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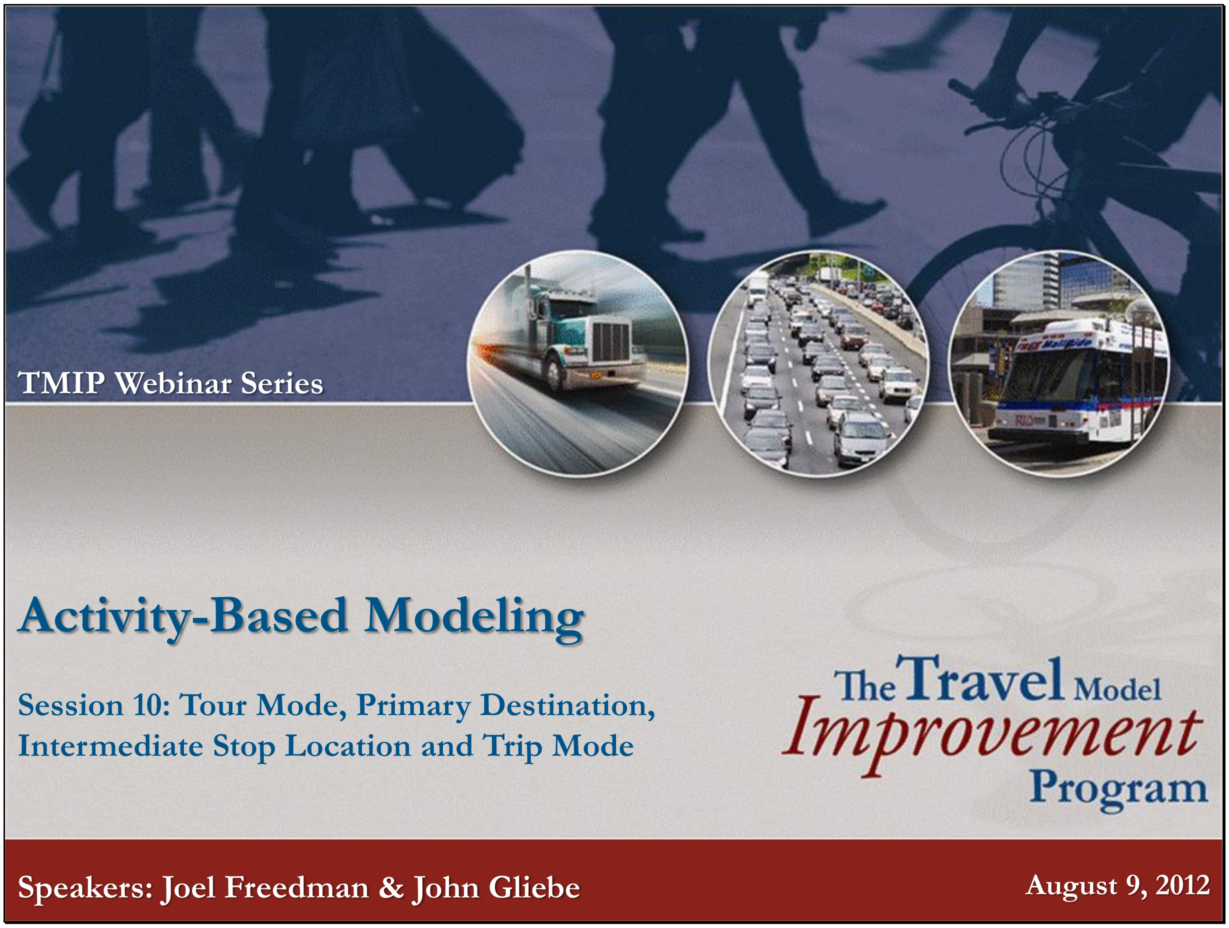

TMIP Webinar Series
Activity-Based Modeling
Session 10: Tour Mode, Primary Destination, Intermediate Stop Location and Trip Mode
The Travel Model Improvement Program
Speakers: Joel Freedman & John Gliebe
August 9, 2012

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.

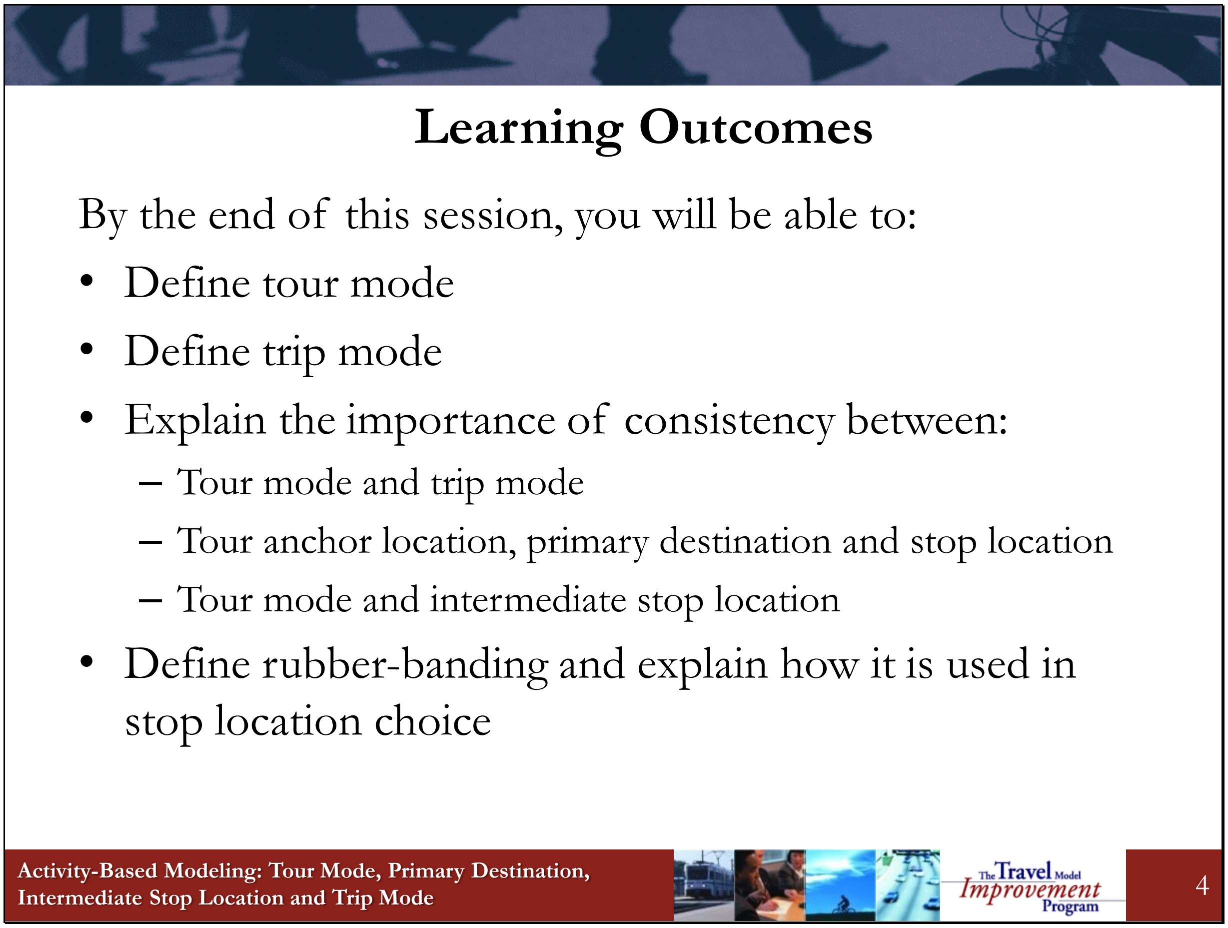
- Joel Freedman and John Gliebe are co-presenters. They were also primarily responsible for preparing the material presented in this session.
- Stephen Lawe is the session moderator.
- Content development was also provided by Jason Chen, Rosella Picado, and Greg Erhardt. Content review was provided by John Bowman.
- Sumit Bindra and Bhargava Sana were responsible for media production, including setting up and managing the webinar presentation.

2012 Activity-Based Modeling Webinar Series

Session	Date
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 Frameworks and Techniques	April 5
Population Synthesis and Household Evolution	April 26
Accessibility and Treatment of Space	May 16
Long-Term and Mobility Choice 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

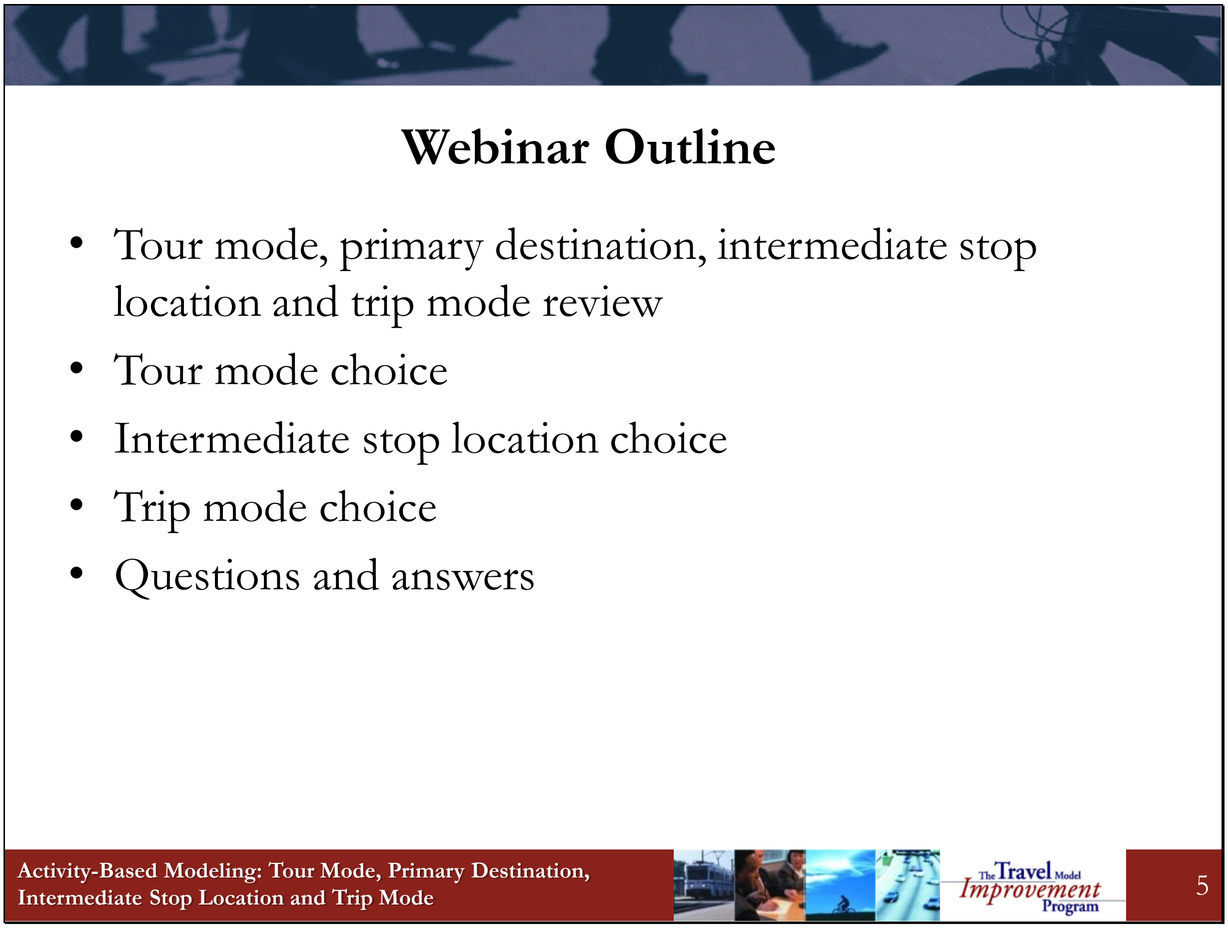
For your reference, here is a list of all of the webinars topics and dates that have been planned. As you can see, we have been presenting a different webinar every three weeks. Three weeks ago, we covered the ninth webinar in the series—scheduling and time of day choice.

Today's session is the seventh of nine technical webinars, where we will cover the details of tour and trip modes and intermediate stop location choices. In three weeks, we will discuss how activity-based modeling demand systems are integrated with network supply models.



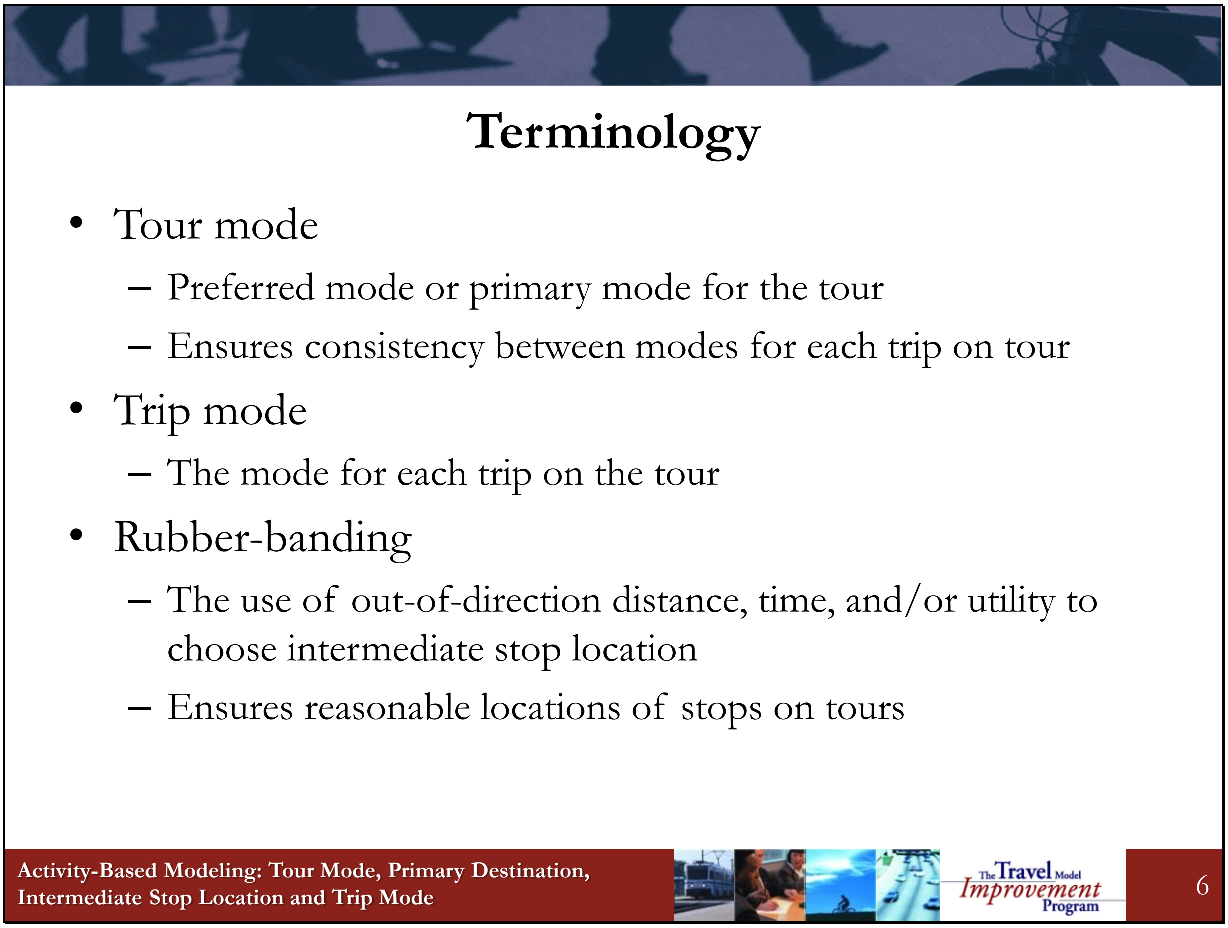
Shown on this Page are the webinar learning outcomes. By the end of this session, you will be able to:

- Define tour mode
- Define trip mode
- Explain the importance of consistency between:
- Tour mode and trip mode
- Tour anchor location\primary destination and stop location
- Tour mode and intermediate stop location
- Define rubber-banding and explain how it is used in stop location choice



In this webinar, we will cover many of the components of activity-based models that predict tour-level characteristics of tours, including the location of out-of-home activities on the tour, and the mode or modes used for the tour. Recall from previous webinars that we distinguish between primary destination on the tour, and intermediate stops on the tour. The primary destination on the tour is the location of the primary activity on the tour, or the main reason for making the tour, whereas intermediate stops are activities that occur between the tour anchor location (home or work) and the tour primary location. Also note that we distinguish between tour mode and trip mode. This concept will be explained more fully in a moment.

We will provide opportunities for questions and answers.



There are three terms that we will use in this session that may be familiar, but are worth defining explicitly, so their meaning is clear.

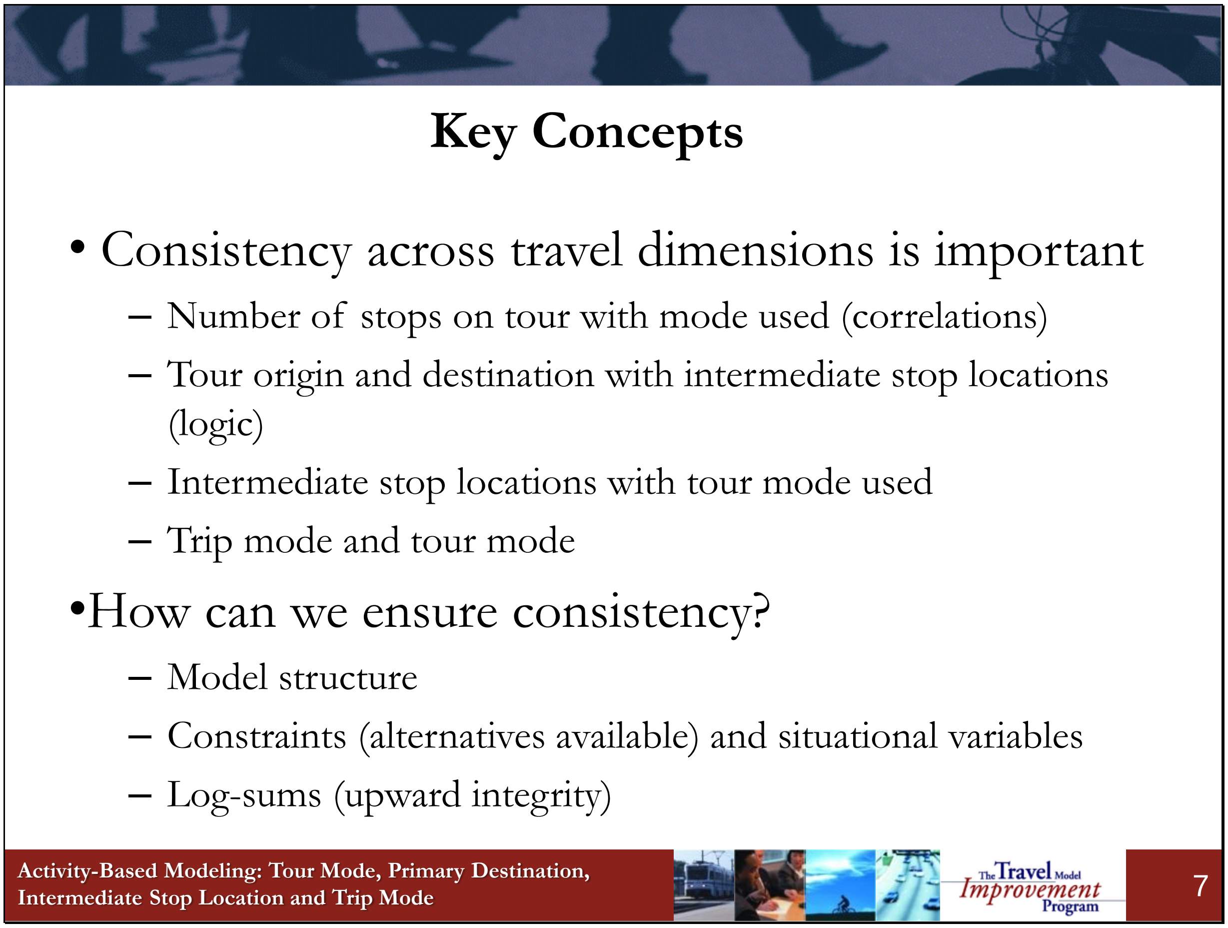
The tour mode is the preferred mode for a series of trips that begin and end at an anchor location (typically either home or work). Note that tour mode is not reported in survey data nor is it directly observed. Rather, it is inferred from the combination of modes used for trips within a tour. It is defined to ensure a reasonable consistency between the modes used for individual trips on the tour, as we shall see.

The trip mode is the mode for an individual movement from an origin to a destination. The trip mode is often, but not always the same as the tour mode that the trip is a part of. It can differ, for example, if someone carpools to work but takes transit home. It can also differ when someone drops-off a passenger, going from a shared-ride mode to a drive-alone mode.

Rubber-banding refers to the method of measuring the impedance to an intermediate stop, which takes into account out-of-direction distance, time, and/or utility to choose an intermediate stop location. In rubber-banding, you can visualize stretching a rubber band between the tour's anchor location and primary destination, holding those two locations fixed. One side of the rubber band is stretched to consider alternate intermediate stop locations. When this is done, the impedance is calculated as:

anchor to stop impedance + stop to primary destination impedance – anchor to primary destination impedance

Thus the amount of "stretch" to the rubber band represents the amount you have to travel out of your way to reach the intermediate stop. This method is utilized in order to choose stop locations that are reasonably related to the tour anchor and primary destination location.



A key difference between an ABM and a trip-based model is that in an ABM, each trip is no longer an independent unit of analysis—it is linked with other trips to form tours. The choices made for one trip affect the outcomes of all other trips on the tour. By accounting for this dependency among trips (trip-chaining), an ABM can capture more of the factors that truly drive travel choices. To be effective, however, the model has to ensure consistency among trips on a tour, and consistency among the different model components. This is a natural extension of good practice in trip-based modeling, where it is important to ensure consistency between transit path-building parameters and mode choice coefficients, among other things.

The number of stops on the tours should be consistent with the modes used. For example, walk and bike trips tend to have fewer stops, probably due to the increased travel time required to access activity locations. Tours in which there are shared-ride trips often have more stops than other modes, due to pick-up/drop-off of passengers. Tours with drive-transit modes also typically have more stops – in fact, one of the motivations for driving to transit is so that the car is available to perform out-of-home activities before or after work.

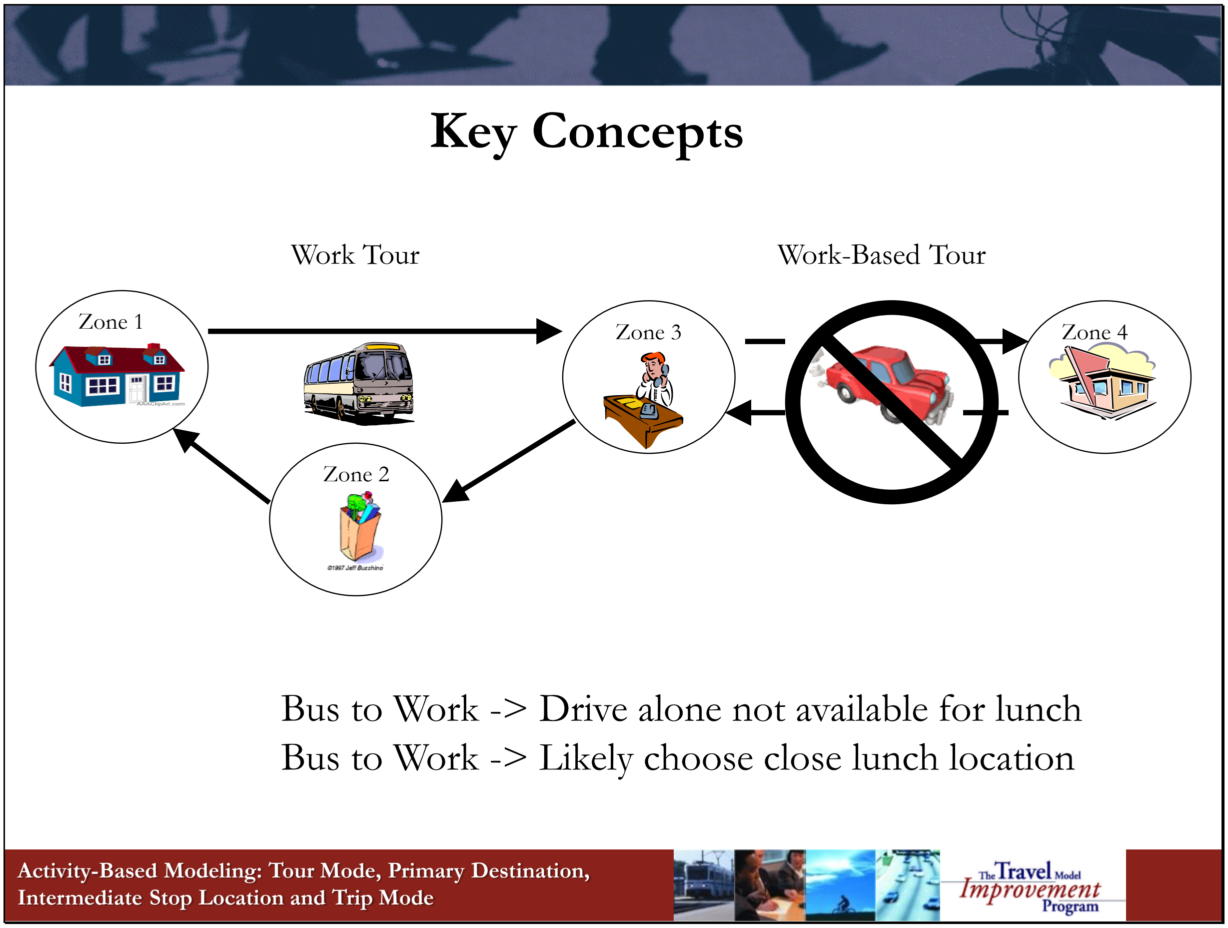
The location of intermediate stops on the tour should be reasonably related to the location of the tour origin and primary destination. Research indicates that travelers generally seek to minimize overall travel time by chaining trips in a logical order. For example, if a traveler needs to stop for groceries on the way home for work, a store is typically chosen near the home or en route between work and home, as opposed to somewhere in the opposite direction from home.

Similarly, the locations of stops on tours are influenced by the mode used for trips on the tour. If the traveler stops on the way to work by transit, the stop location will likely be within walking distance of home or work, or in some cases at a transfer location between home and work. It is unlikely that the traveler will choose a location that is not served by transit or within walking distance of their origin or destination.

So, how can we ensure consistency across these decisions on at a tour-level?

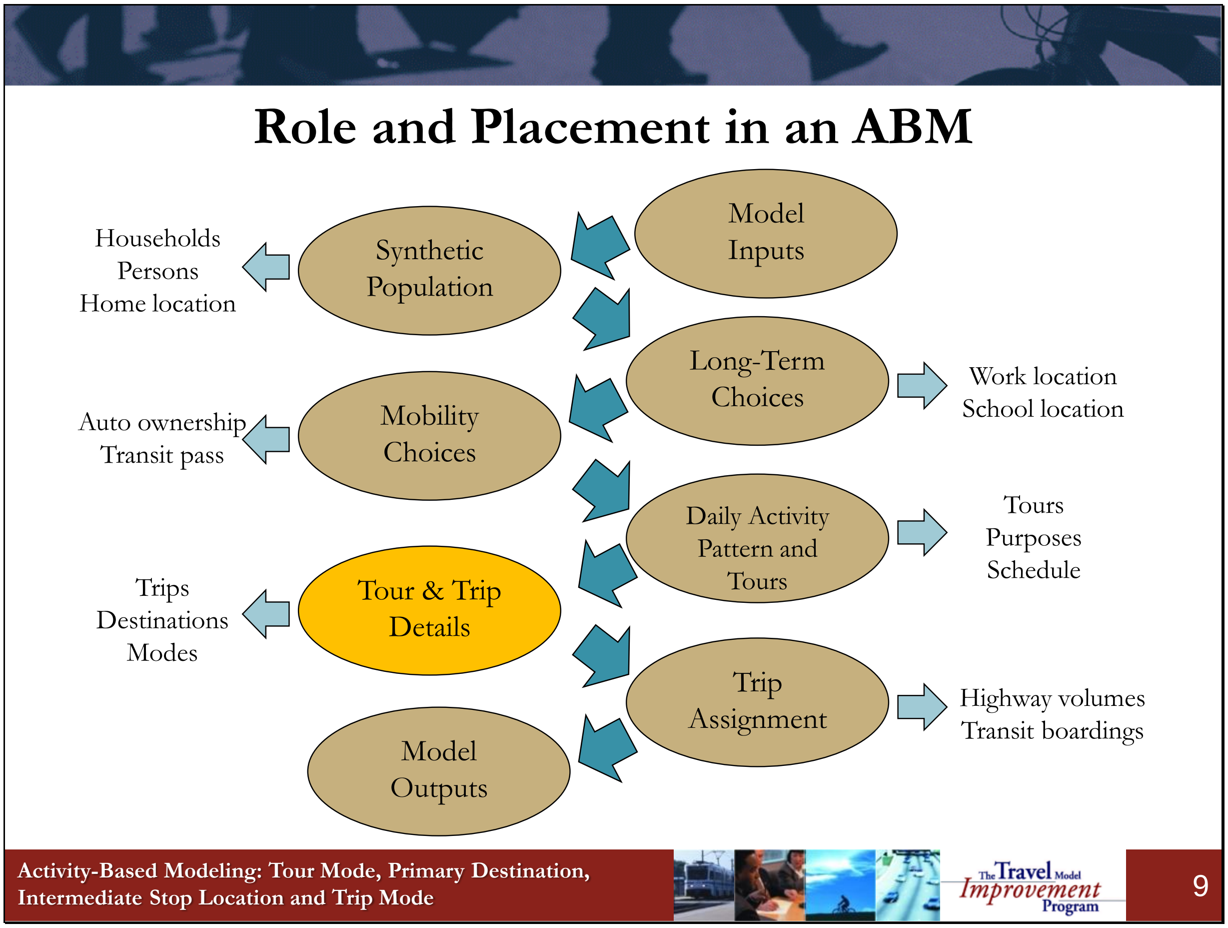
One aspect of consistency relates to the structure of the model chain, and what choices are modeled explicitly versus determined implicitly. For example, model system with an explicit ride-sharing model for escort tours will explicitly predict pickup/drop-off stops on tours, thereby ensuring that stop locations and trip modes are consistently determined across persons in the household, with respect to location (with stops modeled at schools) timing (with all departure and arrival times consistently modeled across tour participants), and mode (with shared-ride modes for appropriate trips on tours).

Constraints and situational variables are also used to ensure consistency. An example of constraints is the use of tour mode to constrain the modes used for trips on a tour. For example, if a traveler chooses walk-transit to work, that traveler cannot use their personal vehicle for intermediate stops on the tour. Therefore drive-alone is prohibited at the trip level for walk-transit tours. Situational variables (variables that are the results of previously applied models) are also used; for example, auto ownership levels influence mode choice. Travelers in zero auto households are more likely to walk, bike, and take transit than multiple-vehicle households. Finally, log-sums are used in choice models to ensure consistency. For example, trip mode choice log-sums are used as explanatory variables in intermediate stop location choice, to ensure that chosen stop locations are consistent with available trip modes.

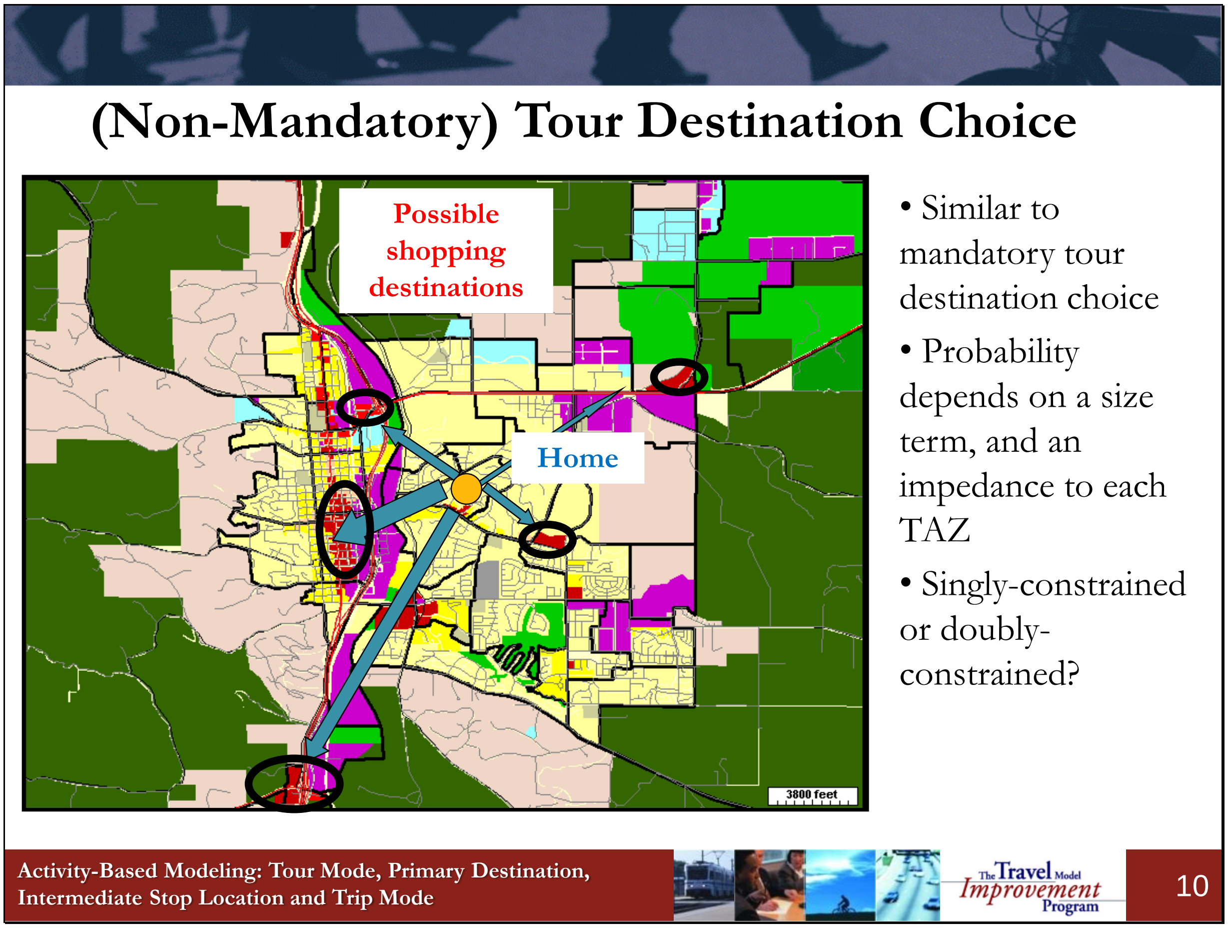


This Page shows a simple example of how a situational variable can be used to ensure consistency. In this case, the situational variable is the chosen mode to work, which is walk-transit. This variable is used to constrain the alternatives available (and the probabilities of the available alternatives) in the work-based sub-tour mode choice model. If a traveler arrives at work by transit, they are unlikely to drive-alone to lunch. In most cases, we can eliminate drive-alone as a potential tour mode for lunch. Additionally, shared-ride is an unlikely choice for this tour, which is reflected by highly negative alternative-specific constants for shared-ride. A much more likely choice is walking or walk-transit to lunch. This is one of the reasons why downtown workers tend to walk to lunch – they do not have their car available for their lunch trip.

Additionally, the choice of a restaurant for lunch should be affected by the mode to work; if an auto is not available, the traveler should choose a lunch-place relatively close to work (within walking distance). This is ensured by the use of a destination choice log-sum in the at-work sub-tour which reflects the chosen mode to work. If the chosen mode to work is walk-transit, the log-sum will reflect a much steeper decay with respect to distance.



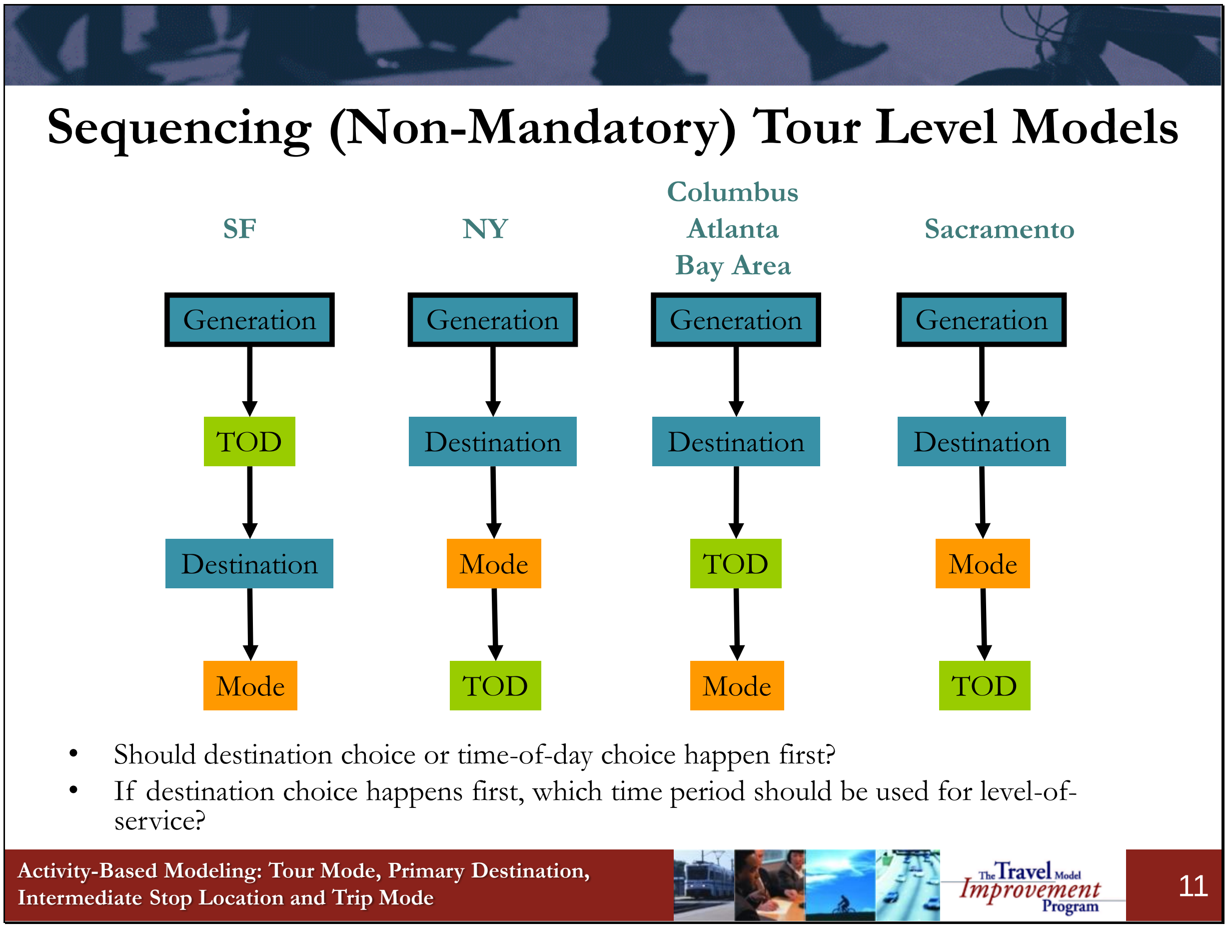
While ABMs can vary in structure, this diagram shows the location of tour & trip detail choices (tour mode, primary destination, intermediate stop location and trip mode) in a typical model stream. The text on the outside shows the types of outcomes predicted by each model stage. When we are ready to predict tour and trip details, we already have a synthetic population of households and persons with their home locations, we have predicted the primary work and school locations, auto ownership and other mobility decisions, and we have generated and scheduled tours using a daily activity pattern model. We do not yet know the primary destination of any non-work and non-school tours, the tour mode, the location of intermediate stops, or the trip mode. Once we are able to fill in these details, we are ready to convert the simulation data into trip tables that can be assigned to the network.



Remember, that we have already determined the primary destination of work and school tours as part of the long-term choices. The method for predicting the primary destination of non-mandatory tours is the same—to use a destination choice model.

In this example, we consider a traveler picking a location to go shopping. They consider the number of retail opportunities in each TAZ (the size), and the impedance to get to each TAZ. TAZs that have many shopping opportunities and are easy to get to will have the highest probability of being chosen. The impedance considers the cost of going there AND back.

Would opening a store in a highly accessible location or an inaccessible location generate more traffic? Depending on how one answers this question, one can choose to use either a singly-constrained or doubly constrained destination choice model. A singly-constrained model refers to one in which the only constraint is on tour origins, while a doubly-constrained model refers to one in which the total tour destinations in each zone are equal to the input tour attractions in that zone. In order to reflect the influence of accessibility on total tour attractions, we often allow non-mandatory tours (shopping, social/recreational, eating out, etc) to be only singly-constrained.

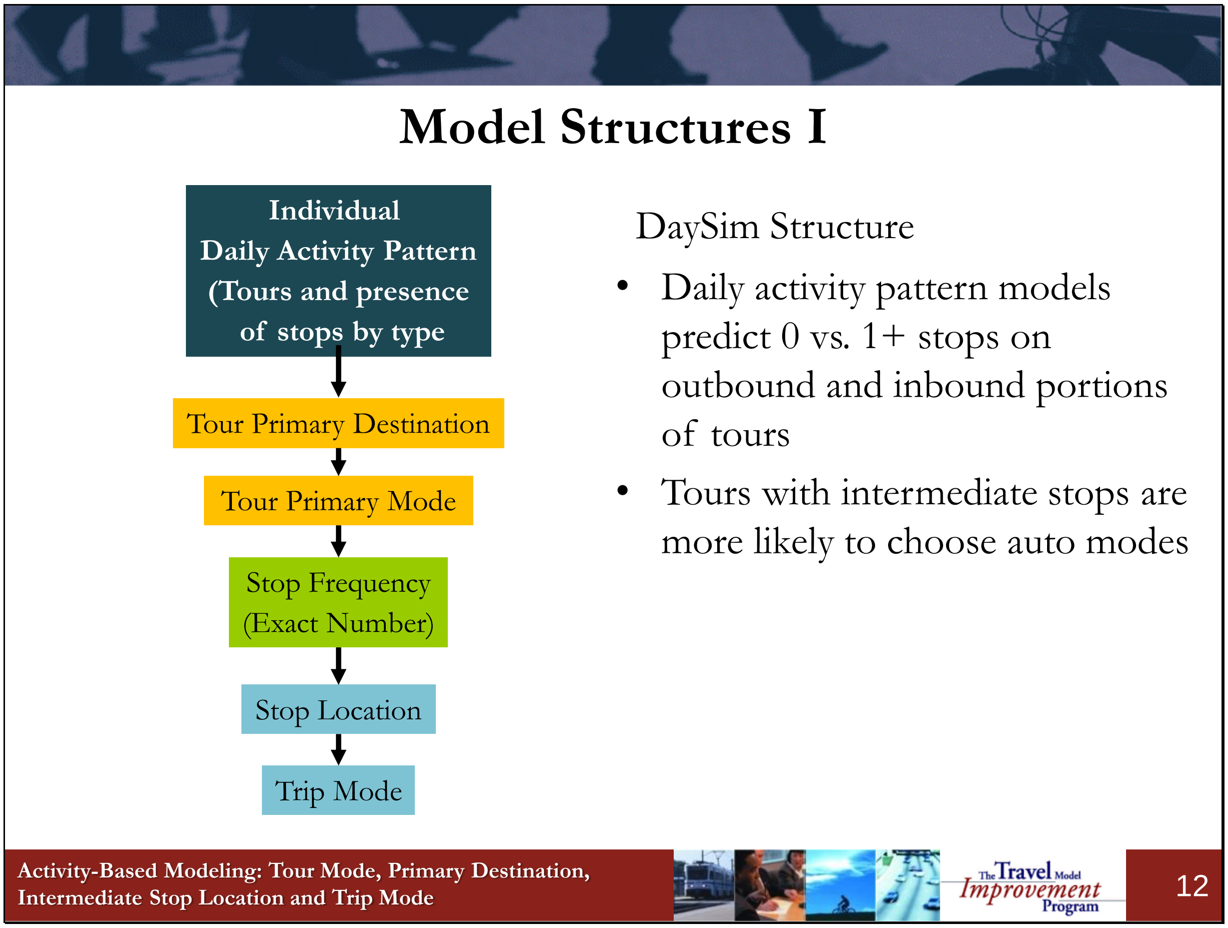


The sequencing of time-of-day choice relative to destination and mode choice is different in various model designs. It is ok that we don't know the mode when we're picking a destination, because we can use a mode choice log-sum, which measures the composite impedance across all modes.

What do we do if we don't know the time periods when picking a destination?

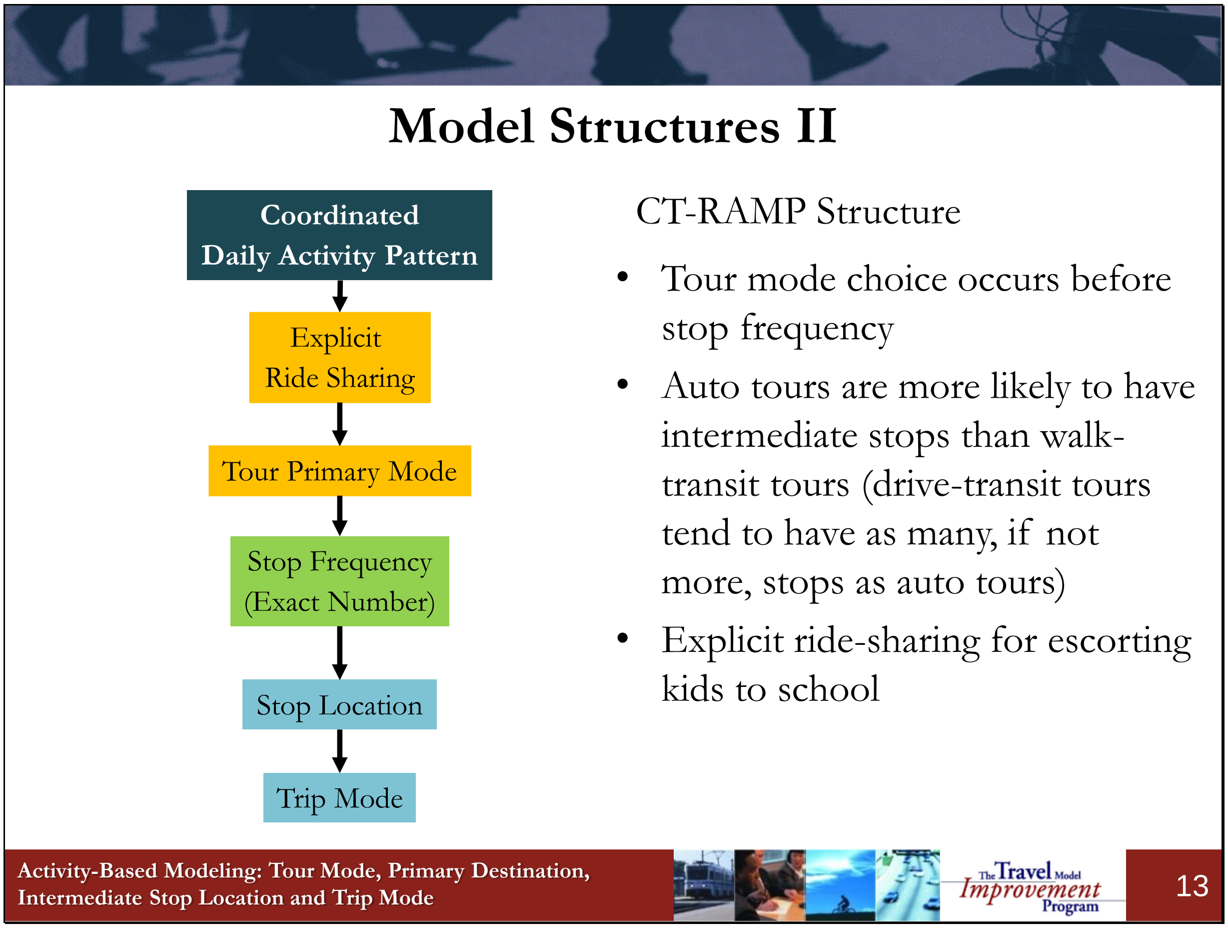
- Assert fixed time periods
- Iterate between time-of-day and destination choice
- Use logit averaging across multiple periods (a time-of-day log-sum)

Many of these issues have already been addressed in the webinar on accessibilities (Webinar 6), and you can refer to that webinar if you need a refresher.

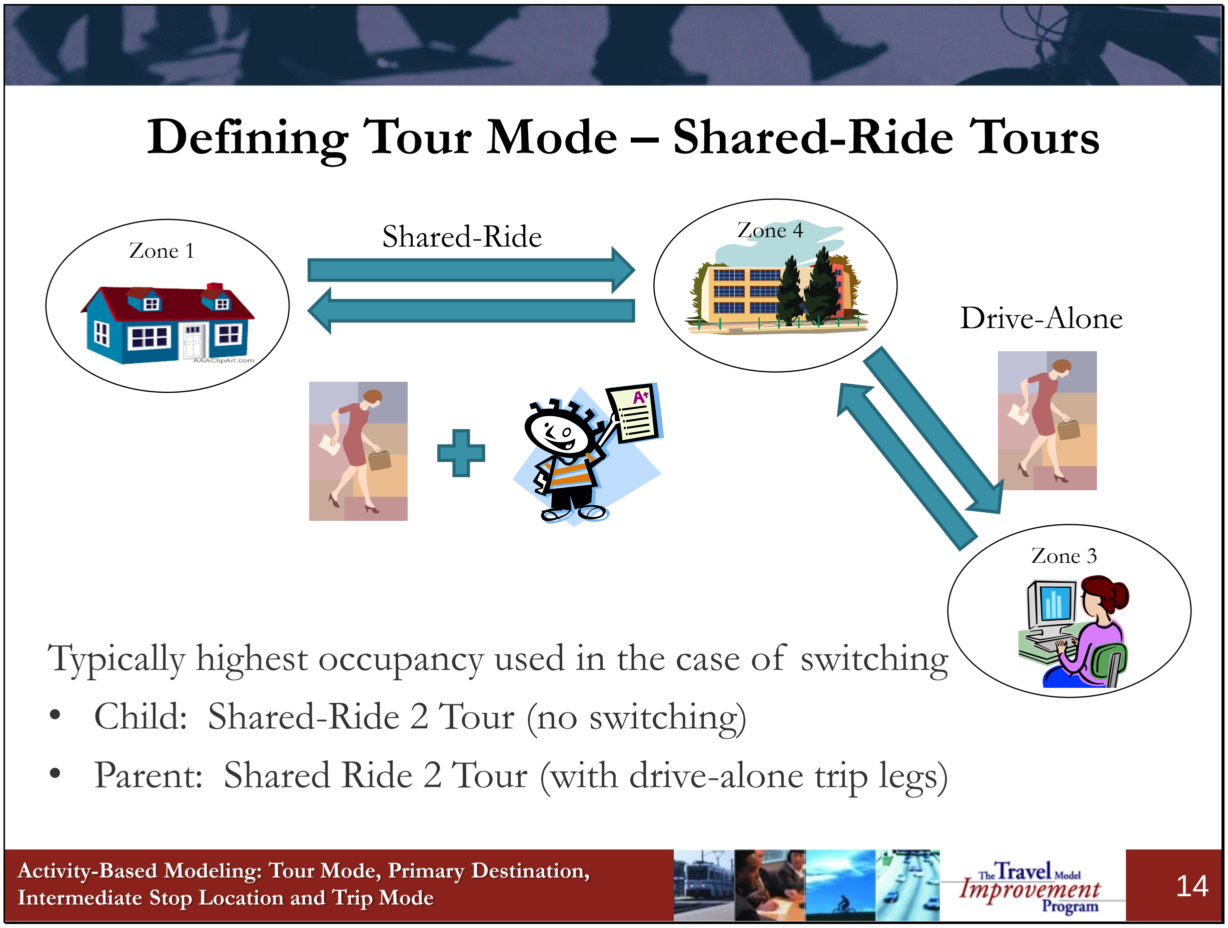


This diagram provides a little more detail on the DaySim model structure currently implemented in Sacramento. The model first generates individual daily activity patterns, defined by a primary tour purpose and by whether the tour will have one or more stops on its outbound half, its inbound half, or both halves. This is followed by choice of locations for the primary activity location (if a non-mandatory purpose), and tour mode.

One advantage to this approach is that, if it is known that there will be some intermediate stops on a tour, an individual is more likely to choose the auto mode. However, DaySim then models the exact number and purpose of stops at the trip level after all tour-level choices for the tour. The model is a stop-repeat model, in which repeat consists of an alternative for each purpose. Once the exact number of stops by purpose has been determined for each half tour, locations and modes are chosen for those trips.

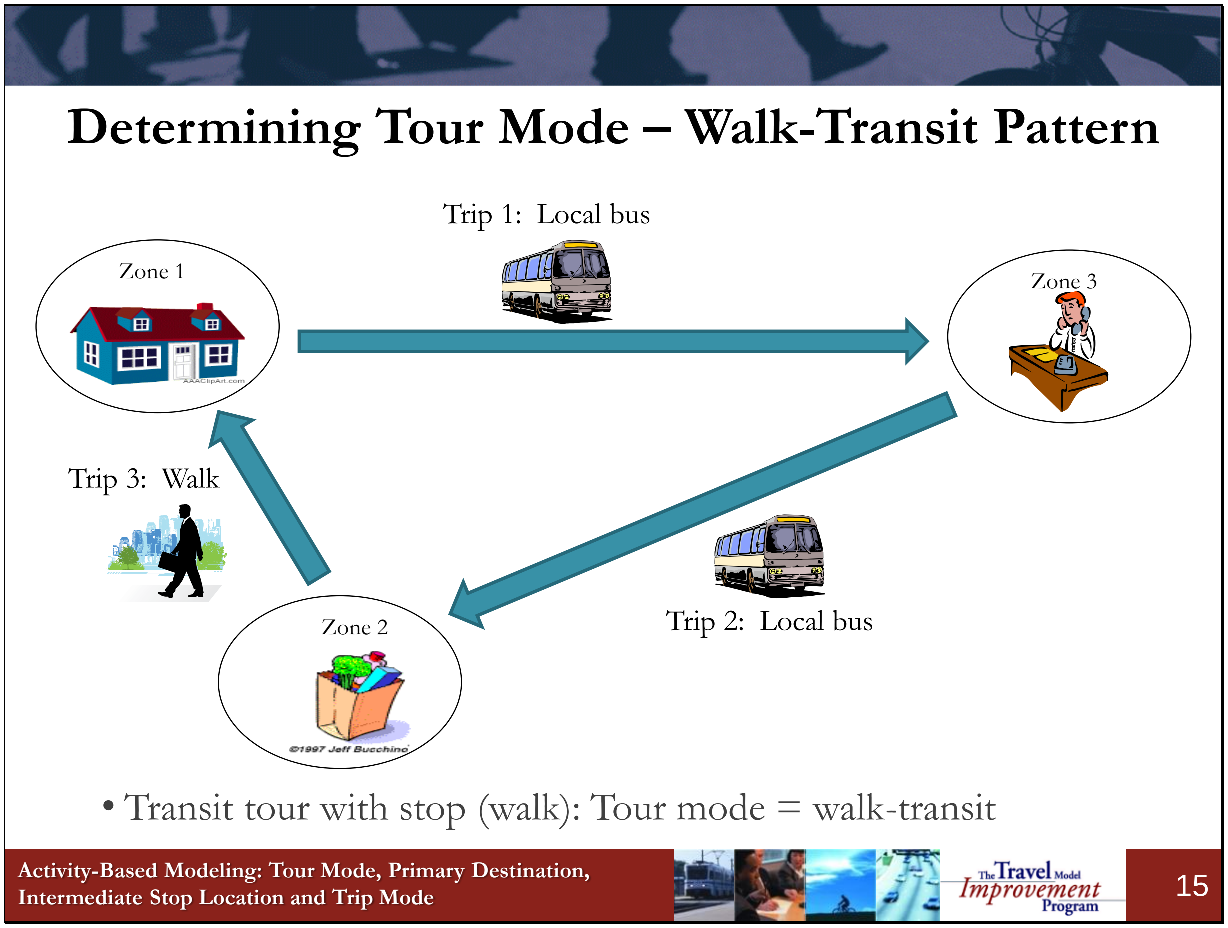


This diagram shows a different model structure, representing the CT-RAMP design. Here, explicit ride-sharing arrangements are modeled prior to choosing a tour mode, so it is known in advance whether a car will be needed and if it will contain multiple occupants, in this case household members. This is the main difference between this model and the version of DaySim just shown. The actual number of stops on the tour is not determined until after tour mode choice. Both model systems assume that the tour mode is known first and conditions the actual number of stops on the tour. Similar to DaySim, this is then followed by stop location and trip mode choice model application.

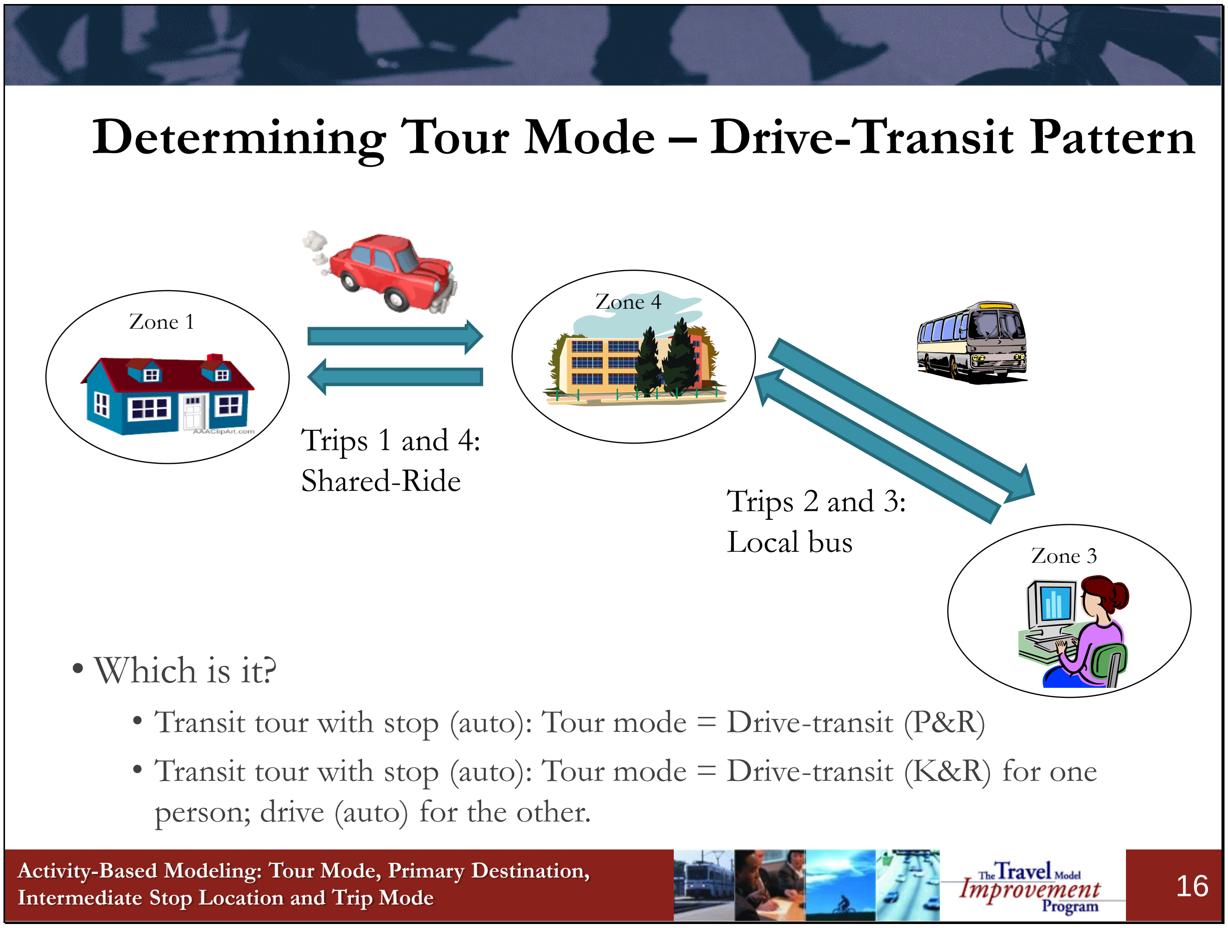


Now let's look at how tour mode can be defined. In some cases, all trips on a tour have the same mode. For example, if a traveler drives alone from home to work and back, there are two drive-alone trips. It is also common to observe mode switching on a tour, and for that reason it cannot be ignored. For example, we often observe parents escorting children to school and other events, on their way to/from work or other activities. This is typically the most common type of tour in which we observe mode switching.

This Page shows an example of such a tour. A worker leaves home with a child, drops that child off at school (in zone 4) and then continues on to work alone. At the end of the day, the worker returns to school to pick up the child and drives home. In this case we observe one school tour with no mode switching (the child school tour with two shared-ride trips) and one work tour with an intermediate stop on the way to work and one intermediate stop on the way back home. The first and last trip of the worker's tour is shared-ride, and the second and third trips on the tour are drive-alone. If mandatory escort tours are modeled explicitly, the modes of the child and worker tours are determined explicitly based upon the persons participating in the tour. But when they are not, we would typically assign a tour mode based upon the highest occupancy mode occurring on the tour. In this case, the highest occupancy mode on the tour is shared-ride, so the tour mode is shared-ride. The reason for doing so is so that we can let the presence of high-occupancy vehicle lanes influence the location of intermediate stops. However, we allow drive-alone to occur on the tour as well. We shall see later how this is addressed in trip mode choice, or “trip switching” models.



Here we see a typical transit tour, where the traveler takes bus to work, and returns home by bus with a stop for groceries. In this case, the intermediate stop is followed by a walking trip home. We would define the tour mode for this tour as walk-transit, with two walk-bus trips and one walk trip. In this case, we'd want to find a shopping stop location that was close to a bus stop, on the route between work and home.



This tour type is a little more complicated because it involves both shared rides and transit. As drawn, this could be either a park-and-ride or kiss-and-ride situation. If multiple persons share a ride to a park-and-ride lot and then take the bus to their respective jobs, and then come home together, then this is a park-and-ride situation for both travelers. On the other hand, if one person is being dropped off (kiss-and-ride) and then goes to work on the bus, then it is a kiss-and-ride (drive transit) trip for the worker, but the person who dropped them off may not be using transit at all, and may have a different pattern.

For this type of complicate pattern, one needs to look at the full tour patterns for both persons and determine whether they are both taking bus after arriving in Zone 4. In addition, the return trip home could be either the same or different.

Tour Mode—Trip Mode Consistency

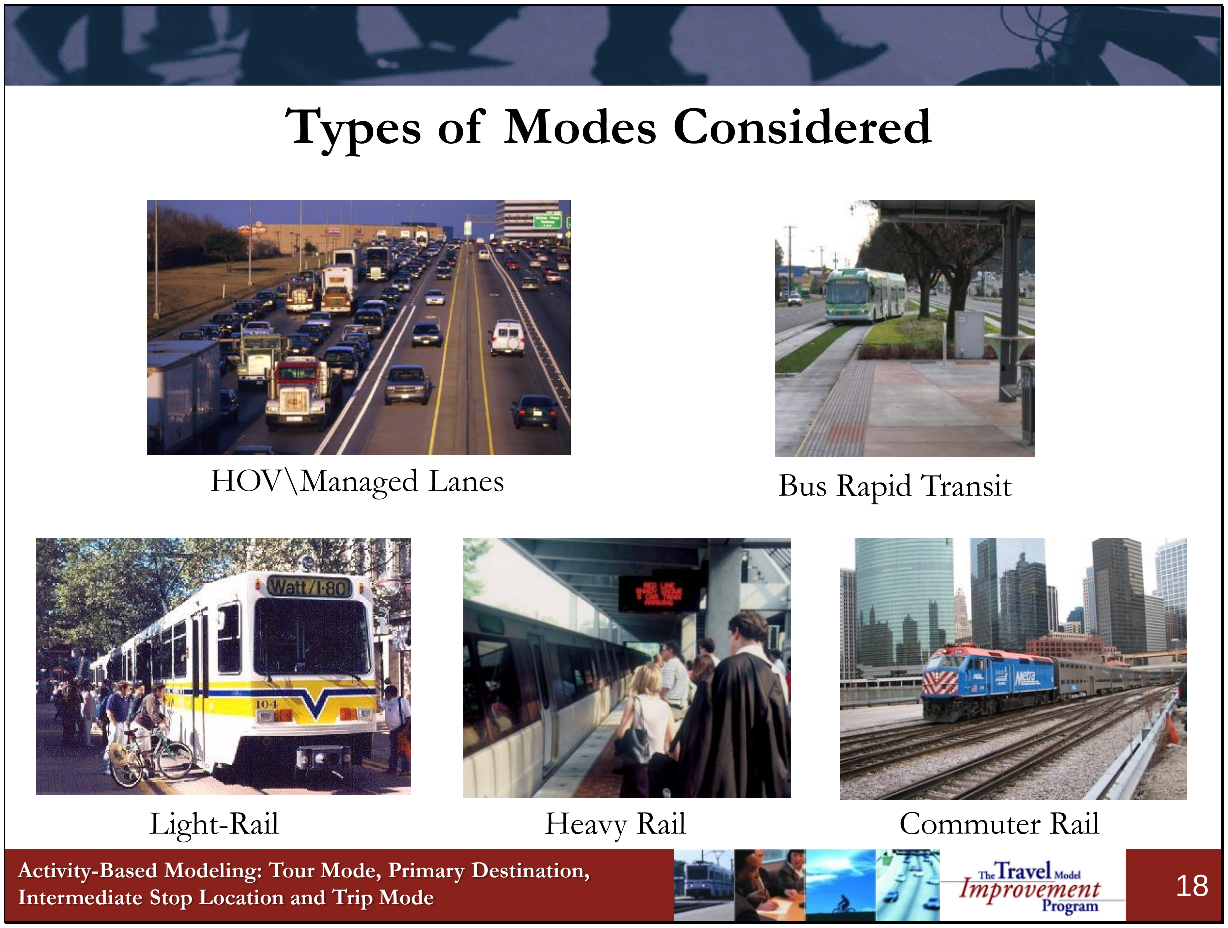
Trip Mode	Tour Mode							
	DA	SR2	SR3+	Walk	Bike	Walk-Tran	PNR-Tran	KNR-Tran
Drive-alone Free	Y	Y	Y				Y	
Drive-Alone Pay	Y	Y	Y				Y	
Shared-Ride 2 Free (GP Lane)		Y	Y			Y	Y	Y
Shared-Ride 2 Free (HOV Lane)		Y	Y			Y	Y	Y
Shared-Ride 2 Pay		Y	Y			Y	Y	Y
Shared-Ride 3+ Free (GP Lane)			Y			Y	Y	Y
Shared-Ride 3+ Free (HOV Lane)			Y			Y	Y	Y
Shared-Ride 3+ Pay			Y			Y	Y	Y
Walk				Y		Y	Y	Y
Bike					Y			
Walk-Local Bus						Y		
Walk-Express Bus						Y		
Walk-Bus Rapid Transit						Y		
Walk-Light Rail Transit						Y		
Walk-Commuter Rail						Y		

Highest occupancy trip mode identifies auto tour mode

Presence of walk-transit identifies walk-transit tour

Now that we've seen some examples of tour and trip mode definitions, let's look at a taxonomy for defining tour modes and trip modes. This correspondence table is taken from the SANDAG activity-based model. It shows the allowable trip modes (rows) for each tour mode (columns). You can see that the trip modes have a lot more detail than the tour modes, and that multiple trip modes are allowed for each tour mode.

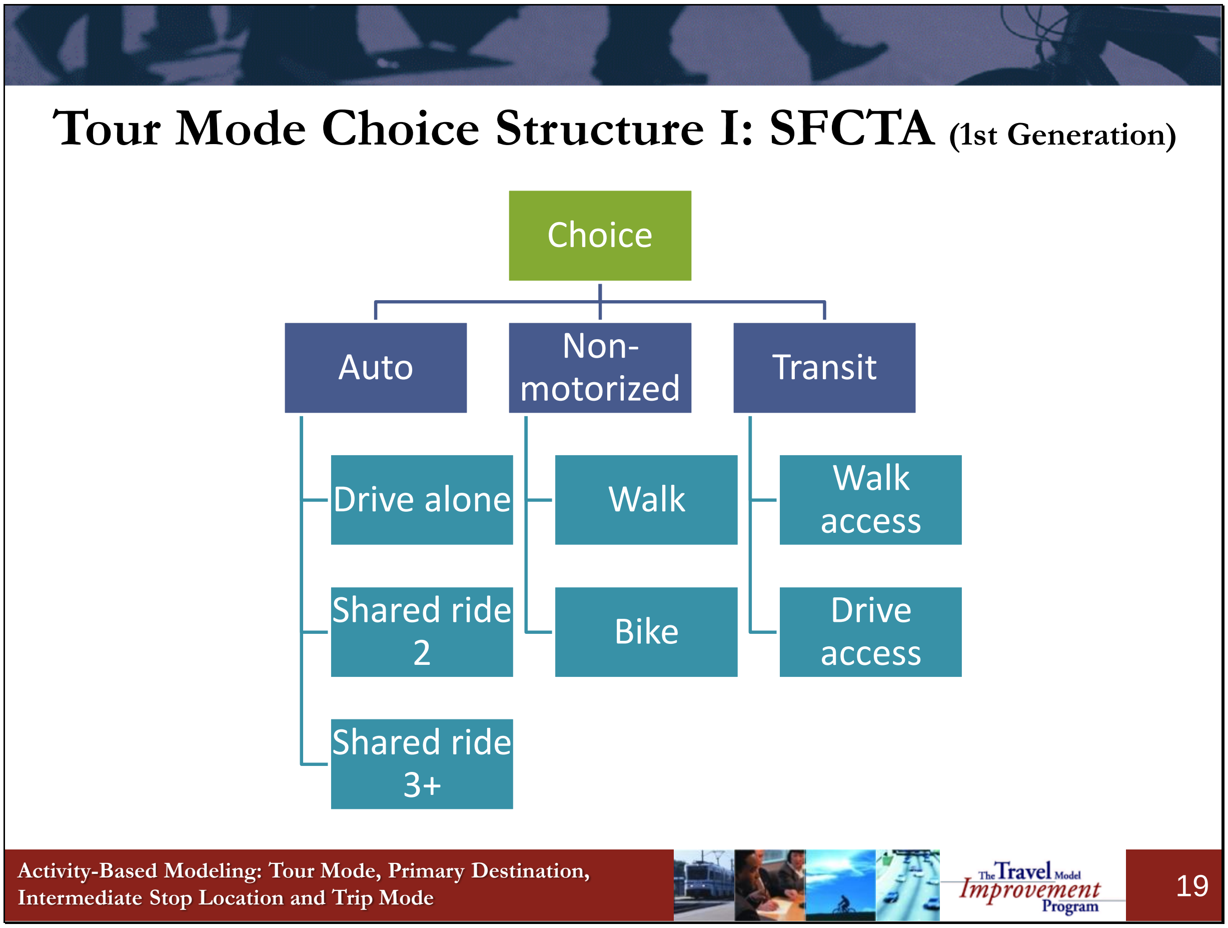
As previously shown, for auto tours, the highest occupancy trip mode identifies the tour mode. Tours with walk-transit trips (and no drive-transit trips) are identified as walk-transit tours (even though there may be shared-ride trip legs on these tours). Tours with PNR-transit trips are identified as PNR-transit tours, even though there may be both drive-alone and shared-ride trip legs on these tours. KNR-transit tours are similarly defined (though drive-alone is typically disallowed on these tours).



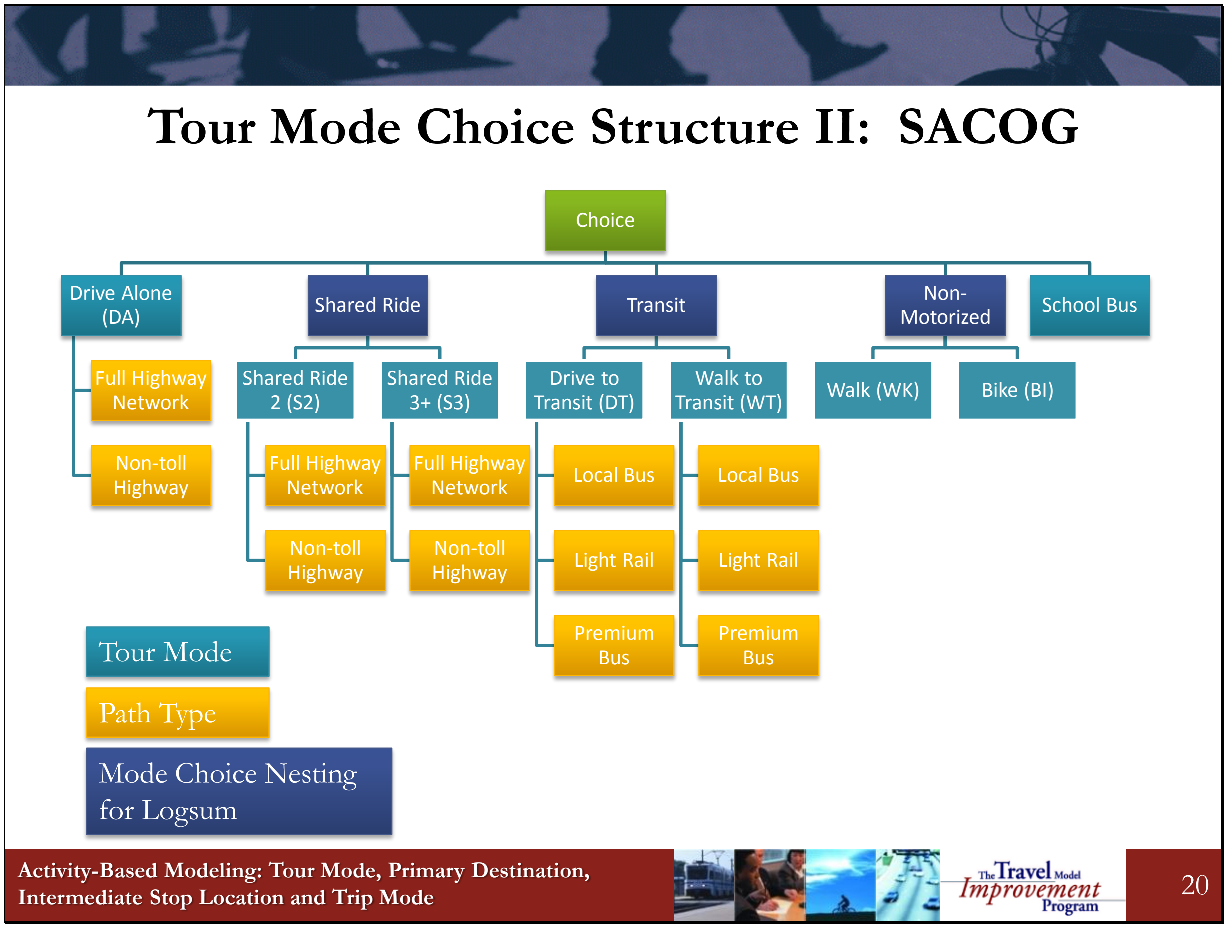
The activity-based mode choice model can consider any number of modes, just like a trip-based mode choice model. These range from more simple definitions (like auto, transit) to more precise descriptions such as managed lanes (including high-occupancy vehicle, high-occupancy toll, and toll lanes), light-rail transit, bus rapid transit, heavy rail and commuter rail.

High-Occupancy Vehicle (HOV) Lanes are lanes in which vehicles are restricted based on occupancy; typically 2 or more persons are required, although some lanes require 3 or more persons. High-occupancy toll lanes are lanes in which vehicles are tolled based upon occupancy. For example, single-occupant vehicles pay a toll while multiple occupant vehicles go free. Bus-rapid transit is a type of transit mode featuring buses that offer operating characteristics similar to rail; these include separate rights-of-way, rail-like station amenities such as covered platforms and/or rider information, and low-board vehicles for easy boarding and alighting. Light-rail transit is a type of rail transit that can operate in either separate right-of-way or in mixed-flow with auto traffic. Heavy rail consists of passenger rail cars operating singly or in trains of two or more cars, on rights-of-way from which all other vehicular and foot traffic is excluded.

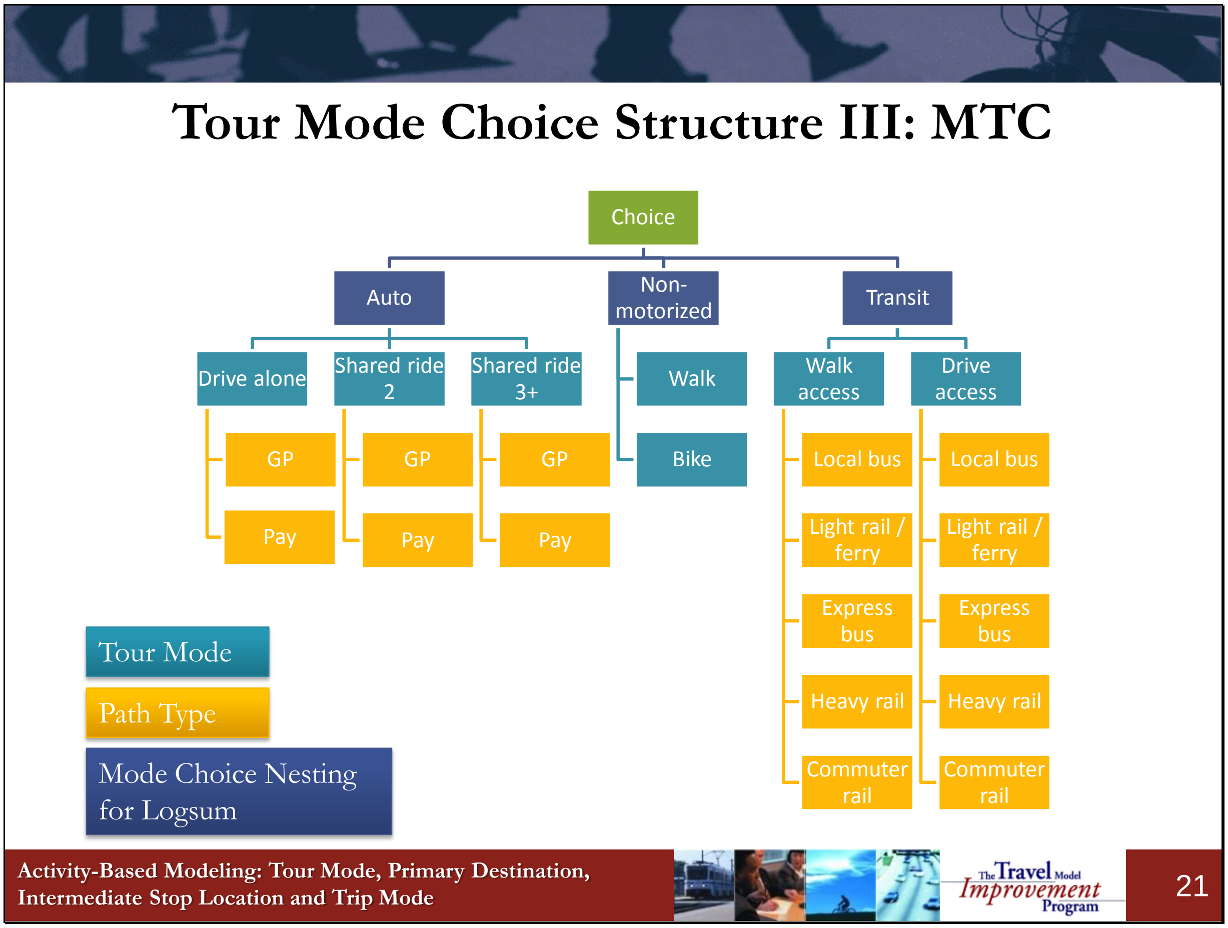
Commuter rail is passenger train service operating between a central city, its suburbs, and/or another central city.



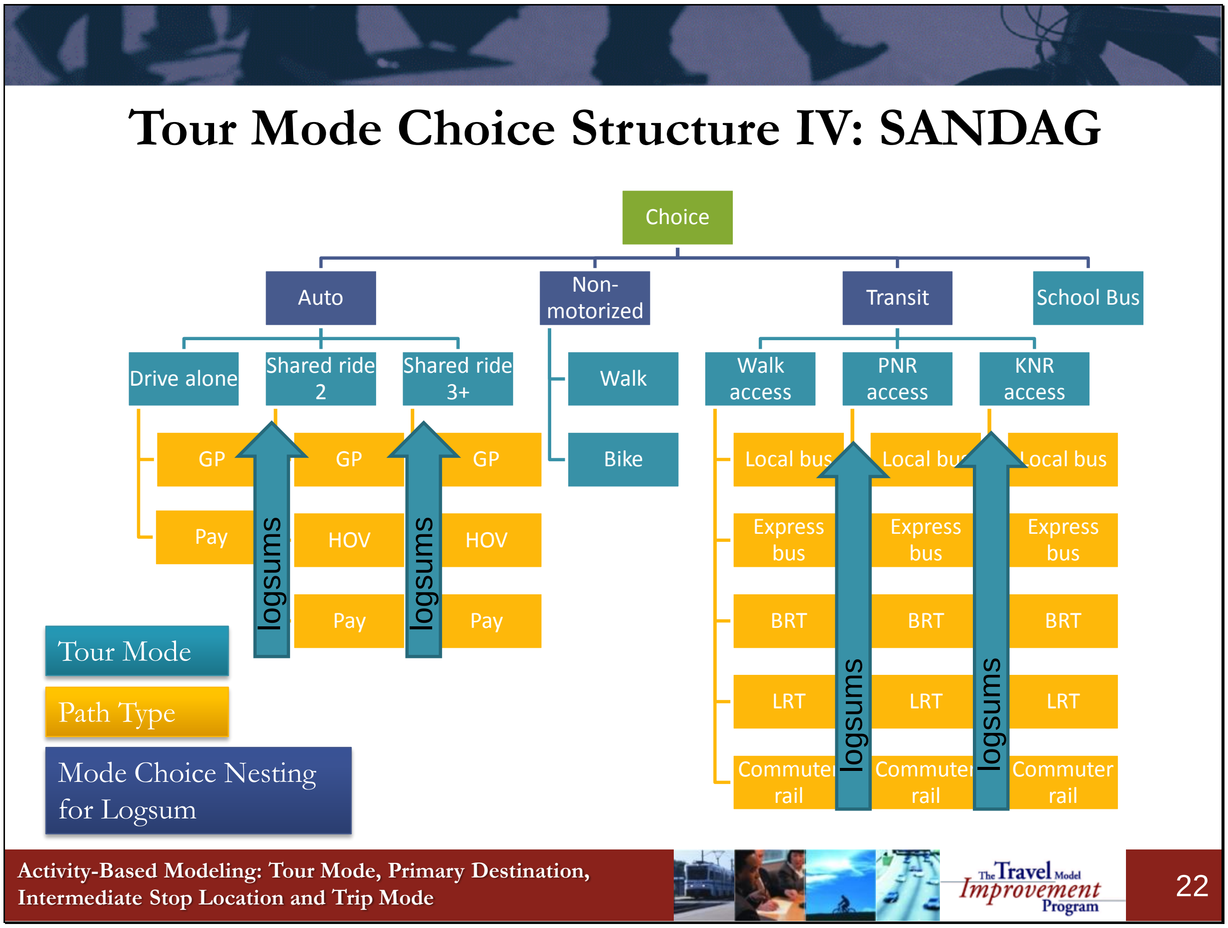
This Page shows the San Francisco tour mode choice model structure. As you can see, the tour modes are fairly aggregate at the tour level. The auto mode is broken out by occupancy, and transit is broken out by mode of access (walk versus drive, which includes both park-and-ride and kiss-and-ride). There are also walk and bike modes.



This Page shows the tour mode choice structure for the SACOG activity-based model, “SACSIM”. This structure shows a bit more detail and includes path type choices below the tour model level. For auto modes, this includes a choice between the full highway network and the non-toll highway network. For transit modes, this includes choices between local bus, light rail, and premium bus.



This Page shows the tour mode choice model for the Metropolitan Transportation Commission. Here there are even more transit modes differentiated.



And here is the mode choice model for San Diego. Note that the path type choice (for example, local bus versus express bus, etc.) is considered by the model by taking a log-sum across all transit path choices, while the tour mode is defined by the more aggregate walk, PNR, or KNR access mode. In other words, trip mode choice is only conditional on the choices allowed for a walk-transit tour, instead of the more limited choices that would be allowed on a walk-local bus tour. This way, travelers have freedom to switch between transit line-haul modes between multiple trips on their tour.

Tour Mode Choice Model Inputs

- **Round-trip** in-vehicle, out-vehicle time, cost
  - For specific time period of travel
  - Sensitivity to both ***outbound*** and ***return*** conditions
- Household and person variables
  - Income, auto sufficiency, gender, age
  - Free parking eligibility
  - Toll transponder ownership
- Land-use\urban form variables
- Tour purpose, joint travel, and other situational variables

Here are typical inputs to tour mode choice models. Note that round-trip in-vehicle time, wait time, access & egress time, and costs for each mode are taken into account. This allows the mode choice models to be sensitive to round-trip levels of service. For example, an improvement of transit in the evening will increase transit ridership in the morning period as well, to the extent that some tours that are ending in the evening period actually start in the morning (and evening service cutbacks will have the inverse effect on morning ridership). The models are also sensitive to income, gender, age, and other household and person level variables. Land-use and urban form variables such as intersection density, land-use mix, presence of sidewalks, etc., can also be used in tour mode choice models, particularly affecting the probability of walk trips and walk-transit trips. Situational variables, which are predicted by models higher in the model chain, also have an effect on tour mode – such as auto ownership, transit pass ownership, toll transponder ownership, and free parking eligibility\parking cost models. Tour purpose, joint travel, number of stops, and other tour variables can also be used in tour mode choice.

Travel Time and Cost Skims

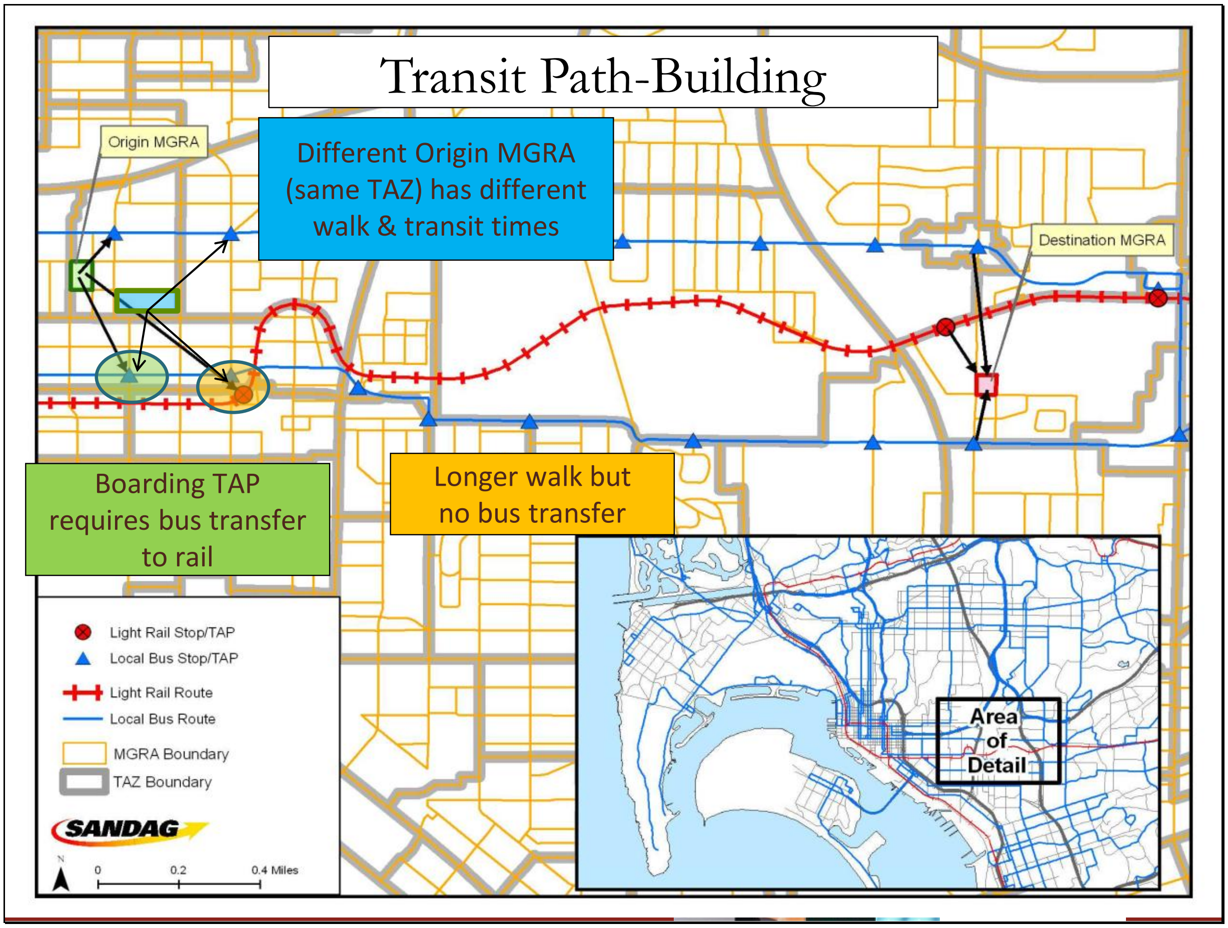
- By Auto Mode and Time Period (and income or socio-economic market)
  - Time
  - Cost
  - Distance
  - Distance traveled, cost on Managed Lane
  - Reliability (e.g. difference between free-flow and congested time)
- By Transit Mode and Time Period
  - In-vehicle Time (by line-haul mode)
  - First and Transfer Wait Time
  - Number of transfers
  - Access, Egress, and Transfer Walk and Drive Time
  - Fare
- Walk and Bike
  - Time
  - Distance (by facility type)

A key input to mode choice models are travel time and cost skims, or level of service matrices, for every zone-pair and time period in the model. Some models also segment skims by income or other socio-economic market, as described below. Most practical activity-based models rely upon static equilibrium assignment methods to produce travel skims.

Auto skims typically include time, cost and distance. One set of skims is prepared for each auto occupancy level, to reflect differences in access to HOV lanes and toll costs. Additionally, if the model distinguishes between free and toll paths, skims must be prepared for free paths where toll lanes in the network are 'turned off', and another set of skims is prepared for toll paths where all pay facilities are 'turned on'. For such models, it is often useful to also skim the distance traveled on managed or pay lanes for each OD pair, as well as the toll cost. It has been shown that transport system reliability is a key factor on traveler decision-making, and therefore it is increasingly common to use some measurement of reliability in mode choice. However, reliability is difficult to measure with a static equilibrium model. One example measurement of reliability uses the difference between free-flow and congested travel time as an indication of the variability of travel time. Income is often used to segment skims where toll lanes play a role, in order to take into account value-of-time on toll path choice (more on this later).

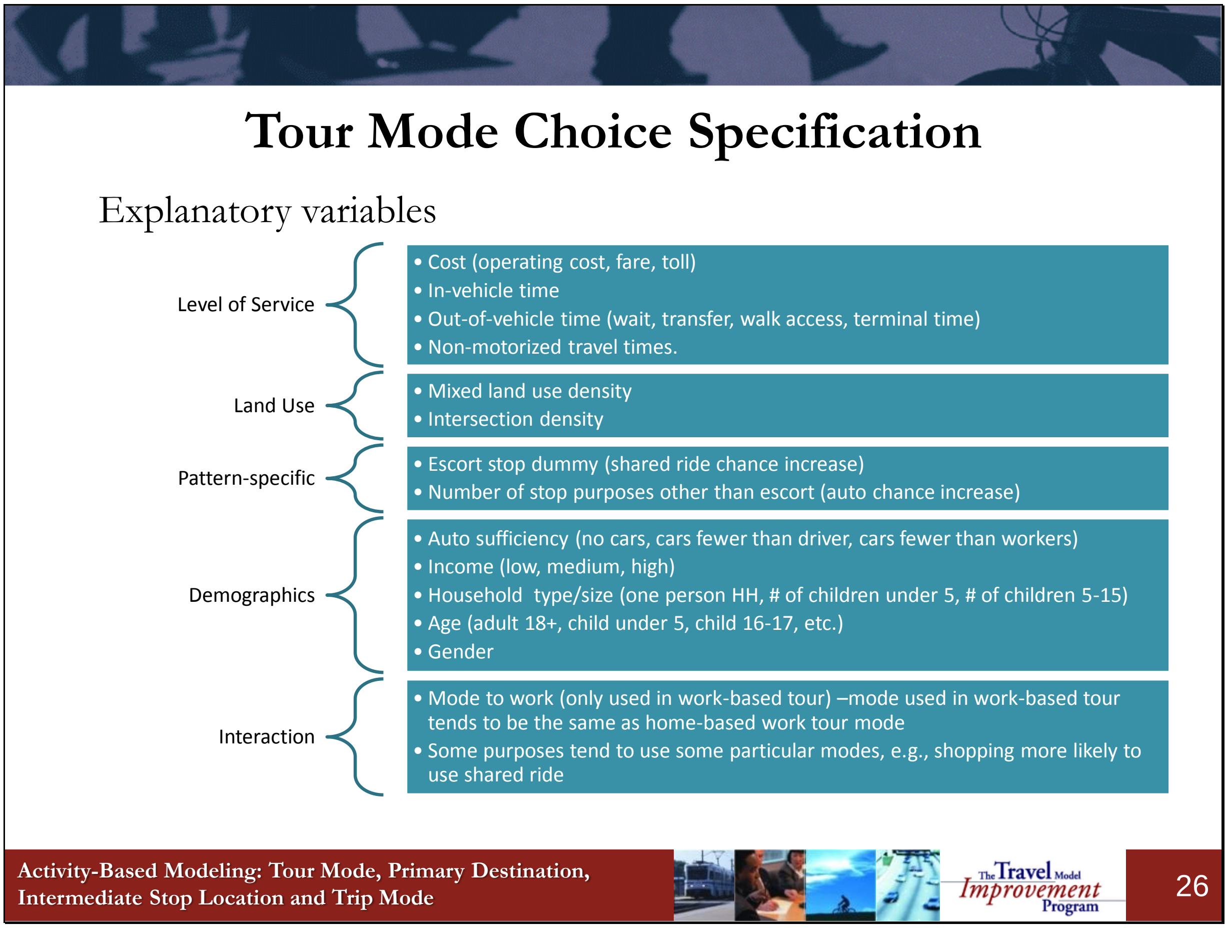
Transit skims include in-vehicle time, typically segmented by line-haul mode so that the model can distinguish between different services available to the traveler. First and transfer wait times, along with number of transfers, describe the frequency of transit service and whether transfers are required. Access, egress, and transfer walk and drive times describe proximity of transit to the trip origin and destination. Finally, transit fare is skimmed. The quality of access and egress times is highly dependent on the level of spatial aggregation in the zone system, where trip ends in large zones have the most error in terms of access and egress times. Some models, such as Sacramento and Denver, compensate for this error by replacing the zonal level estimate of walk access and egress time with the time between the origin and destination parcel and the closest transit stop. The San Diego model uses a novel approach to measuring transit times which we will see next.

Skims must also be provided for walk and bike modes. Often distance on different types of facilities are skimmed and help measure the quality of bicycle trips.



One of the problems in skim-building is that travel skims consume memory and disk space, because a set of matrices is built for every zone pair and time period. The amount of memory and space required to store skims increases squared times; for example, the space required for a 5,000 zone system is 4 times greater than that required for a 2,500 zone system. When the spatial system is highly disaggregate, such as when parcels or micro-zones are used, it is simply not possible to skim the network for each geographic pair. Various methods are used to get around this problem. For example, transportation analysis zones are used for auto skims, since the relative error related to larger TAZs is fairly small at auto speeds. Walk and bike modes, however, suffer from greater error with respect to spatial aggregation, since these modes are slower. The Sacramento and Denver models use parcels for the representation of space, and represent walking and biking times at the parcel level for close-in parcels. Transit access and egress is skimmed at the zonal level, but the nearest bus stop is assumed consistent with skims and time from the parcel to the bus stop is used to replace the skimmed walk time.

The San Diego model employs a novel approach to transit path building in which transit stops are represented explicitly in the transit network. Transit skims are built between stops instead of between zones, and micro-zones, or Master Geographic Reference Areas (MGRAs) are used to represent the origins and destinations in the model. Walk time is measured between the micro-zone centroid and the actual stop, provide an accurate description of the level-of-service between various stop pairs between the origin and destination. This Page shows an example of the approach. The origin MGRA has three stops that provide access to the destination. The stop to the north provides access to a bus line, with no transfers required. The stop immediately to the south provides short walk access to a feeder bus which incurs a transfer at rail. Alternatively, the traveler can walk further to rail and forego the local bus transfer. A different MGRA in the same zone has different access and egress options, where the direct rail access is more attractive due to the shorter walk. The San Diego model builds a utility for each path and these path utilities are used in the mode choice model to influence both mode and path choice.

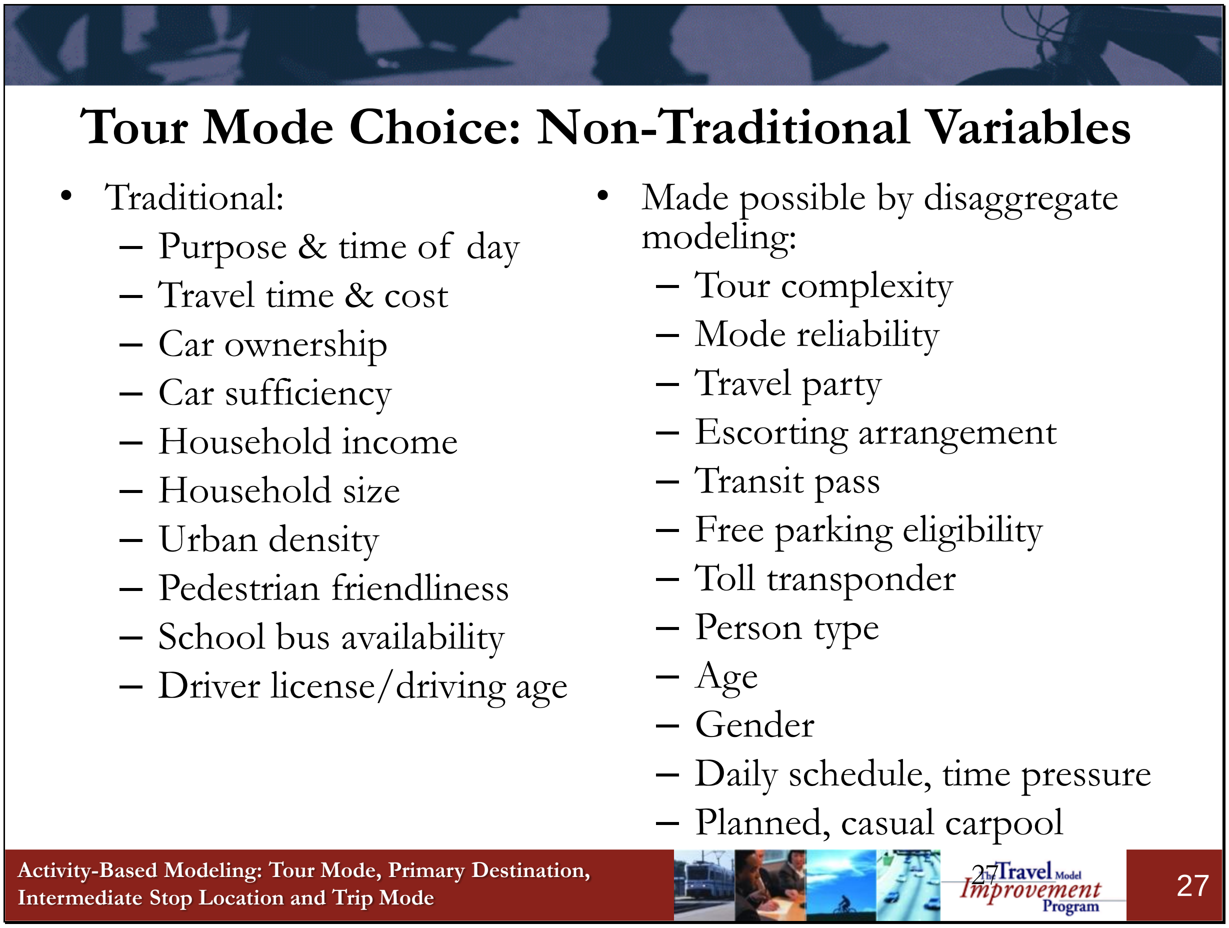


Here is a list of the explanatory variables specified in the tour mode choice model of the Sacramento activity-based model. At the top are the usual level-of-service variables, including in-vehicle and out-of-vehicle travel times, and costs for auto operations, tolls, and transit fares. Below that are land use data variables—mixed use density and intersection density at the destination.

This is followed by a couple of day-pattern pattern-specific variables. First, there is an escort stop dummy variable which, in the absence of explicit household rides, increases the propensity to choose shared ride modes. In addition, there is a variable indicating the number of stops on the tour (other than escort), which increases the probability of choosing auto modes.

Demographic variables also play a major role in endogenous segmentation of tour mode choice. Here, we have listed household auto sufficiency based on cars to workers, income groups, household type defined by single persons and presence of children. In addition, being an individual-based model, we have information on person attributes, such as age and gender.

Finally, it is common to have interaction terms. For example, the work-based sub-tour mode choice model considers the tour mode chosen for the primary work tour. This strongly conditions the mode to be used on the sub-tour and places constraints on what is available. In addition, there are dummy variables that indicate biases—for example, we do not have a completely separate shopping mode choice model, because shopping is grouped within the “home-based other (non-mandatory” tour mode choice model. However, we include a shopping indicator variable in that model that indicates that shoppers are more likely to choose shared ride than persons whose primary tour purpose was something else.



In addition to traditional variables like travel cost, purpose, time-of-day, and household characteristics, activity-based models allow us to use a richer set of variables, and have extended our knowledge and understanding of travel behavior. Here are some new variables available in the AB modeling framework:

- Tour complexity, which can influence mode choice.
- Reliability of travel time, which is most often cited as a key reason for selection of managed lanes, toll facilities, and fixed-guideway transit
- Travel party size – particularly useful for determining auto occupancy and cost sharing
- Transit pass holding – used to determine the cost for transit service
- Free parking eligibility and parking reimbursement level – in parking-constrained areas, many workers have parking either fully or partially subsidized. These travelers are insensitive to parking cost changes. Segmenting the travel market by parking cost is not typically done in four-step models due to computational constraints but is common in activity-based models.

- Toll transponder ownership is used to determine eligibility to use transponder-only facilities (such as the I-15 lanes in San Diego) and/or model toll cost sensitivity.

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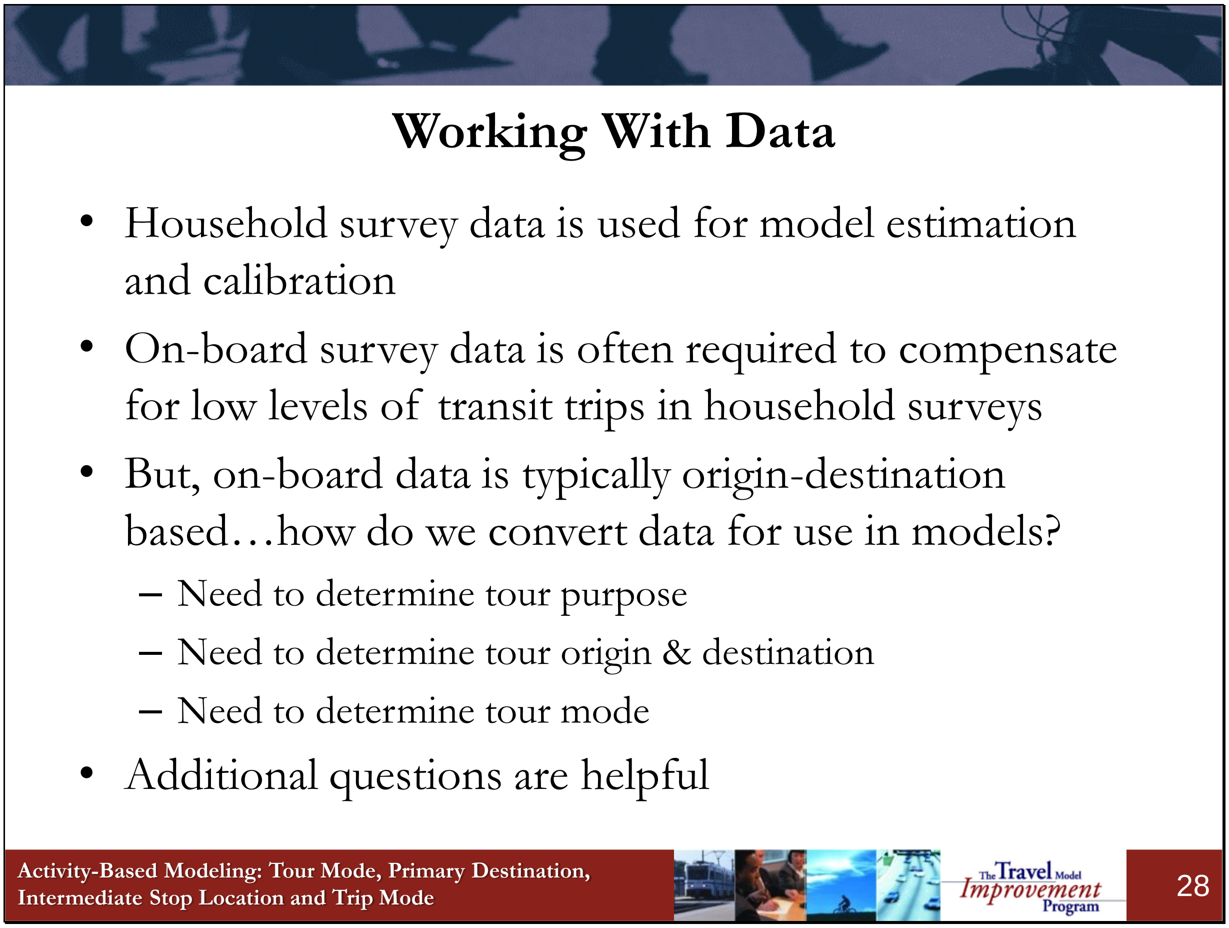


Typically household survey data is used for mode choice model estimation and calibration. However, often household surveys have too few transit observations upon which to estimate and/or calibrate transit choices. Therefore on-board surveys are used in conjunction with household survey data, just as is done to estimate trip-based mode choice models. One issue with the use of on-board surveys is that the surveys are typically origin-destination based. That is, they only ask about the trip that the traveler was observed taking when intercepted on the transit vehicle. In order to be useful for activity-based model development, additional questions should be asked that attempt to identify the ultimate tour purpose, tour origin\destination locations, and/or tour mode. Some example questions are given on the next Page.

On-Board Survey Tour-Level Questions

- Home Address (if not previously reported)
- Work Address (if worker and not previously reported)
- Have you been to work already today (since leaving home)?
- Are you going to work later today (before returning home)?
- Same for school
- If origin is home, how do you plan on returning home? (and vice-versa)

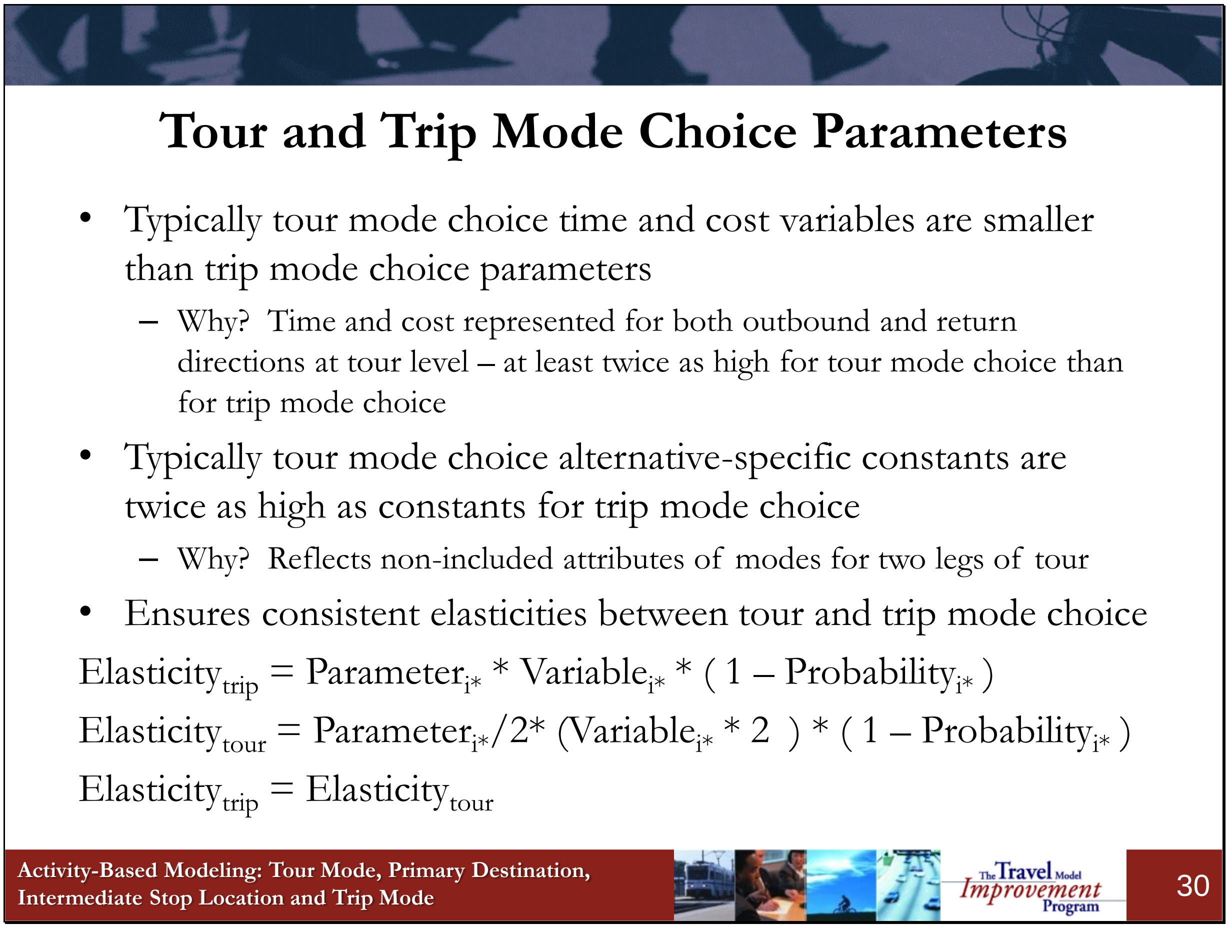
Four Step Purpose versus Tour Purpose

	4Step Model Trip Purpose							
Tour Purpose	HBW	HBO	HBSchool	HBCollege	HBShop	HBMed	NHB	Total
Work	97%	16%	0%	0%	16%	10%	25%	51%
University	3%	6%	0%	100%	6%	3%	17%	13%
School	0%	1%	100%	0%	1%	1%	16%	10%
Maintenance	0%	9%	0%	0%	77%	86%	16%	12%
Discretionary	0%	69%	0%	0%	0%	0%	8%	12%
AtWork	0%	0%	0%	0%	0%	0%	18%	2%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Source, Atlanta Regional Commission 2010 On-Board Survey

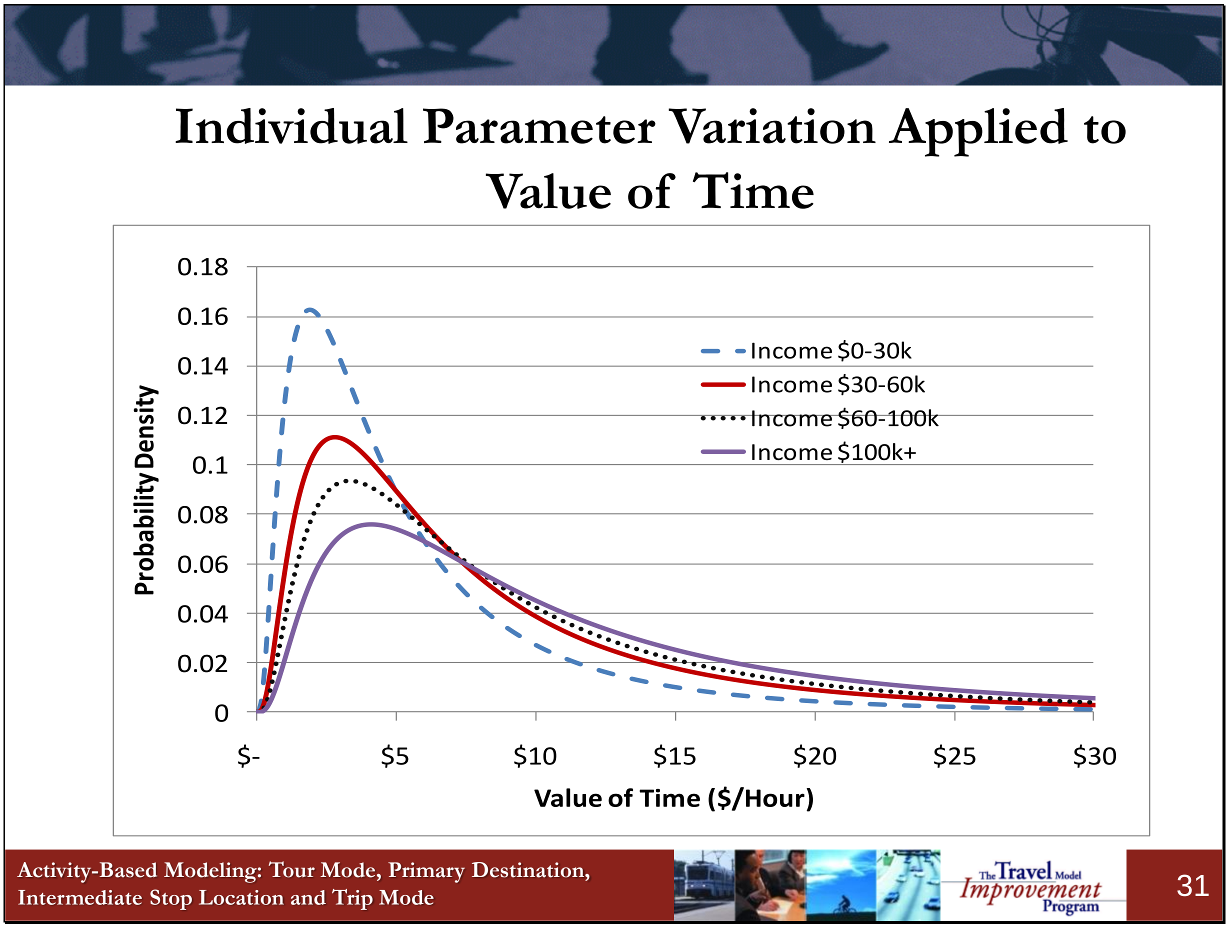
Here are some questions that can be added to an on-board survey to better understand the tour context for the reported origin-destination trip. Home and work (and school) address are useful for identifying the tour origin and primary destination locations. Questions can be added to better identify tour purpose, such as whether the traveler has been or is planning to go to work (or school) on this tour. Questions can also be added to better identify tour mode, such as how the traveler plans to get back home.

The table on the Page shows the cross-tabulation of four-step model trip purpose versus tour purpose. In particular, it shows how 25% of non-home-based trips are made on work tours. A significant portion of Home-based Other and Home-Based Shop trips are also made on work tours.



The parameters of tour and trip mode choice models are typically estimated using maximum likelihood estimators available in logit model estimation software. In maximum likelihood estimation chosen alternatives are compared to non-chosen but available alternatives, and a set of parameters are found which maximizes the probability of selecting the chosen alternatives.

It should be noted that parameter values should be consistent between tour and trip mode choice. That is, tour time and cost parameters should generally be smaller (approximately half the size) of trip mode choice model time and cost parameters. This is because the tour models take into account round-trip levels of service while the trip mode choice models take into account only the trip level of service. In order to ensure consistent elasticities, the parameters in the tour model are approximately half the size of the trip model parameter (as shown in the equations at the end of the Page). Similarly, alternative specific constants at the tour level are approximately twice as high than constants at the trip level (expressed in equivalent minutes), since they represent non-included attributes of alternatives which is being taken across at least two trips.



A key advantage of activity-based models is the use of individual parameter variation to reflect unobserved heterogeneity in the sensitivity to time and or cost. Such heterogeneity is very important when modeling pricing alternatives, to eliminate the aggregation bias associated with the use of average values-of-time. This Page shows values of time that vary probabilistically within household income levels. These distributions were estimated from a combined stated and revealed preference survey conducted in San Francisco. The data were collected as part of a pricing study and was used to enhance the San Francisco activity-based model system to address road pricing alternatives. Each simulated person in the San Francisco activity-based model selects a value-of-time randomly from the distribution corresponding to their household income. This value-of-time is converted into a travel cost parameter that is used for all travel models including mode choice. The curves reflect the typical value-of-time distributions observed in data --for each income group, there are some travelers who have a much higher willingness-to-pay than the average for their income group. Higher than average willingness to pay results from schedule constraints, personal preferences, and other unobserved attributes.

Calibration of Tour Mode Choice Models

- Calibration methodology
- Things to check:
  - Tours by mode and district
  - Tours by mode and socio-economic market segment
  - Tours by mode and time-of-day

	Observed				Estimated			
	Auto Sufficiency				Auto Sufficiency			
Tour Mode	No Vehicles	Vehicles< Adults	Vehicles>= Adults	Total	No Vehicles	Vehicles< Adults	Vehicles>= Adults	Total
Drive-Alone	-	138,616	544,877	683,493	0	138,585	552,000	690,585
Shared 2	7,307	58,993	125,455	191,755	7,520	58,990	127,260	193,770
Shared 3+	4,201	30,976	91,925	127,102	4,330	31,035	93,300	128,665
Walk	6,058	12,612	8,102	26,773	6,305	12,615	8,375	27,295
Bike	2,636	3,632	4,072	10,340	2,715	3,665	4,185	10,565
Walk-Transit	11,995	9,847	10,368	32,210	12,475	9,945	10,685	33,105
PNR-Transit	223	1,278	3,621	5,123	0	1,315	3,830	5,145
KNR-Transit	211	1,083	1,211	2,506	220	1,120	1,275	2,615
School Bus	-	-	-	-	-	-	-	-
Total	32,632	257,038	789,632	1,079,302	33,565	257,270	800,910	1,091,745

Activity-Based Modeling: Tour Mode, Primary Destination, Intermediate Stop Location and Trip Mode

The Travel Model Improvement Program

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Just like trip mode choice models, tour mode choice models are calibrated to reproduce aggregate shares obtained from observed data. Often, tour purpose and auto sufficiency are used to segment alternative-specific constants. Rather simplistically, calibration means adjusting the value of these constants until the model forecast matches the observed shares. In reality, proper calibration often requires revising upper level models and skim building procedures, in addition to revising the value of the model constants. Here we see observed versus estimated work tours by tour mode and auto sufficiency for San Diego.

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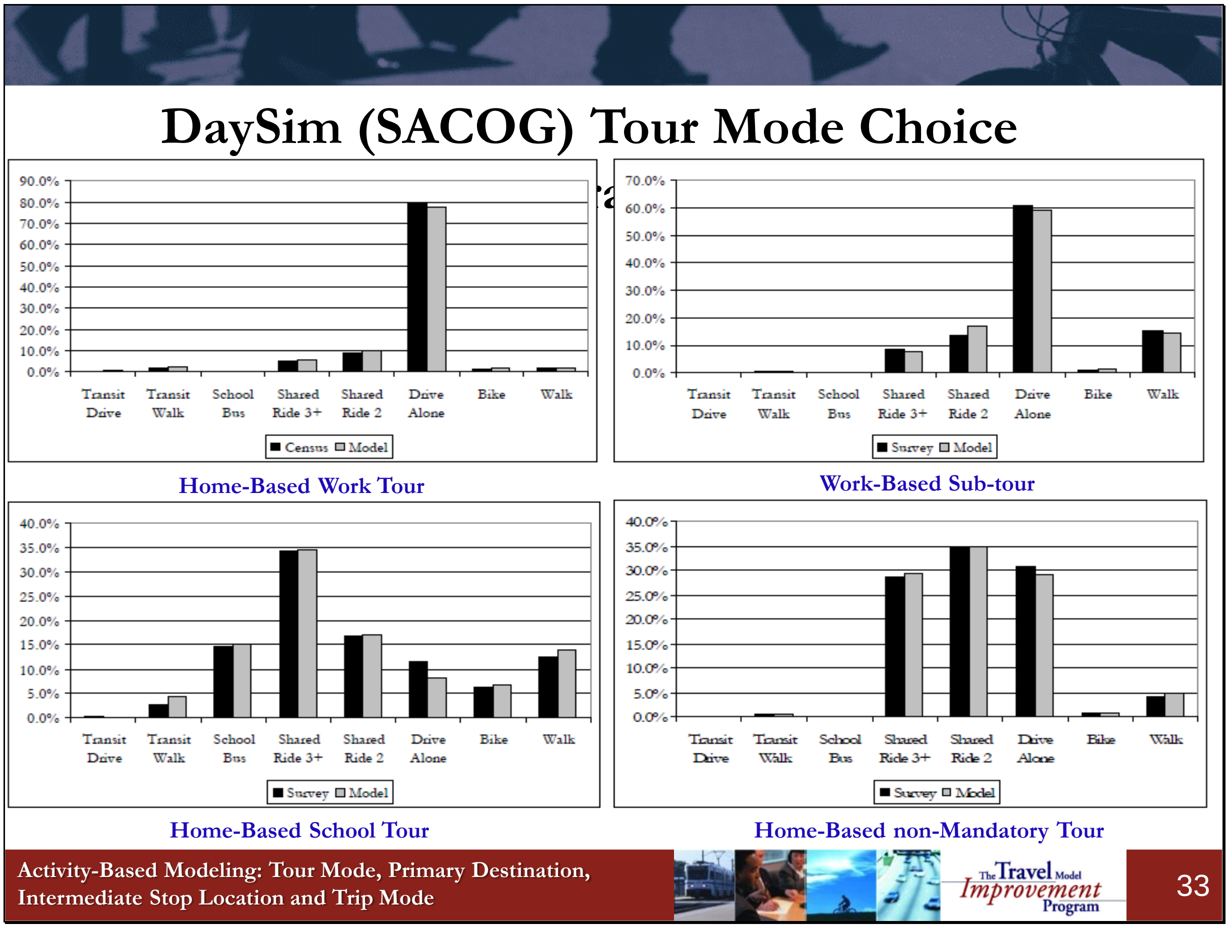
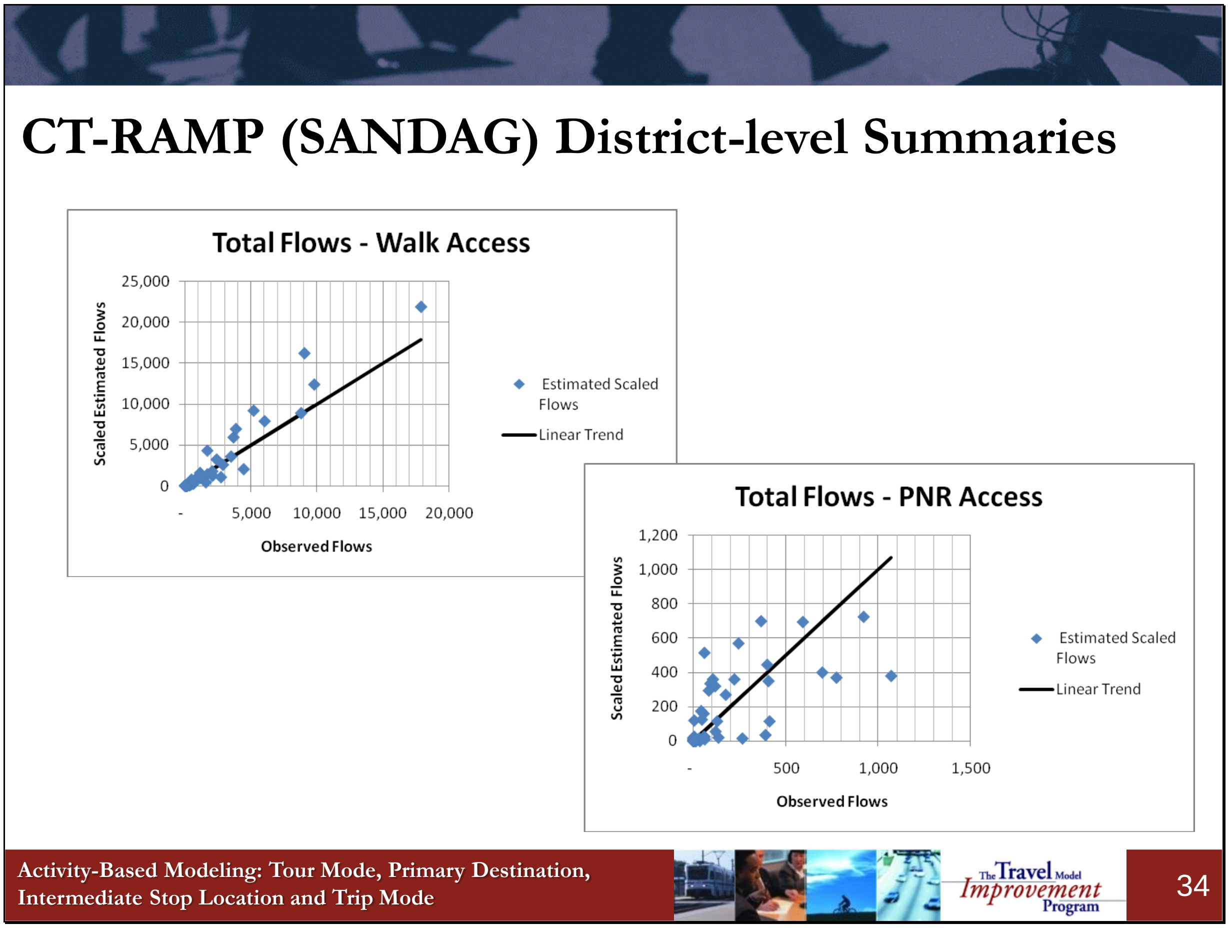
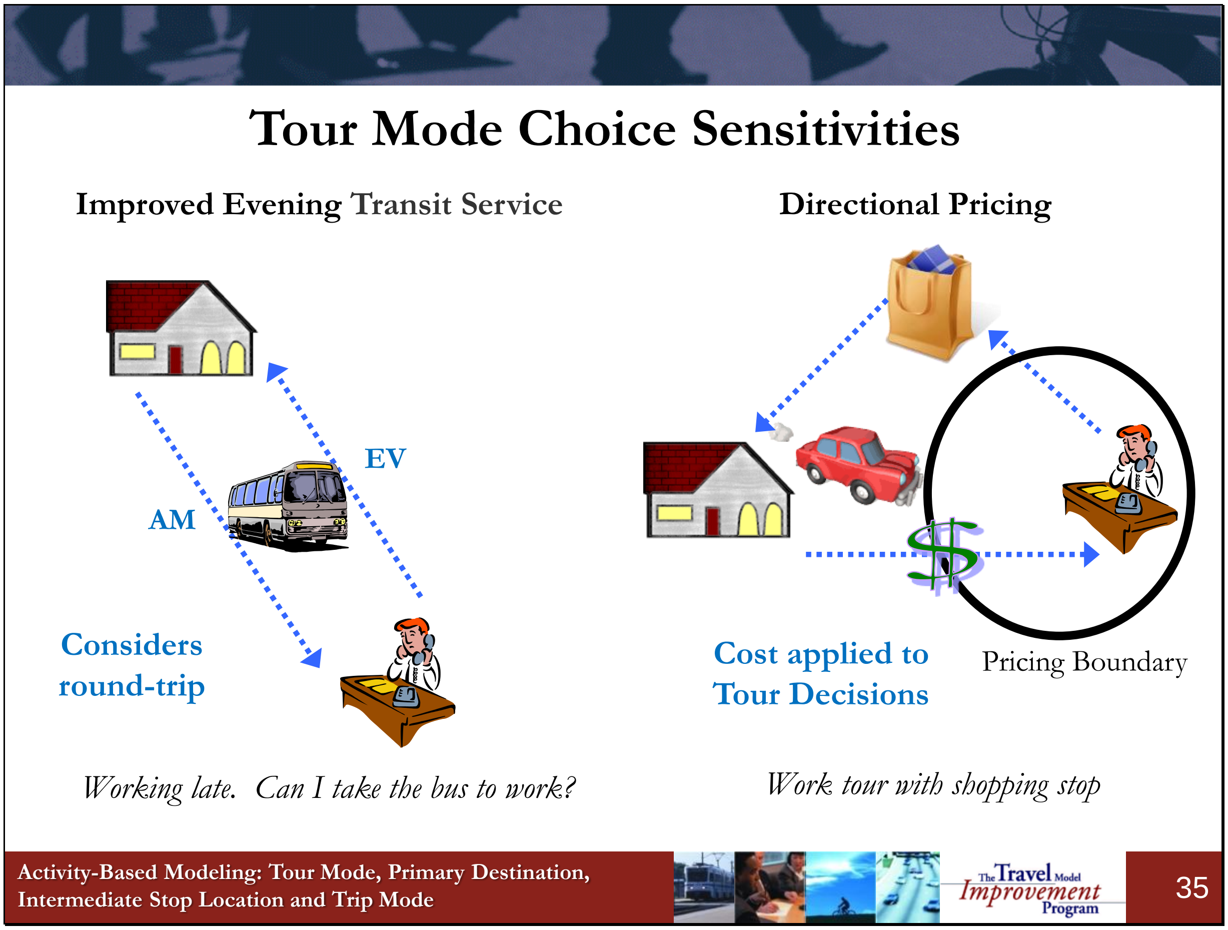


This Page shows tour mode choice model calibration results for the Sacramento activity-based model by tour purpose. As you can see, it is quite easy to match calibration target values for mode shares in the aggregate.



It is also important to check the calibration of the model at more disaggregate levels. This Page shows scattergrams comparing estimated to observed walk-transit and PNR-transit tours by tour origin and primary destination district. The walk-transit comparison looks close to observed, while the PNR-access scattergram reveals some differences which must be further investigated.



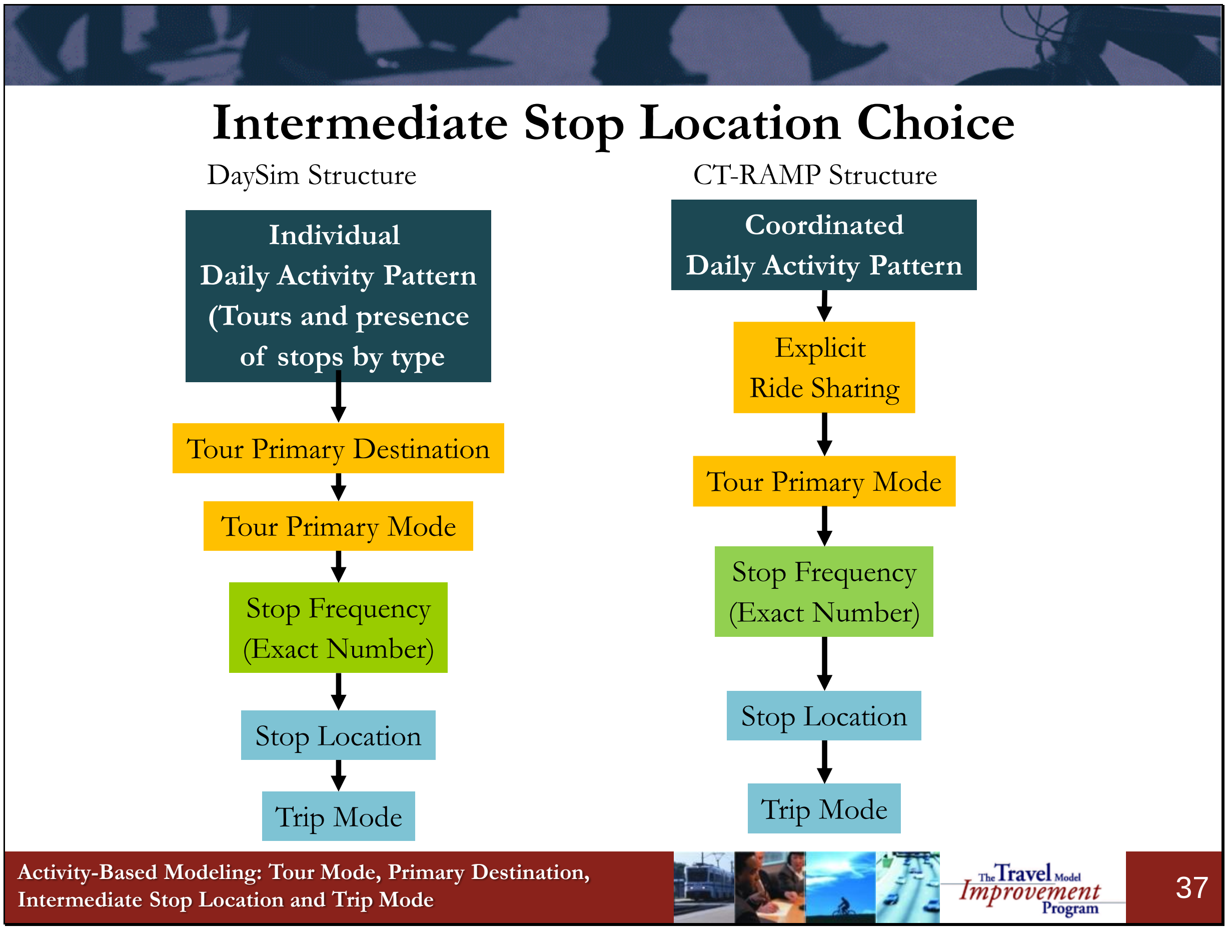
Here are some examples that illustrate the importance of accounting for tour-level conditions on the choice of mode for each trip. The types of effects that are shown here are impossible to capture with a trip-based model.

In the first example, an improvement in evening transit service is reflected in the choice of mode for morning trips. As expected, improving evening transit service, for example by expanding the span of express bus service, results in increased evening transit patronage. It also results in increased morning patronage because workers with long hours at the office can take transit to work and rely upon better transit service to return home. That is, improving the level of service for just one leg of the tour affects the choice of mode for the entire tour.

In the second example, introduction of pricing on the way to work influences not only the mode to work, but potentially the location and mode of intermediate stops between work and home. For example, persons avoiding tolls will follow a different path to work that will offer a different level of access to discretionary activity opportunities and locations. By the same token, persons who choose a tolled path will likely remain on that path for a longer period of time (assuming there is a time-savings incentive) and potentially bypass activity opportunities and locations that would cause them to deviate from that path.

Questions and Answers

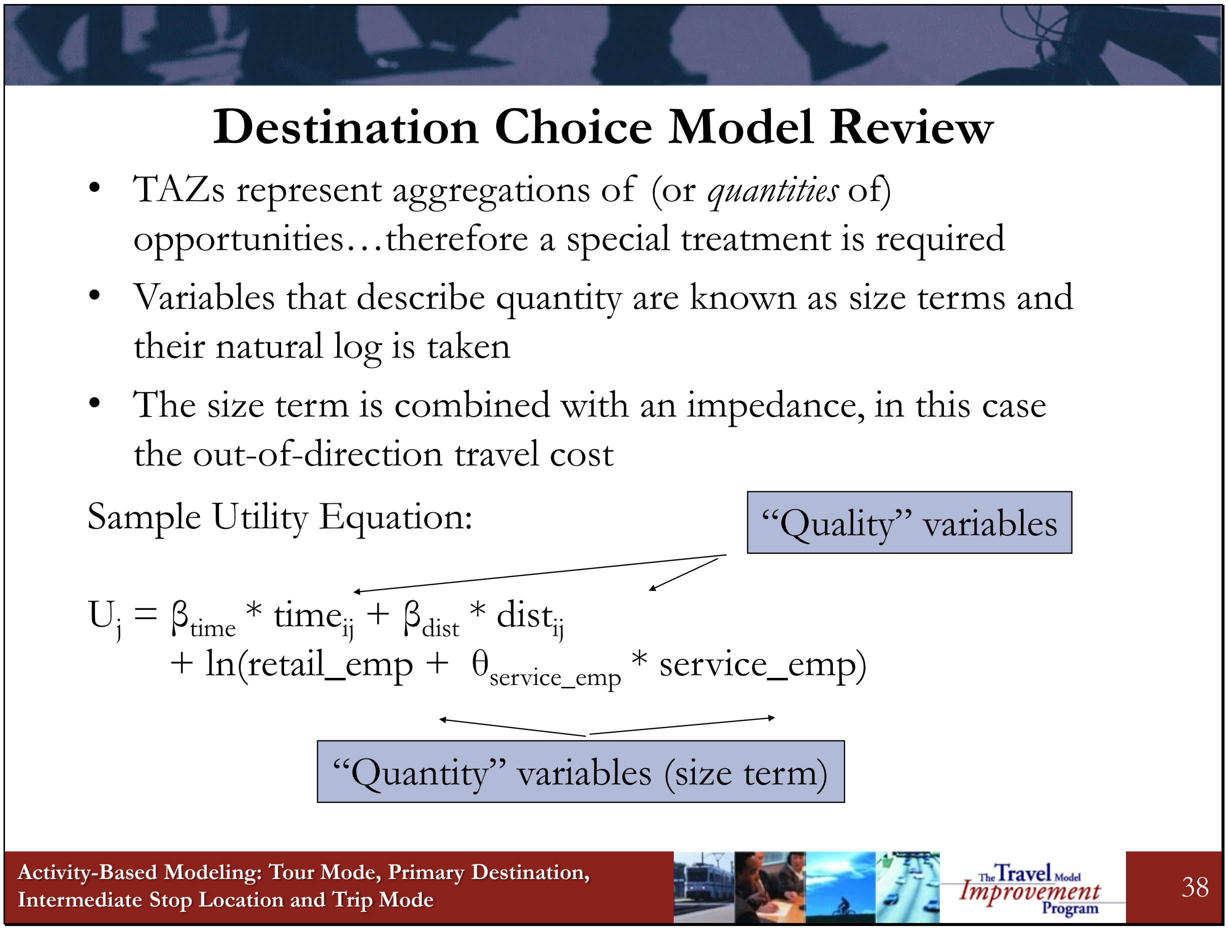
The Travel Model Improvement Program



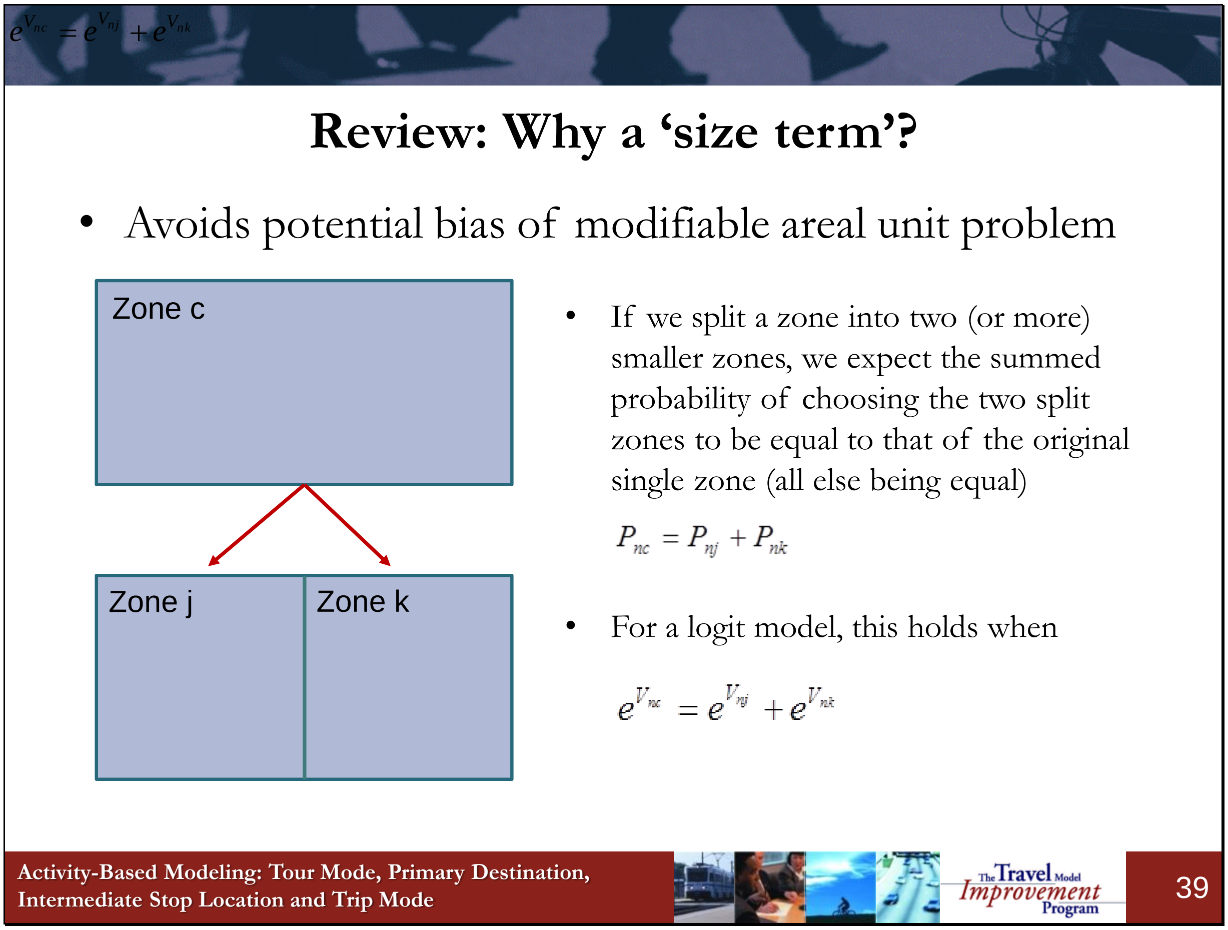
Both DaySim and CT-RAMP choose stop location after tour mode and before trip mode. What is known at this point in the model system?

- The purpose of the tour;
- The origin and destination of the tour;
- The time departing from the tour origin and arriving back at the tour origin (CT-RAMP) or the time arriving at the primary destination and departing from the primary destination (DaySim);
- The preferred mode for the tour (tour mode); and
- The number intermediate stops on the tour, the sequence of each stop on the tour, and the purpose of each stop.

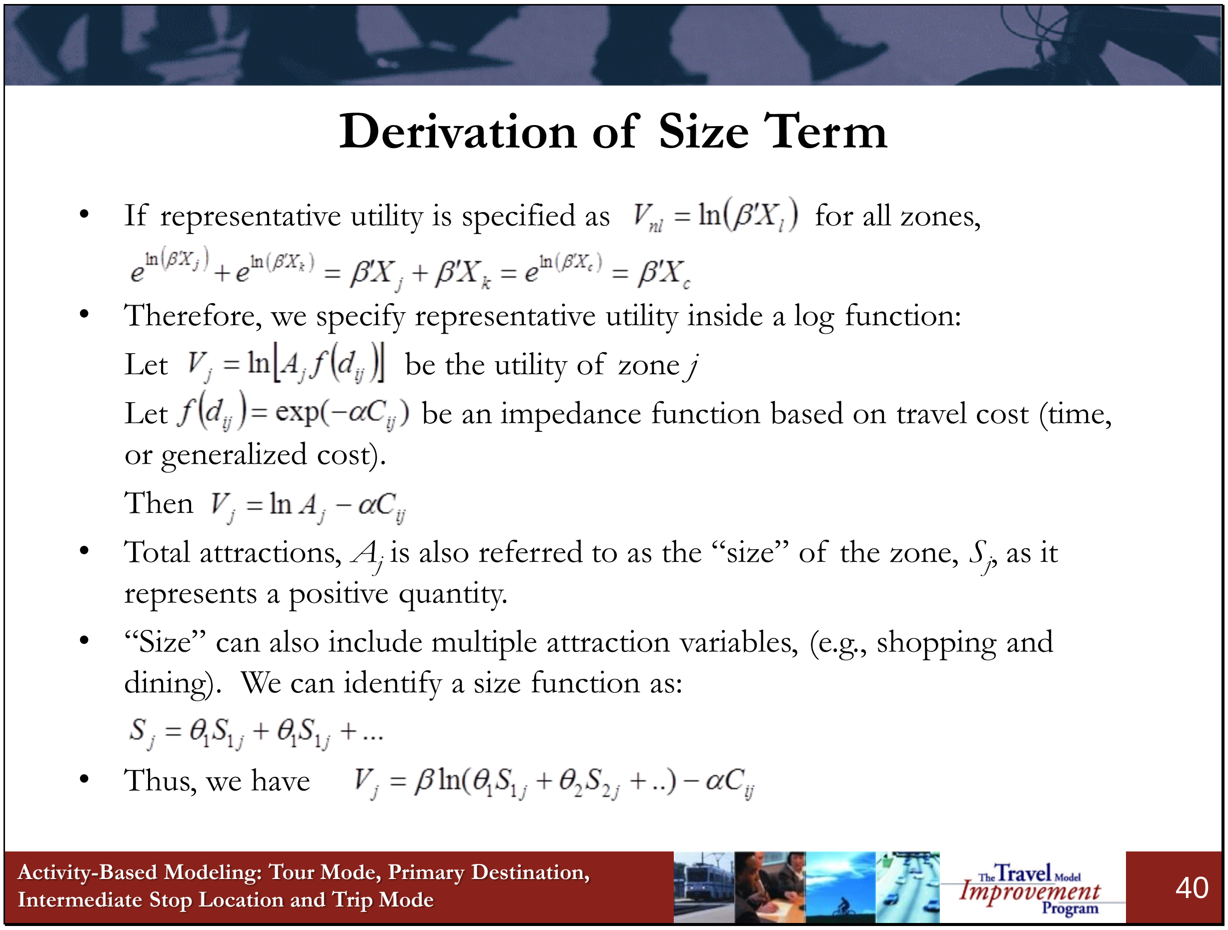
What is unknown at this point in the model system is the location of each stop on the tour, which will be predicted by the intermediate stop location choice model, and the mode used for each trip on the tour, which will be predicted by the trip mode choice model.



Before continuing with intermediate stop location choice models, let's revisit how destination choice models work. A destination choice model takes into account spatial separation between activity locations, as well as the amount of opportunities to engage in the activity in each destination. The number of opportunities in the zone is referred to as the size term in the model. The size of the zone is logged, so that the probability of selecting an alternative is equal to the relative size of the alternative compared to all other alternatives, all else being equal. The spatial separation between the origin and the potential destination is represented by time, distance, and/or mode choice log-sum terms. The process used for modeling spatial separation for intermediate stops is a bit different than that used for tour primary destination choice.

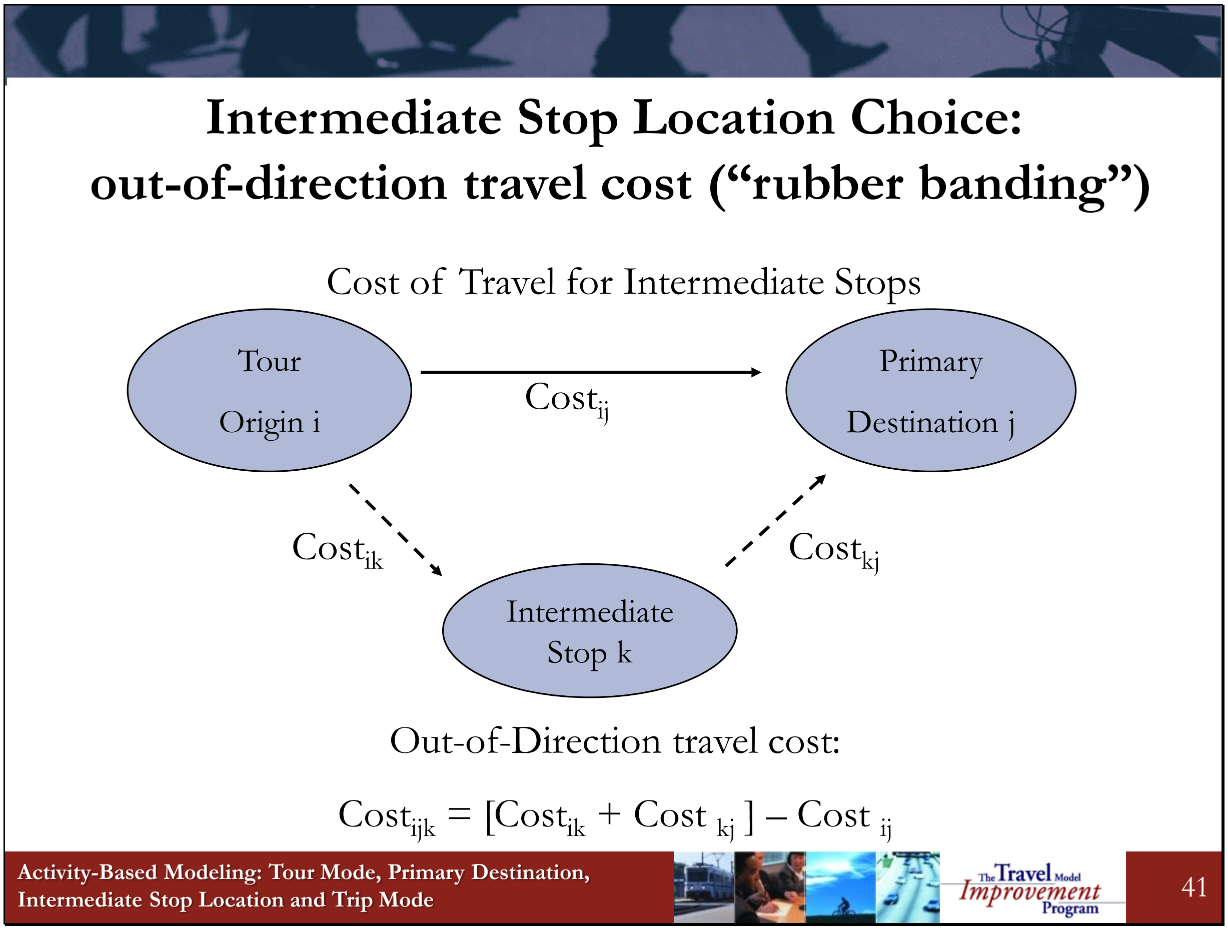


Why do need to create a non-linear size term? Why not just include these quantity variables in the regular utility expression? The size term helps us to avoid one aspect of the "modifiable areal unit" problem, where arbitrarily drawing boundaries around an area unit (like a TAZ) can affect statistical analysis of that unit. If we split a zone into two (or more) smaller zones, we expect the summed probability of choosing the two split zones to be equal to that of the original single zone (all else being equal). For a logit model, this holds when the exponentiated utilities of the two split zones sum to the same value as that of the exponentiated utility of the original combined zone.

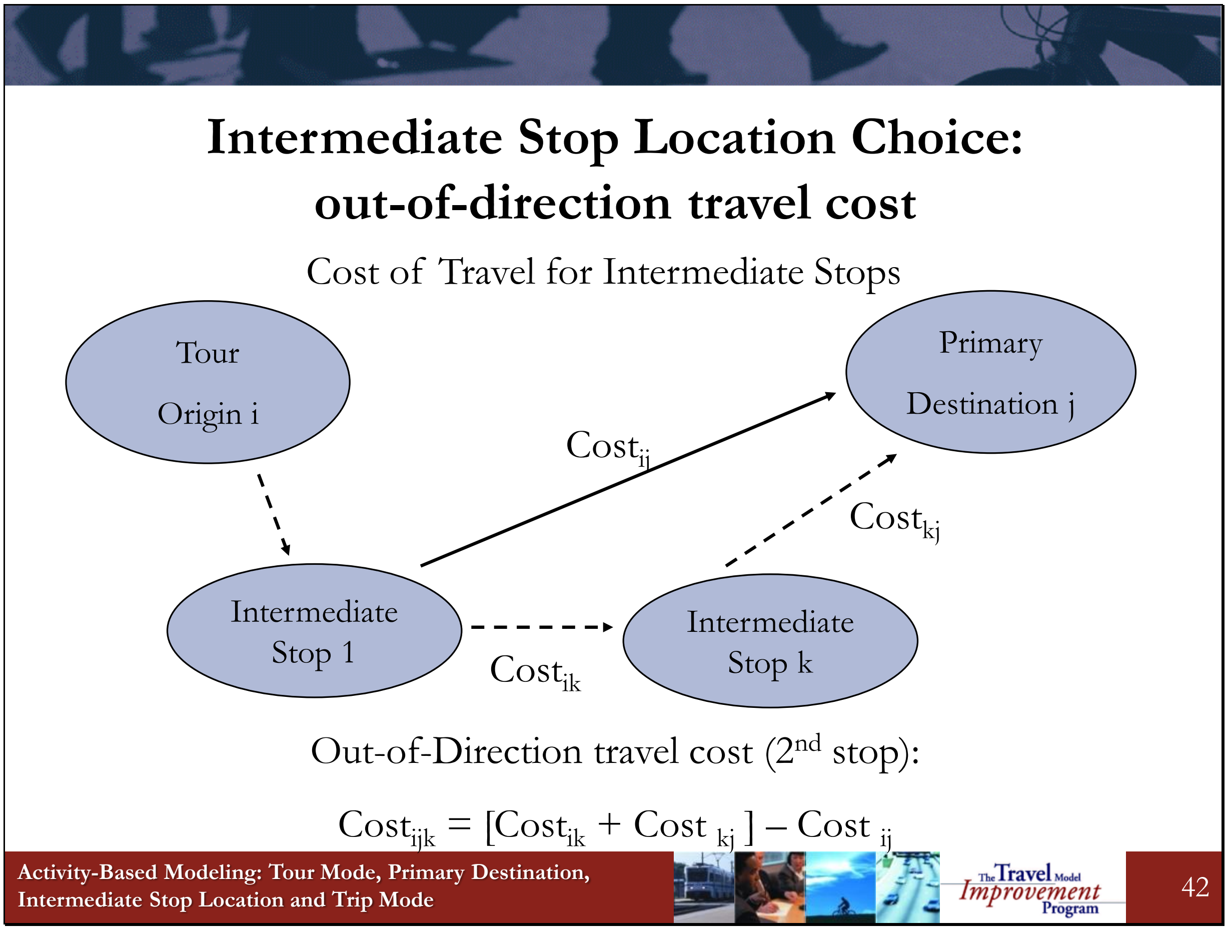


If we specify representative utility as a natural logarithmic function, then the exponentiation will reverse the log function, and we can insure this equality. If we then let the impedance function (distance, travel time, generalized cost) be a negative exponential function, then we have a utility expression that is a combination of a logged attraction term and a linear-in-parameters impedance term. We refer to this attraction term as the size of the zone, because it represents a positive quantity. Since there may be many reasons to be attracted to a zone, for example both dining and shopping, we may have multiple attraction variables within the size function.

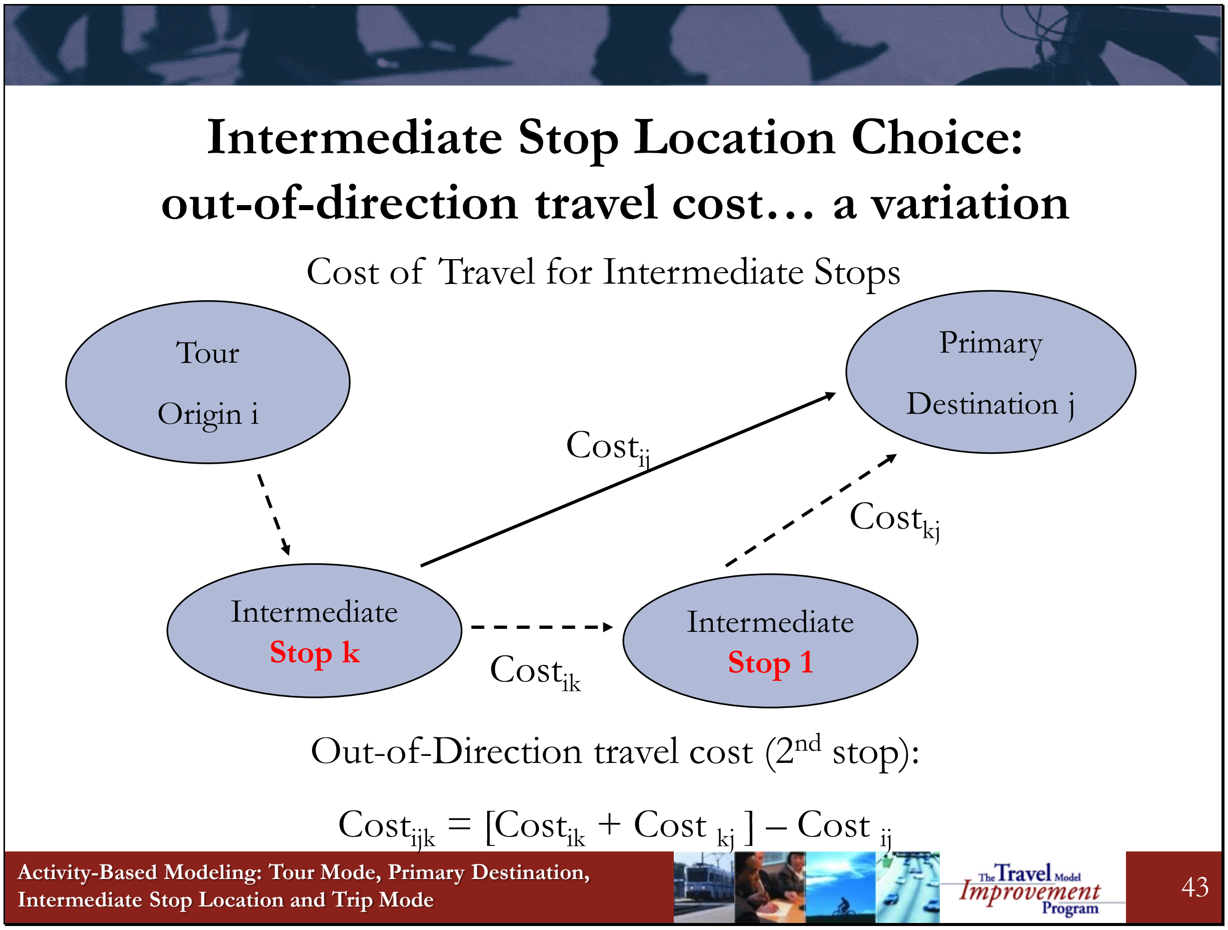
As a practical note, I should mention that the beta term is typically not estimated and fixed to 1.0 in order to avoid complications with interpretation. In addition, at least one of the size variables must also have its parameter fixed to 1.0 (theta) due to parameter identification restrictions in estimation. A third restriction is that the estimated thetas—the size variable coefficients are restricted to have positive values in keeping with the theory that the variables represent positive quantities in which more is considered better (more attractive).



Typically, a process referred to as "rubber-banding" is used to measure spatial separation in intermediate stop location choice models. The process measures the amount of additional impedance between the tour origin and the tour primary destination that would be incurred to travel to the intermediate stop location. This Page shows how the additional impedance is calculated for one stop on the way between a tour origin and primary destination. The concept behind this calculation is that travelers seek to minimize total travel cost, and will therefore tend to find intermediate stop locations that are reasonably on the route between origin and destination. However, this is not always the case, so there are no hard limits set on out-of-direction travel cost. Instead, the utility of the intermediate stop alternative decreases with respect to out-of-direction cost.



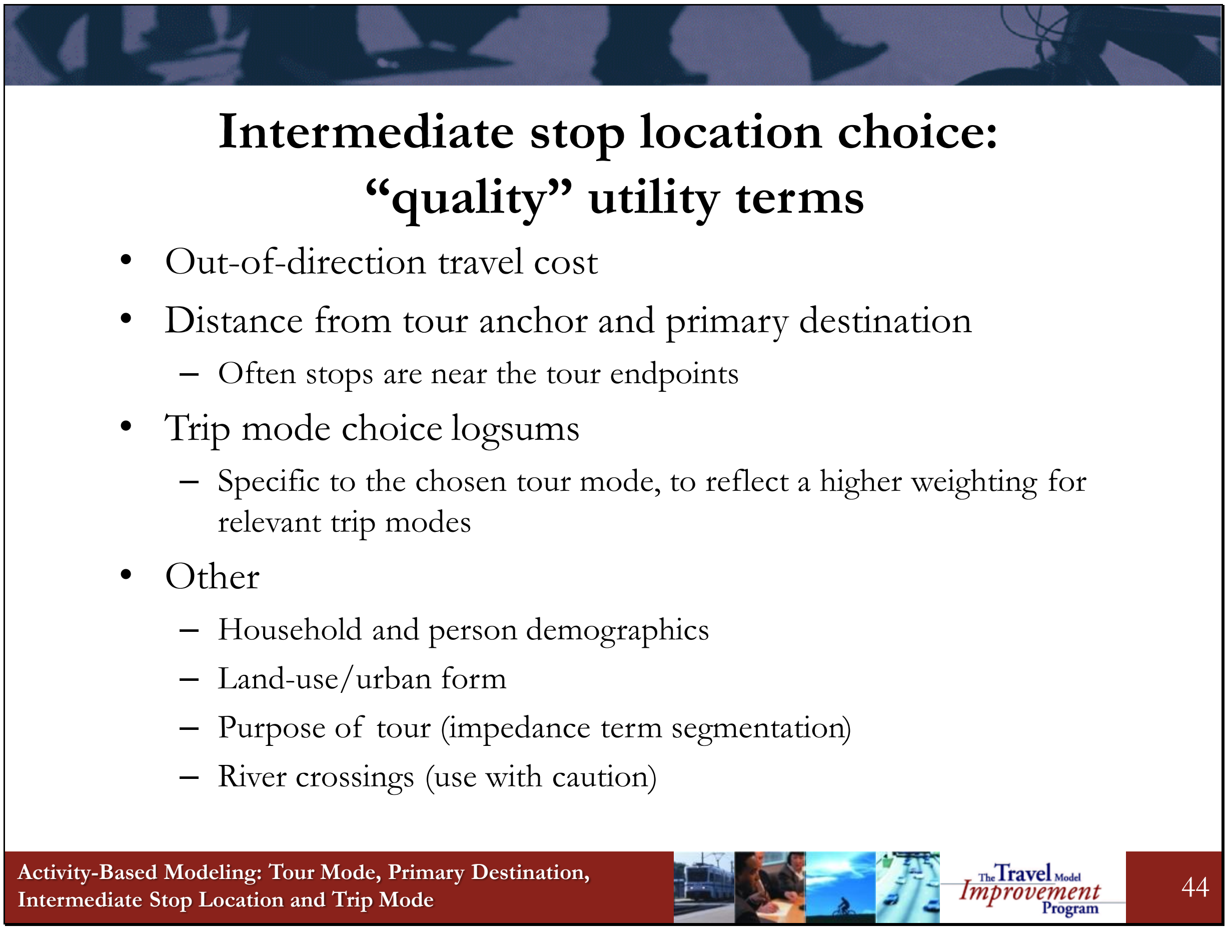
This Page shows the same calculation for a tour with two stops. In this case, the first intermediate stop location has been determined, and we are now choosing the second intermediate stop location. The out-of-direction travel cost in this case is based upon the previously-chosen stop location as the origin and the previously chosen tour primary destination as the destination.



This Page looks very similar to the previous one, with one important difference. The previous Page reflected the approach used in CT-RAMP.

An important difference between DaySim and CTRAMP is that DaySim models tour **destination** arrival and departure times at the tour level, whereas CTRAMP models **origin** departure and return times at the tour level. This is a somewhat fundamental difference that has significant implications for the trip-level models. While the method of calculating cost is analogous, in DaySim the first stop added is "adjacent" to the tour destination. When a second stop is added, it is added backwards between the first intermediate stop and the origin. The implication is that arriving on time at the primary destination and leaving on time and is more important, and that additional stops will serve to push back/forward home departure times and arrival times.

It is unclear whether this offers any behavioral or practical advantage. For example, one could argue that home departure and arrival times are more important under many circumstances.



Other time and cost terms can be considered in intermediate stop location choice models. For example, it has been found that the distance between the tour origin and the tour primary destination influence the stop location, particularly for long tours, since people tend to be more familiar with areas immediately around their home and workplace and are therefore more likely to choose stop locations near these habitual locations. Trip mode choice log-sums (or generalized costs consistent with the tour mode) are often used instead of distance or time, so that the stop location reflects accessibility according to the chosen tour mode. For example, if the chosen tour mode is walk-transit, one can use a log-sum taken across trip mode choice (which will reflect a higher waiting for transit and non-motorized modes) or use transit time, walk time, or some average of the two to represent accessibility.

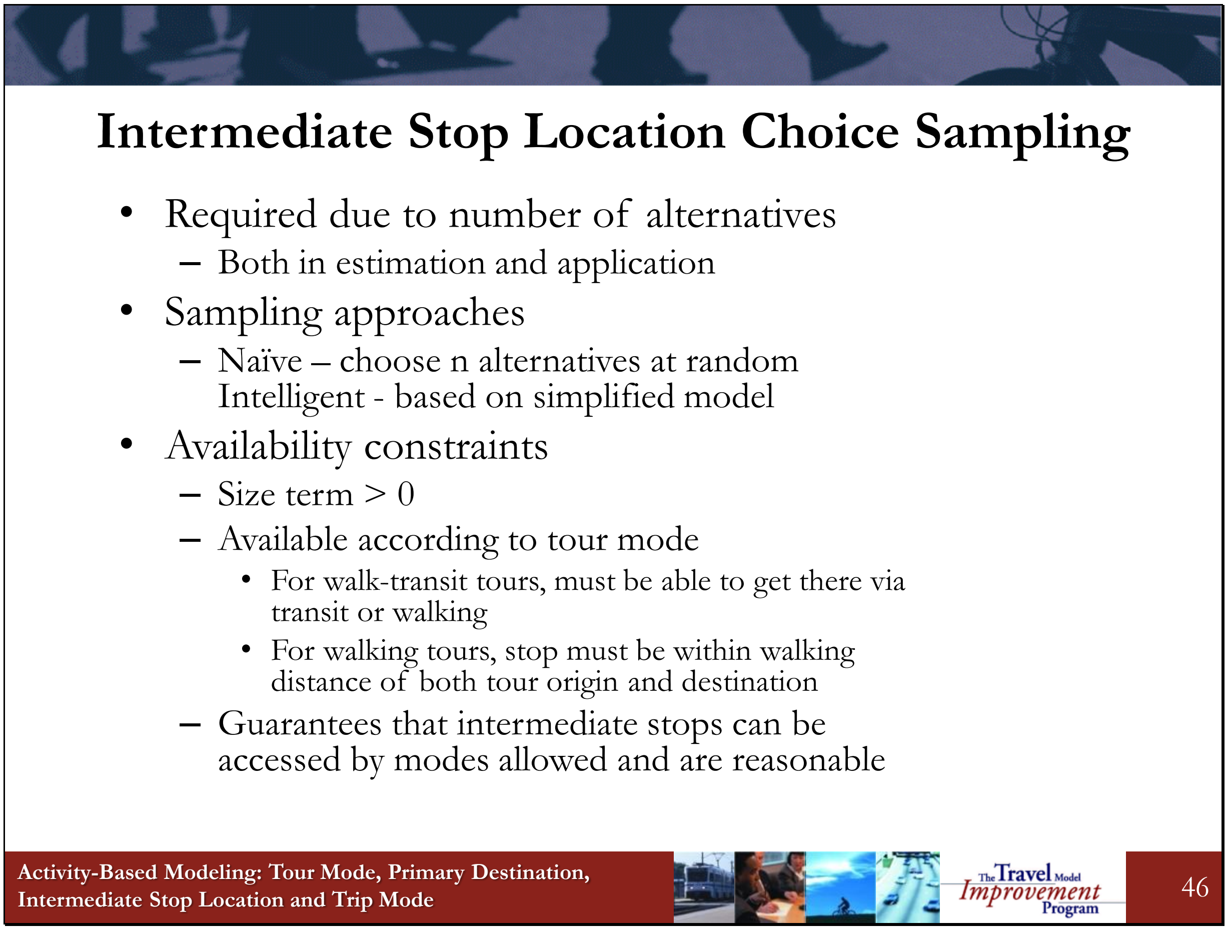
Other explanatory variables can include household and person demographics, land-use and/or urban form, the purpose of the tour, and alternative-specific constants such as river crossings – though these constants should be used with caution.

Intermediate Stop Location Choice Size Terms

- Stop purpose used for size term

	Tour Purpose					
Variable	Escort	Shop	Maint	Eat	Visit	Discr
Retail employment		1.00	1.00			0.22
Prof., bus services			0.85			
Amusement						0.02
Hotel						0.03
Restaurant, bar				1.00	0.33	0.14
Personal services			2.46			
Religious						1.00
Federal non-military			0.72			
Households	1.00			0.55	1.00	0.65
Enrollment	0.44					

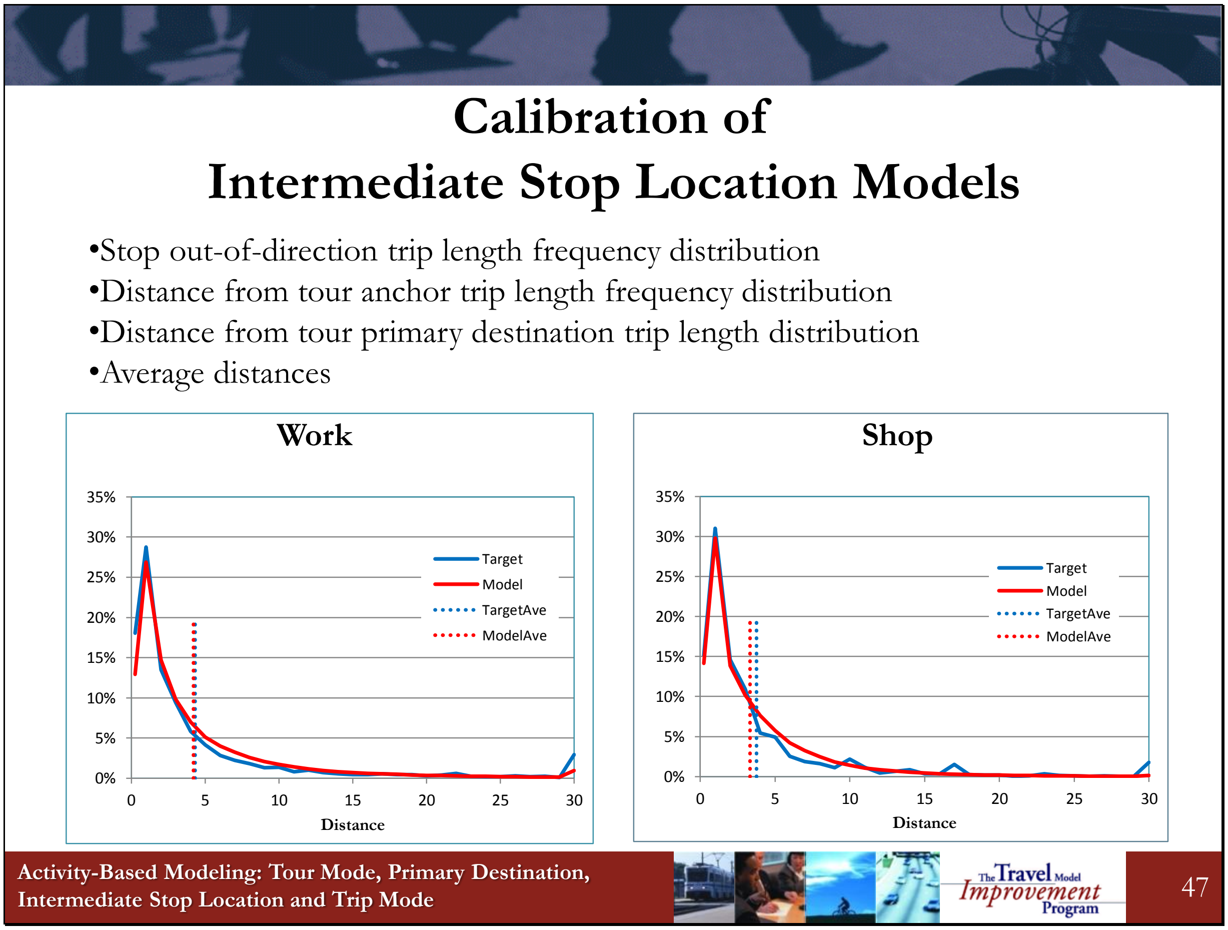
Size terms are equivalent to trip attraction equations in a gravity model. Here we see the size terms for stop purposes used in the San Diego activity-based model. Each stop purpose is shown as a column, and micro-zone variables are shown as rows. Each cell has the coefficient for the size term variable. For each tour purpose one of the variables is arbitrarily chosen as the base variable, and its size term coefficient is set to1.0. This allows one to compare the effect of other variables relative to the base variable. For example, let’s look at the escort purpose; each school enrollee is equivalent to 44% of a household, in terms of attractiveness of stop locations.



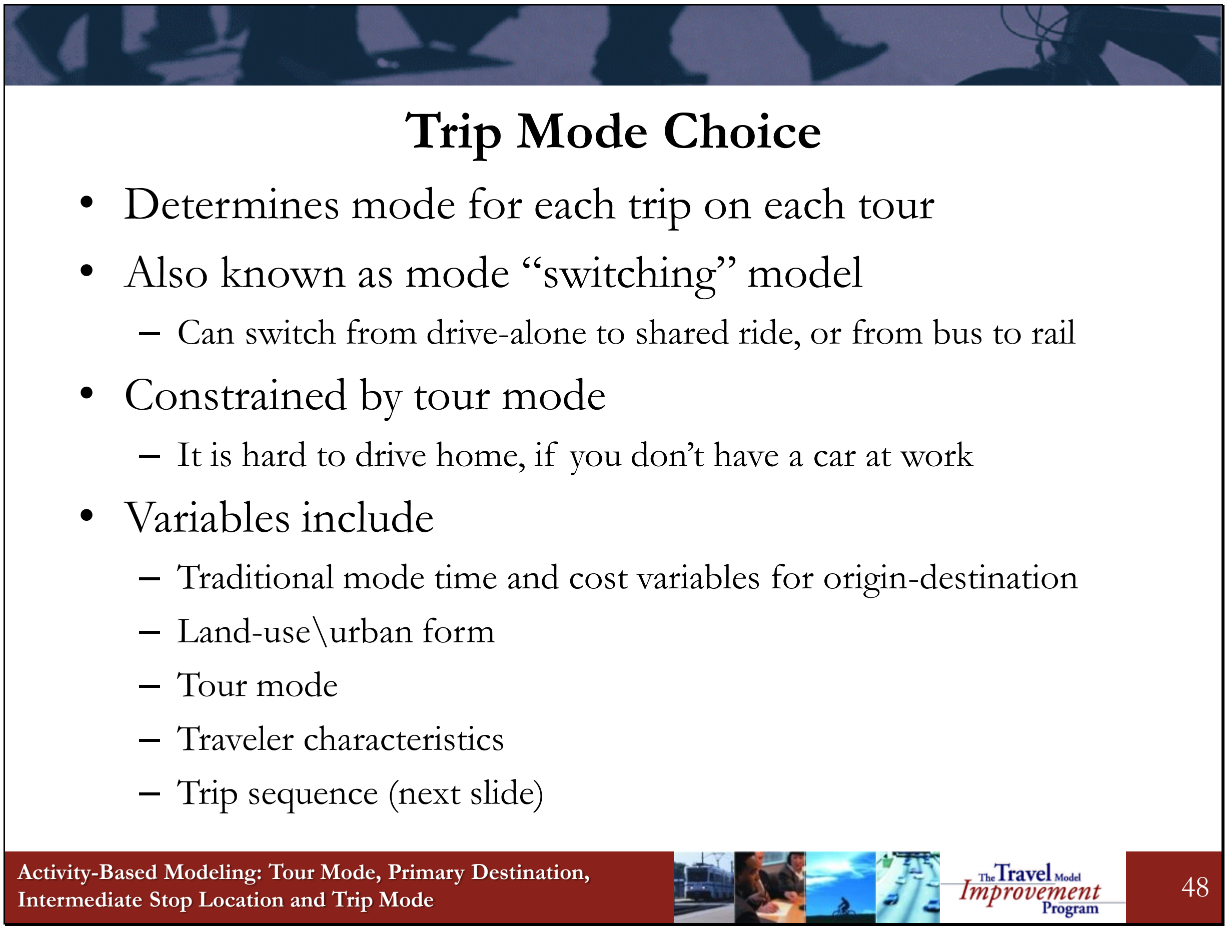
Often sampling is required for intermediate stop location choice estimation and application, due to the number of alternatives considered. This is especially true if the model system utilizes a highly disaggregate spatial system, such as micro-zones or parcels, where the number of alternatives ranges in the tens of thousands. In such cases, it would be computationally infeasible to calculate probabilities for each potential destination. Alternatives sampling first requires creating a selection set, then computing a utility for each sampled alternative and finally selecting an alternative from the sample.

There are number of alternative approaches to sampling, ranging from naïve to intelligent. A naïve approach would be to simply selecting *n* alternatives at random, and relying upon the number of alternatives to ensure that at least a subset of alternatives is reasonable for the tour. A more intelligent approach involves the use of a simplified destination choice model to generate a probability of inclusion for every potential destination, selecting a subset of alternatives according to that probability distribution, and then applying the full model to the sample set. The intelligent approach provides a more realistic choice set, but at the cost of more computational time required.

Constraints are used to ensure that alternatives in the model are realistic. A simple constraint is that each alternative must have relevant variables for the specific stop purpose; for example, zones without retail employment are not available for shopping stops. Another typical constraint is that stop availability is constrained by tour mode. For example, stops on transit tours must be available by either transit or walking. For walk tours, the stop must be within maximum walking distance (3 to 4 miles typically) of both the tour origin and primary destination. These constraints ensure that intermediate stops can be accessed by the modes allowed and that are reasonable given the tour mode, the origin and primary destination of the tour, and all other intermediate stop locations.



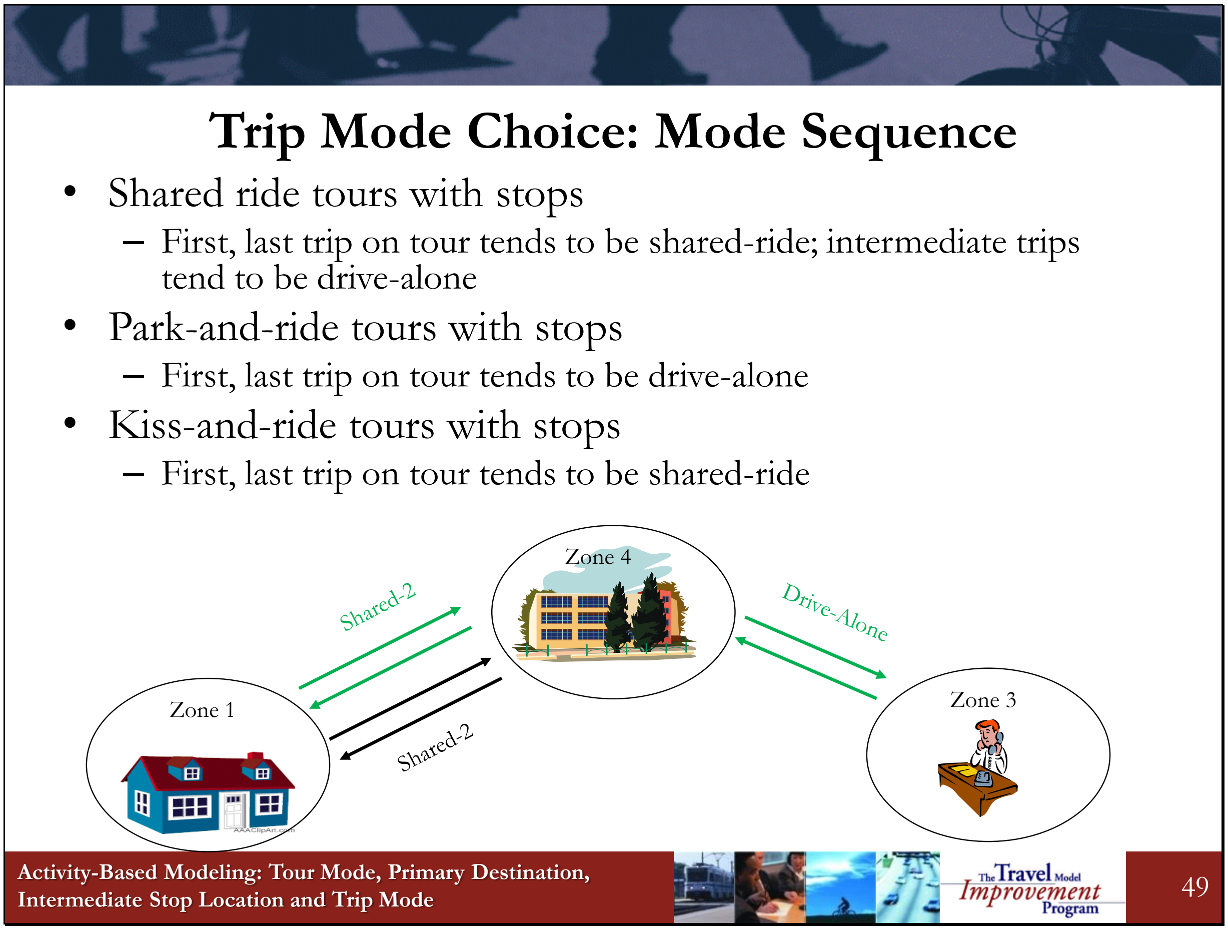
Intermediate stop location choice models are calibrated similar to gravity models and trip-based destination choice models. Average trip lengths and trip length frequency distributions are used to ensure reasonableness of results based upon comparisons to expanded household survey data. In addition, out-of-direction distance, distance from home, as well as distance to primary destination can be summarized. Shown on this Page are trip length frequency distributions for out-of-direction distance for stops on work tours and shop tours. Both cases show a good match between estimated and observed distributions.



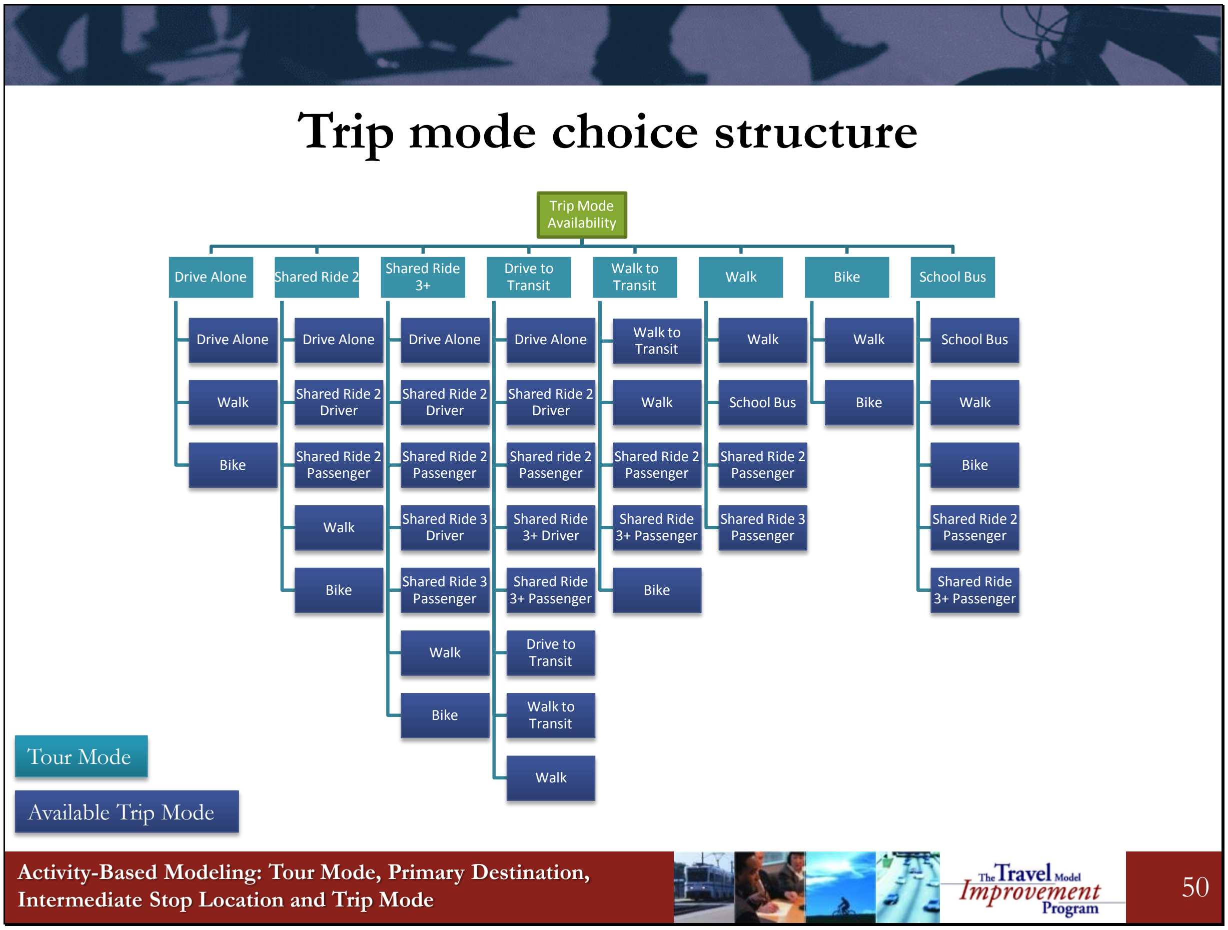
Now that we’ve explored intermediate stop location choice models, let’s move on to trip mode choice, or trip switching models. These models determine the mode for each trip on a tour. They are referred to as mode switching models because they account for the likelihood of switching modes on a tour. For example, on a shared-ride tour, it is frequently observed that some trips are drive-alone and some trips are shared-ride. This model determines which trips are taken by each mode.

Trip mode choice models are heavily constrained by the chosen tour mode, to ensure consistency between modes for each trip on the tour. These consistency relationships are defined in the tour mode/trip mode table shown earlier, and enforced by constraining the availability of trip modes for each tour mode, as well as alternative specific constants that are segmented by tour mode. For example, if the tour mode is walk transit, typically drive-alone is not allowed, because the traveler does not have their car on their tour. This is an example of an enforced constraint on mode availability. Additionally, shared-ride has a low probability of selection on walk-transit tours, because of the difficulty of finding a ride and the additional disutility imposed on a driver, but may still be one of the available modes on walk-transit tours. In this case, shared-ride would have a negative alternative-specific constant for walk-transit tours, to reflect the disutility of the choice, resulting in a low probability of selection.

Variables in trip mode choice models include typical time and cost variables for each mode, for the trip origin-destination pair and relevant time period, as described above under tour mode choice. Land-use and urban form variables, traveler characteristics, and tour mode are all potential explanatory variables. Also, the sequence of the trip on the tour is an important explanatory variable, as we shall see next.



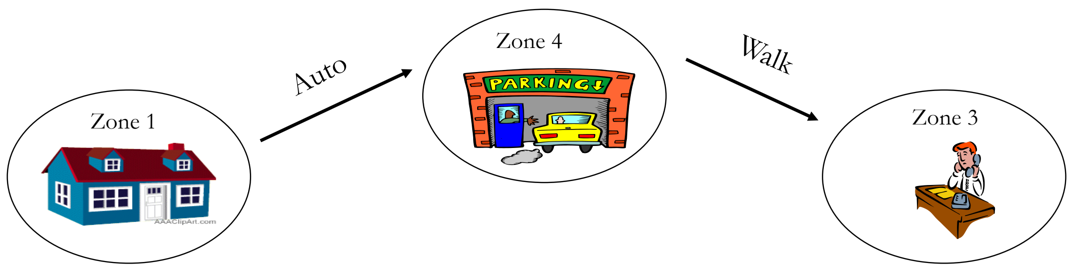
The sequence of the trip on the tour is an important consideration for trip mode switching. For example, shared-ride tours with an intermediate stop for escort involve dropping off other household members or picking them up on the way to or from some other activity, like work. When this travel pattern isn't modeled explicitly, the trip mode choice model predicts which trips are shared-ride and which trips are drive-alone. Typically, the first and last trips on the tour (the ones to/from the escort activity) are the shared-ride trips, while the inner trips on the tour (between the escort activity and the individual activity such as work) are the drive-alone trips – as shown on the graphic. Similarly, on park-and-ride tours with intermediate stops, the first and last trips on the tour are taken via auto (such as working out at the gym after work) while the inner trips on the tour are transit trips. Walk transit tours with intermediate stops are often characterized by short walk stops close to home with a longer transit trip to/from the primary destination, though there is considerable variation in walk-transit tours.



This diagram portrays the trip mode choice availability structure, where trip mode is conditional upon tour mode. The logic in this structure is based on observed trip modes for a given tour mode. It is also somewhat hierarchical, based on what has been excluded in the trip mode choice set. For example, on a Drive-Alone tour, shared-ride trips have been excluded. Shared-ride trips for two persons (driver or rider) are available on Shared Ride 2 tours, but Shared Ride 3+ has been excluded. Shared Ride 2 and 3+ (driver and rider) are available on the Shared Ride 3+ tours. Shared Ride 2 and 3+ as a passenger, not a driver, are also available on drive-to-transit and walk-to-transit tours, as well as on Walk and School Bus tours.

Trip Mode Choice: Parking Location Choice & Capacity Restraint

- Destination choice model predicts parking TAZ for every auto trip to parking constrained area (CBD)
- Explanatory variables
  - Walk time to destination
  - Parking cost
  - Household income
- Requires parking inventory (spaces, rates, costs) for capacity constraint
- Equivalent method can be applied to park-and-ride lots



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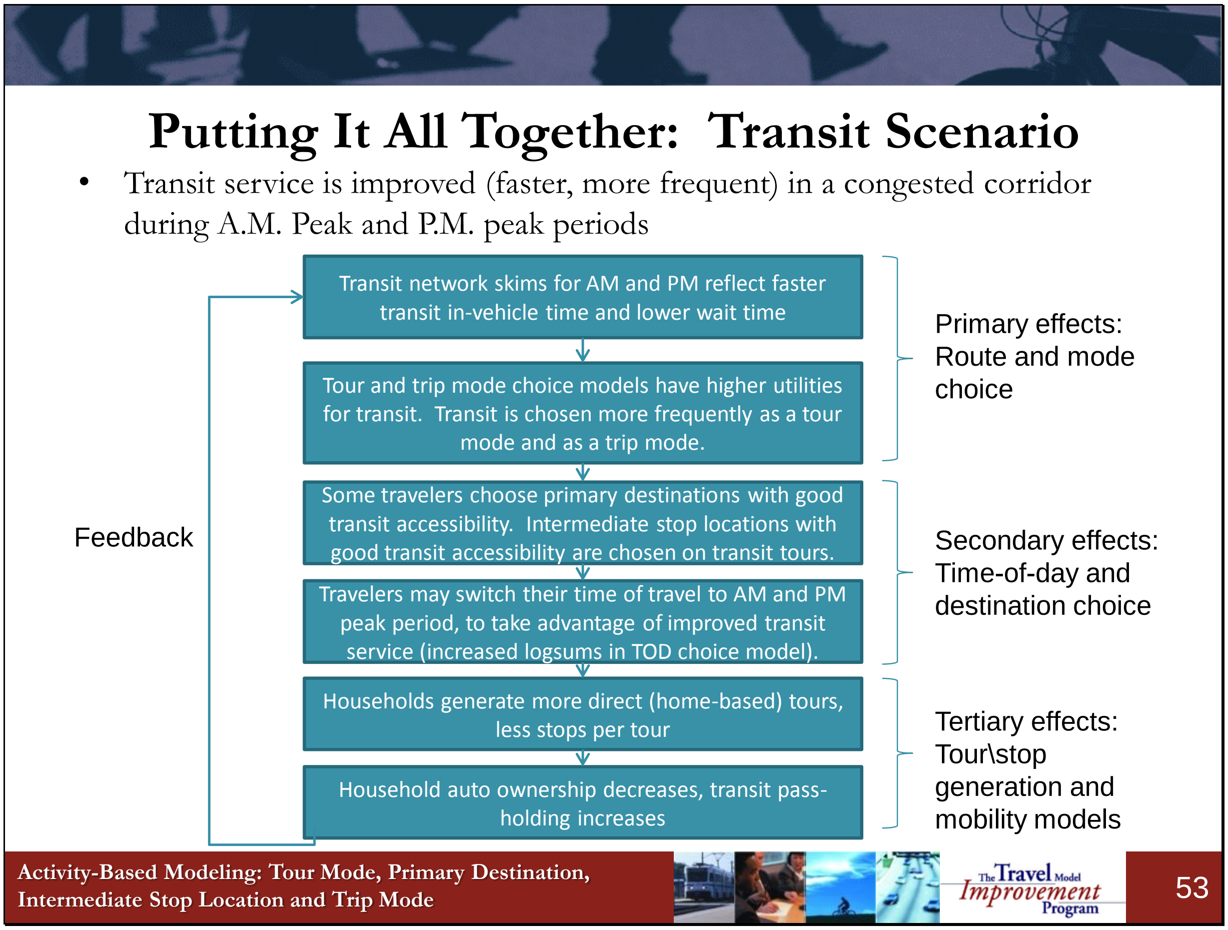
Parking location choice is often addressed after stops have been located and trip mode has been determined, specifically for auto trips to parking constrained areas. In such areas, it is common for drivers to park in a zone that is not necessarily the same zone as their destination, either because of parking availability constraints or due to price differences. Travelers trade off the cost of parking with the time required to walk to their final destination. Parking location choice models rely upon the availability, spatial distribution, and cost variation of parking supply around the central business district to improve traffic assignments in downtown areas, and model policies that constrain parking supply or change parking cost. Parking location choice models are also useful when modeling the impact of transit circulator projects, particularly on college campuses where parking is often expensive and highly constrained.

Calibration of Trip Mode Choice Models

- Calibration methodology
- Things to check:
  - Trips by tour mode and trip mode
  - Transit trips by district
  - Transit trips by transfers
  - Other summaries
- Reasonableness of constant terms (FTA New Starts)

	Observed						
	Tour Mode						
Trip Mode Collapsed	**Drive-Alone**	**Shared 2**	**Shared 3+**	**Walk**	**Walk-Transit**	**PNR-Transit**	**KNR-Transit**
Drive alone	1,476,827	254,733	173,819	-	-	3,309	-
Shared Ride 2	-	256,731	78,274	-	1,675	1,147	1,650
Shared ride 3+	-	-	155,109	-	1,331	-	79
Walk	-	2,785	1,455	41,354	4,984	1,347	868
Walk Transit	-	-	-	-	59,650	1,389	3,164
PNR Transit	-	-	-	-	-	10,245	-
KNR Transit	-	-	-	-	-	-	3,759
Generic	Non-Toll/Free	HOV	Toll	Local	Express	LRT	Commuter Rail
Total	2,385,672	8,949	10,065	35,536	4,358	34,742	3,571

Trip mode choice models are calibrated based upon observed data tabulations from household interview data and/or on-board transit surveys. Typically one compares trips by tour mode and trip mode for each purpose, as shown in the Page. Other summaries include trips by mode and district (though if tour mode choice was sufficiently calibrated, these summaries should be good without any adjustment), transit trips by number of transfers, and trips by mode and trip length. Typically, alternative-specific constants for transit line-haul modes should not differentiate between tour mode or socio-economic market segment.



Here is a practical, concrete example of how an activity-based model might respond to a network scenario. In this scenario, we are modeling increased transit service in a congested corridor during the AM and PM peak periods. Note that this is the same scenario that was described in the accessibilities webinar. However, in this case we can see a bit more clearly now that we understand the full model structure.

Obviously, once we code better transit service in our network, the first change one might see is that level-of-service skims for affected zone-pairs will reflect the improved transit in-vehicle and out-of-vehicle times. As a result of these network (and skim) improvements, transit has a higher probability of selection in route choice (transit riders with a choice of routes will choose the improved transit routes more). Now we know that there are actually two different mode choice models, both of which take into account the improved transit service. There will be more transit tours predicted by the tour mode choice models, and more transit trips on those tours as predicted by the trip mode choice model.

The primary destination choice model and intermediate stop models take into account transit level-of-service via mode choice log-sums, which reflect the transit improvement. These improvements lead to higher probabilities of selection for zones in the improved transit corridors, and therefore more primary destinations and intermediate stops in those corridors. The time-of-day choice also takes into account mode choice log-sums that vary by time-of-day. To the extent that these log-sums reflect increased transit level-of-service in the AM and PM periods, more travelers will travel in these periods as a result. Note that with feedback, some auto travelers may shift back into the peak periods since some of them have chosen to switch to transit, freeing up some capacity. These effects are represented by the feedback loop to the left of the diagram.

The improvement in the destination choice log-sum has tertiary effects on tour and stop generation models and medium-term mobility models. Households that reside in the corridor may generate more direct tours with less stops per tour, as they change their travel patterns to take advantage of the transit service. Households may opt to own fewer cars and more transit passes as a result of the improvement. All of these potential travel behavior changes are represented in activity-based models with well-formulated tour and trip mode choice models and intermediate stop location choice models.

Here is another example of how an activity-based model might respond to a policy input. In this case, we are looking at increased land-use density\development in some corridor. This would be reflected by a change in the land-use input file to the model.

Primary effects of land-use changes are in destination choice. Both the tour primary location choice model and the intermediate stop model would reflect increased destinations in the corridor, due to the increase in opportunities. Since work and school (mandatory) location choice models are constrained to match employment and enrollment respectively, these models would show a proportional increase in destinations to the increase in jobs and enrollment in the corridor. Non-mandatory models would also show an increase in destinations; however, since these models are typically not doubly-constrained, the increase may not be proportional to the increase in opportunities. The increase in destinations would also be a function of how convenient the corridor is to households – in trip-based model terms, the trip attraction rate for non-mandatory tours (and especially intermediate stops on tours) is a function of both the quantity of employment in the zone as well as the accessibility of the zone to households. For intermediate stops, the amount of stop-making will depend on whether the corridor is accessible to both households and primary destinations or workplaces. A corridor that is en route between a bedroom community and a major employment center would be expected to show more intermediate stops than one that was not.

The secondary effects of increased corridor land-use density would be on mode choice; in this case, the direction of the change would depend on the quality of transit service, whether the corridor is served by a toll facility, etc. If transit service in the corridor is better than other parts of the region, then those trips that change destinations would be more likely to choose transit and therefore overall transit ridership would likely increase. Similarly, if the corridor is served by a toll facility that offers a relatively good time savings to toll cost ratio, then an increase in toll trips is likely. Typically, increases in density also increase non-motorized mode share; because there are more opportunities closer together, trip length decreases and non-motorized modes are more competitive for shorter trips.

Tertiary effects include time-of-day changes, tour/stop generation changes and mobility model changes. The magnitude and direction of these changes is highly dependent on the quality of service of the modes that serve the corridor with increased density and the level of congestion in the corridor. If the increased density results in a more congested corridor overall, and improvements in transit service in the corridor are not significant, one might observe changes in time-of-day of trips in and through the corridor to less congested (off-peak) periods. Similarly, there may be changes in the quantity of tours generated and the complexity of those tours. Typically households that are in denser areas generate more direct tours with less stops per tour, while households that are in less dense areas generate fewer tours with more stops per tour. The effects on tour and stop generation will depend to a large extent on where households reside with respect to the corridor of interest. There may also be changes on mobility models including auto ownership, transit pass holding, etc.

What are the advantages offered by the activity-based model treatment of tours and stops?

- Greater consistency between modes chosen for all trips on tour
- Greater consistency in destinations chosen between home-based and non-home-based trips
- Less aggregation bias in 'typical' variables such as parking cost, toll cost, access to transit and non-motorized time and distance
- Ability to incorporate additional household, person land-use and level-of-service throughout the day

Shown here is a recap of some of the advantages offered by activity-based models, compared to traditional trip-based techniques.

- Activity-based models offer a greater consistency between modes chosen for all trips on a tour. This is ensured by use of tour mode to constrain trip modes on the tour, use of trip or path log-sums to influence trip mode, choosing intermediate stop destinations that are accessible by tour modes, and constraining work sub-tours based upon tour mode.
- Activity-based models offer greater consistency in destinations chosen for home-based and non-home-based trips. Trip-based models operate on each trip purpose independently, whilst activity-based models constrain intermediate stop locations on the tour origin and primary destination, ensuring a logical relationship between all three.
- Activity-based models have less aggregation bias in commonly-used variables such as parking cost, toll cost, access to transit, and non-motorized time and distance. The aggregation bias is overcome in activity-based models through the use of simulation-based modeling of individuals rather than an entire zone of households of a certain types.

- Activity-based models offer the opportunity to incorporate more variables than trip-based models, including household, person, land-use variables and level-of-service that varies throughout the day.

Ongoing research and advancements

- Finer resolution of path attributes and skims
  - Routing from parcels, micro-zones for short-, non-motorized trips; transit-walk access
  - Bicycle and pedestrian route choice models
  - Parking capacity constraints and pricing
  - Use of transit stop attributes in mode choice (traveler info, covered stops, fare machines, safety\lighting, other amenities)
- Incorporating mobility attributes (see Webinar 7)
  - Strong conditioning effects of: transit pass, transponder holdings; bicycle ownership/usage; employer vehicle requirements, parking subsidies; persons with disabilities.
- Joint choices of destination, mode and time of day
- Choice set constraints using space-time prism concepts

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The concept of tour modes conditioning trip modes is well accepted. The concept of "rubber-banding" to find locations for intermediate stops on tours is also fairly well accepted. Much of the advancement in this area is really in details related to creating better explanatory variables. For example, we provided you with some examples of detailed routing between micro-zones and transit stops. How to better represent short trips and pedestrian and bicycle paths continues to be an area of ongoing research, and a couple of agencies in San Francisco and Portland have developed bicycle route choice models. Work on the Chicago ABM is focusing on incorporating transit stop attributes in mode choice, building upon some previous work in Portland and for the TCRP. These include attributes such as traveler information, presence of covered stops, fare machines, safety\lighting of stops, and other nearby amenities).

The mobility attributes that we discussed in Webinar 7 are also very important, because they have a strong conditioning effect on mode choices. This includes models that predict transit pass and transponder holdings; bicycle ownership/usage; employer vehicle requirements and parking subsidies; and persons with disabilities. In addition, there is some ongoing research on representing the multi-dimensional choices of destination, mode and time of day in a unified decision structure; however, thus far, these models have not been easy to implement in practical models. There is also a lot of recent research on using space-time window concepts to constrain choice sets for both destinations and modes and how to best implement that in a tour context.

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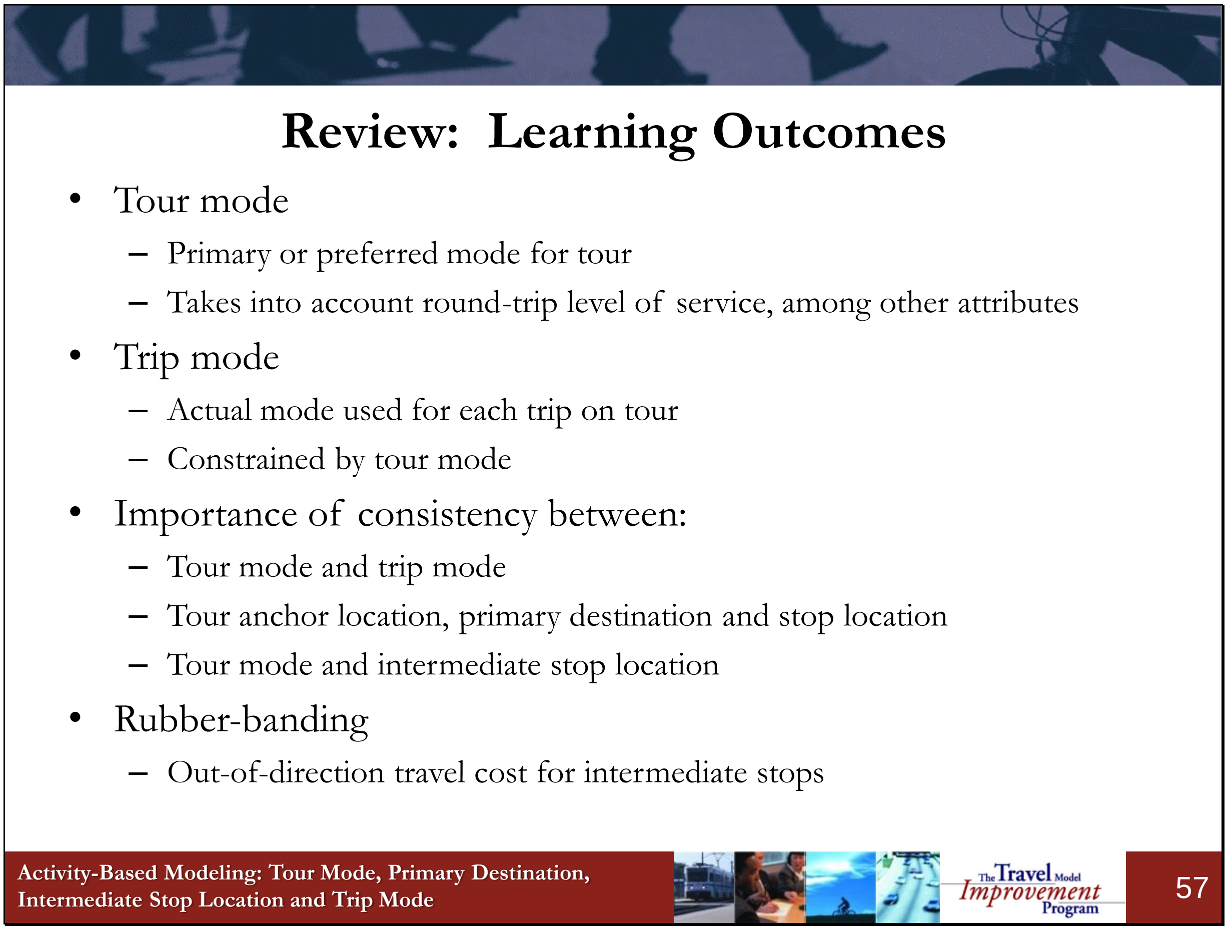

In today's session, we covered tour mode choice models, trip mode choice models and intermediate stop location choice models. A tour mode is the primary or preferred mode for the tour. The tour mode ensures consistency between stop locations on the tour and between modes used for trips on the tour. The tour mode choice model takes into account the round-trip level of service between the origin and primary destination of the tour.

Trip mode is the actual mode used for each trip on the tour. Trip mode choice typically takes into account one-way level of service between the trip origin and destination, but is constrained by the tour mode.

Consistency is very important between choice dimensions, include tour mode and trip mode, the location of intermediate stops on the tour with respect to tour origin and primary destination, and the consistency between modes used and locations of stops. These consistencies are ensured through constraints and situational variables.

The process of rubber banding refers to the measurement of the out-of-direction travel cost incurred by stop locations on a tour.

Questions and Answers

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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 Frameworks and Techniques	April 5
Population Synthesis and Household Evolution	April 26
Accessibility and Treatment of Space	May 16
Long-Term and Mobility Choice 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
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Session 10 Questions and Answers

Would a difference between the number of tours attracted to a zone and the socio-economic data in that zone (in a singly-constrained model) indicate some problem with the data?

Joel: It very well might, but it is probably a question of magnitude. If the rate of attractiveness was very different for the same employment type in the different parts of the region, it could indicate that the assumed land-use for the area with a relatively low rate of tour/stop attractions was too ambitious. However, there are differences in trips attracted through the region; some stores have fewer attractions per employee but sell more expensive items (super-stores, major appliance stores). They might be less accessible but still economically viable. It all depends on the magnitude of the difference and the amount of differentiation between employment types or size term variables.

Is it possible to track the driver of autos on shared-ride tours?

Joel: Yes, this is one of the motivations for explicit ride-sharing models. However, this is being tackled for intra-household ride-sharing. Inter-household ride-sharing has not been addressed by activity-based models yet.

Is the size of bike-transit too small to model it explicitly?

Joel: It depends on the region and the interest in policies that involve biking to transit. The same argument can be made for inclusion of any choice or variable in the model system. For example, the bicycle-to-transit share in Eugene Oregon is higher than the drive-transit share. This is due at least in part to the size of the University travel market in Eugene (University of Oregon). They are also very interested in modeling bicycle lanes and bike capacity on transit. So it might be useful to add bicycle as an explicit access mode in their model system. However, modeling bike as an access mode to transit is somewhat challenging. Some travelers bike to transit but leave their bike at the boarding location and therefore only have bicycle as an access mode, whereas some travelers take their bicycle on transit and therefore have bicycle for both access and egress modes. Still other travelers would like to take their bicycle on transit but cannot due to capacity constraints and therefore end up biking all the way to their final destination (or waiting for the next transit vehicle). One would need to determine how to address these issues in order to model bike-transit explicitly.

Doesn't the use of both time and distance in the utility lead to multi-collinearity? This is particularly true in the case of logit models which are more susceptible to multi-collinearity?

Joel: Often, we do not use both time and distance in the destination choice model. Instead, we use a mode choice log-sum and distance. In a perfect world, we would not need both mode choice log-sum and distance in a destination choice model; mode choice log-sum would explain all aspects of accessibility. However, mode and destination decision are made on different time scales, so a fully consistent model is not necessarily appropriate. Distance is often needed in order to correctly measure how travelers perceive space when choosing a location, as opposed to choosing a mode. Co-linearity between a mode choice log-sum and distance variables can be a problem in model estimation. Often transformations of distance are used in estimation in order to minimize the problem (log of distance, distance-squared, distance-cubed, etc.). Alternatively, one might estimate a model with only a mode choice log-sum, and then constrain that parameter to its estimated value and adjust distance terms in calibration in order to match the observed trip length frequency distribution.

Are the outcomes from an activity-based model better for modeling managed lanes than in trip-based models?

Joel: We will cover this in more detail later, but the short answer is that yes, they are better. The models provide more information for modeling managed lanes – path choice, time-of-day choice, mode choice, and even tertiary effects.

In the absence of a longitudinal survey, isn't it a bit risky to model tertiary effects? Is it reaching too far?

John: Is it riskier to ignore them? We are relying upon cross-sectional data to inform choice elasticities. However, it would be riskier to ignore the effects of variables on those choices. While it would be ideal to have longitudinal data upon which to estimate the effects of changes in inputs, this data is very difficult and expensive to collect. Therefore cross-sectional data is the only data available, and we need to use it in order to capture important relationships. For example, it is clear that sensitivities to level-of-service, land-use effects, etc. are important determinants of auto ownership. Cross-sectional survey may not be a perfect data set but it is appropriate and very necessary to measure the effect of such variables.

Has anyone modeled policies such as electric bicycles?

Joel: There is research exploring potential market penetration of electric bicycles and so forth, but not any activity-based models that we are aware of that model such technologies explicitly. However, one advantage of activity-based models is the use of models to do scenario-based planning. In such exercises, one asserts the share or market penetration of a new technology, such as electric vehicle penetration, and adjusts alternative-specific constants to reflect that assertion. Then the model is run and outputs are summarized to determine the effects of that policy on travel demand. The Metropolitan Transportation Commission has performed similar analyses using their activity-based model for their Regional Transportation Plan and presented their work at the 2012 Transportation Research Board Conference.

What are the key tour purposes used in activity-based models?

Joel: Mandatory – work, school. Maintenance – escort, shop, other maintenance. Discretionary – visiting, eating out, other discretionary. Additionally, tours are classified as to whether they are home-based or work-based (according to their origin or anchor location). Finally, some models explicitly model joint travel; therefore, another classification is given to fully-joint or partially-joint tours. See webinars 3, 4, and 8 for more details.