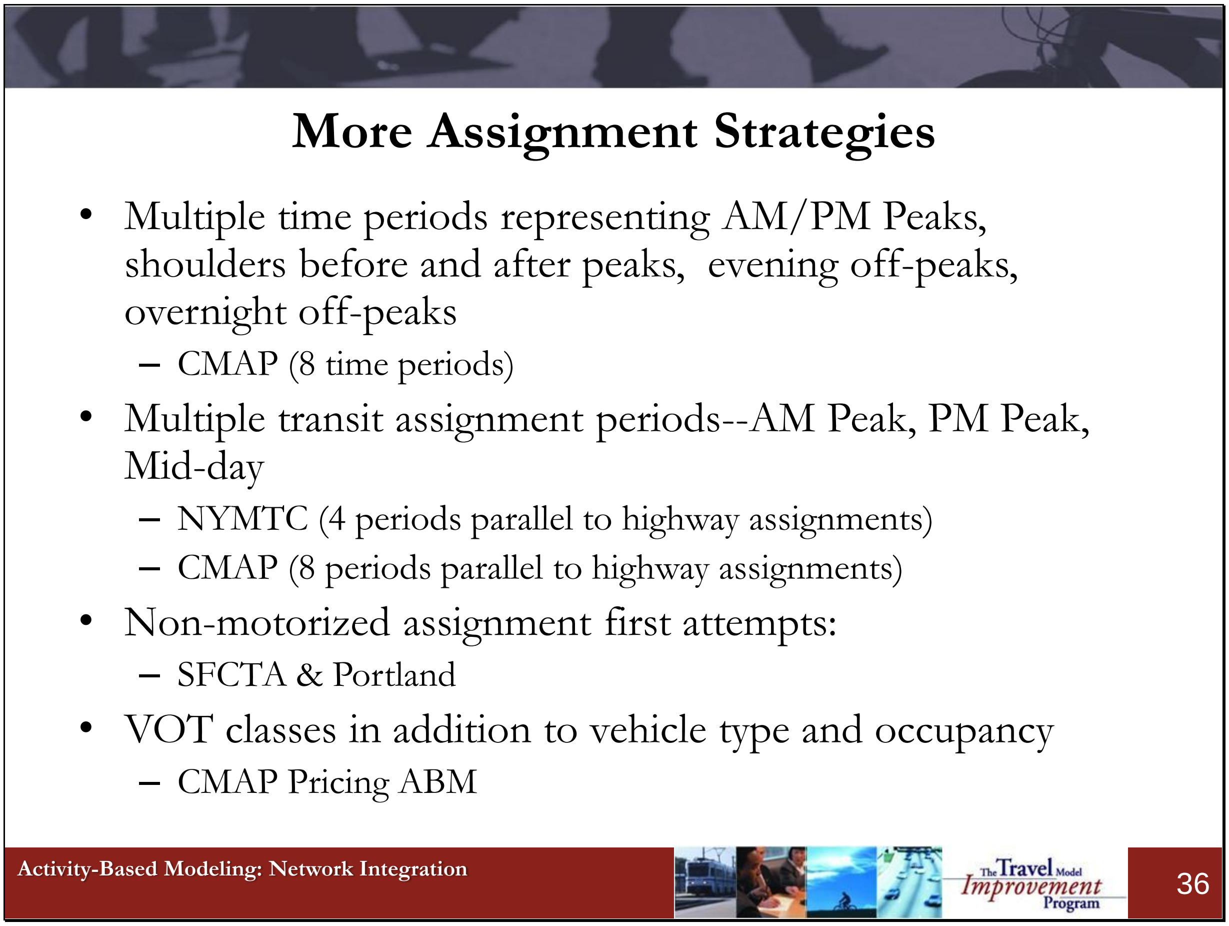
In contrast to trip-based models, most activity-based models employ more detailed time period information when integrating the demand and network supply components of the model system. Some of the earliest activity-based models systems implemented in the United States used relatively aggregate time periods for skimming and assignment, even when the demand models operating using quite detailed time-of-day models.



In contrast to trip-based models, most activity-based models employ more detailed time period information when integrating the demand and network supply components of the model system. Some of the earliest activity-based models systems implemented in the United States used relatively aggregate time periods for skimming and assignment, even when the demand models operating using quite detailed time-of-day models.

For example, the MORPC demand model uses 1-hour time periods when generating and scheduling activities, but only employs two time periods when feeding back skim information to the demand model. In contrast, the SFCTA integrated model system uses a consistent set of time periods for generating and scheduling activities, and for network assignment and skimming, but these time periods are much broader than one hour. The recent updates to the SACOG model have resulted in an implementation in which the demand model uses half-hour time periods for generating and scheduling activities, and uses 12 time periods for network assignment and skimming (hourly during the peaks, and broader time periods during the midday and evening/night).

All of the models described above incorporated fairly detailed auto and transit sub-model alternatives in the demand model, and an analogous market segmentation in the demand and network supply model linkages. In a sense, we can also consider the representation of space in the model system as a type of geographic segmentation.



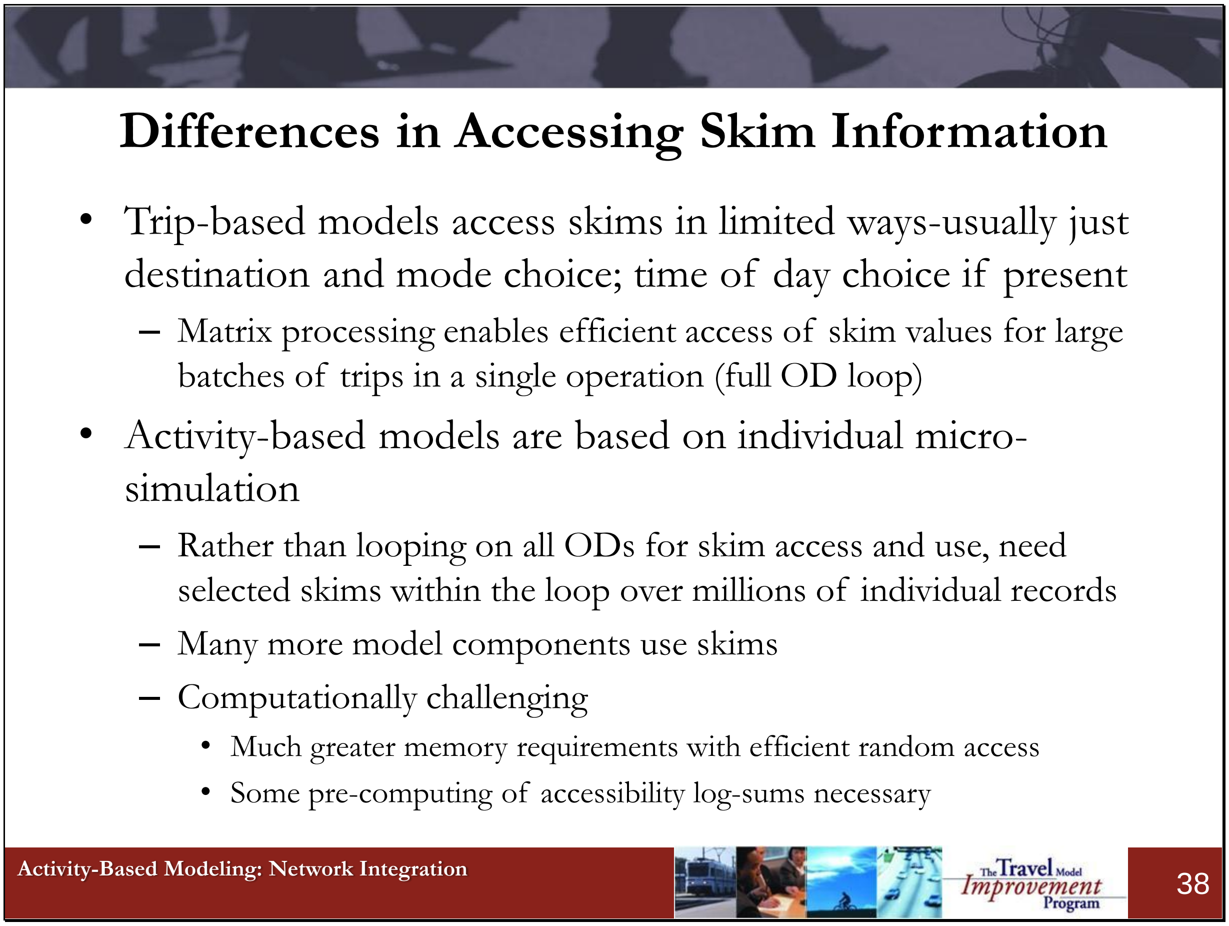
In general, there is a pronounced move towards incorporating greater levels of temporal detail in both roadway and transit assignment and skimming, as evidenced by recent work in Chicago, New York, Sacramento, and other regions.

In addition to the detailed segmentation by time of day, some advanced activity-based demand and network supply model integration efforts are incorporating more advanced assignment and skimming approaches that included non-motorized modes such as bikes, or that include roadway assignments and skimming that incorporate value-of-time segmentation to capture different time and cost tradeoffs.

CMAP Multi-Class Assignment Classes

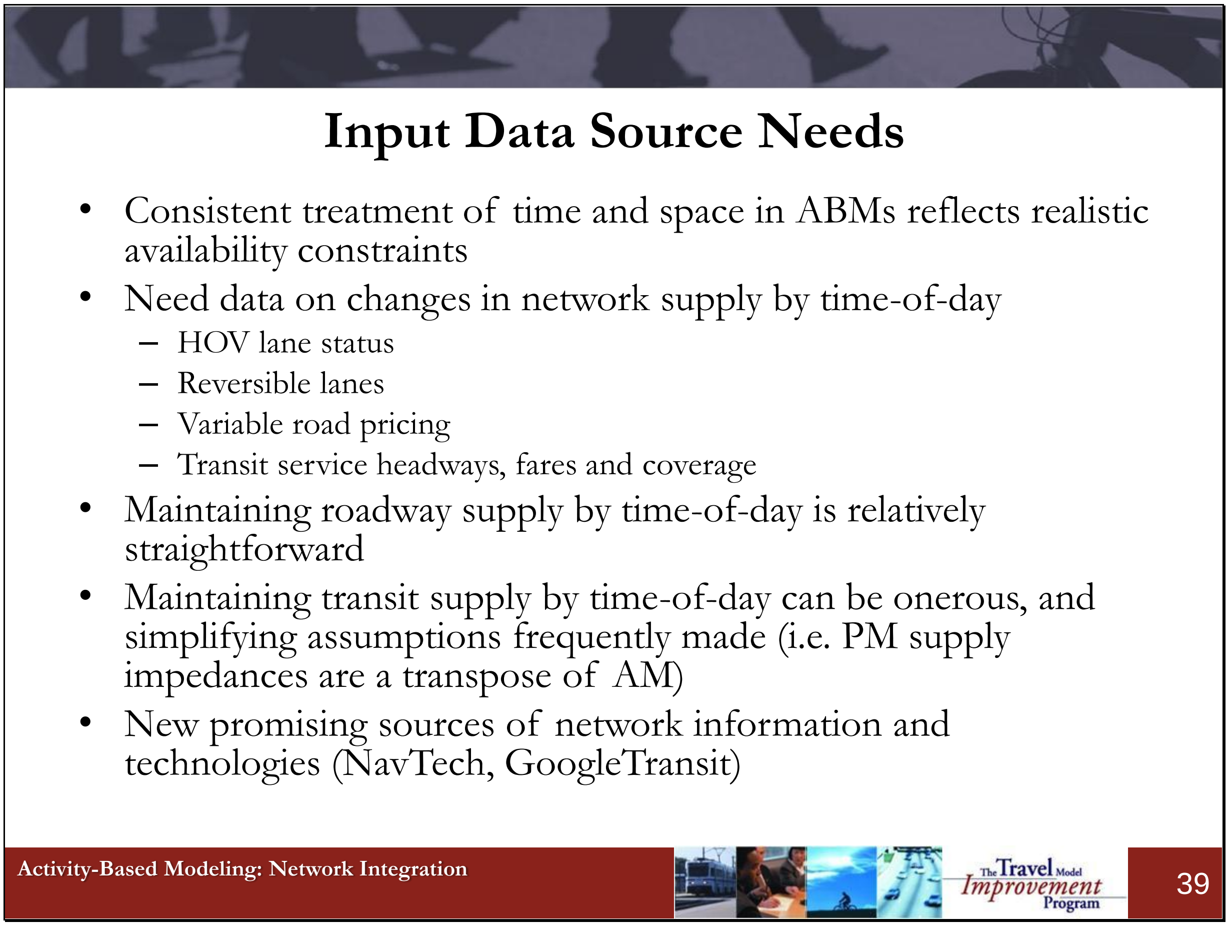
Vehicle Type & Value-Of-Time	Non-toll SOV	Non-toll HOV2	Non-toll HOV3+	Toll SOV	Toll HOV2	Toll HOV3+
Auto + external + airport low VOT	1	3	5	2	4	6
Auto + external + airport high VOT	7	9	11	8	10	12
Commercial	13			14		
Light truck	15			16		
Medium truck	17			18		
Heavy truck	19			20		

This is an example of a multi-class assignment setting use for the Chicago activity-based model. After addressing vehicle types, occupancy categories, and value of time categories at least for the most important classes it results in 20 classes. It is difficult and computationally onerous to add more details in this aggregate setting. Individual micro-simulation DTA is a long-term solution.

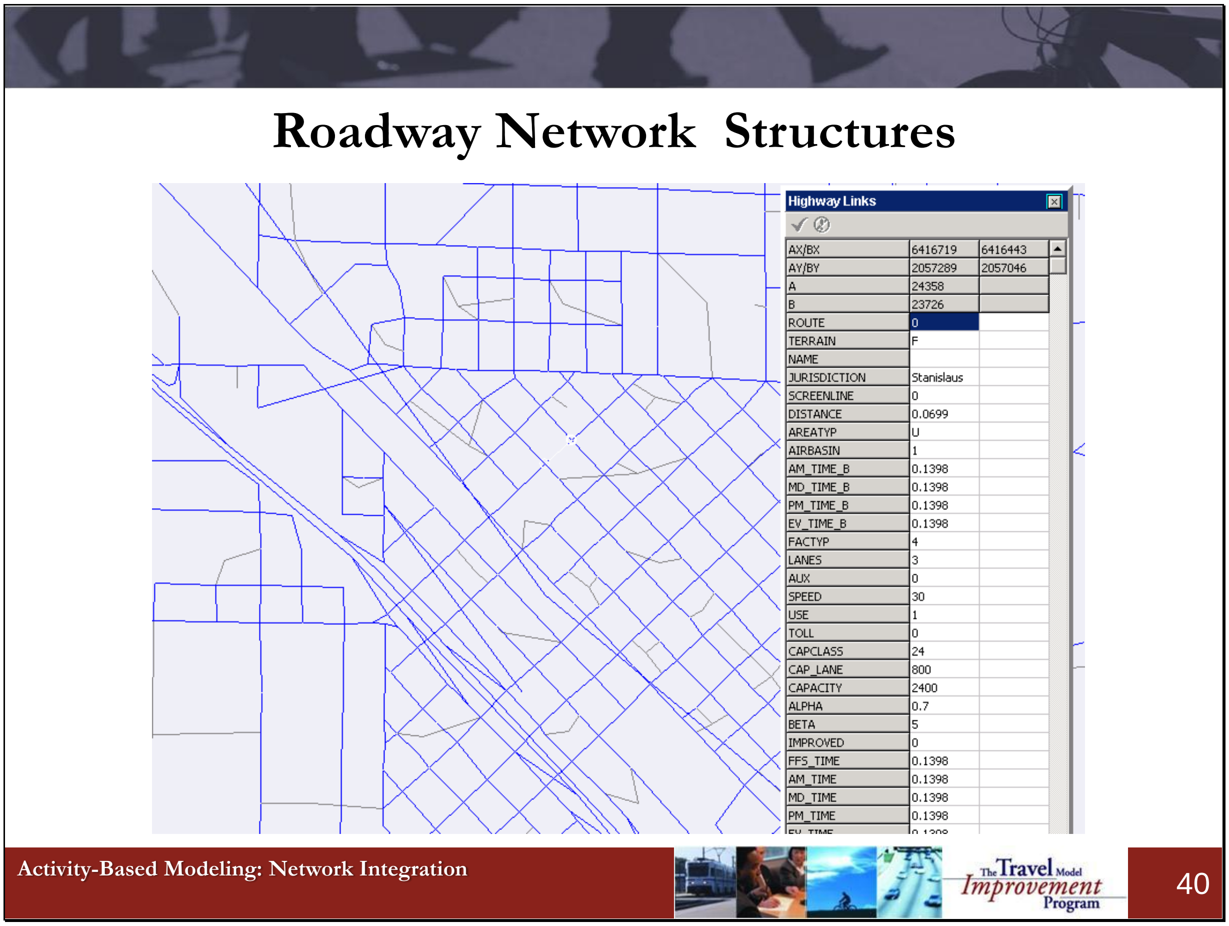


An interesting implementation issue relates to differences in the way that activity-based models access and use skims relative to trip-based models. First, trip based models do not typically use skims as comprehensively throughout the model system as activity-based models. Of course, mode choice models use skims, and distribution models typically do as well. In the rare instances where a trip-based model incorporates a time-of-day component then this model will also use skims. But trip-based models are implemented within a matrix framework, looping first on origins and then over destinations. This approach allows for efficient access to skim values for large batches of trips in a single operation.

In contrast, activity-based models incorporate skim information throughout virtually all components of the entire model system – destination choice, mode choice, time of day choice, and in the generation of accessibility measures used as input to activity generation. Due to the agent-based micro-simulation framework in which the activity-based model is applied, random access of skims during the simulation is required. This is computationally challenging, and necessitates much greater memory requirements, and efficient means of retrieving the skim data.

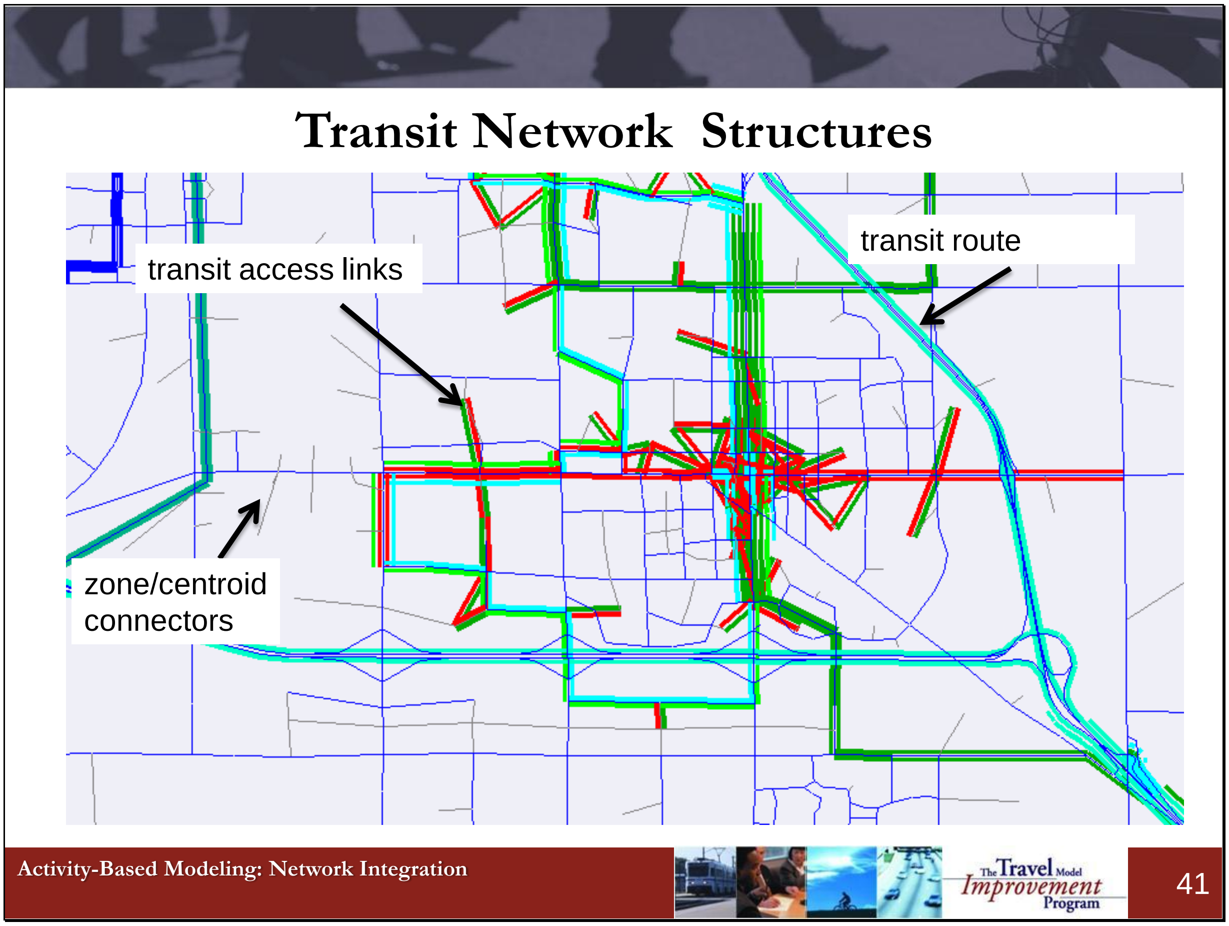


The input network supply data needed to integrate with an activity-based model system are not significantly different than required to integrate with a traditional trip based model, but more temporal and modal detail is typically required. A key advantage of activity-based models is that they provide a framework for the consistent treatment of time and space and reflect realistic availability constraints. To maintain consistency with and provide good information to the activity-based demand model, the network supply model should ideally also incorporate detailed information on network supply, particularly by time-of-day. This should include information on changes in capacity by time-of-day, such as the presence of HOV and reversible lanes, and transit service headways fares and coverage. Coding and maintaining information about roadway supply by time of day is relatively straightforward as this information can usually be simply coded as an attribute on a common base network. Coding and maintaining information on transit supply by time-of-day can be considerably more onerous due to the significant numbers of variations in transit route alignments and service levels. For example, a single transit route may have a number of patterns with different termini and service frequencies. In some cases, agencies have developed detailed transit network by time of day, while in other instances simplifying assumptions are made, such as PM transit service as a transpose of AM service.

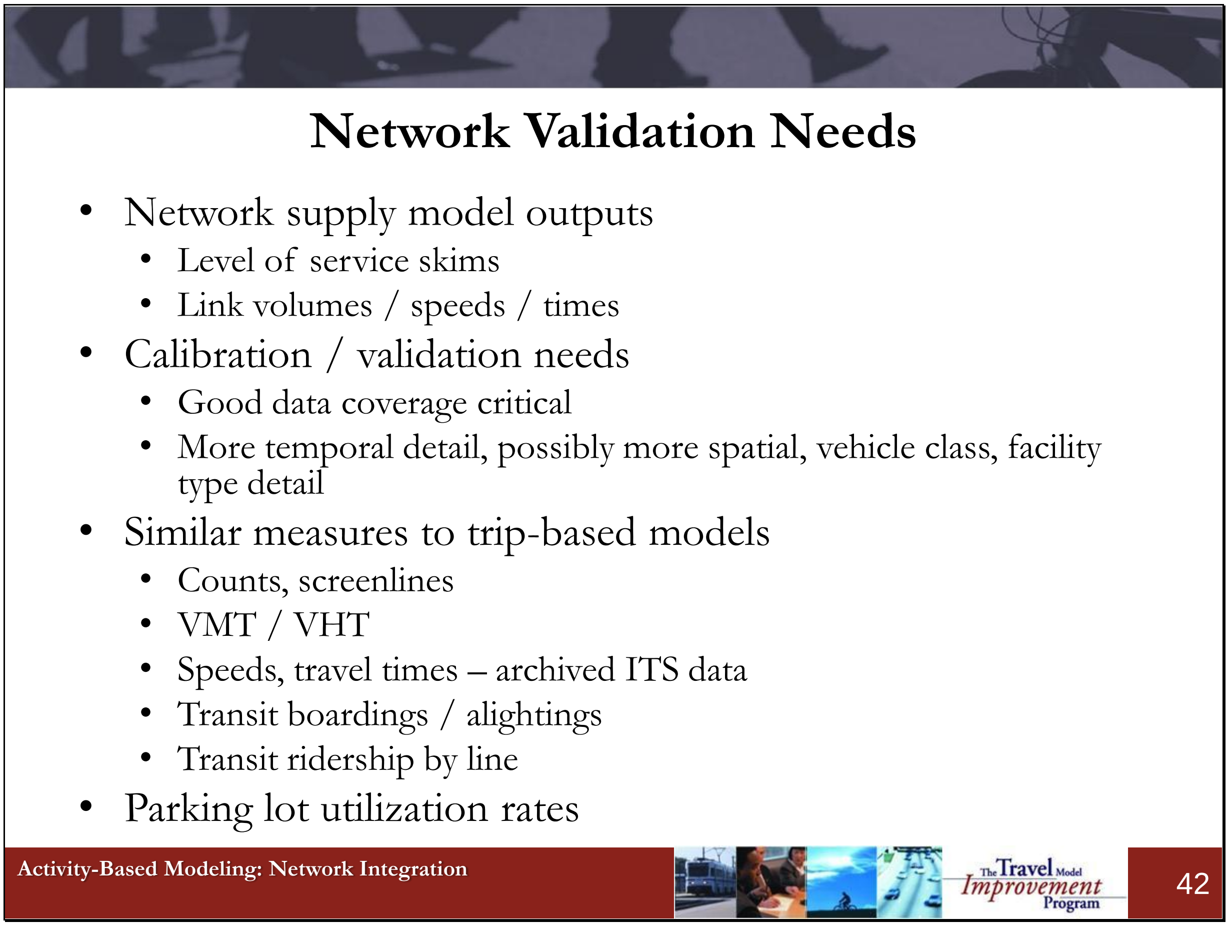


This picture shows a small section of a highway network model in link-node format. This should be familiar to most modelers out there. The gray box on the right lists important attributes of links such as:

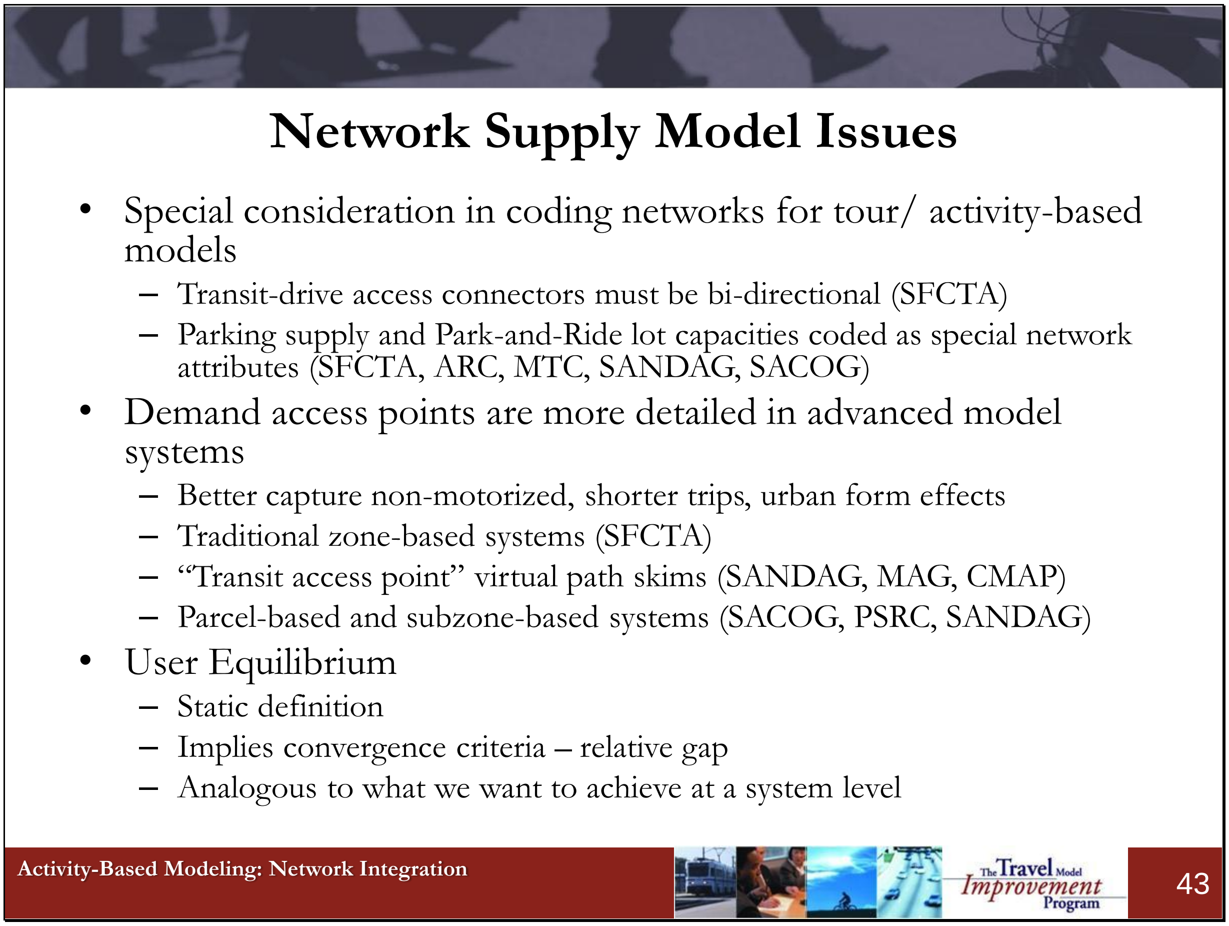
- Link A/B Nodes
- Direction
- Toll
- Facility Type
- Area Type
- Speed Limit
- Capacity
- Number of Lanes



This slide shows a small section of hyper (highway/transit) network. Shown are links, nodes, zone/centroid connectors, and transit access links. Transit routes are highlighted by color based on different routes (turquoise for an express route following the freeway; red and green for local routes on surface streets). This should be familiar to most travel modelers.



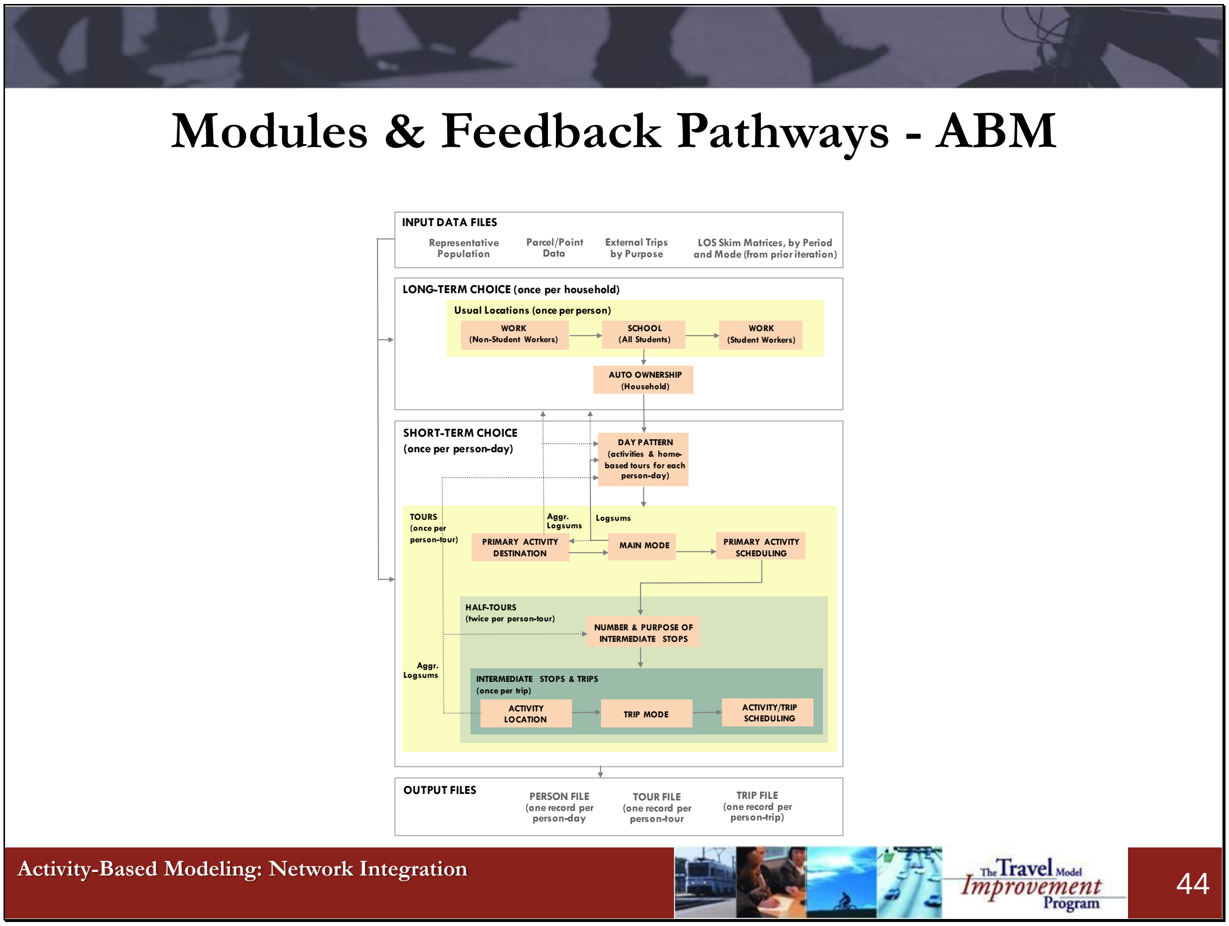
We've been discussing the network skims as a critical output of the network supply model because it is the information contained within these skims that make the model system truly integrated, where each component is informing the other. However, most practitioners are also interested in other key outputs from the network supply model, link and segment-based volumes and speeds. To assess how well both the network supply model as well as the overall demand-supply model system are performing, it is critical to have a robust model validation dataset. In general, the types of measures used to validate an integrated activity-based travel demand model systems are very similar to those used to validate a traditional trip-based models: a distribution of counts and speeds across different locations, facility types and vehicle classes, as well as transit boardings, alightings, and loads. The most significant difference is that these validation data are ideally available at a level of temporal detail that are consistent with the time periods used in the network assignment model. This may presents a minor additional burden as the time period detail is greater than that used in most trip-based models. In addition, there are also some validation data related to model components unique to the activity-based model system, such as park-and-ride lot utilization.



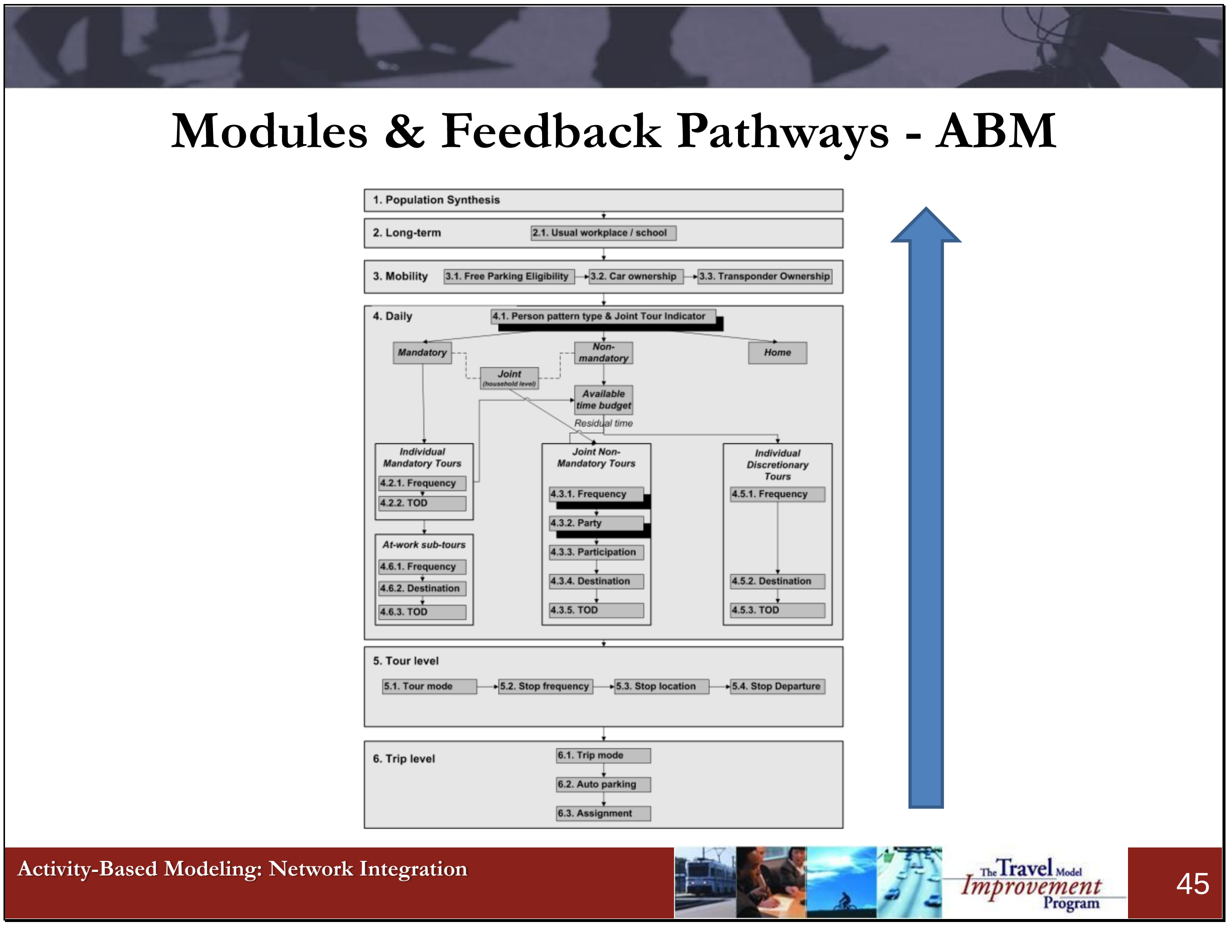
Given the detailed information that is required to support the integration of the activity-based demand model and the network supply model, there are a number of special issues that must be considered. For example, in addition to the more detailed transit sub-modal detail that is usually embedded in activity-based model systems, the tour-based nature of activity-based models and their more comprehensive treatment of the temporal dimension necessitates the explicit treatment of the directionality of transit network coding. For example, transit drive access connectors must be bidirectional in order to represent the fact that people from park-and-ride lots back to their homes after work – most network software builds one-directional drive access links. Also related to park-and-ride, the explicit representation of parking lot capacities supports a more realistic treatment of drive access transit.

In addition, careful consideration should be given to the coding of demand access points in travel model system networks. While some activity-based model systems have been implemented using traditional travel analysis zones (or TAZs), many recent AB model development efforts have used finer grained representations of space, such as subzones that are similar to census blocks, or actual parcels. In addition, some model systems simultaneously use multiple levels of geography that reflect transit, roadway and non-motorized impedances; however, in most cases the network components of these model systems do not directly used this same detailed geography. The relationships between different levels of spatial resolution in the model system should be explicit.

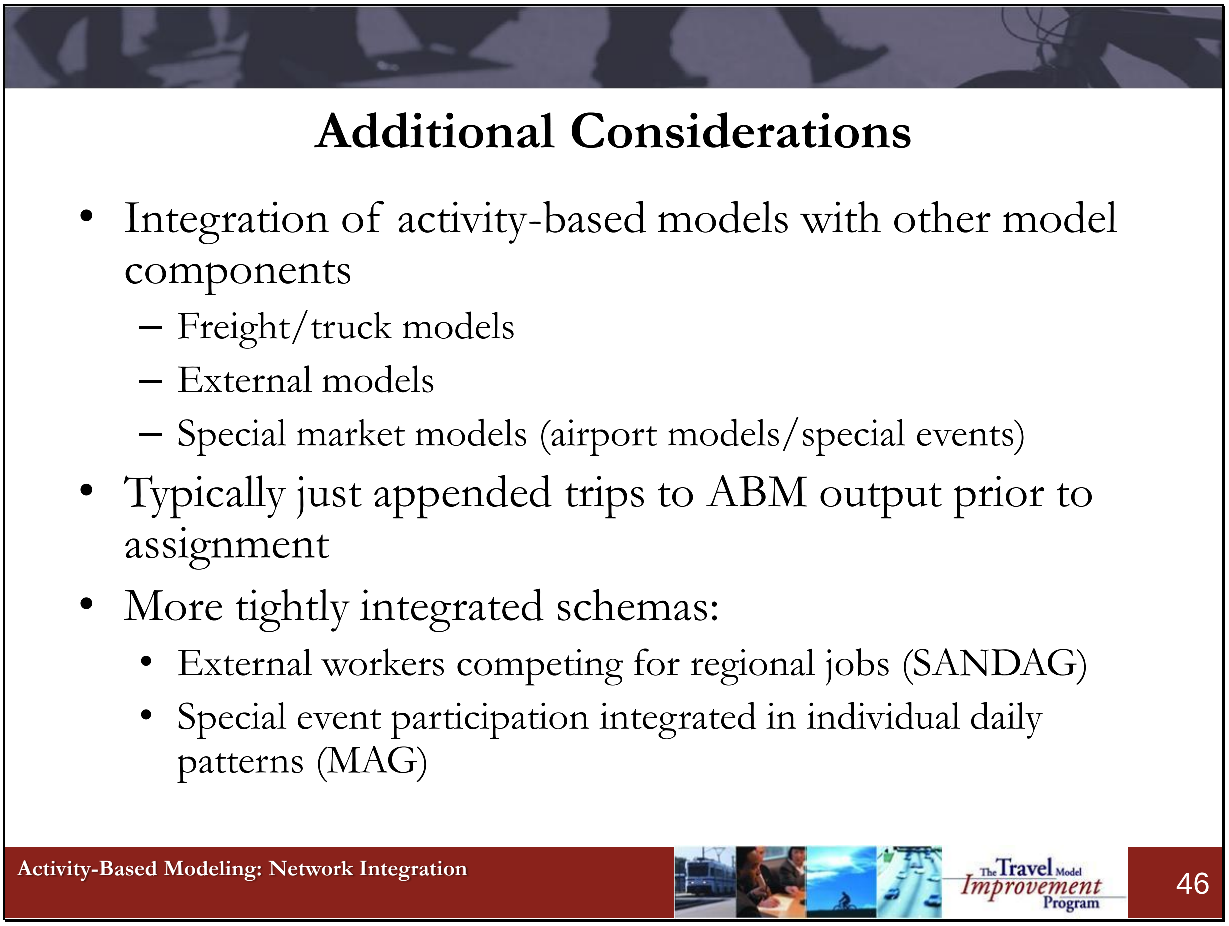
Finally, most of the following discussion assumes the use of an activity-based model system integrated with a traditional static network assignment model that converges to a static user equilibrium solution. Other assignment methodologies may also be used in connection with activity-based models, and the final section of this webinar considers current research linking activity-based model systems with dynamic traffic assignment models.



This slide shows the modules and feedback pathways in an activity-based model system (Day Pattern Style)

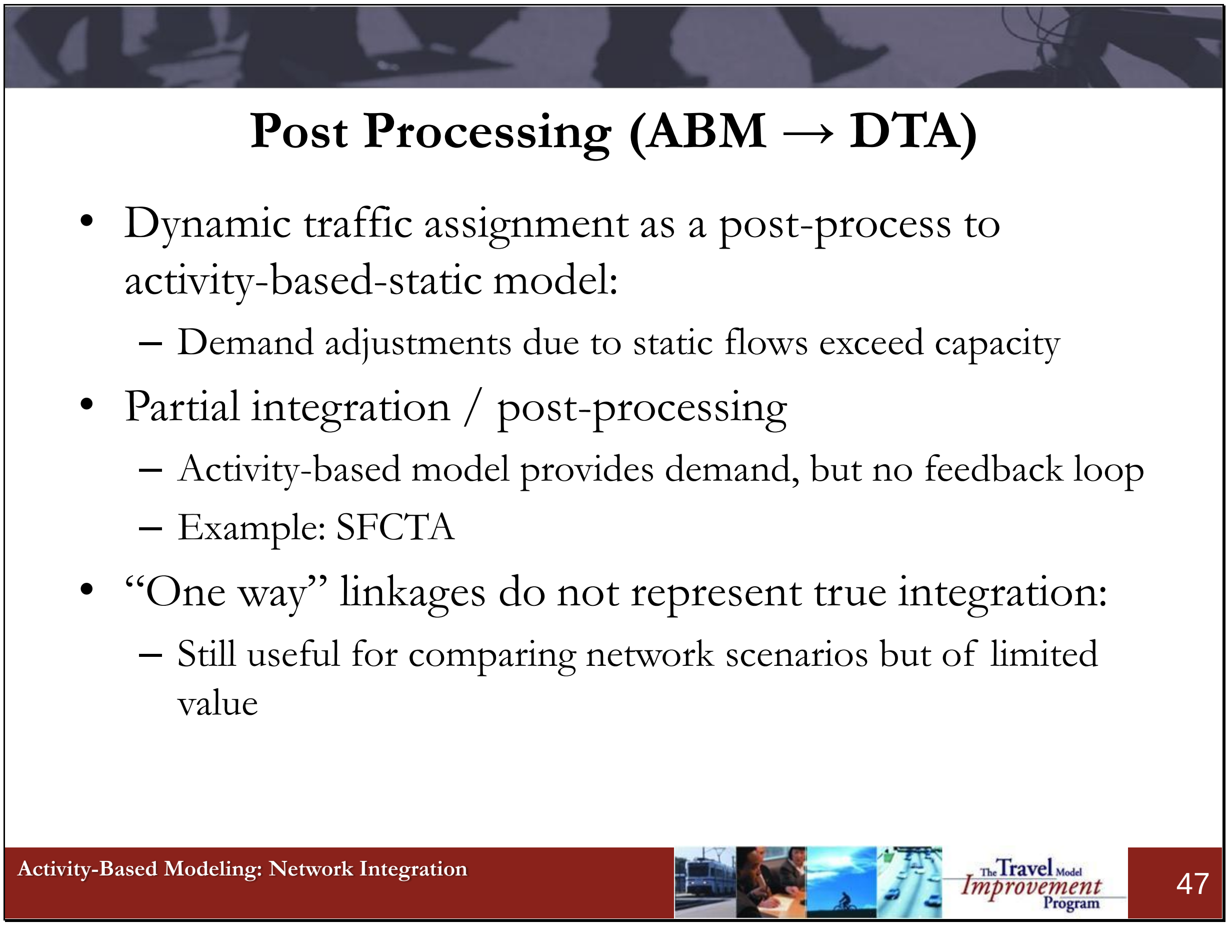


This slide shows the modules and feedback pathways in an activity-based model system (CT-RAMP Style)



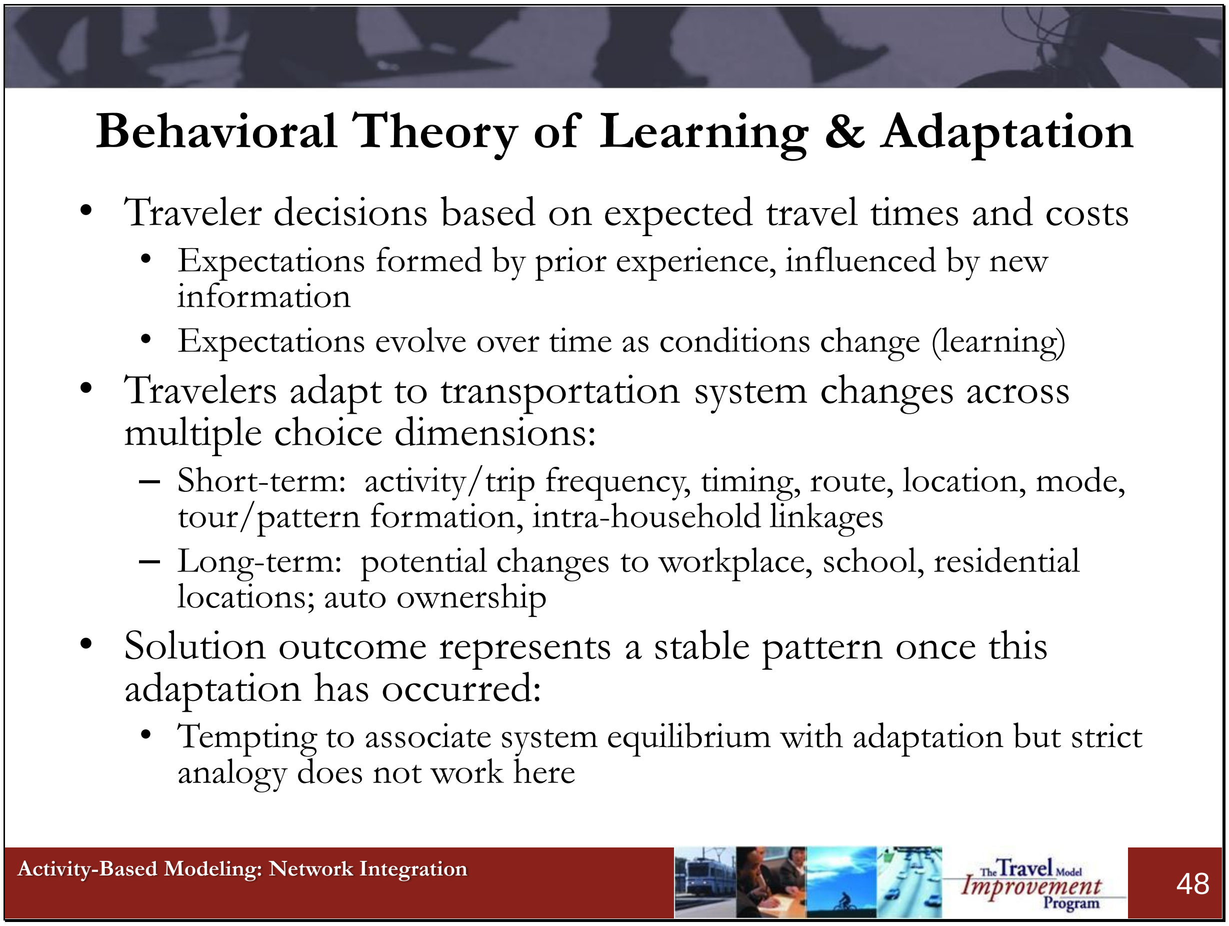
The personal travel demand that is represented in the activity-based model system typically accounts for approximately 80% of roadway volumes, with about 20% of volumes associated with freight and commercial vehicle travel, external travel with either one or both trip ends outside the study area, or special generators such as airports. Therefore, in addition to considering the integration of the activity-based demand components with network supply components, it is also necessary to consider the integration of the network supply components with these “auxiliary” models. Depending on the nature of the auxiliary models used to generate this demand, the integration may be relatively straightforward or may be more involved.

For example, in some cases these demand estimates are fixed, are not sensitive to changes in network performance, and are simply appended to the activity-based model trip just prior to assignment. In these cases, it may simply be sufficient to ensure that the temporal and spatial detail of this demand is consistent with that generated by the activity-based demand model. However, in cases where these demand estimates are dynamically influenced by network performance, it may be necessary to ensure that the auxiliary model is specified in such a way that it will be sensitive to changes in network performance, and that the outputs can also be integrated with the demand generated by the activity-based model component.

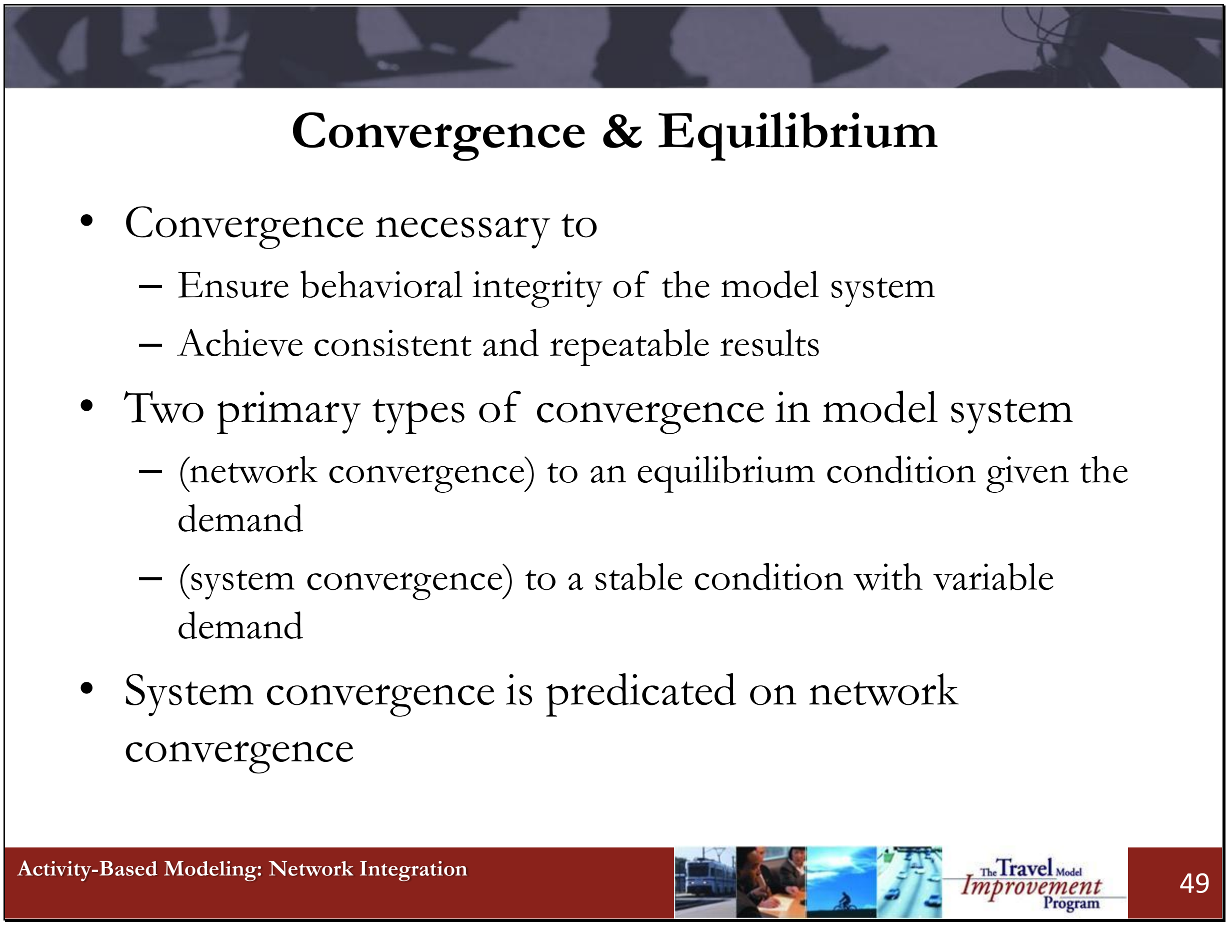


All of the discussion above assumed that a two-way linkage was established between the activity-based demand component and the network supply model. Despite the wide degree of detail and fidelity that may characterize such linkages, these two-way linkages define these model systems as "integrated" – the demand patterns influence the network performance, and the network performance influences the demand patterns.

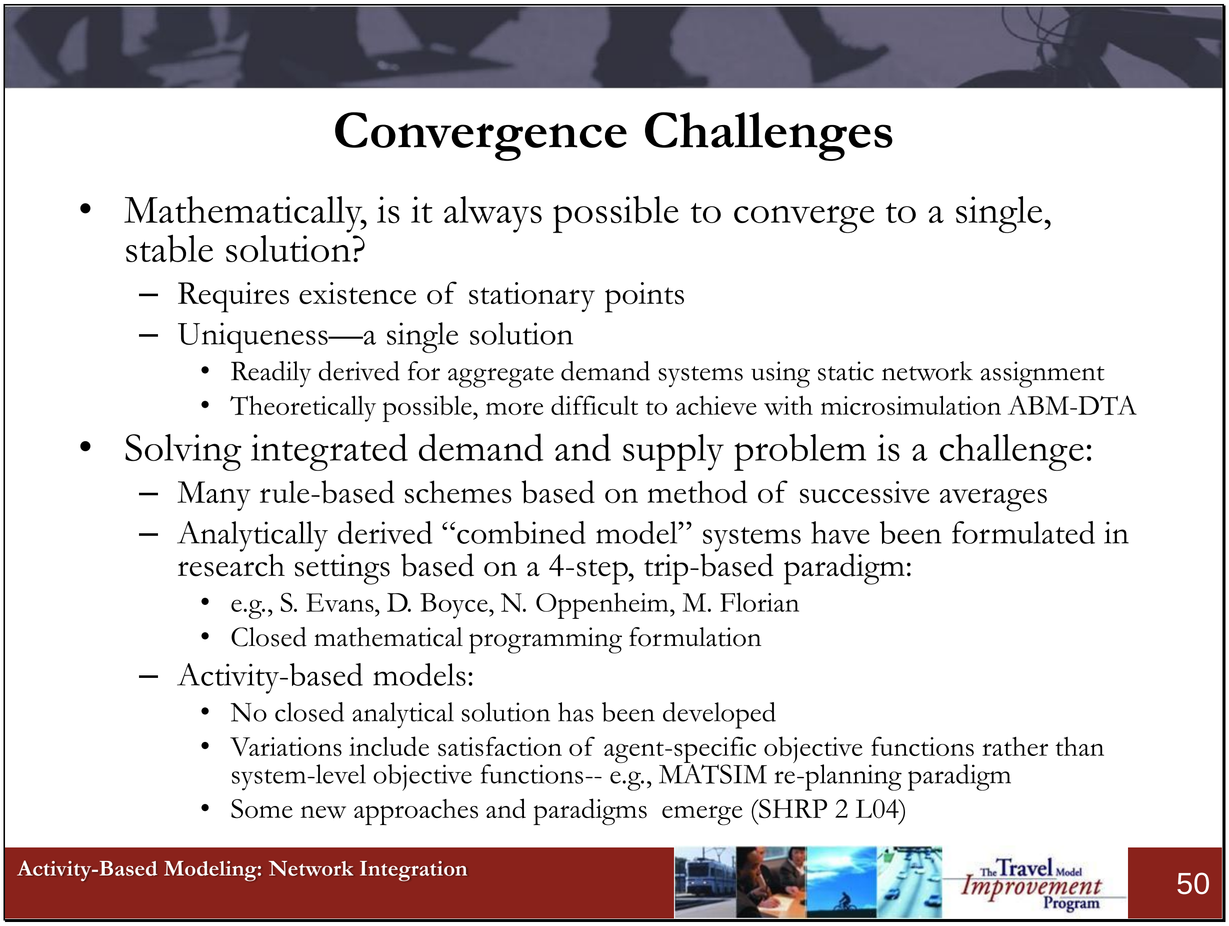
It is possible to implement simpler "one way" linkages, but such cases don't truly represent integrated models. There has been substantial research devoted to linking disaggregate activity-based models with similarly disaggregate dynamic traffic assignment (DTA) models. The temporally and behaviorally detailed information produced by an activity-based model system can typically easily satisfy the input requirements of DTA models in a way that more aggregate trip-based models cannot. Oftentimes trip-based models outputs are significantly post-processed and distorted in order to facilitate the use of trip-based model demand in the DTA. Activity-based model demand may not require the same degree of manipulation in order to provide the inputs to DTA, but until a feedback loop is implemented in which the DTA provides estimates of network performance for input to the activity-based model, an integrated model has not been established.



There are a set of core behavioral principles that address the necessity of network integration and which also guide how network integration can be achieved. First, when making decisions, travelers use information on expected times and costs. In an integrated model system, these expected times and costs can be thought of as the information in the network skims that are input to the demand model. These expected times and costs influence long-term choices such as usual workplace school locations, as well as short-term choices such as the number and types of activities to participate in and whether to coordinate with other household members, what locations to visit, and what travel modes, times-of-day, and routes (roadway or transit) to use . Collectively, these choices result in travelers' new "experienced" levels of network performance which, when combined with prior expectations, then inform travelers' new expectations about travel times and costs. As a result of these new expectations, travelers may revise the long-term and short-term travel choices. This evolution of these expectations and associated changes in travel choices can be thought of as a learning process. Travelers will continue to adapt their choices until the times and costs that they experience are consistent with the times and costs they expected, at which point their choices will become stable. This overall iterative travel model system may be considered an analog for this learning process.



Model convergence is necessary to ensure the behavioral integrity of the model system, and to ensure that the results will be useful in a policy context. The network performance or level-of-service measurements used as the basis for accessibility measures and as key inputs to demand model components must be approximately equal to the travel times and costs produced by the final network assignment process. In a travel model system, there are at least two types of convergence that we need to consider: network convergence and system convergence. When we talk about convergence, we are implicitly talking about convergence “to” something. Typically this means for networks that we are converging to an equilibrium condition (usually a deterministic user equilibrium where, for each time period-origin-destination combination all used routes have equal travel times, and no unused route has a lower travel time). For the overall model system, this usually means that we are converging to a stable solution (rather than an optimal solution as in the network context). It should be noted that in the context of an integrated demand and network simulation model system, an essential precondition for pursuing overall model system convergence is establishing network assignment convergence.

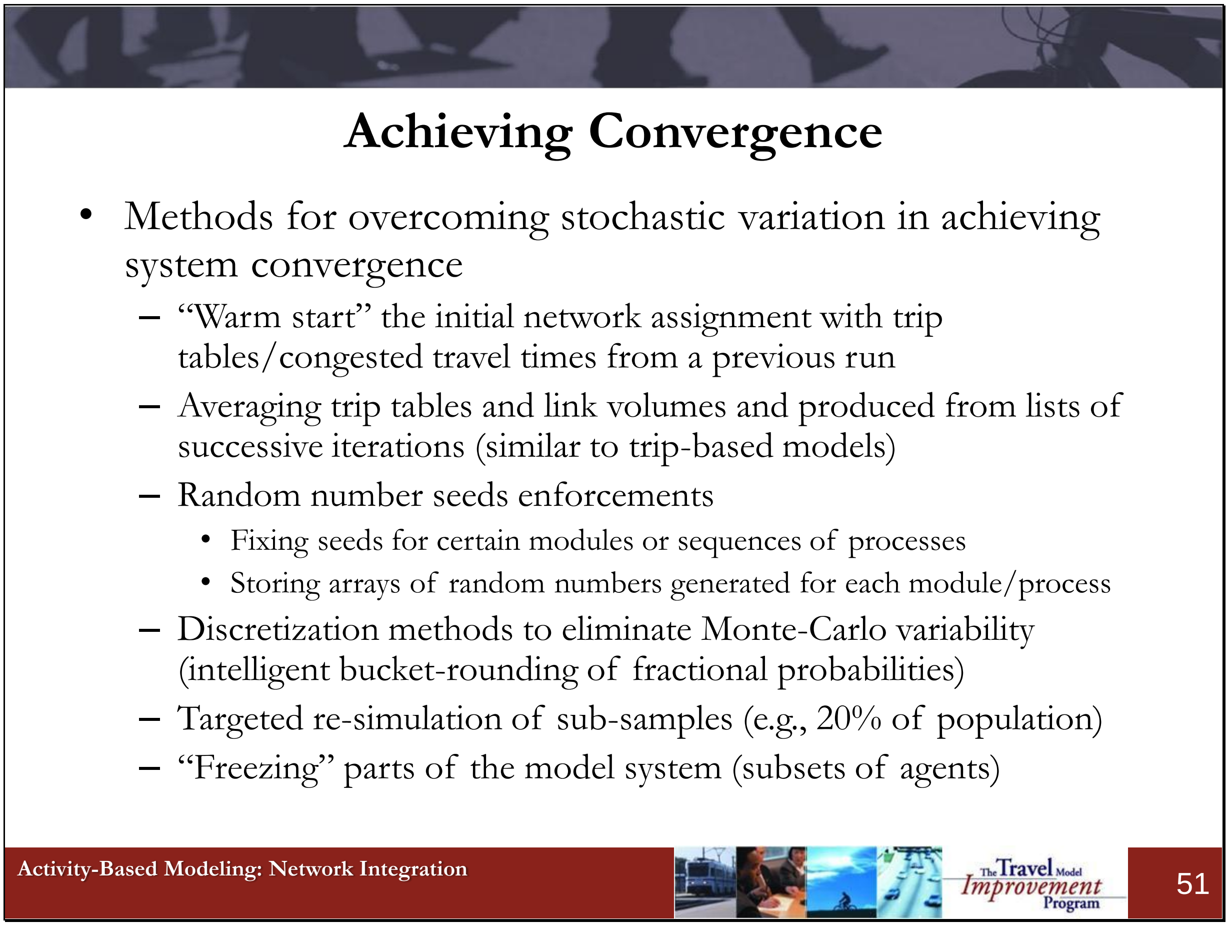


Prior to discussing different methods and measures for pursuing convergence, it is necessary to identify some of the challenges to achieving convergence in the context of an integrated activity-based demand and network supply model system.

The first challenge is that it is not possible to confidently assert the existence of a single solution in the context of such an integrated mode. Although it may be theoretically possible to achieve such a solution when using a stochastic activity-based demand model in conjunction with static network assignment model, it is not as easily provable as with a deterministic trip-based demand model system.

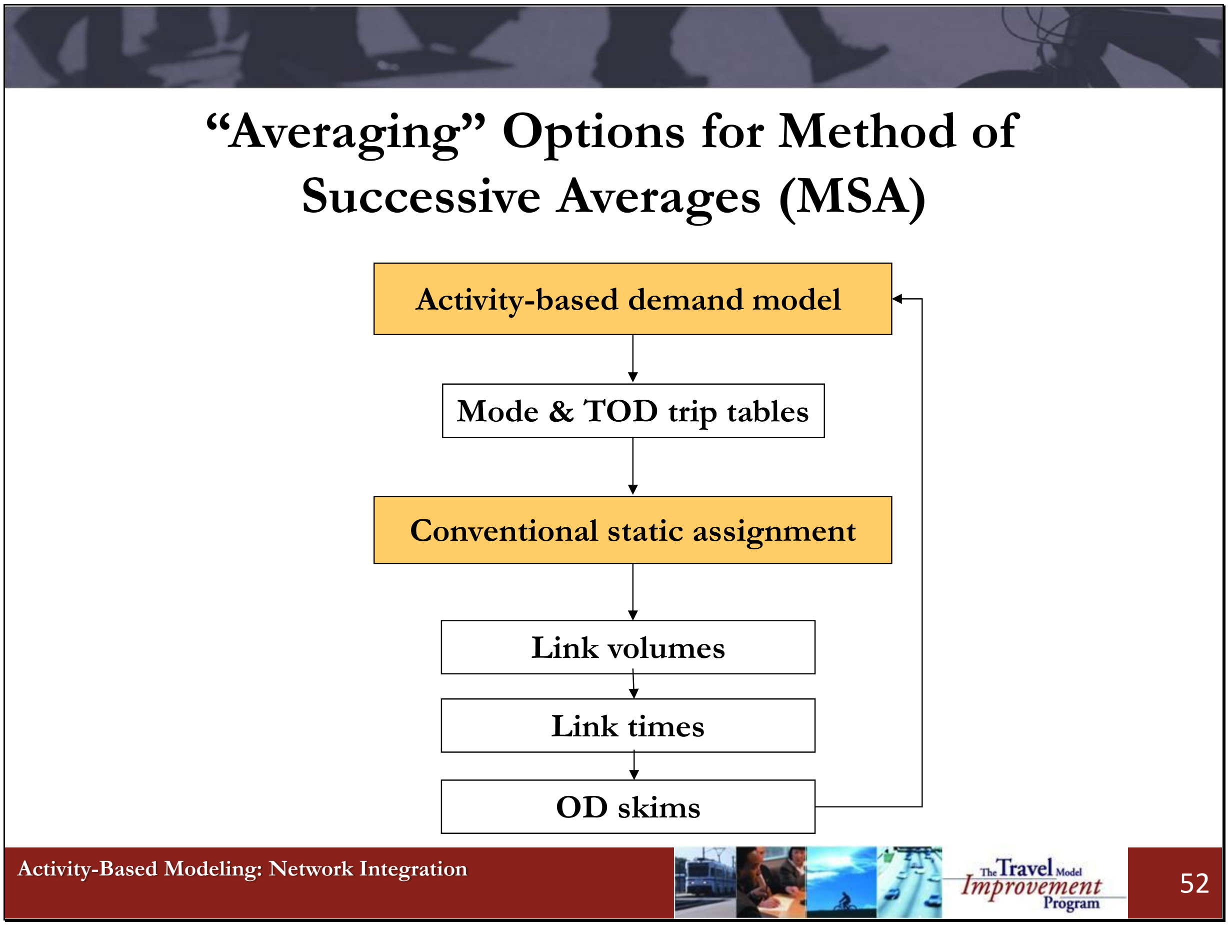
While analytically derived combined demand and supply models have been formulated in research settings, such combined models necessitate the use of many simplifying assumptions, which compromises their usefulness in practice. In addition, even these combined models rely on complex mathematical programming formulations.

In the context of activity-based models systems, no tractable analytical solution shave been developed. Instead, both researchers and practitioners have primarily relied on heuristics such as the method of successive averages in order to achieve stable results, although some agent-based satisficing objective functions rather than system-level objective functions have been successfully implemented.



These challenges notwithstanding, a number of strategies have been successfully employed to pursue convergence in the context of an integrated activity-based demand model and network supply model. Some of the more successful approaches have included:

- "Warm starting" network assignments with trip tables of congested travel times from a prior run;
- Averaging trip tables, link volumes, or skims from successive iterations;
- Fixing random number seeds and sequences that are used in the implementation of the Monte Carlo simulation;
- Using more intelligent bucket round methods such as discretizing probabilities;
- Simulation or re-simulation of subsamples of the population; and
- Holding some model components fixed.



The method of successive averages (MSA) is a basic and reliable method for achieving convergence in travel demand model speed-feedback procedures. The methods used in activity-based (micro-simulation) models operate on the same general principle as those used in activity-based models. The demand model produces trip tables by mode and time of day, which are run through a static network assignment process. Common practice is then to compare changes in link volumes or travel times, or OD interchange values between iterations.

Stopping Criteria

- Based on either changes to link volumes and/or trip tables… usually both
- Comparisons made for each relevant demand segment
  - E.g., SOV, HOV, Large trucks, Small/Medium trucks
- Link volume criteria example
  - Stop when 90% of link volumes change by less than 5%
  - Often limited to higher-level facilities (e.g., freeways and arterials)
- Trip table criteria example
  - Stop when 80% of table cells change by less than 10%
  - Often limited to minimum number of trips per cell (e.g., 100)

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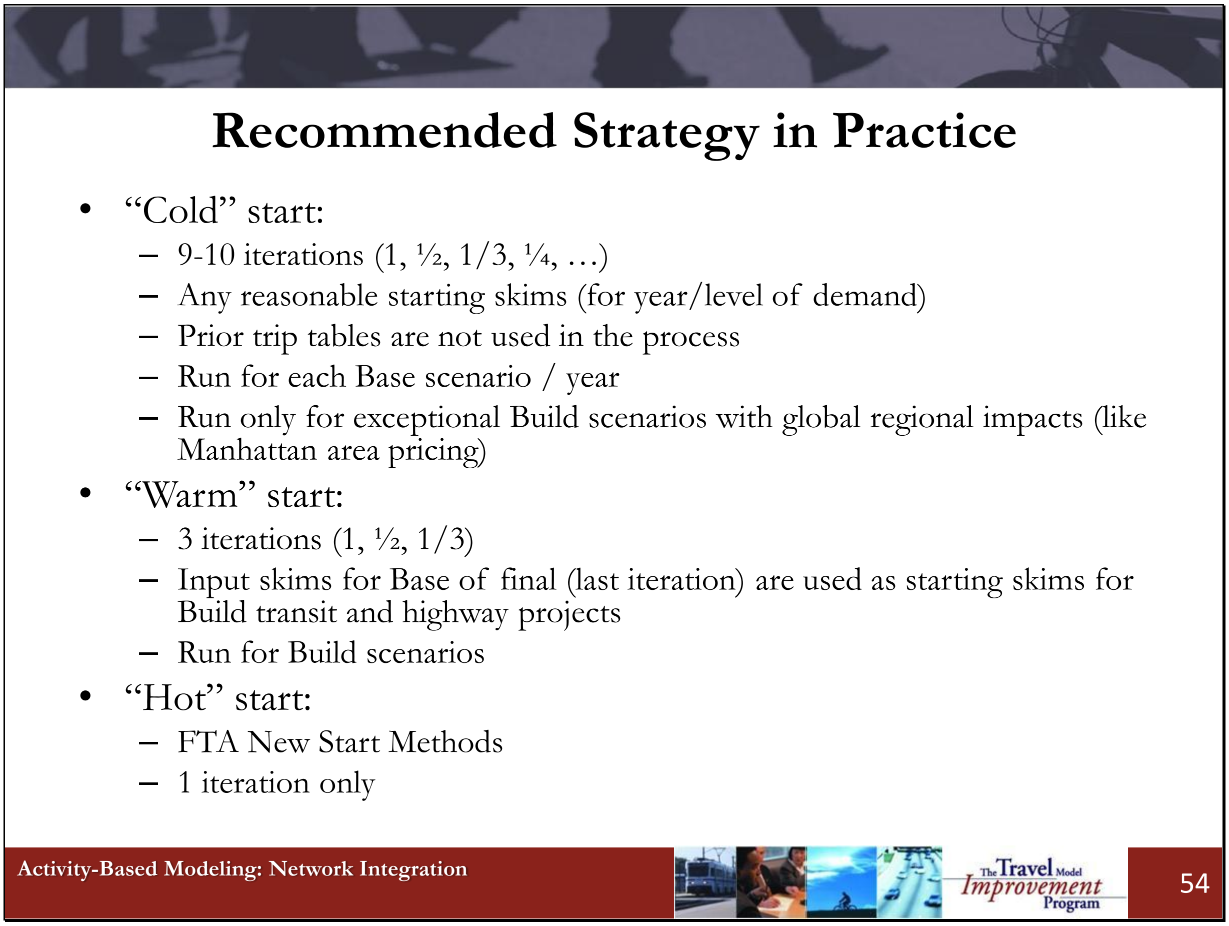
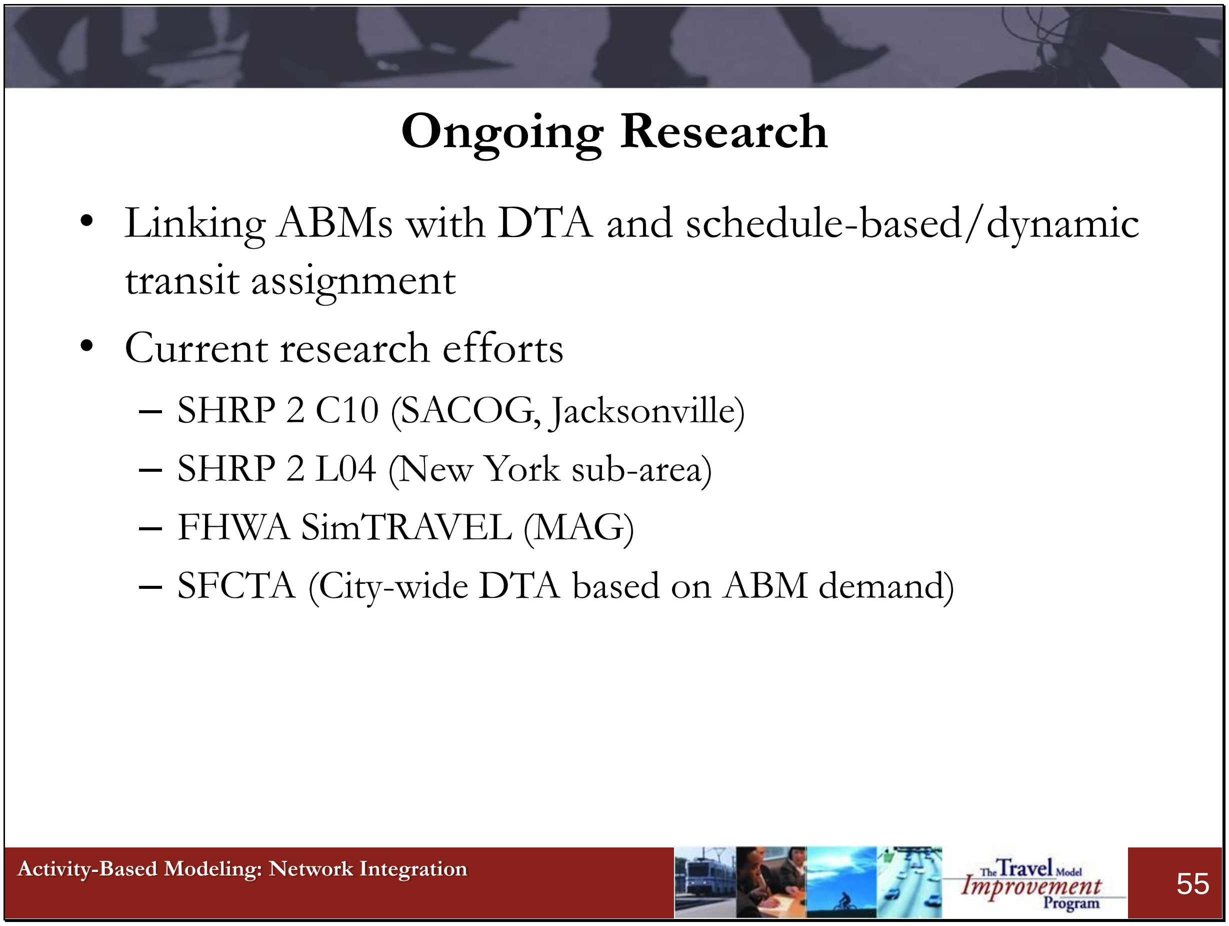
In addition to established methods for achieving convergence, it is also necessary to establish measures for assessing model system convergence. Thus far, many of the convergence stopping criteria used with integrated activity-based network supply models are similar to those used in more traditional trip-based model systems. Many stopping criteria are based on looking at changes in link volumes, or changes in trip table flows. The changes can be assessed in aggregate across all demand segments, or may be considered for each segment independently. The specific criterion can vary, but typically involves establishing that a significant share of link or cell elements change less than an established threshold; for example, that 90% of link volumes change by less than 5%. These criteria may also impose minimum size requirements, such as to exclude all low volume links or low demand zone pairs.



There are a number of strategies that can be used to guide the exchange of information between the demand and supply components, in order to pursue system convergence. The selection of a particular approach can be informed by the model application context, model runtimes, and other factors. For example, a “cold start” configuration involves the assumption of some reasonable starting skims assuming a given year and level of demand. “Base case” alternatives are usually run using a cold start approach, and this strategy typically requires more demand-supply model system iterations. Alternatively, a “warm start” approach uses the final “base case” skims to seed the model system, which typically requires running fewer demand-supply model system iterations. Warm starts may be more appropriate for testing build alternatives. Finally, “hot starts” assume that the build alternatives pivot directly off of the base alternatives, with no demand-supply iteration.



As suggested earlier in the webinar, challenges arise when attempting to link disaggregate activity based travel demand models which incorporate more detailed temporal, behavioral, and potentially spatial resolutions with the static assignment models traditionally used in trip-based models. A critical advantage of activity-based models is their improved temporal sensitivity, and to fully exploit this sensitivity it is necessary to have a network supply component that can produce realistic estimates of changes in network performance by detailed time of day. Dynamic traffic assignment and dynamic transit assignment tools can provide this additional temporal detail, and have many other advantages as well such as:

- Incorporation of fine-grained operational attributes in network representations;
- Use of realistic models of traffic flow to produce estimates of delay rather than volume delay functions which can produced implausible results; and
- Fully disaggregate nature of these models, which facilitate advanced demand-supply model interactions.

A number of research efforts are currently underway that exploring different aspects of this problem. The SHRP2 C10 projects in Sacramento and Jacksonville are linking the Daysim activity based model to dynamic traffic and transit assignment software and subjecting these model systems to sensitivity testing, while the SimTravel project is developing integrated models of the entire urban system including location choices of households and firms, activity and travel patterns of passengers and freight, and emergent traffic flows on time-dependent networks. In San Francisco, the SFCTA is developed a fully detailed integrated activity-based and DTA traffic model to evaluate a variety of real-world projects.

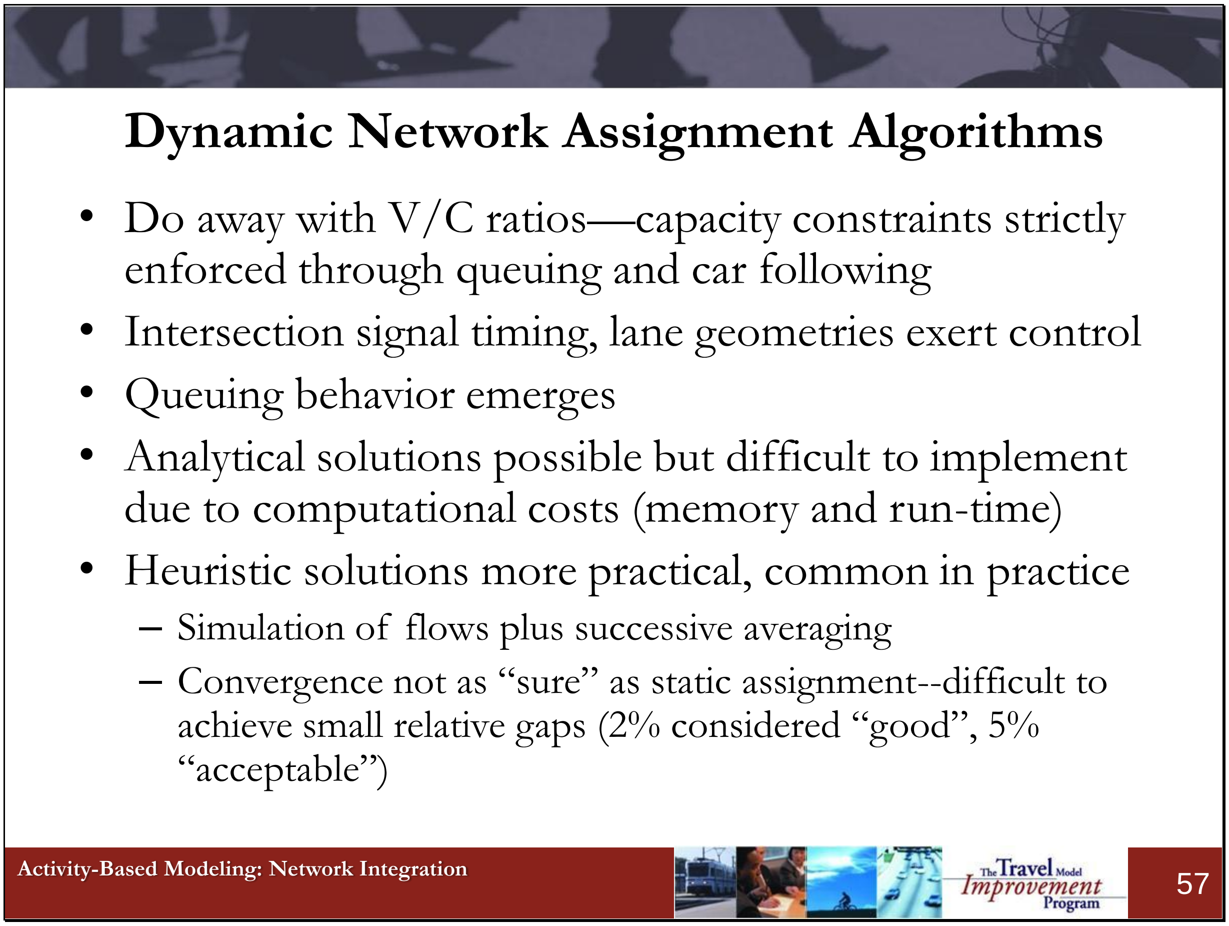
Dynamic Traffic Assignment (DTA)

- Advantages: capture time-varying network and demand interactions in a more realistic way
- Sensitive to…
  - Time-varying demand
  - Operational attributes (signal coordination, optimization, priorities)
  - Traffic dynamics (car following, queuing)
  - True capacity constraints
- Deployment scales
  - Project/corridor-level
  - Regional-level (supports integration with regional demand model)

Dynamic traffic and transit assignment models are intended to provide more detailed means to represent the interaction between travel choices, traffic flows, and time and cost measures in a temporally consistent and behaviorally sound framework. More traditional static assignments have a number of limitations, most critically their reliance of volume delay functions (VDFs). Volume delay functions may be unreliable predictors of network performance because of their dependence on volume/capacity ratios, which may counter-intuitively exceed 1.0, do not incorporate critical operational attributes, do not reflect actual traffic phenomena such as queuing, and do not reflect changes in impedances over time

In contrast, dynamic traffic assignment methods seek to explicitly represent the time-varying nature of travel demand. This is achieved by implementing a number of fundamental departures from static assignment methods, such as the incorporation of operational attributes which change over time (for example, signal coordination) as well as the explicit representation of detail such as the lane configurations. In addition, DTA models rely on traffic flow theory such as car following and queuing to estimate delays, rather than using volume delay functions based on assumed capacities. This detailed modeling of traffic flows can provide better estimates of the true capacity and performance of different facilities based on realistic operational constraints.

At present, DTA methods are increasingly used to support project-level analyses. However, such applications typically represent "one way" linkages between the demand model and the DTA model, and in fact demand model outputs are often extensively post-processed prior to use by the DTA model. The projects cited on the prior page represent some of cutting edge attempts to deploy DTA approaches at a regional scale. Such a deployment is necessary in order to truly provide useful information and integration with a regional activity-based model system.

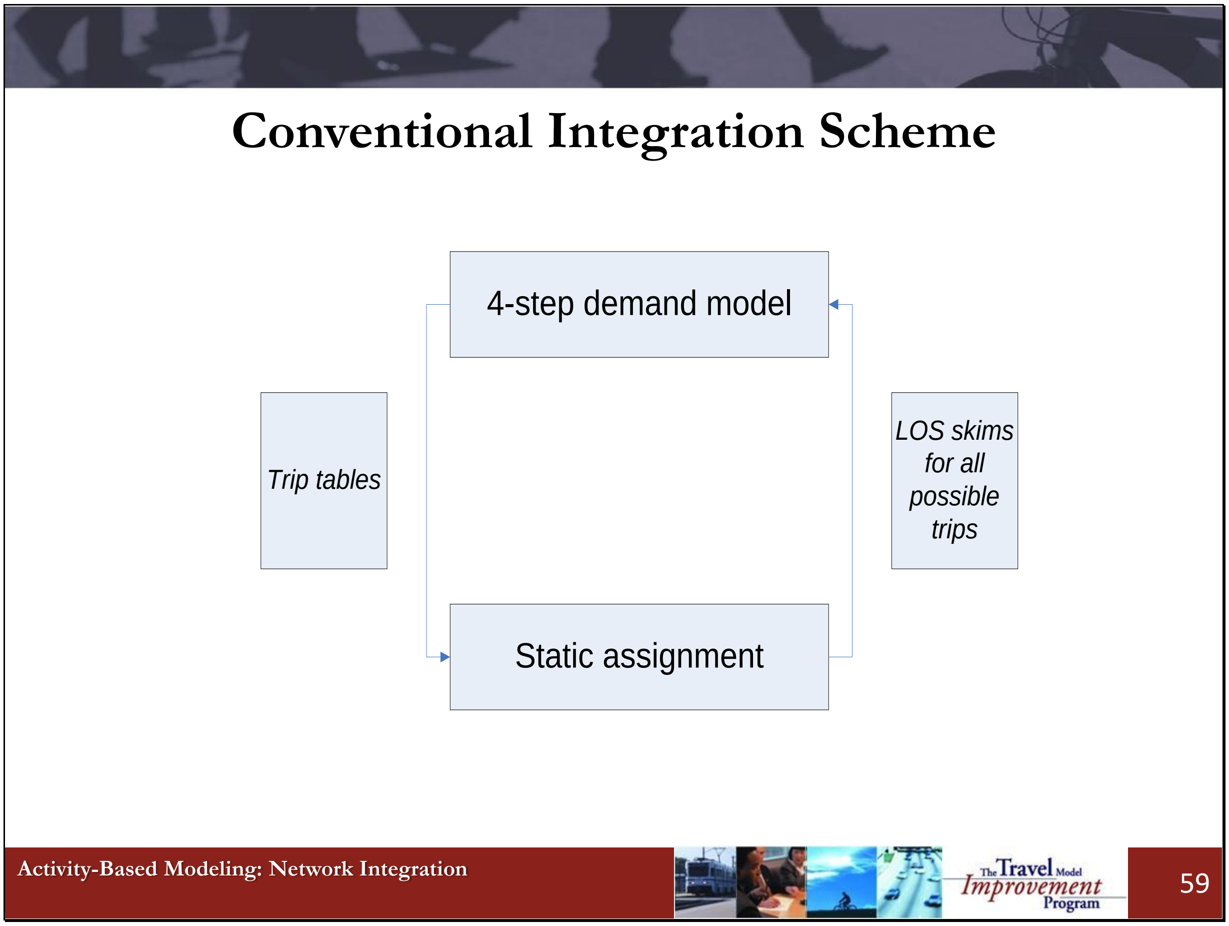


As described on the previous slides, DTA methods offer a number of compelling advantages over traditional static assignment methodologies, such as more realistic representations of true capacity constraints, operational attributes, and driver behavior. However, integration of DTA models with regional activity-based demand models in order to achieve a fully disaggregate and detailed travel demand models system is fraught with a number of challenges. Perhaps the most significant challenge is that model system convergence is predicated on network supply model convergence, but that network convergence using DTA methods is challenging. Although analytic solutions are possible, they are extremely difficult to realize given the high computation costs and runtimes. In practice, heuristic methods have proven to be more practical, but have not been widely embraced by either the practitioner or research communities. And even the most effective heuristic methods are unable to achieve levels of convergence that are easily achieved using static methods. For example, convergence to a 2%-5% gap is typically considered good by the DTA community, while convergence of 0.01% is usually easily achieved using static methods.

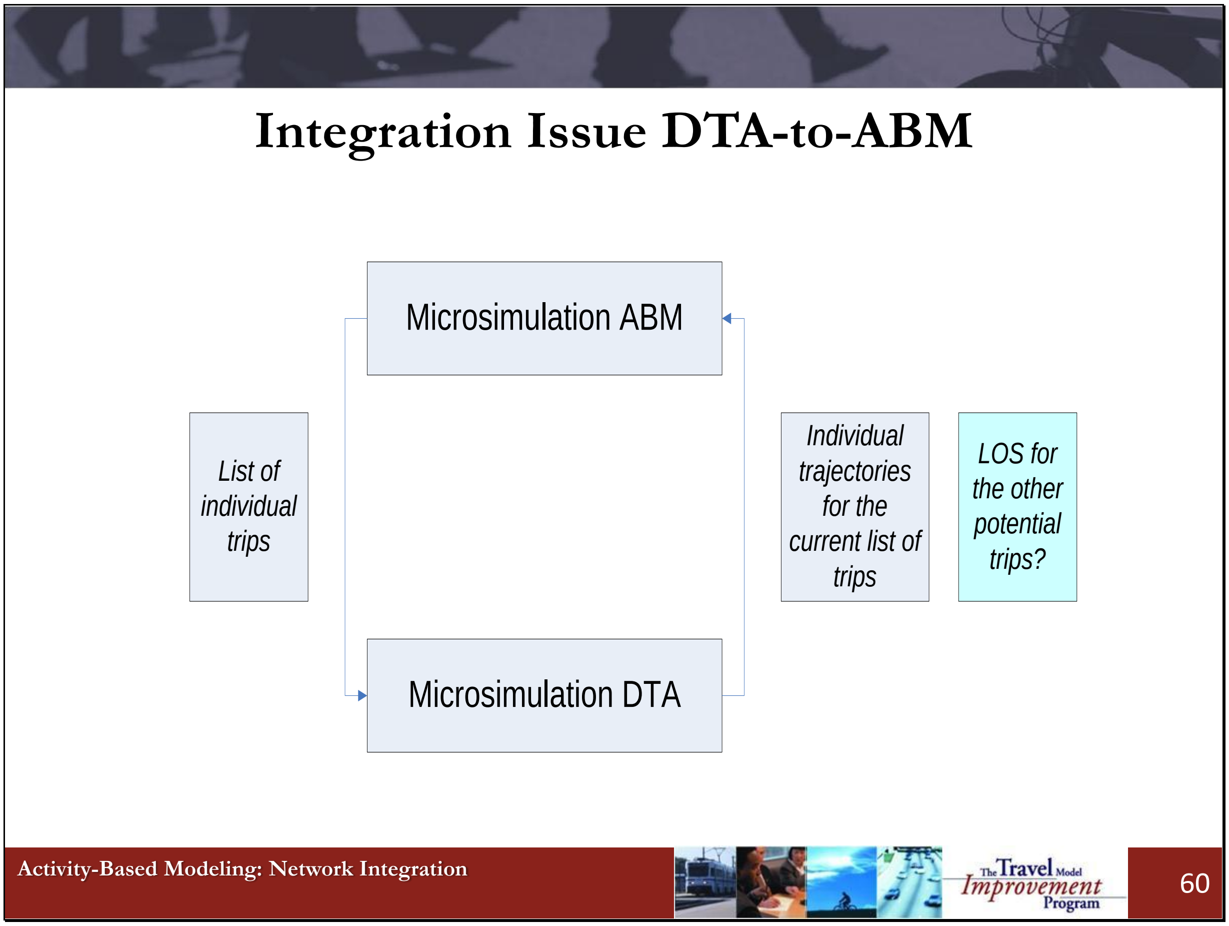
ABM/DTA Integration

- Activity-based model provides demand to dynamic traffic assignment
  - Disaggregate trip list
  - Aggregate matrices at fine temporal resolution
- Dynamic traffic assignment provides temporally detailed network performance indicators to activity-based model
  - In practice, 22-48 time periods has been accomplished
  - Ideally, "on-the-fly" impedances
  - Examples: C10, MORPC

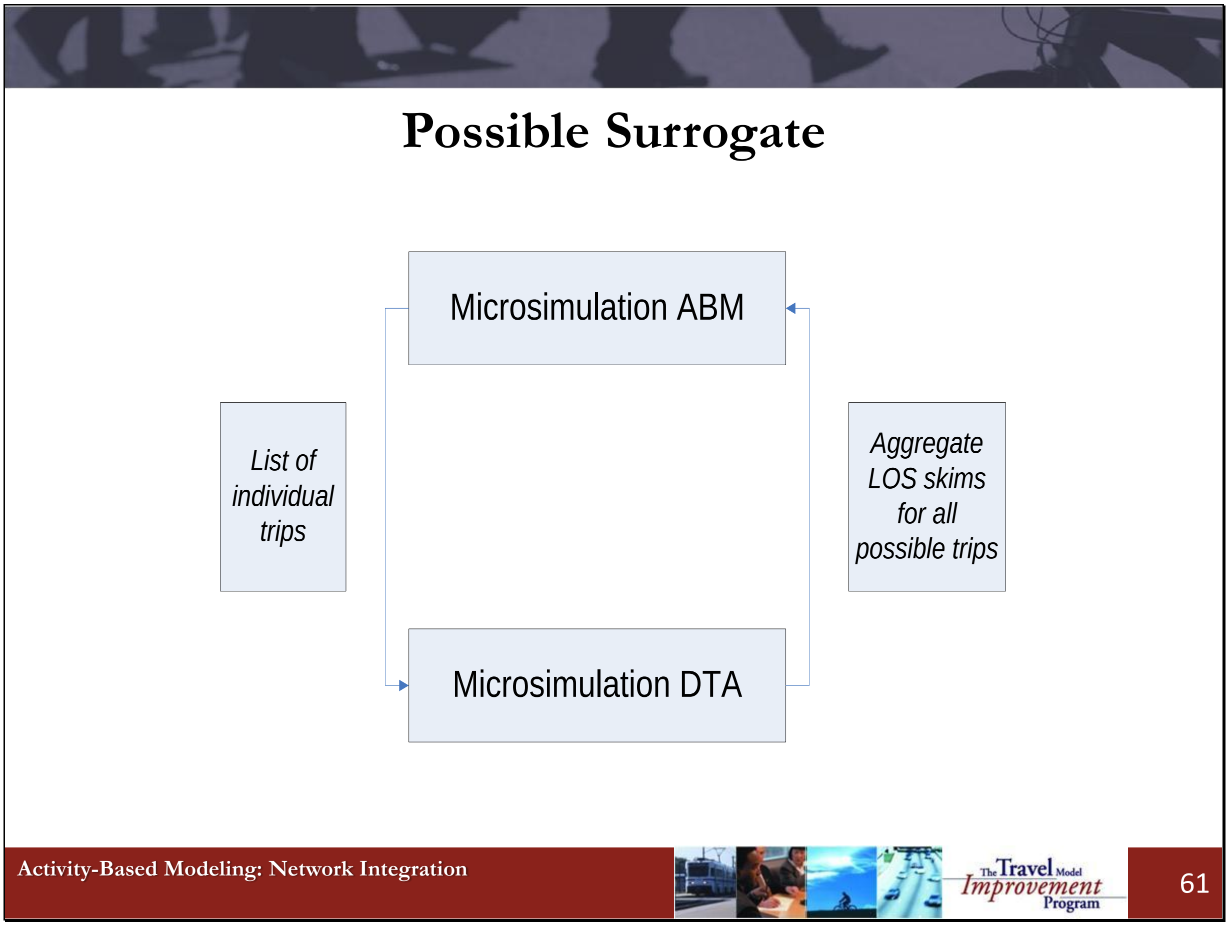
Many of the integrated activity-based and DTA model systems mirror the structure of more traditional integrated models. That is, the demand model provides estimates of the type, timing, destination, and model used for travel, while the supply model takes these estimates of demand as fixed and uses them to generate estimates of network performance. Of course, the fully disaggregate nature of both tools supports the implementation of unique model integration methods. The activity-based demand model may feed the DTA model a trip list, or may aggregate this trip list to spatially and temporally fine grained matrices. The DTA model, in turn, can provide more detailed and consistent estimates of network performance by time of day. At present, these tools have achieved integration using skims as detailed as 48 ½ hour time periods, although in theory skims may one day be generated "on the fly" rather than developing a full set of segmented skims prior to the demand model simulation.



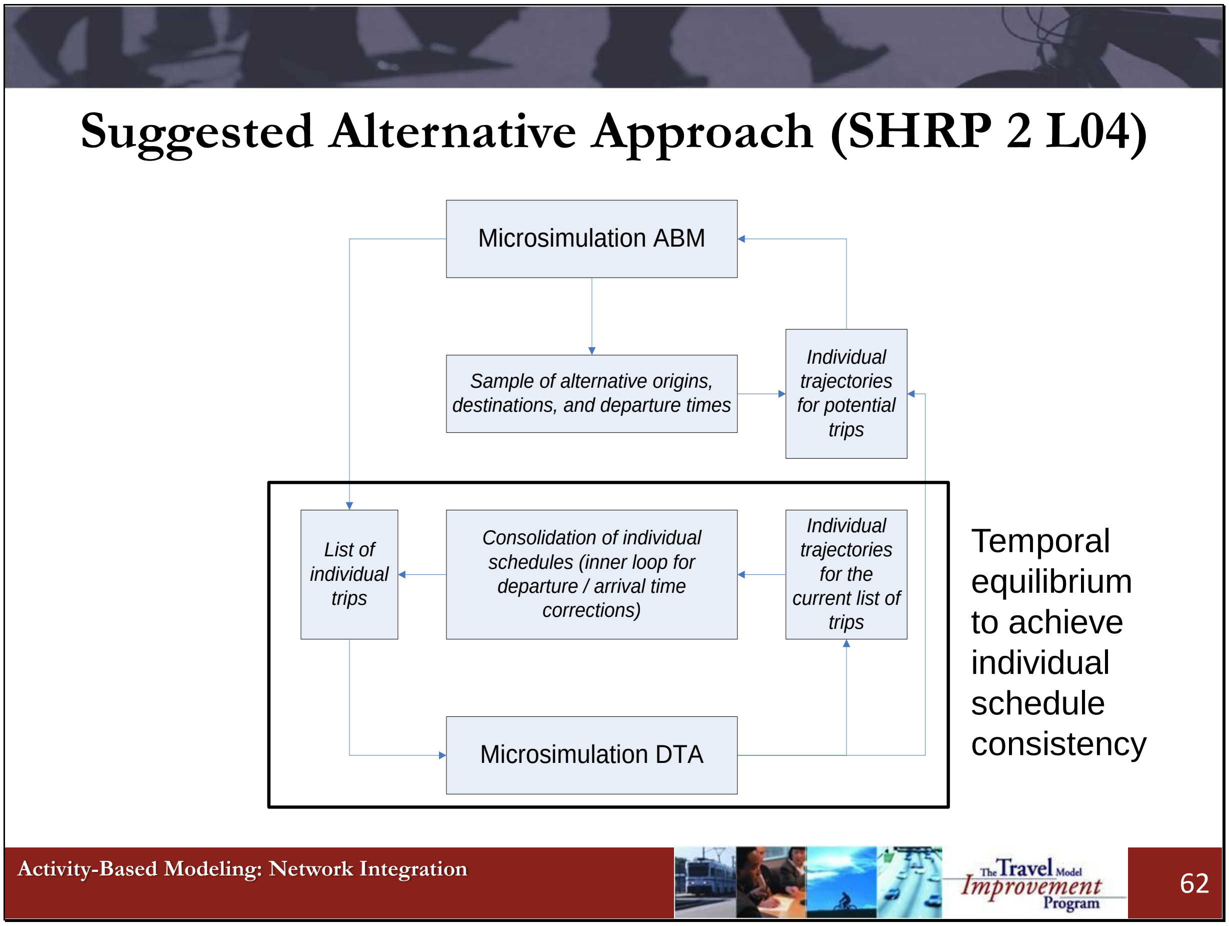
This is a reminder of the essence of conventional integration scheme in a 4-step model. Note that trip tables and LOS skims are in exactly the same matrix format.



The same idea does not work for DTA-ABM integration directly. The crux of the problem is that the feedback from DTA to ABM is not straightforward. DTA only produces individual trajectories for the current set of trips. This is not enough to support an ABM across all travel choice dimensions and for all potential trips.

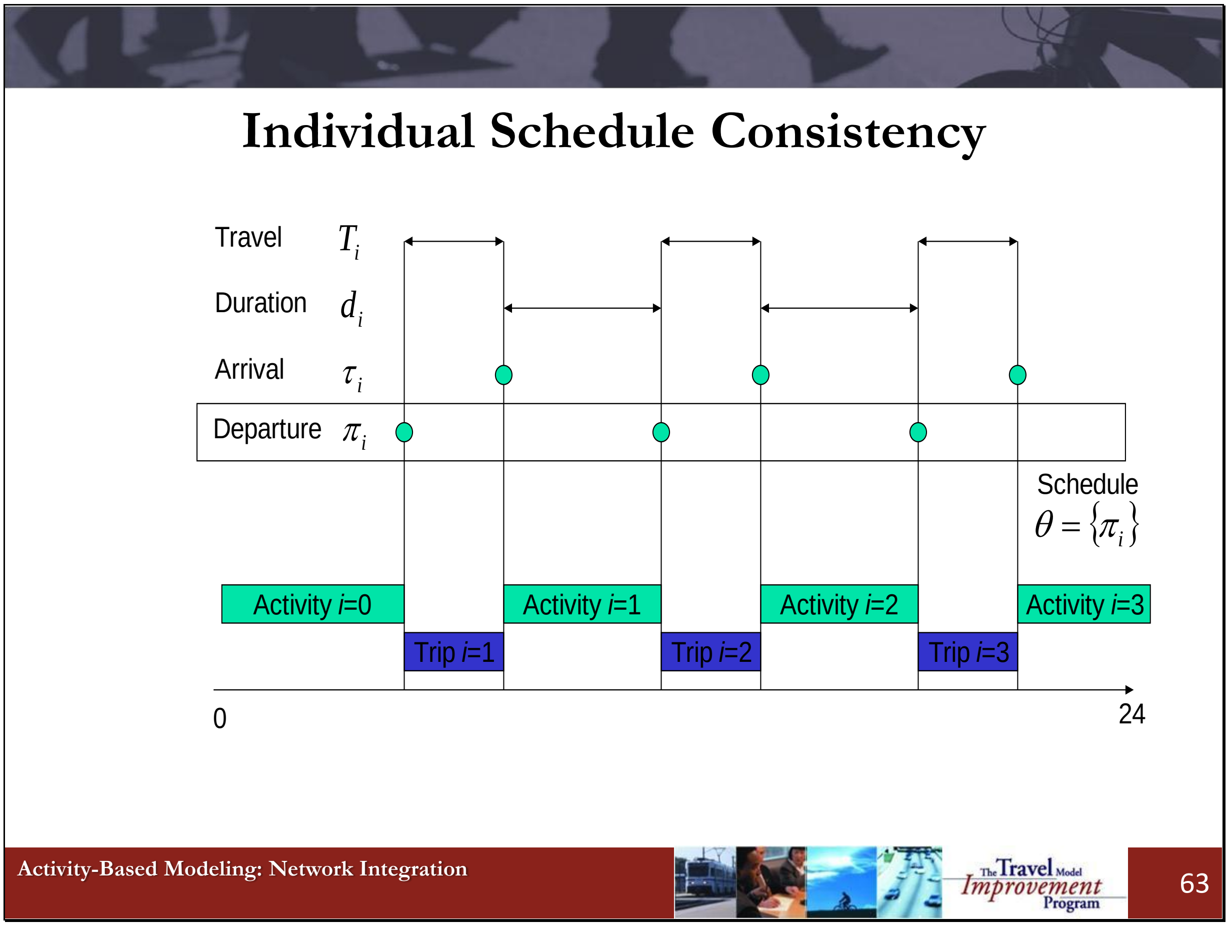


A possible surrogate solution that solves some problems in practical terms is to use aggregate LOS skims instead of individual trajectories. This so far has been the main strategy, but it must be understood that a lot of individual information is lost in the aggregation of these data.

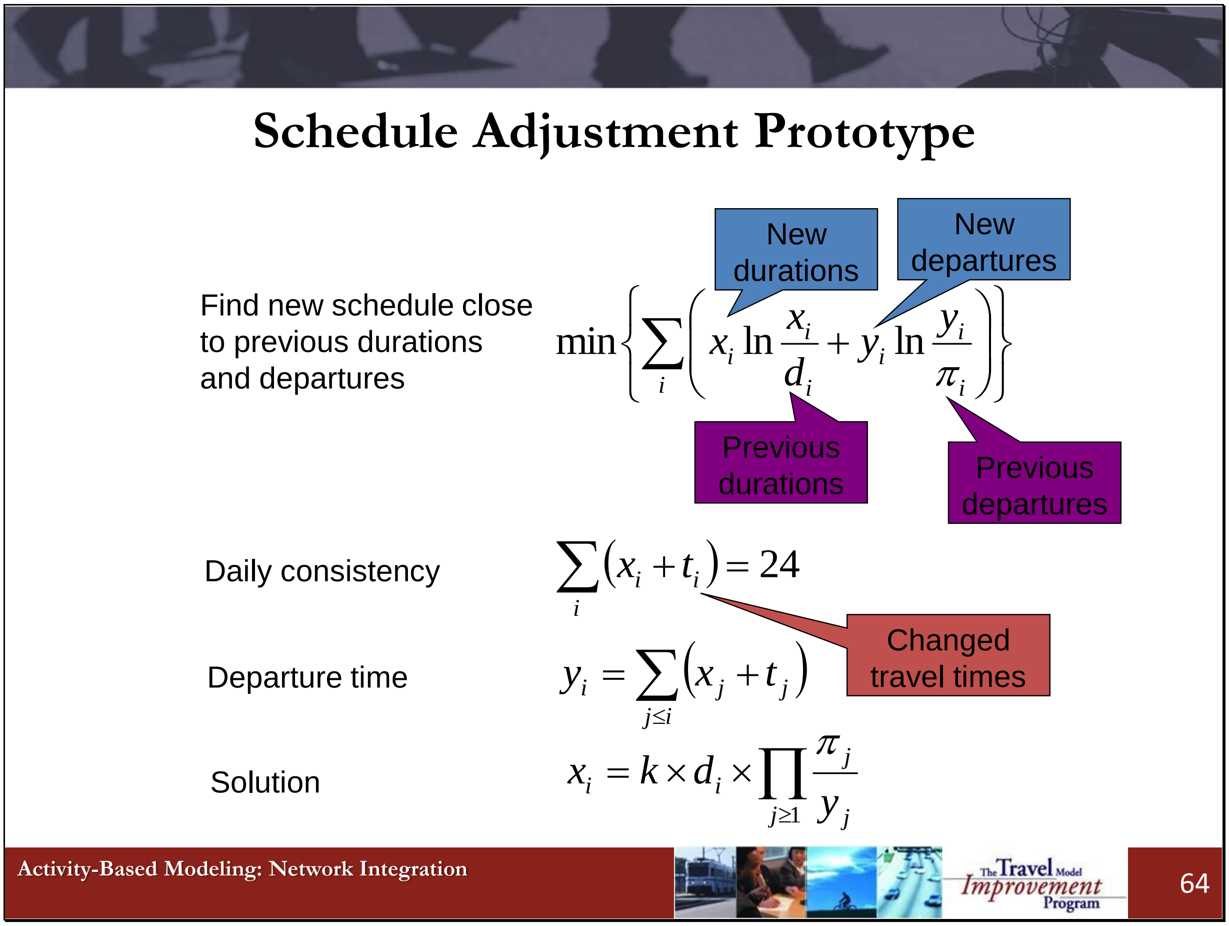


New methods of equilibration for ABM and DTA are presented, where two innovative technical solutions are applied in parallel. The first solution is based on the fact that a direct integration at the disaggregate level is possible along the temporal dimension if the other dimensions (number of trips, order of trips, and trip destinations) are fixed for each individual. Then, full advantage can be taken of the individual schedule constraints and corresponding effects. The inner loop of temporal equilibrium includes schedule adjustments in individual daily activity patterns as a result of congested travel times being different from the planned travel times. It is very much helps the DTA to reach convergence (internal loop), and is nested within the global system loop (when the entire ABM is rerun and demand is regenerated).

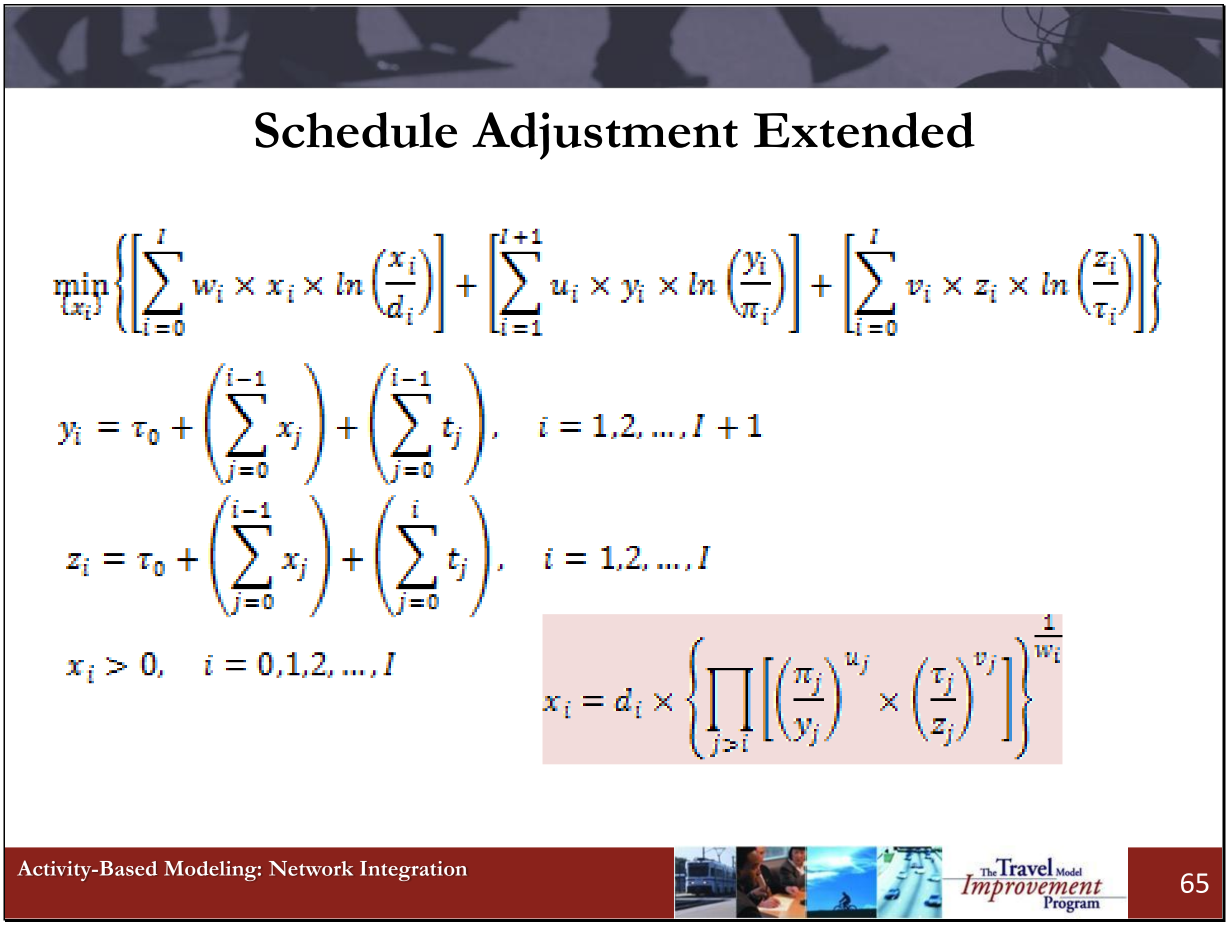
The second solution is based on the fact that trip origins, destinations, and departure times can be pre-sampled and the DTA process would only be required to produce trajectories for a subset of origins, destinations, and departure times. In this case, the schedule consolidation is implemented though corrections of the departure and arrival times (based on the individually simulated travel times) and is employed as an inner loop. The outer loop includes a full regeneration of daily activity patterns and schedules but with a sub-sample of locations for which trajectories are available.



Individual schedule consistency means that for each person, the daily schedule (i.e., a sequence of trips and activities) is formed without gaps or overlaps as shown on the slide. In this way, any change in travel time would affect activity durations and vice versa.



Adjustment of individual daily schedule can be formulated as an entropy-maximizing problem of the following form. Solution is easy to find by iterating and balancing durations and departures.



This model was further extended to incorporate various schedule constraints and priorities. The essence of this formulation is that in presence of travel times that are different from the expected travel times that the user used to build the schedule, he will try to accommodate new travel times in such a way that the schedule is preserved to the extent possible. The preservation relates to activity start times (trip arrival times), activity end times (trip departure times), and activity durations. The relative weights relate to the priorities of different activities in terms of start time, end time, and duration. The greater is the weight, the more important for user to keep the corresponding component close to the original schedule. Very large weights correspond to inflexible, fixed-time activities. The weights directly relate to the schedule delay penalties as described below in the section on travel time reliability measures. However, the concept of schedule delay penalties relates to a deviation from the (preferred or planned) activity start time (trip arrival time) only, while the schedule adjustment formulation allows for a joint treatment of deviations from the planned start times, end times, and durations.

Weights for Schedule Adjustment

Activity type	Duration	Trip departure (to activity)	Trip arrival (at activity location)
Work (low income)	5	1	20
Work (high income)	5	1	5
School	20	1	20
Last trip to activity at home	1	1	3
Trip after work to NHB activity	1	5	1
Trip after work to NHB activity	1	10	1
NHB activity on at-work sub-tour	1	5	5
Medical	5	1	20
Escorting	1	1	20
Joint discretionary, visiting, eating out	5	5	10
Joint shopping	3	3	5
Any first activity of the day	1	5	1
Other activities	1	1	1

This is an example of typical weights applied in the schedule consolidation algorithm. These weights can be further individualized. Note the extreme cases with high weights that correspond to fixed schedule components. Lower weights correspond to flexible schedule components.

Pre-Sampling of Trip Destinations

- Primary destinations are pre-sampled:
  - 300 out of 30,000 for each origin and travel segment,
  - 30 out of 300 for each individual and travel segment
- Stop locations are pre-sampled:
  - 300 out of 30,000 for each OD pair and travel segment
  - 30 out of 300 for each individual and travel segment
- Importance sampling w/o replacement from expanded set of destinations 300×30,000 and 30×300 to ensure uniform unbiased samples
- Efficient accumulation of individual trajectories in microsimulation process

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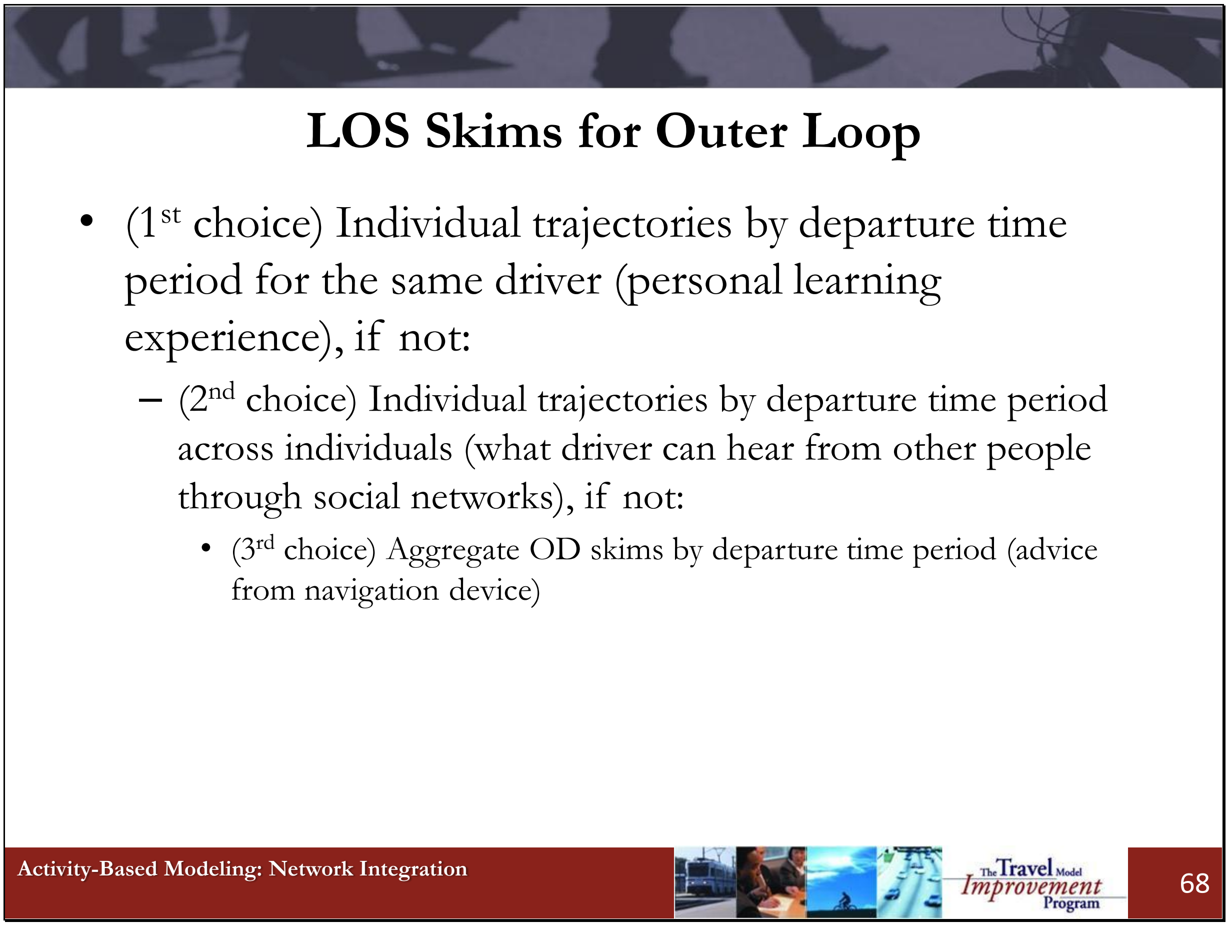
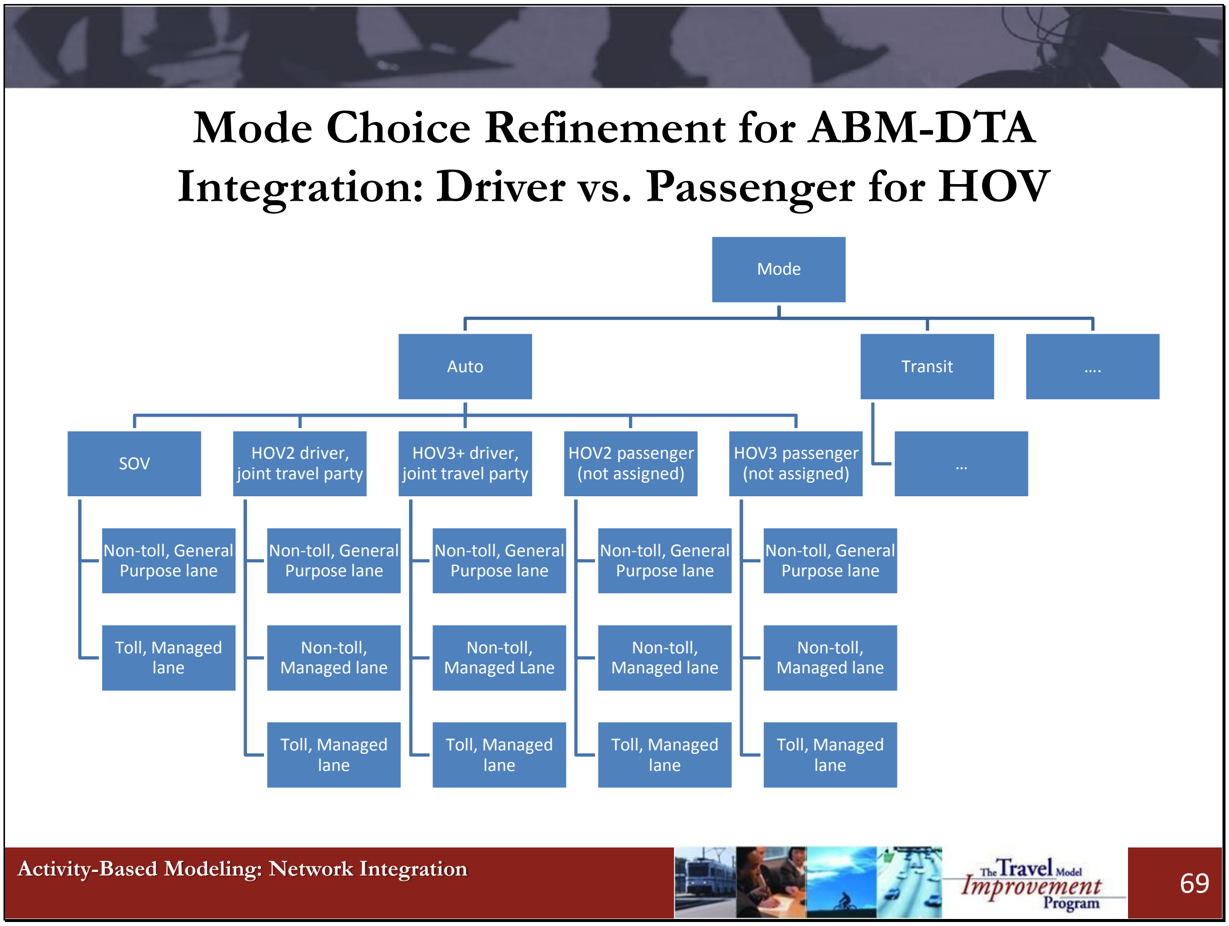
This method is intended to resolve one of the fundamental problems associated with integration of micro-simulation ABM and DTA – the calculation of individual LOS variables for non-observed destinations and times of days (i.e. for trips that were not simulated at the previous global iterations). It is also behaviorally more appealing to assume that an individual does not always scan all possible location in the region for each activity but rather operate within a certain spatial domain where he explores options over time and make choice based on the past experience.

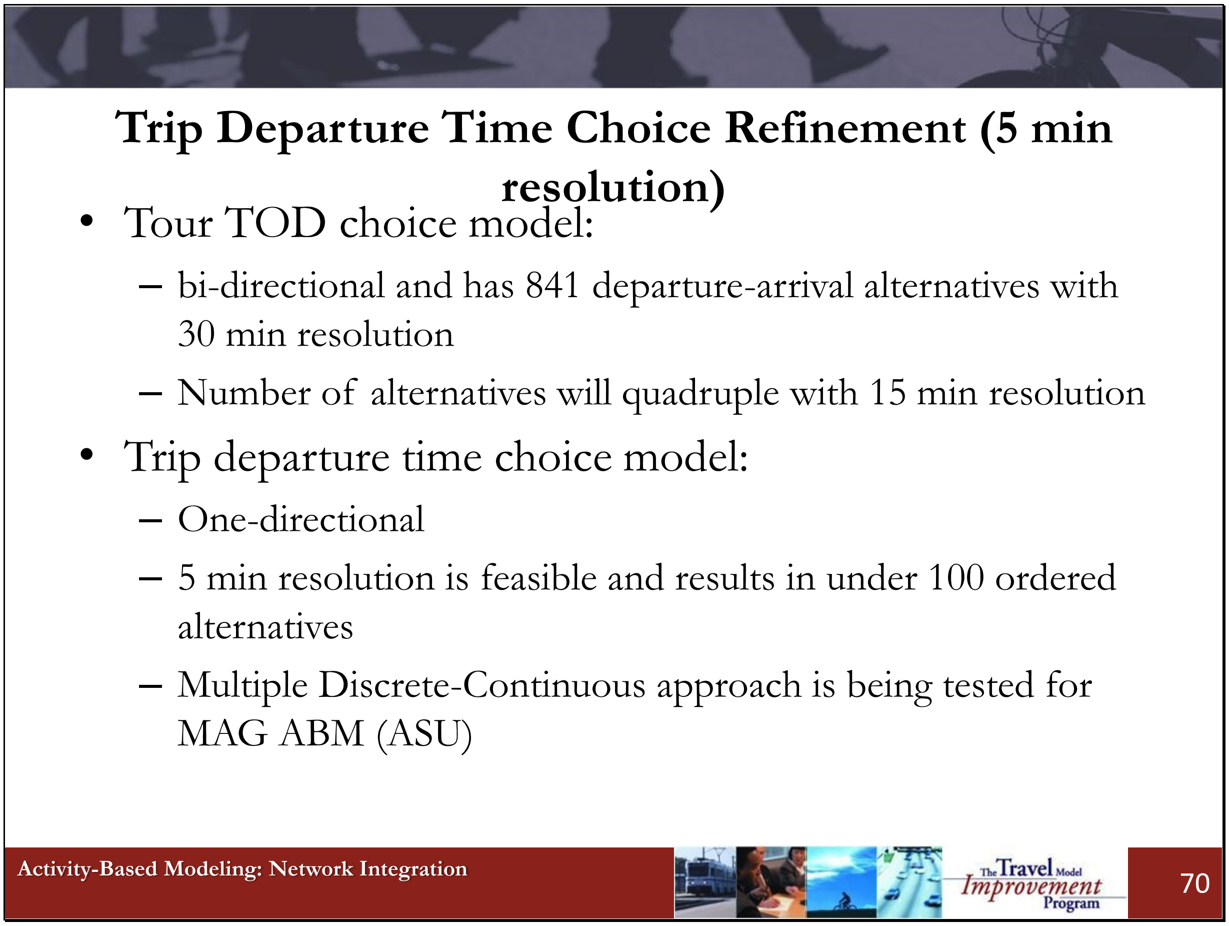


Pre-sampling of destination constrains the variation of destinations for each individual and allows for an efficient accumulation of individual trajectories in the micro-simulation process. With this technique, the LOS variables will be defined at each subsequent iteration as follows:

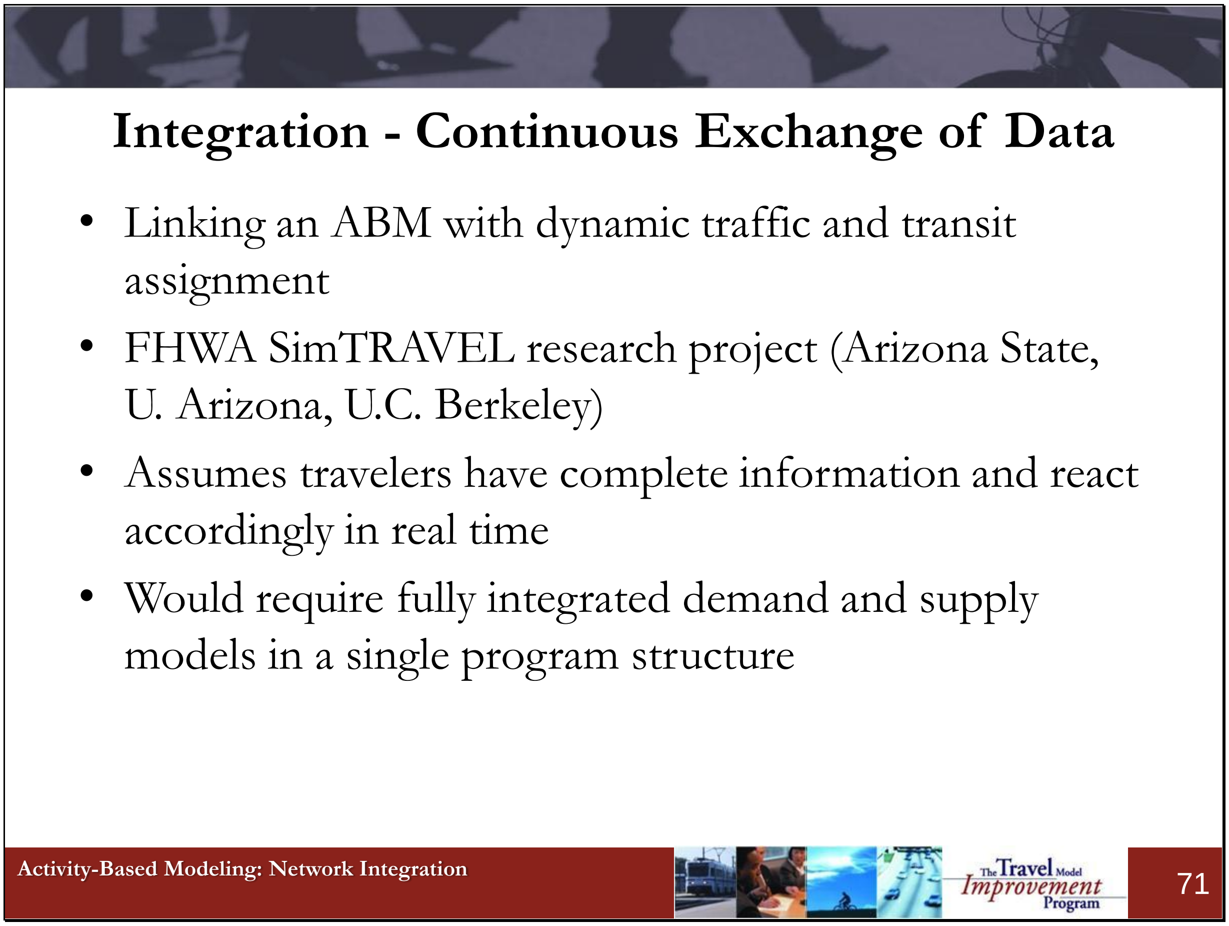
- First, individual trajectories to the same destination by departure time period for the same driver (or some other driver from the same household) are used if present in the previous simulation; behaviorally, this corresponds to personal learning experience; having only 30 possible destinations enhances this probability for each individual; if not:
- Individual trajectories to the same destination by departure time period across all individuals are used if present in the previous simulation (if several of them are available, the average can be used); behaviorally this corresponds to social networking when the driver can hear from other people about their experience; having only 300 possible destinations for each origin MAZ enhances this probability, if not:
- Aggregate LOS skims by departure time period will be used as the last remaining option; behaviorally it can be thought of as using an Advice from an advanced navigation device.



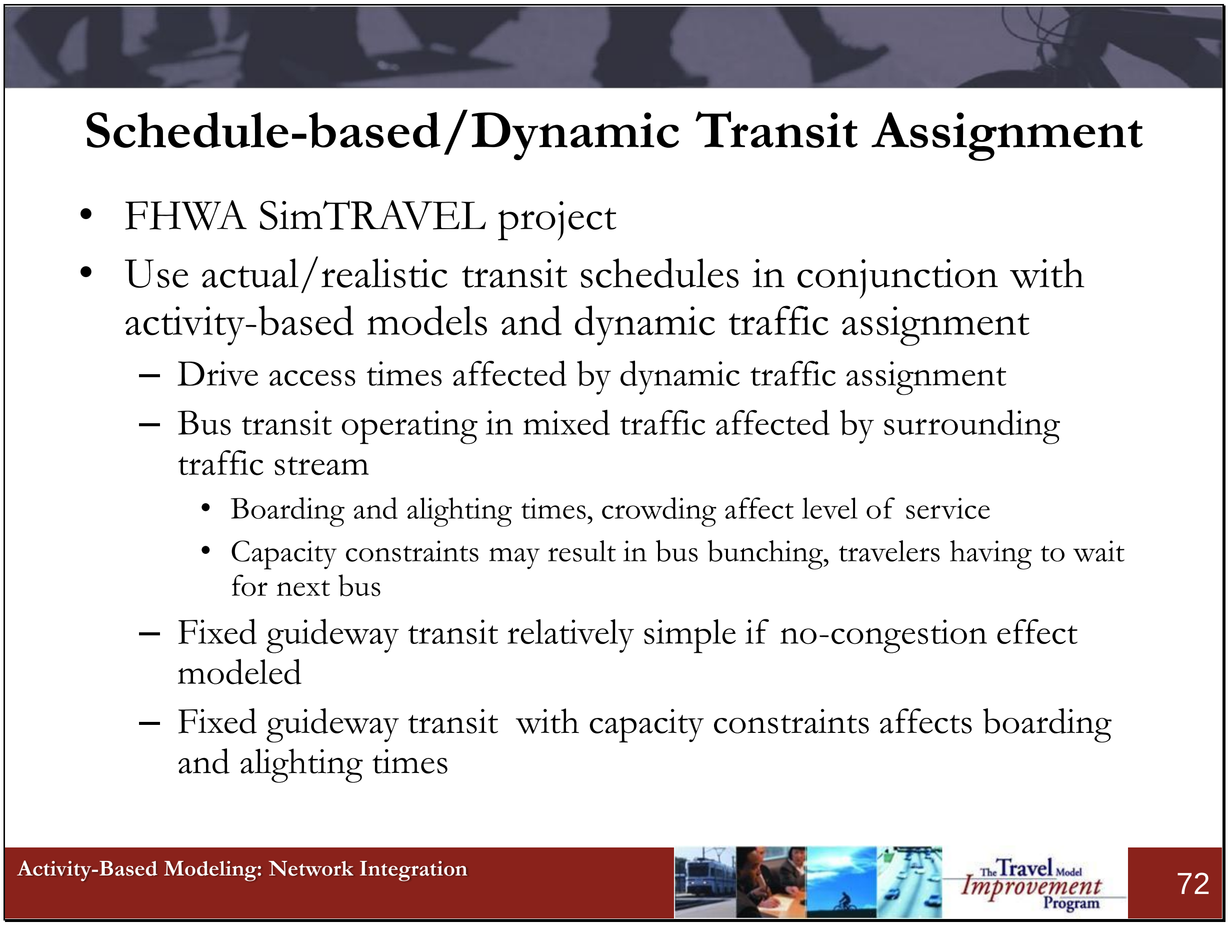
An advanced ABM incorporates intra-household carpools explicitly (joint travel by household members is a separate travel segment) and inter-household carpools implicitly in the mode choice process. This provides the necessary background for the refinement of mode choice that should include both car occupancy and driver-passenger roles explicitly. In this way, the ABM output in terms of person trips will be fully compatible with the DTA input required vehicle trips by occupancy. Moreover, for more advanced integration schemes, the individual driver and travel party characteristics including VOT and VOR can be carried over from the ABM to DTA.



In order to make the ABM compatible with the temporal resolution of DTA, we suggest an enhancement of the temporal resolution of the trip departure time choice model to 5 min. The tour-level time-of-day choice model is characterized by a complicated two-dimensional choice of outbound and inbound times that results in approximately 1,000 alternatives with 30-min resolution. This choice dimension is difficult to further improve in terms of temporal resolution. Also, in behavioral terms, there is no need in too much temporal detail in tour-level scheduling anyway, since it does not yet have full information on the number/location of destinations visited along the tour, so the exact timing and LOS information is only indicative at this point in the simulation. However, trip-level choice of departure time that is conditional upon the entire-tour time-of-day choice can be refined to 5 min, since the choice structure is one-dimensional and more details about each particular trip origin and destination can be used.

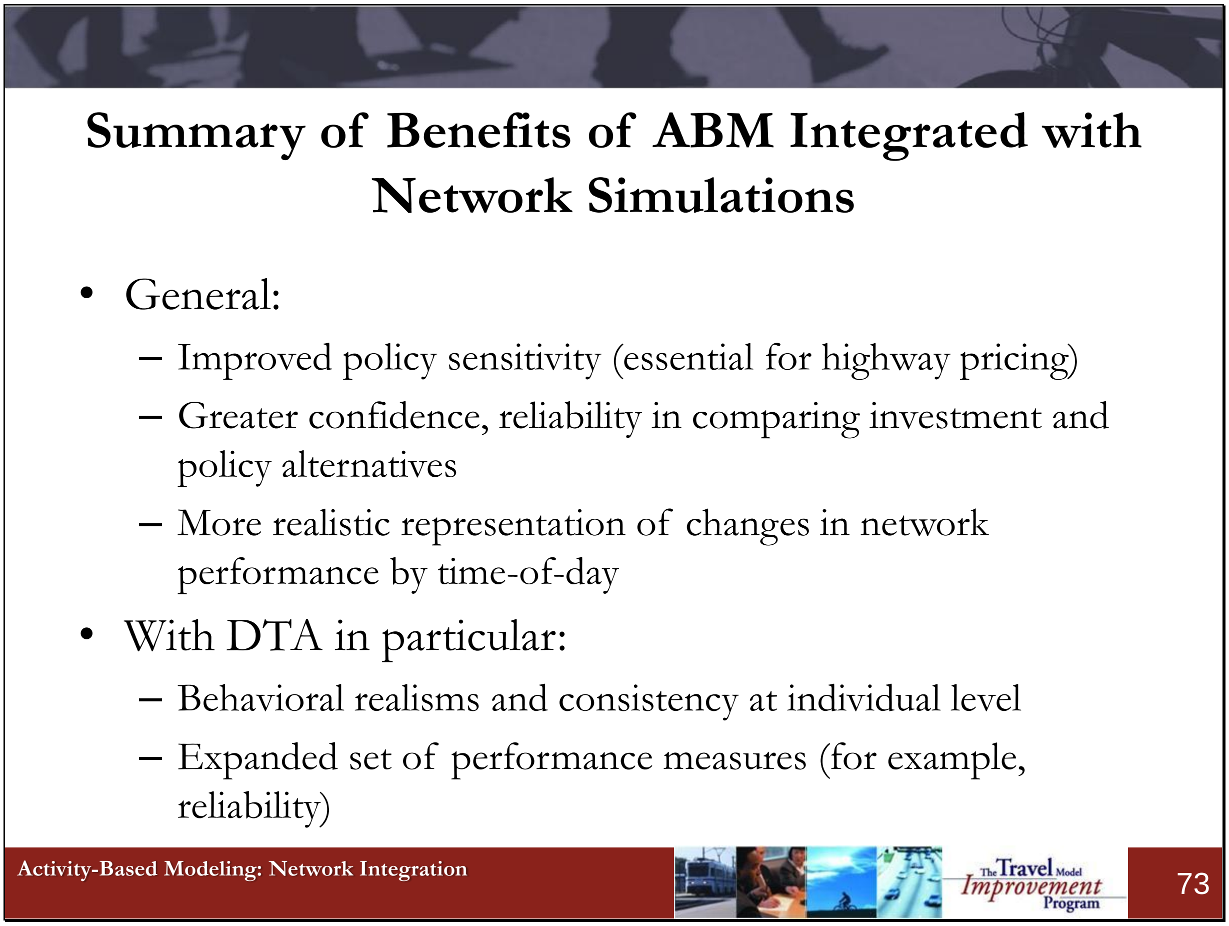


One of the more ambitions research efforts currently underway is the FHWA sponsored SimTravel project. This wide-ranging project is developing integrated models of the entire urban system including location choices of households and firms, activity and travel patterns of passengers and freight, and emergent traffic flows on time-dependent networks. Unlike integrated models which seek to achieve an equilibrium condition by the repeated exchange of demand and supply data, much of the early SimTravel work around demand and supply integration is focused on “real time” interactions between the demand and supply components. Ultimately, such an approach seems as though it may require fully integrated demand and supply models in a single program structure. However, such an approach may also offer compelling application and analysis capabilities.



There have been several recent initial attempts to use actual/realistic transit schedules in conjunction with activity-based models and dynamic traffic assignment. Specific efforts have included attempts to model the following behavior:

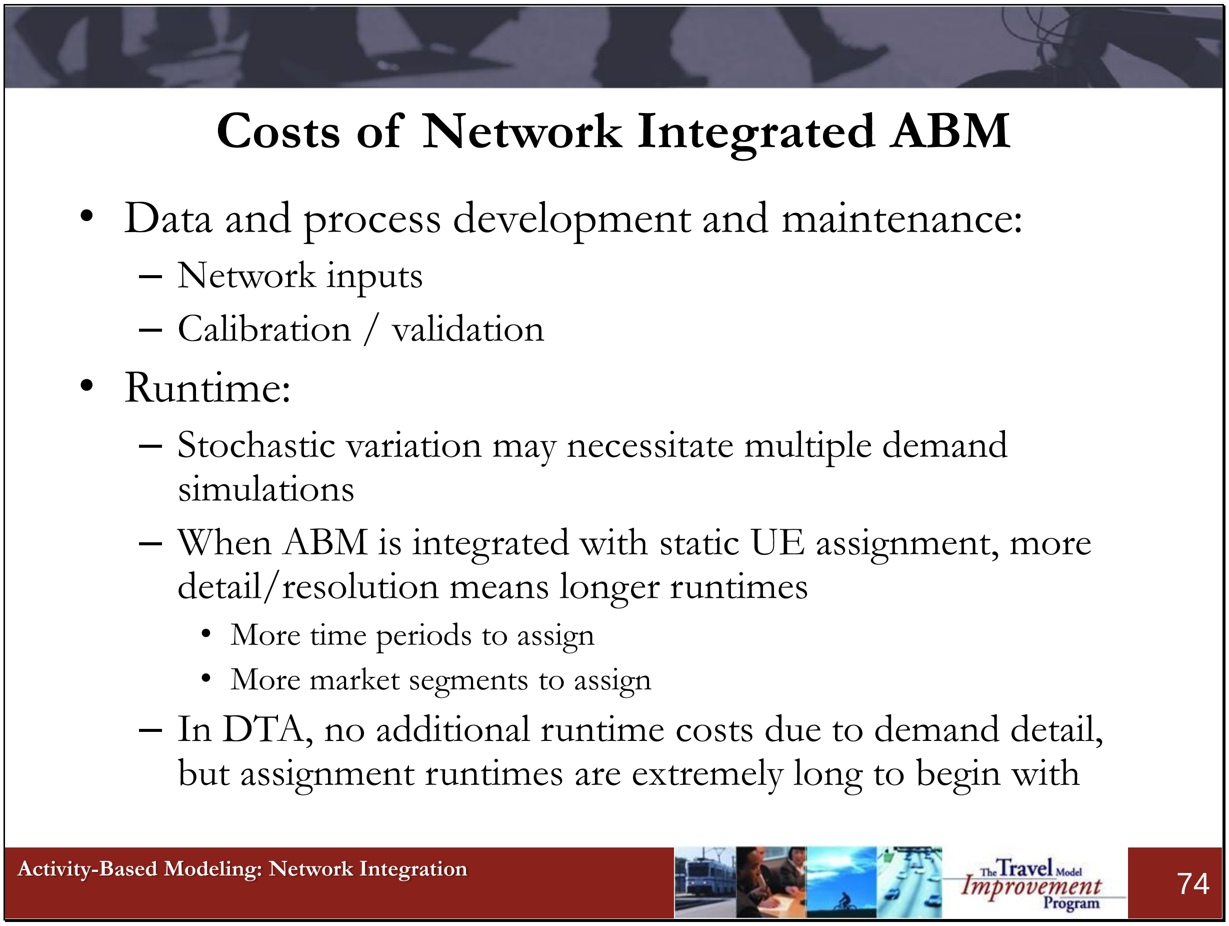
- Drive access times affected by dynamic traffic assignment;
- Bus transit operating in mixed traffic affected by surrounding traffic stream;
- Boarding and alighting times, crowding affect level of service;
- Capacity constraints may result in bus bunching, travelers having to wait for another bus;
- Fixed guideway transit relatively simple if no-congestion effect modeled; and
- Fixed guideway transit with capacity constraints affects boarding and alighting times.



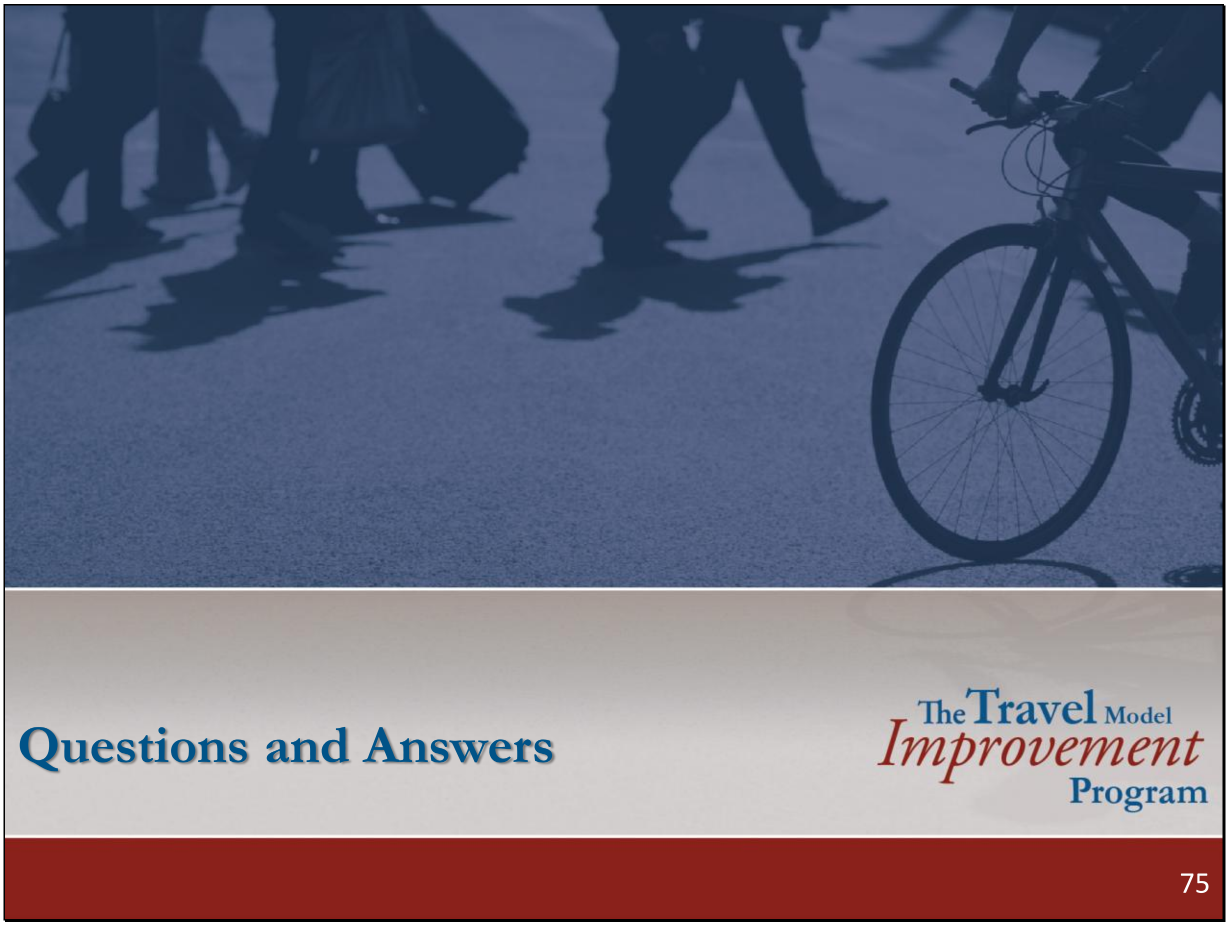
The most significant benefit of an activity-based model system that has been carefully integrated with a network supply model is improved policy sensitivity and by extension, greater confidence when comparing investment and policy alternatives. This improved policy sensitivity is critical, as decision-makers rely on travel demand models for answers to more complex policy questions, and expect that these models are appropriately sensitive to the complex behavioral responses.

Whether evaluating the impacts of a pricing scenario on the use of specific routes, timing, mode, destination or activity generation choices, or considering the impact of land use or travel demand management strategies, these complex questions necessitate models that appropriately and consistently capture the relationship between travel demand and supply. If network pricing is to change by time-of-day, then ideally network information (times, costs) at a time resolution consistent with this pricing scenario can be fed back from supply model to demand model.

Similarly, if value-of-time distribution information is used when predicting demand, then ideally this segmentation would be reflected in the configuration of the supply model. Greater detail and greater consistency between the demand and network supply components of the model system lead to improved behavioral realism. In addition, this greater detail in both the demand and supply components supports an expanded set of performance measures.



However, this improved policy sensitivity comes at a cost. From a data management perspective, the development and maintenance of network inputs does require additional effort, and more fine-grained calibration and validation efforts are also associated with this additional detail. From a production standpoint, the additional time period and market segmentation results in longer runtimes when using static assignment methods, although these runtimes differences become less significant with improvements in network software and increases in hardware computing power. Within the context of DTA, these runtime differences associated with additional may detail become even less relevant. Depending on the specific application context, stochastic variation associated with the use of the Monte Carlo simulation based activity model may also necessitate multiple simulations and additional runtime, although the demand components of most activity-based model systems typically account for only a small fraction of total model runtimes.


Questions and Answers
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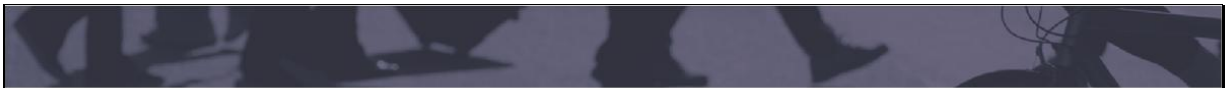

Next Webinar

Executive and Management Sessions	
Executive Perspective	February 2
Institutional Topics for Managers	February 23
Technical Issues for Managers	March 15
Technical Sessions	
Activity-Based Model Framework	April 5
Population Synthesis and Household Evolution	April 26
Accessibility and Treatment of Space	May 17
Long-Term and Medium Term Mobility Models	June 7
Activity Pattern Generation	June 28
Scheduling and Time of Day Choice	July 19
Tour and Trip Mode, Intermediate Stop Location	August 9
Network Integration	August 30
Forecasting, Performance Measures and Software	September 20

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Session 11 Questions and Answers

On slides 32 & 33 there was a depiction of a trip-based model with feedback and an activity-based model and all of its components. Is it because we are working with travel behavior of individuals in the synthetic population that the feedback can occur in any of these model steps?

Joe: No, I wouldn't say it is because we are working with a synthetic population that all of this feedback is possible. You could incorporate accessibility measures in a trip-based model, going all the way back to auto ownership and trip generation. There are generally more components in an activity-based model, and a conscious attempt to ensure upward and downward consistency by incorporating feedback. But, it is not intrinsic to using a synthetic population. That being said, by using individual agents, you can include more person-level and household-level attributes that may be related to accessibility, so the structure does facilitate a more focused use of those variables.

You mentioned some of the dangers of models that do not converge. Could you mention some possible model simplifications to help an un-converging model find convergence?

Peter: There are methods to analyze the entire model system and identify trouble-makers. There are specific components such as traffic assignment and mode choice for which we have very good strategies for achieving convergence. What might be a problem is an attempt to make trip generation or daily activity pattern, time of day, or destination choice over-sensitive, causing oscillation and difficulty reaching convergence. The first important step is to diagnose which model components are contributing to the lack of convergence, and there are diagnostic tests that can be performed to identify the source. Secondly, one of the best ways to deal with non-convergence is to apply differential averaging strategies. Many people use a simple MSA strategy or a naïve equilibration scale. These might need to be adjusted to achieve a better convergence. Normally if you observe wild behavior, it's likely that one of the model components needs fixing before worrying about convergence.

Could one assume that demand and supply convergence go hand in hand? Are there circumstances where one converges and the other does not?

Joe: It is dependent on the specific assignment method that is being used and the methods that are used in the specific activity-based model. On the assignment side, if we are using a traditional static-user-equilibrium method, and exposing the model to the same, converged demand matrix, you should see convergence in the traffic assignment. As we get into advanced network models such as dynamic traffic assignment, then it becomes more complicated, and it might be found that you don't see the same convergence. We might even need to reconsider how we define convergence. Another issue is the Monte Carlo simulation in the demand models. There are methods to hold the random seeds fixed, so that if you expose the activity-based model to the same skims, you will see exactly the same trips. Then there issues in the specific issues in the way the models are interacted with each other. So, while you do expect the convergence to go hand in hand, there are instances where it can't be assumed, depending on the nature of the implementation of the model.

This question concerns the potential of using DTA instead of static assignment, and what we do if we are not using volume-to-capacity (V/C) ratios. Could V/C ratios be capped during static assignment to better represent capacity constraints? If we are doing away with V/C ratios, what criteria do we use to establish level of service?

Peter: This goes back to better understanding the differences between static assignment and volume delay functions versus the simulation techniques such as car-following and queuing rules in a dynamic assignment. There have been many publications showing that V/C ratios cannot reliably establish travel time estimates, especially when V/C goes over one. This mechanism is replaced by simulation in a DTA, and when volume approaches capacity, a variety of things happen such as gridlock and queue spillback that more realistically address reality and do not allow V/C to rise above one. The publications show that the DTA methods more accurately estimate travel times during congestion. Whenever you try to just cap V/C to get more accurate travel times or stronger volume-delay functions, which we have tried to do, it doesn't work. The right way to go is have a tool such as DTA that actually represents the physical situation on the road. We need a new approach, but I do understand the concern for simplified practical solutions. While I don't recommend capping V/C, you can scale time estimates from static assignment based on observed values to provide a better matrix. But this is a temporary, surrogate solution, and I think we need to take DTA seriously. This is the way to go.