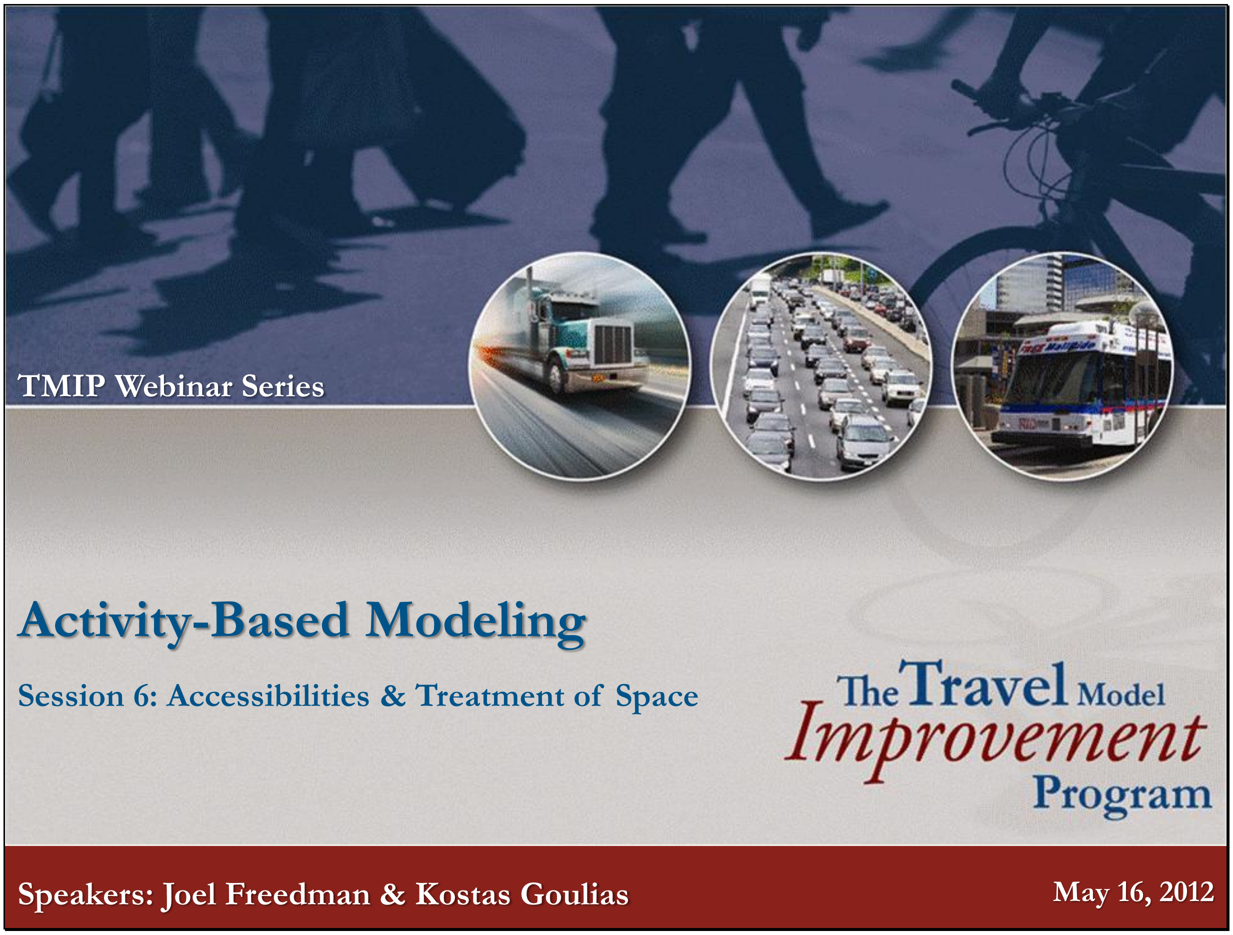
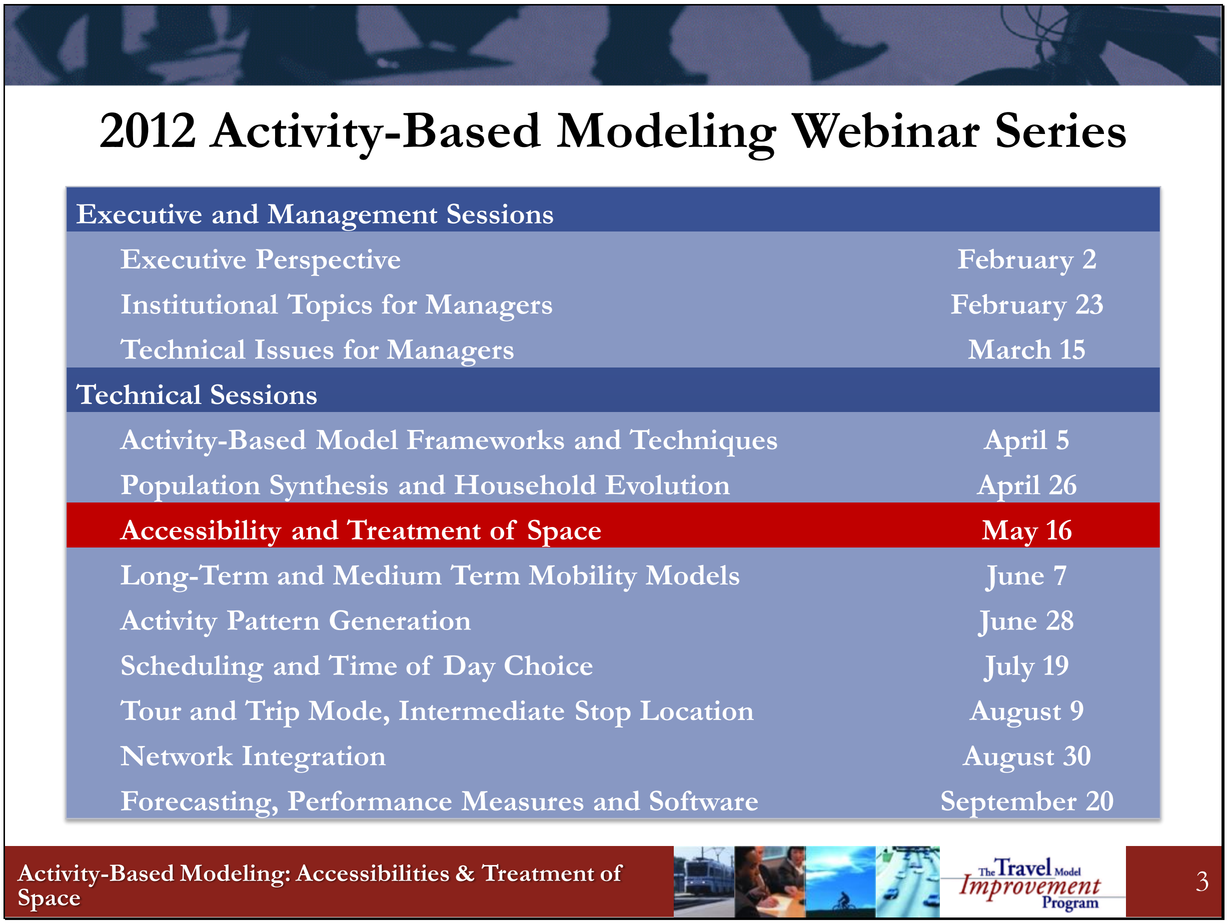

TMIP Webinar Series
Activity-Based Modeling
Session 6: Accessibilities & Treatment of Space
The Travel Model Improvement Program
Speakers: Joel Freedman & Kostas Goulias
May 16, 2012

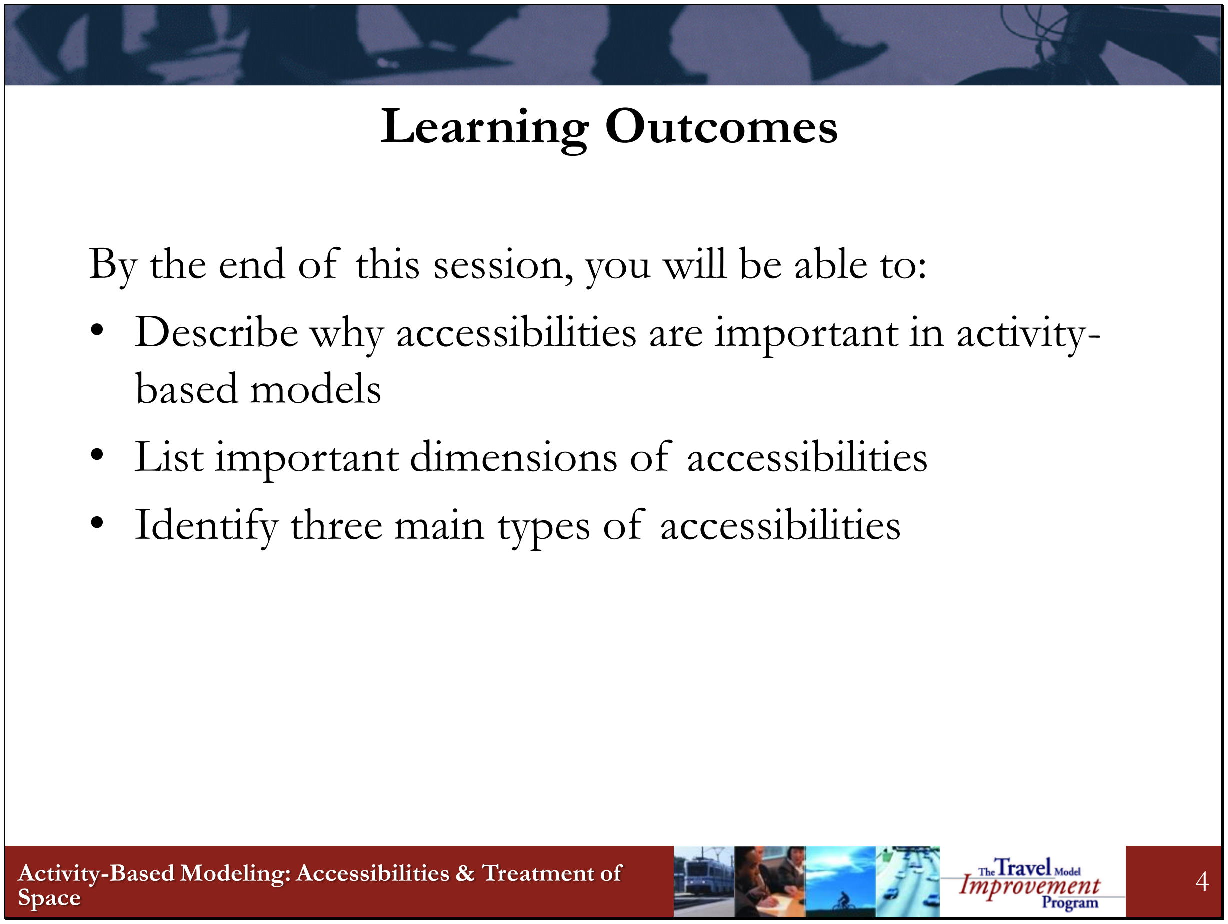
Resource Systems Group and Parsons Brinckerhoff have developed these webinars collaboratively, and we will be presenting each webinar together. Here is a list of the persons involved in producing today's session.

- Joel Freedman and Kostas Goulias 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 John Gliebe and Rosella Picado. John Bowman and Mark Bradley provided a review of the material.
- Bhargava Sana was responsible for media production, including setting up and managing the webinar presentation.



For your reference, here is a list of all of the webinars topics and dates that have been planned. As you can see, we will be presenting a different webinar every three weeks. Three weeks ago, we covered the fifth topic in the series—Population Synthesis and Household Evolution. This session covered the creation of synthetic populations for use in an activity-based model simulation.

Today’s session is the third 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 treat space, including both zone-based and parcel-based systems. We will also cover how accessibilities are calculated and used in activity-based models, and why they are important.



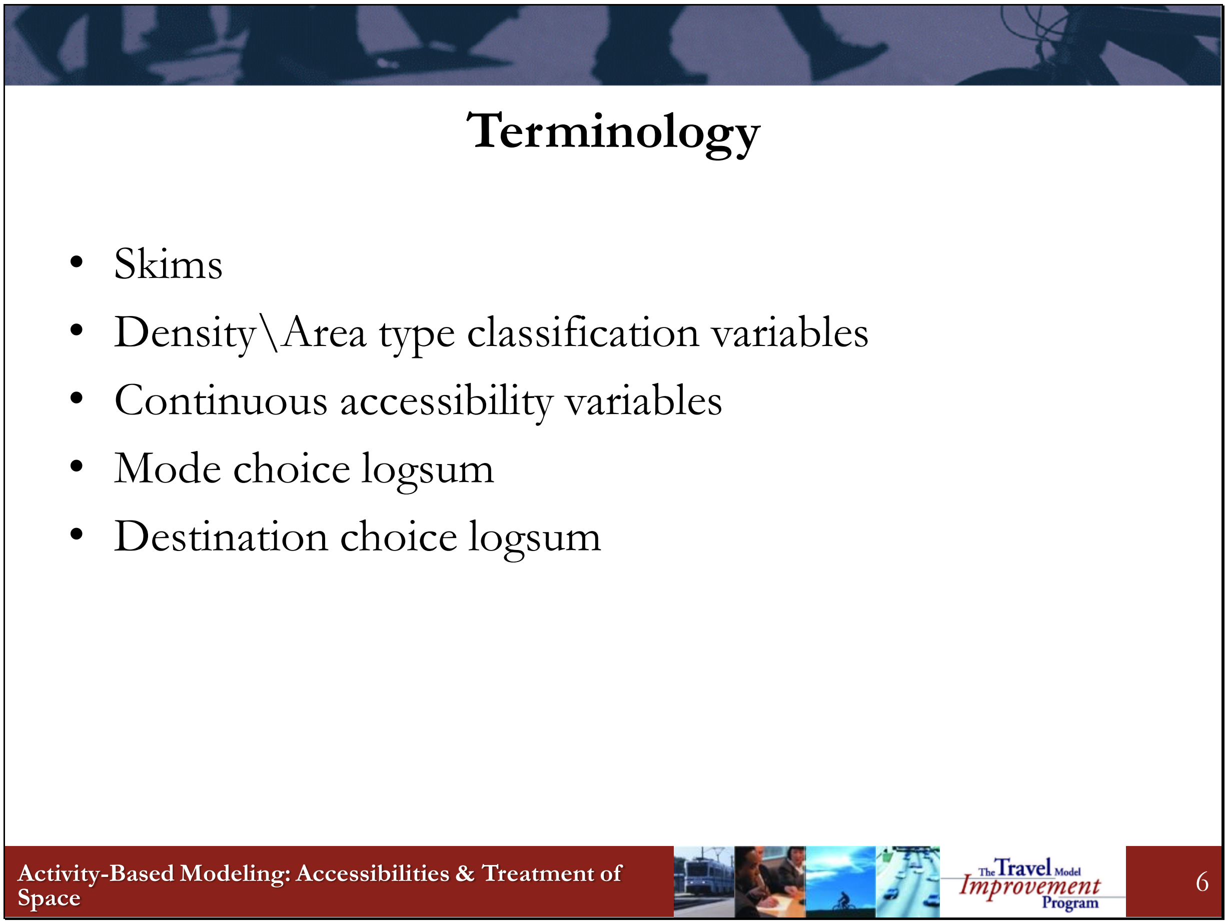
In today's session, we will be covering the treatment of space and accessibilities in activity-based models. At the end of this session you should be able to:

- Describe why accessibilities are important in activity-based models
- List important dimensions of accessibilities
- Identify two main types of accessibilities

Webinar Outline

- Basic terminology
- Need for accessibility measures
- Important dimensions of accessibilities
- Data needs
- Types of accessibilities
- Impact of accessibility on activity and travel choices
- On-going research
- Questions and answers

In this webinar, we will cover the different types of spatial treatments and accessibility measures used in many activity-based models. We will discuss why accessibility measures are necessary, what are the important components or dimensions of accessibility measures, and the impact of accessibilities on activity and travel choices. We will talk about the treatment of space in activity-based models, and implications for different treatments of space in terms of data needs and computational burden. Finally, we will cover on-going research into accessibility measures and provide time for questions and answers.



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

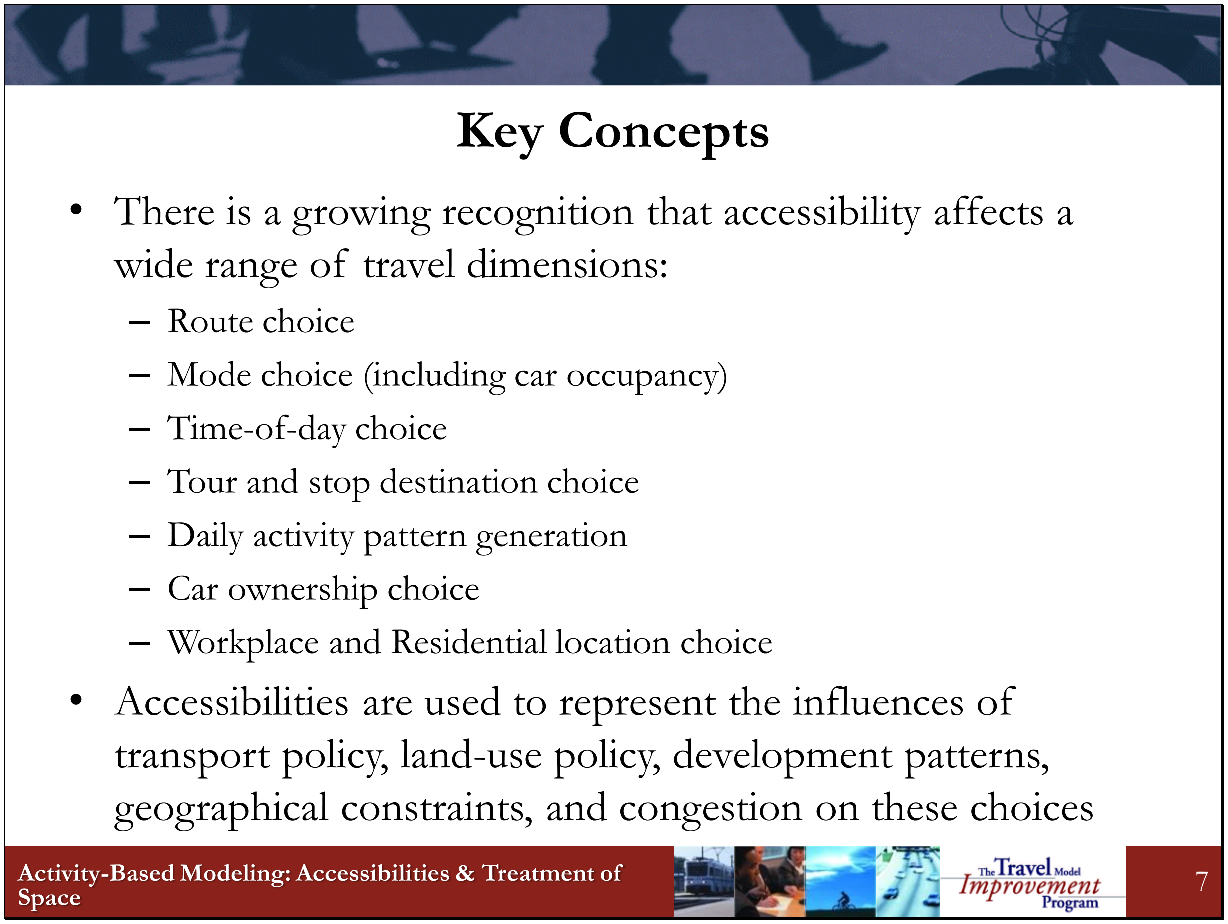
Skims: Matrices containing level-of-service information (travel time, distance, cost) for each origin-destination zone pair (or transit stop pair), for a given mode (drive-alone, shared-2, walk, walk-transit, etc)) and time period (e.g. AM, midday, PM, etc).

Density\Area Type Classification: Each TAZ is classified as belonging to one of a set of mutually exclusive, categorical area types, such as Central Business District (CBD), urban, suburban, and rural. The classification typically considers zones size, employment, and population, but does not consider level-of-service by mode. This is the most basic method of accessibility classification and is not recommended for an activity-based model.

Continuous accessibility variables: The ease of travel to a destination or set of destinations, for one or more household\person types, by one or more modes of travel, for one or more times of day, for one or more activity purposes. Note key dimensions – destinations, household\person types, modes, time periods, activity purposes. Preferred for activity-based models because they incorporate transportation system level of service and can be formulated to vary across these key dimensions.

Mode Choice Log-sum: The natural log of the denominator of the mode choice model. A measure which reflects accessibility by all modes of transport, according to the measured attributes of those modes (e.g. time, cost, etc.), the traveler perceptions (or weights) for those attributes, and the non-included attributes of the mode (reliability, safety, comfort, and traveler biases). The measure essentially weights the contribution of each mode according to its probability. A mode choice log-sum is useful when origin, destination, purpose, and time of travel are known.

Destination Choice Log-sum: The natural log of the denominator of the destination choice model. A measure which reflects accessibility by all modes of transport (see mode choice log-sum, above) to all possible activity destinations. The measure essentially weights the contribution of each destination according to its size, or attractiveness, and the mode choice accessibility from the origin to the destination. A destination choice log-sum is useful when origin, purpose, and time of travel are known. Note that destination is not known.



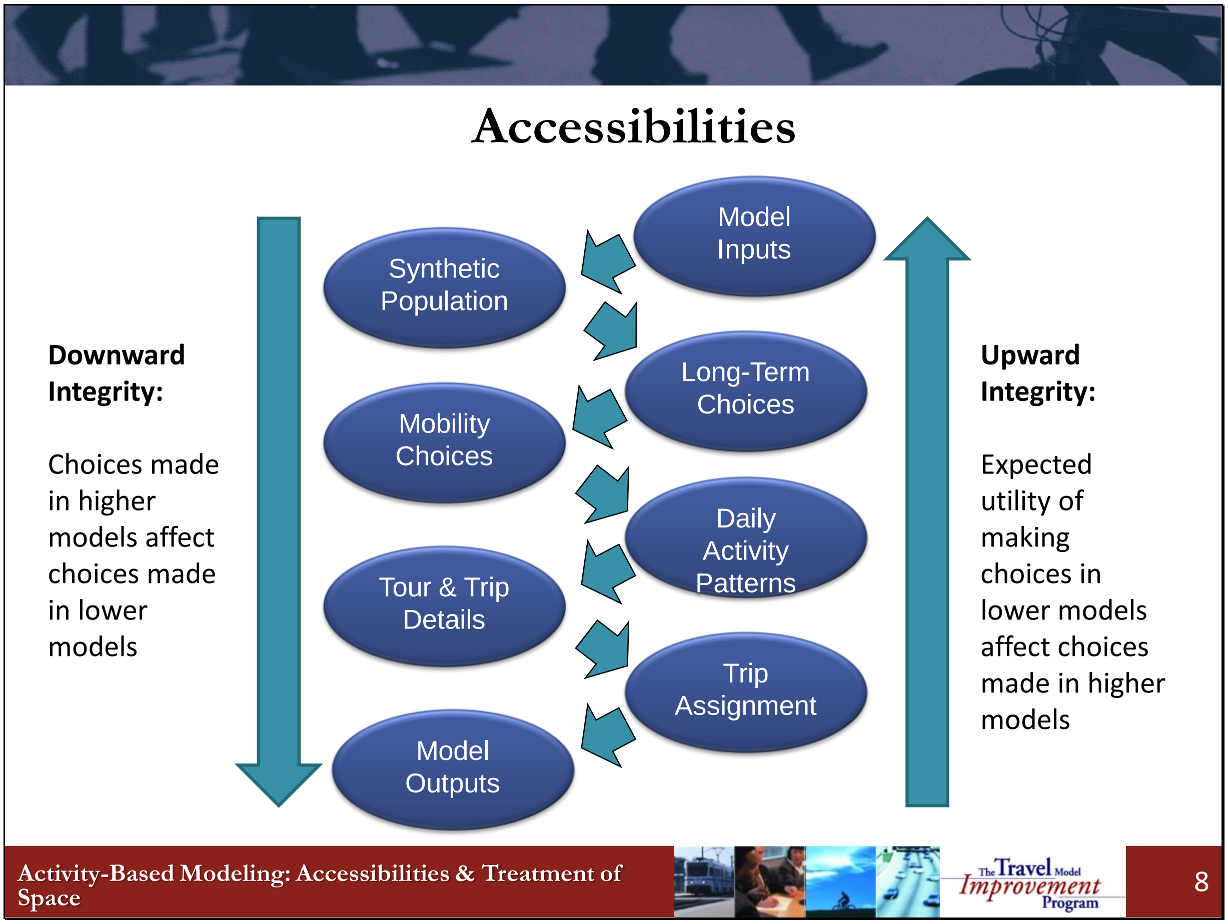
There is a growing recognition that transport accessibility to land-uses affects a wide range of travel dimensions. One of the primary motivations for adopting an activity based model is so that accessibility provided by the transportation system can be treated in a consistent and comprehensive manner on travel decisions and thereby improve policy analysis. Here is a listing of how accessibilities might affect travel behavior:

- Route choice: as a function of different route options and congestion levels
- Mode choice (including car occupancy): Accessibility is generally higher for origin\destination pairs with a greater range of available and attractive modes
- Time-of-day choice: An important consideration of travel behavior is how congestion and accessibility influences the timing of tours and trips, and the influence of congestion on peak spreading
- Tour and stop destination choice: The probability of choosing a destination for a tour or intermediate stop is directly related to the accessibility to that destination, where more

accessible destinations typically have a higher probability of selection, all else being equal

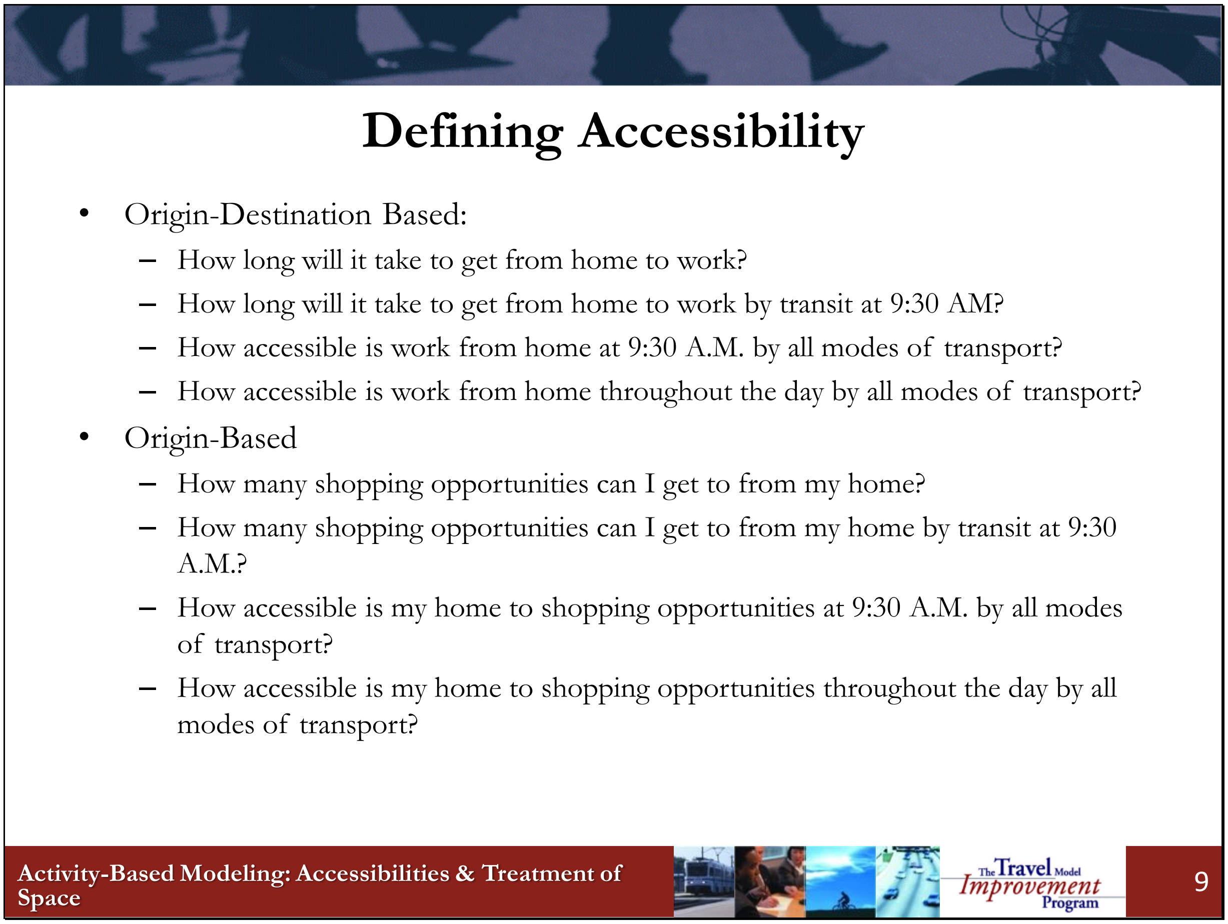
- Daily activity pattern generation: Generally travelers residing in more accessible locations tend to make more tours on average, and less stops per tour, than travelers who reside in less accessible destinations
- Car ownership choice: Households located in areas with better transit and non-motorized accessibilities tend to own fewer cars, on average, than households in less accessible locations
- Workplace and Residential location choice: areas with higher accessibility tend to be more attractive places to work and to move to. A classic concept in economics is the 'bid-rent' curve, which shows that higher-accessible locations tend to have higher land-values due to the greater demand for those locations due to their accessibility

Accessibilities are used to represent the influences of transport policy, land-use policy, development patterns, geographical constraints, and congestion on these choices.



This diagram was presented in Webinar 4, but it is important to review this concept before we continue. While activity-based models can vary in structure, this diagram shows the location of tour and trip detail choices (tour mode, primary destination, intermediate stop location and trip mode) in a typical model stream. As the model system progresses, travelers make decisions: whether to travel, where to go, how many stops to make, what mode to choose, and so on. Earlier decisions influence and constrain the decisions made later; for example, the number of vehicles owned, modeled in the auto ownership (mobility) model, influences the number of tours and the mode used on each tour. The mode used for the tour then influences the location of stops on the tour, and so on. This is referred to as 'downward vertical integrity'.

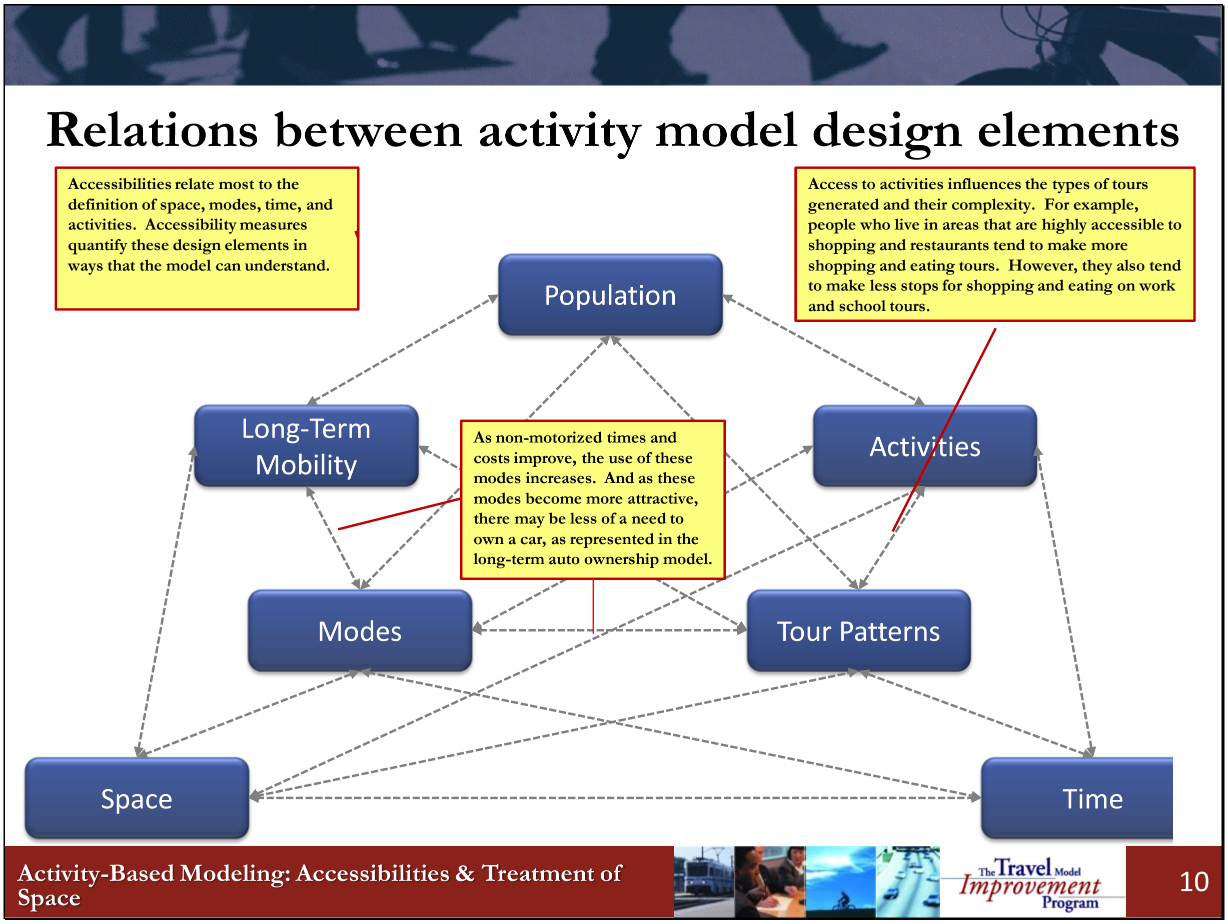
Activity-based models also use information from models that are lower in the model chain to inform the choices made by decision-makers in upper-level models. This information typically takes the form of accessibilities that are based upon all of the information that is relevant for a lower level choice. For example, a mode choice log-sum, which reflects accessibility by all modes of transport, can be used to inform the choice of destination for the tour or stop. This is referred to as “upward vertical integrity.” The upward integrity of the model system is represented via accessibility terms.



There are a number of ways to define accessibility, and we will be exploring them all in this webinar. There are two common types of accessibility measures. One is based upon a given origin-destination pair. It quantifies the time and\or cost of travel between two points in the region (for example, home and work). The slide starts with asking a naïve question: how long will it take to get from home to work? However, this is a naïve question because it is missing two key aspects of travel – by what mode, and at what time of day?

The next question is much more specific – "how long will it take to get from home to work by transit at 9:30 AM?" Now that the question is asked more specifically, it can be answered with some fairly straight-forward calculations, as we shall see later in this webinar. The question can also be asked in a more general sense – "what is the accessibility of home to work throughout the day by all modes of travel?" Calculating accessibility across multiple time periods and/or modes is possible, and we will cover this concept later in the webinar.

Another type of accessibility measure is an origin-based accessibility. A naïve question might be "How many shopping opportunities can I get to from my home?" But again, without specifying a mode and/or time, this is difficult to answer. However, it demonstrates that origin-based accessibilities are typically specified for a certain activity purpose; in this case, shopping, from a certain origin, in this case, the home, to all destinations. The next question includes both a mode and a time. The last two questions summarize accessibility across all modes and or times. Again, there are different ways of calculating these accessibilities, as we shall see.



Hopefully you saw this diagram in the last webinar on population synthesis. It serves as a backdrop for describing the relationships between key design elements in activity-based modeling. These elements include: defining the population, modeling long-term and mobility-related choices, defining activity types, defining modes, defining tour patterns and an entire day-pattern elements, as well as the treatment of space and accessibility and treatment of time. The elements that relate most directly to accessibilities are shown in red. They include the definition of space, of time, the modes that the model considers, and the types of activities that people undertake. Accessibility measures are ways to quantify various amounts of these elements.

Accessibilities influence all facets of an activity-based model system. After all, one of the key purposes of a travel demand model is to measure the affects of transport and land-use changes on travel demand and system performance. Accessibility variables measure transport and land-use system performance.

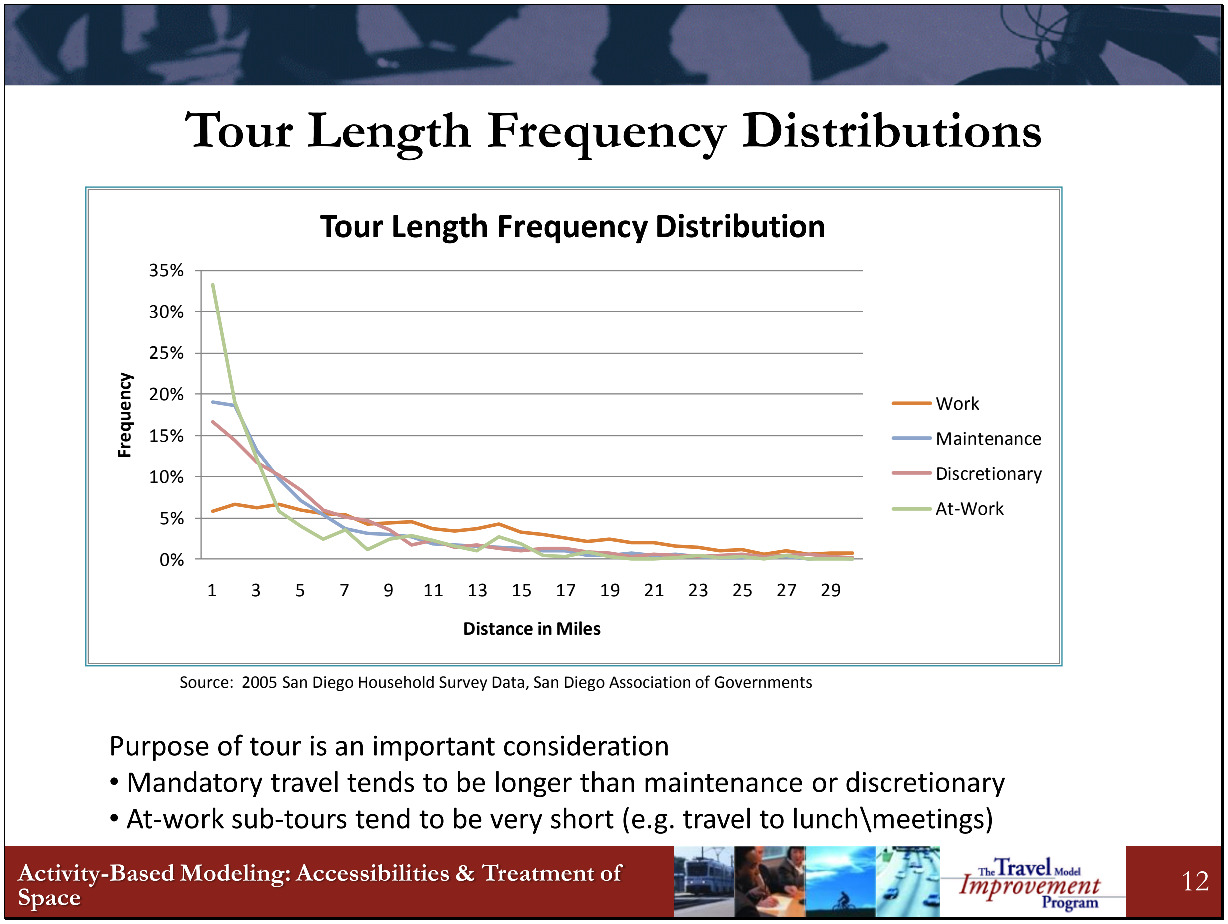
Why are accessibilities important?

- Peak spreading
  - As congestion grows, travel shifts out of the peak hour into shoulders of the peak period and off-peak period
- Transit analysis
  - Capture the affects of transit service changes on auto ownership
- Toll road and managed lane analysis
  - Toll roads and managed lanes provide the opportunity for travelers who are willing to pay the toll to travel in congested time periods, so it is important to capture the effect of toll roads on time-of-day
- Land-use policy analysis
  - Policies that encourage densification and mixing of households and employment have effects on the frequency of travel, the types of tours generated, trip length and mode choice

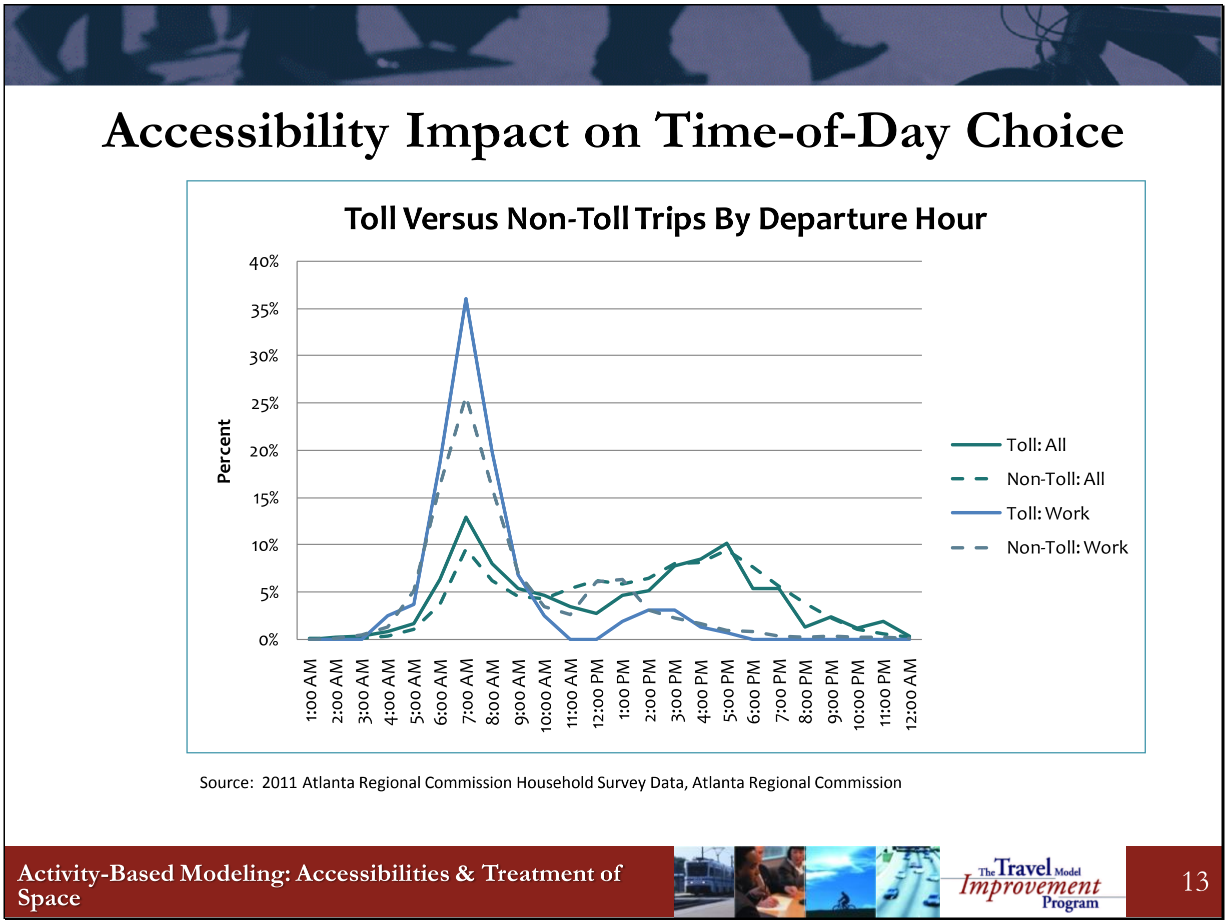
Here are some example policy effects that are important to capture in an activity-based model, and in fact are primary motivations for agencies to adopt activity-based models.

Peak spreading occurs as a result of increasing congestion in a region. Time-of-day choice models capture the effects of congestion on the choice of when to travel. These affects are measured in terms of the accessibility provided between the origin and destination of the tour at different times of day. All else being equal, more congested times of day are less desirable times to travel. We will see exactly how this works in the session on tour scheduling on July 19.

Transit analysis can be improved by consideration of transit accessibilities on auto ownership. This is common in some of the more advanced trip-based models as well. However, activity-based models can consider the accessibility for specific workers based upon where they live and work in the household auto ownership decision. We will see exactly how such variables are included in auto ownership models in the Session #7 on long-term and mobility models on June 7.



This slide shows tour length frequency distributions by tour purpose (distance is one-way between tour origin and primary destination). It demonstrates the importance of considering tour purpose in accessibilities and how different tour purposes have different sensitivities to distance. For example, work tours tend to be much longer than shopping (maintenance) tours.



This slide shows trip departure hour for toll and non-toll trips. Note that toll trips are more peaked; the increased accessibility (faster travel times) provided by toll lanes provides greater opportunity for travelers to depart in the peak period; much more so for work trips than other trips.

Accessibility Impact on Tour & Trip Generation

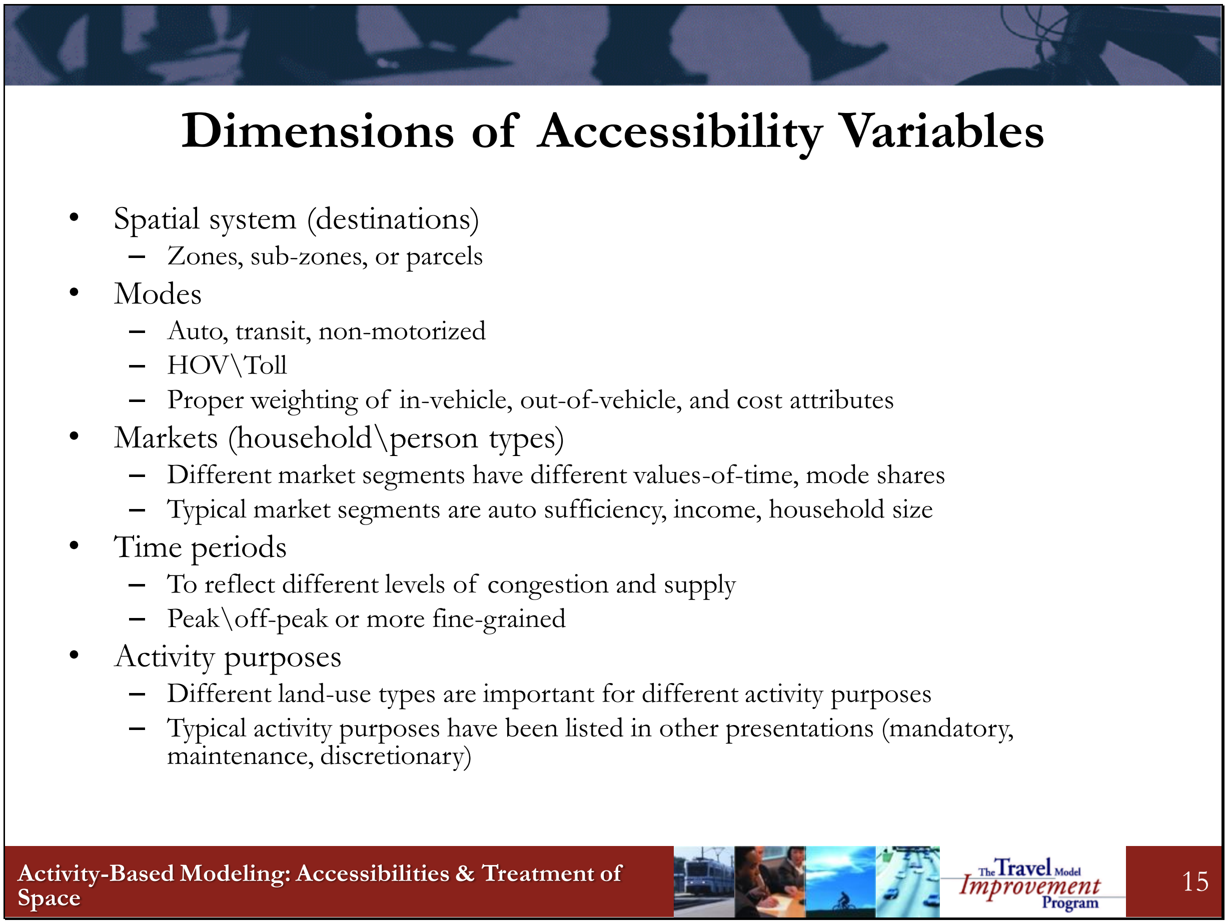
Residential Area Type	Tours Per Household	Tours Per Person	Stops Per Tour
CBD	4.34	2.49	0.57
Urban Commercial	4.30	2.40	0.55
Urban Residential	4.77	2.40	0.60
Suburban Commercial	5.33	2.36	0.62
Suburban Residential	5.00	2.17	0.61
Exurban	5.88	2.32	0.58
Rural	5.49	2.24	0.70
Average	5.35	2.28	0.62

Source: 2000 Atlanta Regional Commission Household Survey Data, Atlanta Regional Commission

- Tours per household are lower in urban areas because household sizes tend to be smaller
- Tours per person tends to be higher in urban areas due (in part) to increased household accessibilities
- Stops per tour tend to be much higher for rural areas due to decreased accessibility around the home

This slide shows a simple tabulation of tour and stop rates by area type from an older Atlanta household survey. Tours per household tends to decrease with respect to density because household size tends to decrease with respect to density. However, tours per person tends to increase with respect to density, due in part to increased accessibility in more dense parts of the region. Conversely, stops per tour tends to be relatively flat, but are typically greater in more rural areas, where persons who live in those areas typically link together multiple trips due to the lower accessibility to activities around the home.

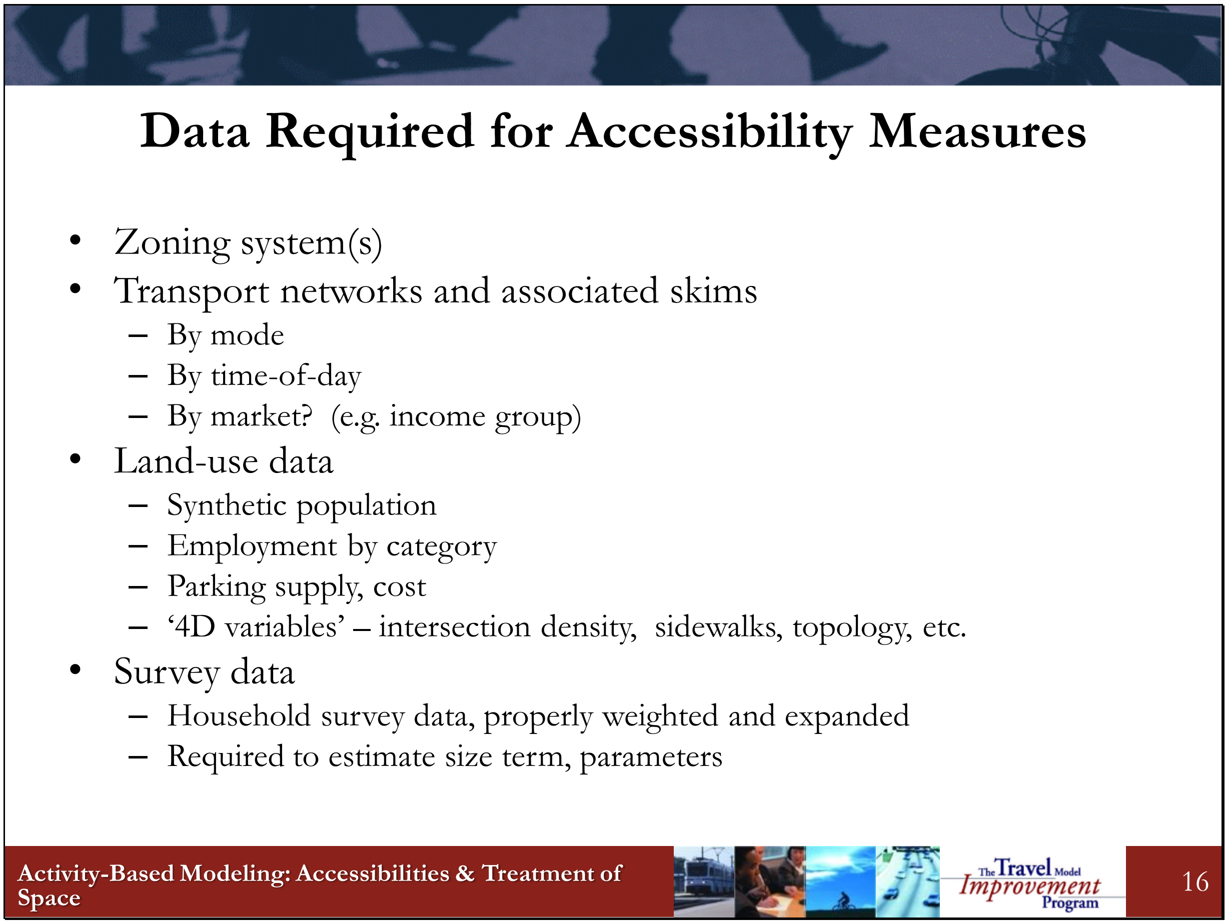
Notes: Most recently-developed activity-based models utilize continuous measurements of accessibility as opposed to area-type classifications (or dummies) as shown in this slide. However, such definitions are helpful to visualize differences in the data. This webinar will address the calculation of continuous accessibility measures in later slides.



As can be seen from the previous slides, early measures of accessibility were rather limited. They considered only land-use data, but not transport accessibility (as in the case of ARC's area type measure). Or they considered transport accessibility, but only in a limited fashion (as in the case of PAG's transit buffer). There are a number of components or dimensions of accessibility measures of which activity-based models are currently taking advantage. They include:

- More refined spatial systems, such as micro-zones or parcels
- More comprehensive sets of modes, with proper weighting of in-vehicle, out-of-vehicle, and cost attributes (using a mode choice log-sum, which we will explain more about later)
- Consideration of various market segments of the population, including auto sufficiency, household income, and/or household size
- Consistent treatment of time-of-day, such as the influence of modal options and congestion throughout the day, and even the availability of different activities by time-of-day (such as store hours)

- Consideration of a full range of activity purposes, by considering land-use and employment types that are relevant for various categories of activities – such as retail employment for shopping accessibility, and bar and restaurant employment for eating out accessibility



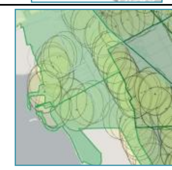
This slide shows the typical data required for calculation of accessibility measures. They include:

- The zoning system used for representation of space, which also defines access to the network and is typically the basic unit of analysis for level-of-service representation.
- Transport networks including highway and transit representation. Networks are skimmed to create level-of-service matrices, typically by mode and time-of-day. For example, highway skims might be created for single-occupant vehicles and multi-occupant vehicles, and further segmented by free and pay alternatives. Transit skims can be created for local bus versus premium transit services. The skims are typically created for different time periods, such as AM peak, midday, PM peak and evening. Finally, networks can be skimmed by market segment, such as income, in order to reflect willingness-to-pay differences between income groups (for example, low income travelers may be unwilling to pay for higher price toll and transit alternatives).
- Land-use data is required in order to represent the opportunities available to travelers, such as jobs or retail employment for shopping. The more land-use categories that are

available, the better models will capture differences in accessibilities for various types of out-of-home opportunities, but this comes at the cost of maintaining and forecasting many employment categories. This is why land-use models are often desired. Parking supply and cost is also useful to represent the increased cost of auto for certain areas such as CBDs, and urban form or ‘4D’ variables are also helpful to describe the ease of non-motorized travel.

- Finally, survey data is necessary to measure the influence of accessibilities on travel behavior; model parameters are estimated using household and other survey data.

Spatial Systems

Spatial Representation	Diagram
Zones •Already exists for most MPOs •The most aggregation error, particularly for non-motorized and transit modes	
Sub-zones • Created by buffering around transit lines, stops • Improves representation of walk-transit, but can result in inconsistent transit times between buffers and skims • Doesn't help with non-motorized representation (intra-zonals)	
Micro-zones • Created by sub-dividing zones (7-10:1) • Best representation of transit accessibility when coupled with stop-stop skims • Improved representation of non-motorized time	
Parcels • Created via parcel database • Best representation of short distances and travel times • Precise measurement of size and neighborhood effects • Improves representation of walk-transit, but can result in inconsistencies between walk times and skims	

Now we will begin to explore the data required for accessibilities mentioned on the previous overview slide. This slide shows commonly-used spatial systems in activity-based models, and describes some trade-offs between them. They will be described in more detail in following slides.

TAZ Advantages:

- Readily available
- Generally easy to estimate land-uses

TAZ Disadvantages:

- Aggregation bias w.r.t intra-zonal and close-in travel, particularly for transit access/egress and non-motorized travel

Aggregate Sub-zones Advantages:

- Commonly used in trip-based models
- Easy to create using simple GIS buffering procedures
- Improved representation of transit access/egress

Aggregate Sub-zones Disadvantages:

- Still some aggregation bias w.r.t. transit skims
- Not helpful for non-motorized travel

Micro-zones Advantages:

- Relatively easy to code
- Relatively easy to allocate households to geography using Census blocks
- Very precise measurement of transit access when coupled with transit stop network
- Overcomes most of the aggregation bias in representation of non-motorized/intra-zonal travel

Micro-zones Disadvantages:

- Employment data can be difficult to allocate

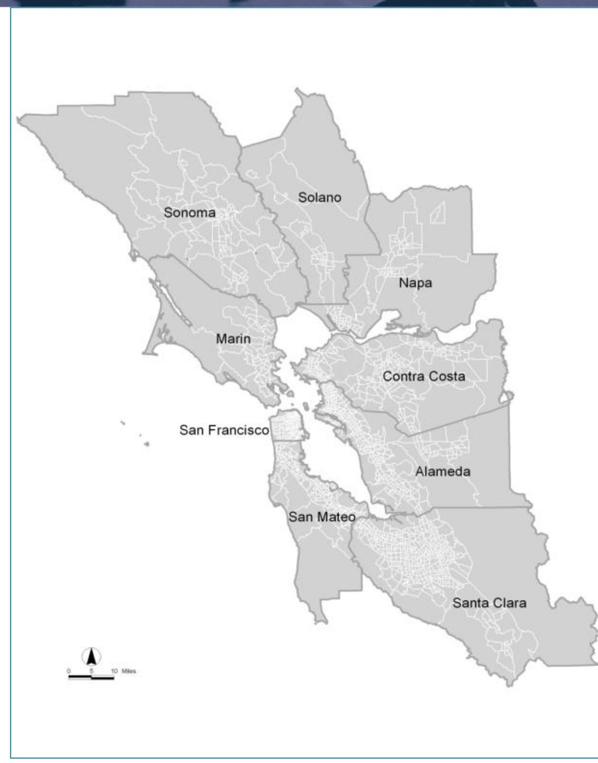
Parcels Advantages:

- Sometimes available from existing sources.
- Improved representation of transit access/egress times
- Most precise measurement of short distances and travel times.

Parcel Disadvantages:

- Parcels are not necessarily stable across time
- Allocating employment data to parcels can be challenging.
- Time from parcel to closest transit stop can be inconsistent with times in zone-zone transit skims.

Metropolitan Transportation Commission Transportation Analysis Zones



Activity-Based Modeling: Accessibilities & Treatment of Space

The Travel Model Improvement Program

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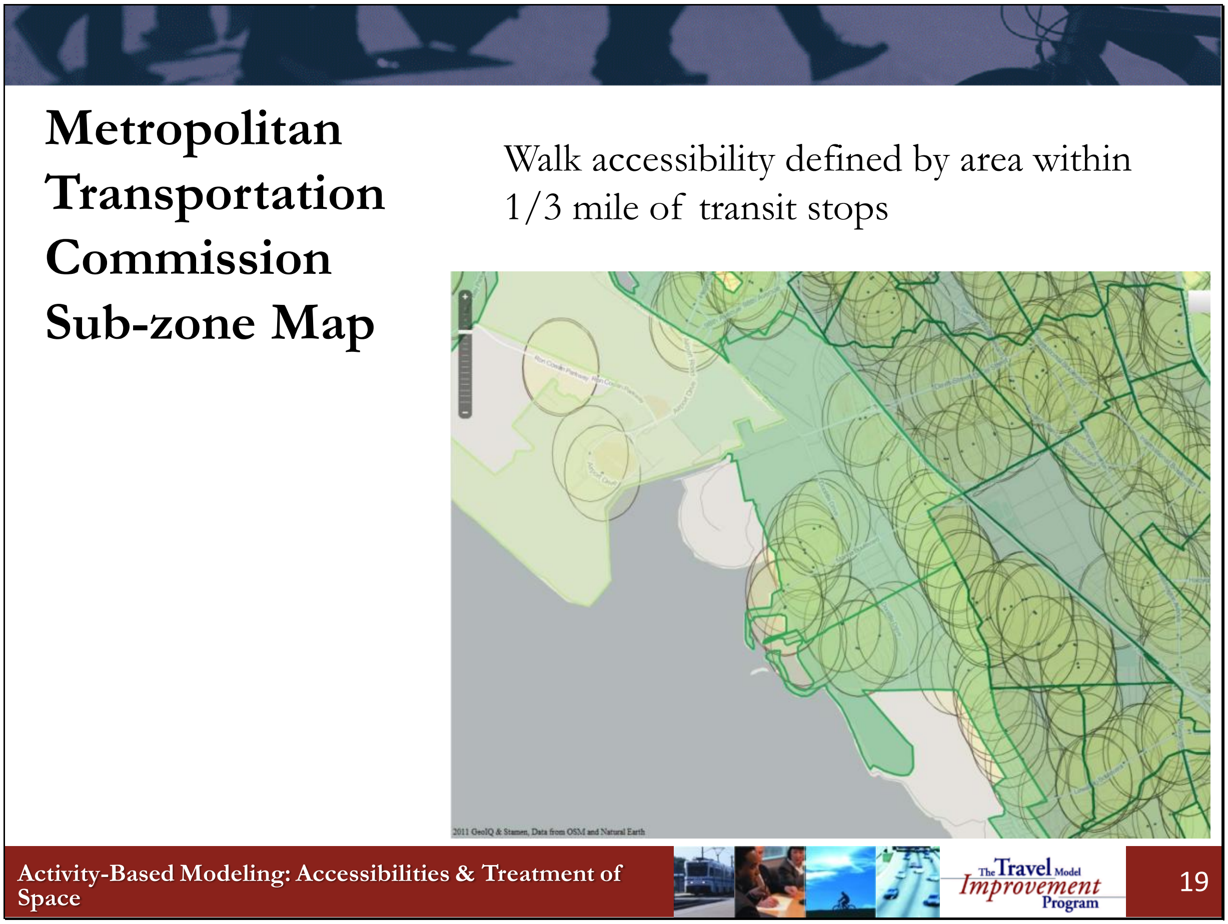
This map shows the zone system used in the Metropolitan Transportation Commission activity-based model, which covers the nine-county San Francisco Bay Area. There are approximately 2,000 TAZs, ranging from very small (<.25 acres) in CBD to very large (over 100 sq. miles) in outlying counties.

Note that MTC is currently updating their TAZ system, and will likely be moving to either a micro-zone or parcel representation, specifically because the large zones cause problems in the representation of non-motorized accessibility – both in terms of walking within a zone, as well as the walk-accessibility to transit.



Several activity-based models (Columbus, MTC, ARC, Chicago) currently use transit sub-zones in their representation of transit accessibility. This method is consistent with many trip-based models, in which the transit network is overlayed on the TAZ system, and a "walkability" buffer is created around transit stops or routes to identify the portion of the TAZ within short or long walk to transit (typically 1/3 mile is used for short walk, 2/3 mile for long walk). Each TAZ is then split proportionally into short, long, and no-walk to transit shares, effectively tripling the number of potential activity locations (although certain zones are 100% short walk or 100% no-walk, which results in less than zones^3 locations.

Zone-based skims are still used to calculate transit times and costs between zone-pairs. However, the walk-access time is then segmented by the portion of the zone in which the origin/destination pair resides. For example, let's assume that a particular a trip origin is in a large zone, but the zone is split into short walk (25% of the area), long walk (50% of the area) and no-walk (25% of the area). Then, we draw a random number and determine which segment the trip is in. If the trip is in the short-walk portion of the area, the potentially long time that was calculated in the transit skims (due to the long centroid connector) is over-ridden by a short walk time, equivalent to 1/6 of a mile (since the walk buffer for short walk is 1/3 mile, the average walk time would be ½ of that buffer).

A novel approach to representation of space initially developed by SANDAG and applied to a number of other ABMs since including Phoenix and Miami is the use of "micro-zones". These are smaller than zones (approximately 10:1) but larger than parcels. They tend to follow Census block boundaries (though not always) and relate to the underlying street system. However, use of micro-zones does not require the system to address how parcels may change over time, which is a clear advantage in terms of complexity. MAZs typically rely upon census data for base-year population\household totals, and land-use data (zoning, space inventory, etc) to allocate employment to MAZs. Micro-zones are often used in conjunction with an explicit transit stop database. We will explore this topic further in the session on mode choice.

Parcels

(Sacramento Area Council of Governments)

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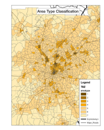
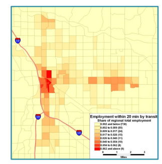
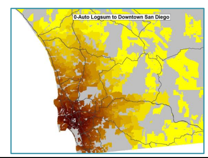
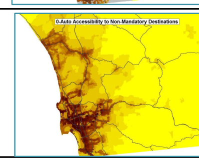
A number of activity-based models rely upon parcels as one of the representations of space, as shown. Parcel-based systems offer the most accurate measurement of non-motorized (walk and bike) times for close-together pairs of parcels. Parcel systems also allow one to more accurately measure urban design variables such as land-use mix.

Typically, parcel based systems are also used to represent transit accessibility. Each parcel is coded to its closest transit stop for each transit sub-mode, and that time replaces the skimmed walk-transit time. It is mainly suitable for relatively simple transit systems, because in more complex transit systems with several possible competing routes between zones, the parcel-to-stop time may not be consistent with the skimmed zone-zone in-vehicle and out-of-vehicle times or mode combinations used in those skims. For example, the zone-zone transit skim may represent an LRT path with a bus transfer at each end. Since skims do not represent the order of the path, it may not be possible to identify which transit stops to use for the trip. It may be possible to use the method described earlier for micro-zones, to combine the access time from each parcel to different stops with stop-to-stop transit skims. However, as we shall see later, this may impose a huge computational burden on the model system.

Parcels require a parcel inventory\database, a method to deal with how parcels may change over time, and a method to allocate base and future-year employment data to parcels. Methods are being developed to use “templates” for future year new development areas, so that the land use and accessibility measures will be accurate for that type of neighborhood, without having to specify exactly where each new parcel and local street will be located. All-streets networks may also be used with both micro-zones and parcels to better represent the influence of physical barriers on walk time.

Different Methods of Calculating Accessibilities

Accessibility	Diagram
Area Type •The most aggregation error •Does not consider network level-of-service, by time period • Discrete, lumpy	
Buffer Variables • Example: Number of jobs within 30 minutes transit service • Can be extended by time period • Typically limited to one mode, employment type	
Mode choice logsum (Origin\Destination Based) • Represents all modes\network level-of-service • Weighted by traveler perceptions **• Either limited to one time period, or used with simulated time period**	
Destination choice logsum (Origin-based) • Represents all modes\network level-of-service, weighted by traveler perceptions • Also represents land-use (opportunities) at destination	

There are a number of different ways to calculate accessibility measures, as we shall see in this webinar. They each have advantages and disadvantages, and specific uses within the activity-based model system.

The simplest form of accessibility measure is the flat area-type measure, which classifies each zone as CBD, urban commercial, urban residential, suburban commercial, suburban residential, and rural (or some variation thereof). The advantage of this measure is that it is easy to calculate. But there are a number of disadvantages, the biggest of which is that it completely ignores network level-of-service. Therefore any changes to the network (such as introduction of transit service or toll lanes) would have no effect on this measure. For this reason, its use has been limited to only the earliest activity-based models.

Buffer variables typically search around a zone and measure the accessibility of the zone to employment within a certain range of travel time. For example, a buffer variable might measure the number of retail jobs within 30 minutes of transit service. These measures can be calculated for specific modes and time periods, and do take into account network level-of-service. But they are specific to a certain mode or time period, which can also be a disadvantage. For example, maybe I want to measure the time by both walking and biking. How do I correctly weight the influence of each in travel time?

That is where mode choice log-sums provide a key advantage. They measure accessibility across multiple modes, applying appropriate weights on the components of time and cost associated with each mode, according to traveler preferences (as revealed by the mode choice model). However, when time of travel is not known, a simple mode choice log-sum is insensitive to changes in transport conditions that vary by time of day, so either a joint mode-time log-sum or a mode log-sum that uses a probabilistically simulated time of day is needed. Mode choice log-sums are specific to an origin-destination pair and are usually case-specific; that is, they are calculated for a particular choice situation taking into consideration the characteristics of the household, person and tour.

An extension of the mode choice log-sum is the destination choice log-sum, which measures accessibilities across multiple modes, from a specific origin to all destinations. Destination choice log-sums take into account the amount of activity at each destination. That activity is often represented as purpose-specific. As with the mode choice log-sum, when time of travel is not known, the log-sum should be enhanced to account for variations in conditions that occur across the possible times of day.

Now we’ll take a closer look at how each accessibility measure is calculated.

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Area Type Stratification ("Dummy") Variables

Population Density$_i$ = population$_i$ / acres$_i$ * 0.25

Employment Density$_i$ = [(10* retail$_i$) + commercial$_i$ + (0.3* industrial$_i$)]/acres$_i$ * 0.25

Where i is a "floating zone", or 1 mile buffer around the zone of interest

Population Density	Employment Density						
	0-0.05	0.06-0.32	0.33-6.65	6.66-12.44	12.45-25.10	25.11-57.97	57.97+
0-0.43	Rural	Rural	Exurban	Sub. Com.	Sub. Com.	Urb. Res.	Urb. Com.
0.42-0.78	Rural	Exurban	Exurban	Sub. Com.	Urb. Res.	Urb. Res.	Urb. Com.
0.79-2.38	Rural	Exurban	Sub res	Sub. Com.	Urb. Res.	Urb. Com.	Urb. Com.
2.39-3.48	Exurban	Sub res	Sub res	Sub. Com.	Urb. Res.	Urb. Com.	Urb. Com.
3.49-5.40	Exurban	Sub res	Sub res	Sub. Com.	Urb. Res.	Urb. Com.	CBD
5.41-8.07	Sub res	Sub res	Sub res	Urb. Res.	Urb. Res.	Urb. Com.	CBD
8.07+	Sub res	Sub res	Sub res	Urb. Res.	Urb Com	Urb. Com.	CBD

Activity-Based Modeling: Accessibilities & Treatment of Space

The Travel Model Improvement Program

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Here we show how area types were calculated for the Atlanta region for their activity-based model, originally developed in the early 2000's. Population and employment densities are calculated and used to code each TAZ to one of seven area type categories. Similar methods have been used in other regions, and are common in trip-based travel models. Area type classifications offer advantages and disadvantages. In our opinion the disadvantages outweigh the advantages and therefore are typically not used in activity-based models.

The advantages of area type classifications are as follows:

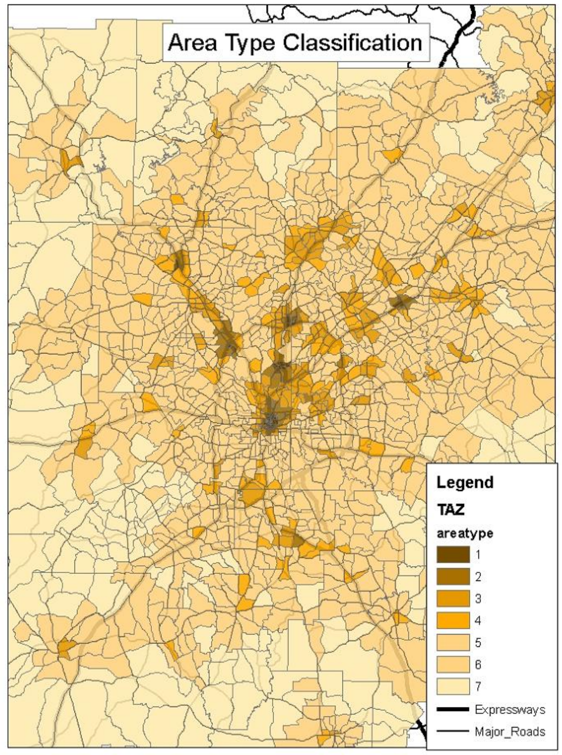
- It is relatively easy to calculate and apply the codes to TAZs.
- The use of classification measures allows fairly simplistic analysis of tour and trip rates as shown on the previous slide.

The disadvantages of area type classifications are as follows:

- They not take into account network level-of-service

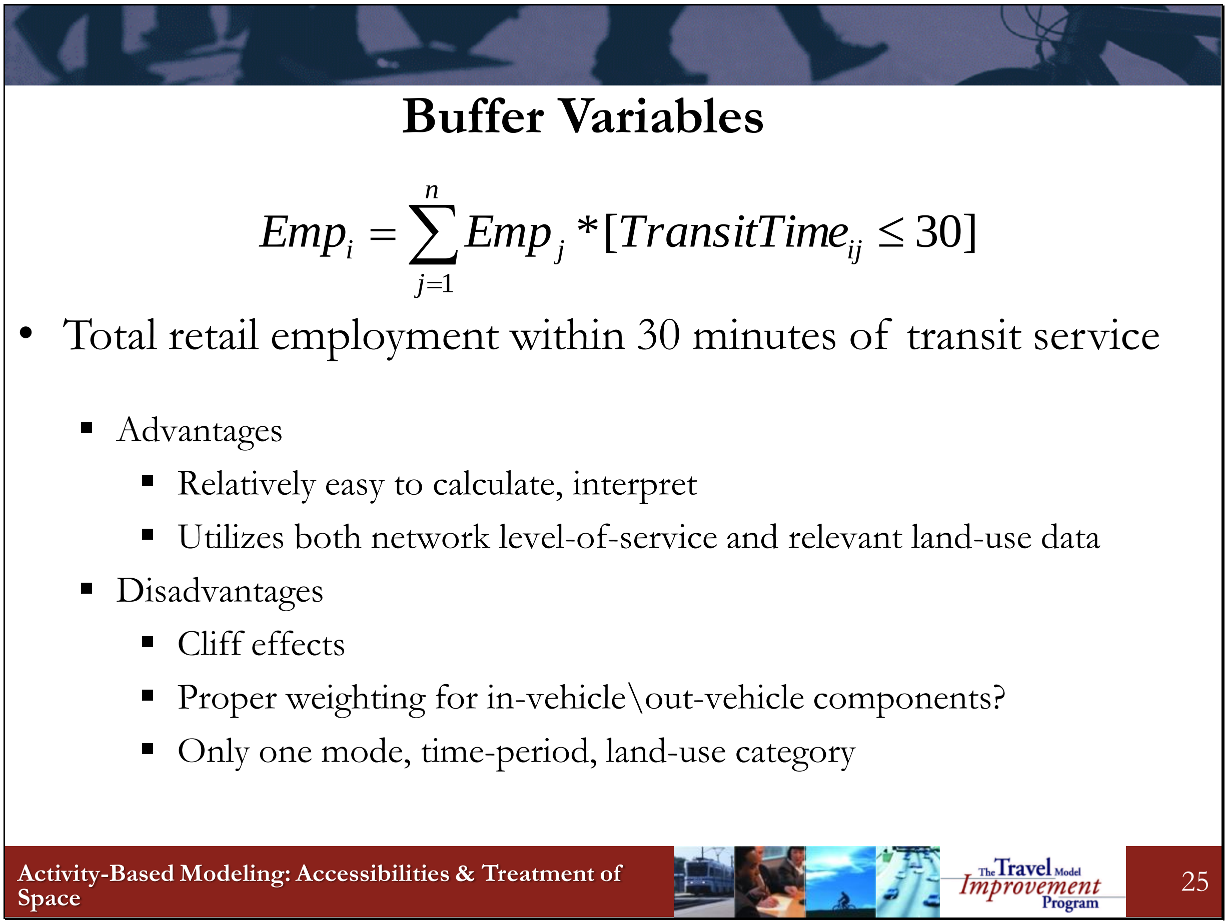
- They not take into account specific purpose of travel
- They rely on fairly ad-hoc procedure for allocating to specific categories of area type
- Area type effects are “either-or” in models, resulting in potential cliff effects

Atlanta Regional Commission Area Type Map



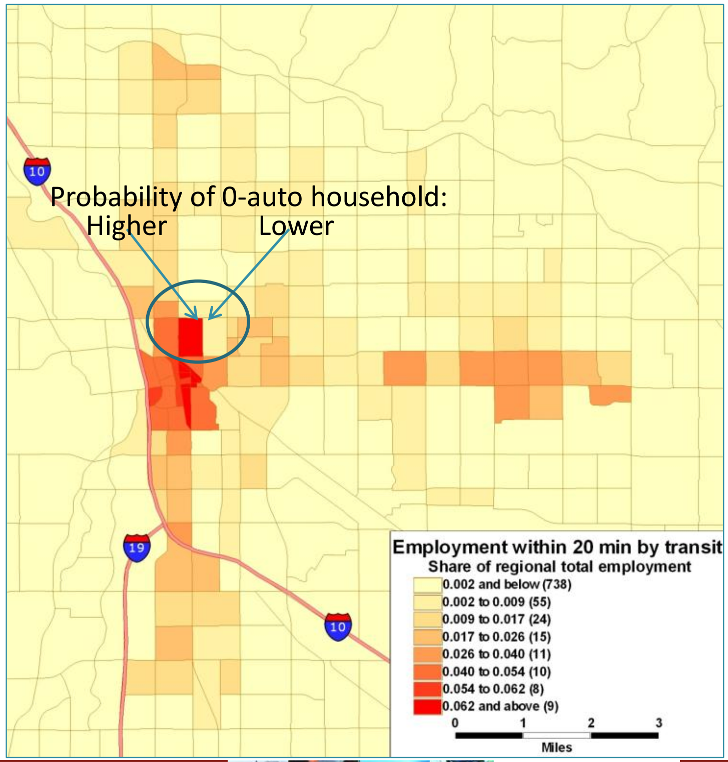
- Easy to calculate and use
- However, does not consider:
  - transport accessibility
  - purpose of travel
  - temporal affects
- And is somewhat 'lumpy'

Here is a map of the Atlanta Regional Commission area type classification system, focusing on the more populated part of the 20-county ARC region. As you can see, the area types are somewhat lumpy, with clear pockets of dense and less dense area types, which is somewhat exacerbated by the use of large transportation analysis zones as the spatial unit in the model (more on this later). However, the ARC activity-based model system was one of the first activity-based models to be developed in the United States, and is therefore more aggregate than many of the more recent models developed, as we shall see.



Accessibility measures such as the one shown on this slide use buffers to count or aggregate the number of opportunities within a certain distance or threshold around the TAZ given some modal level-of-service. The example shows a count of the number of retail jobs within 30 minutes transit time to measure transit accessibility. This is an improvement over the dummy area type variable shown in the previous slide, because it takes into account network level of service. However, it still has a number of disadvantages, such as cliff effects (that zones are either within or outside the buffer), and that only one mode, time period, and land-use category are considered.

Pima Association of Governments Transit Buffer Map



Activity-Based Modeling: Accessibilities & Treatment of Space

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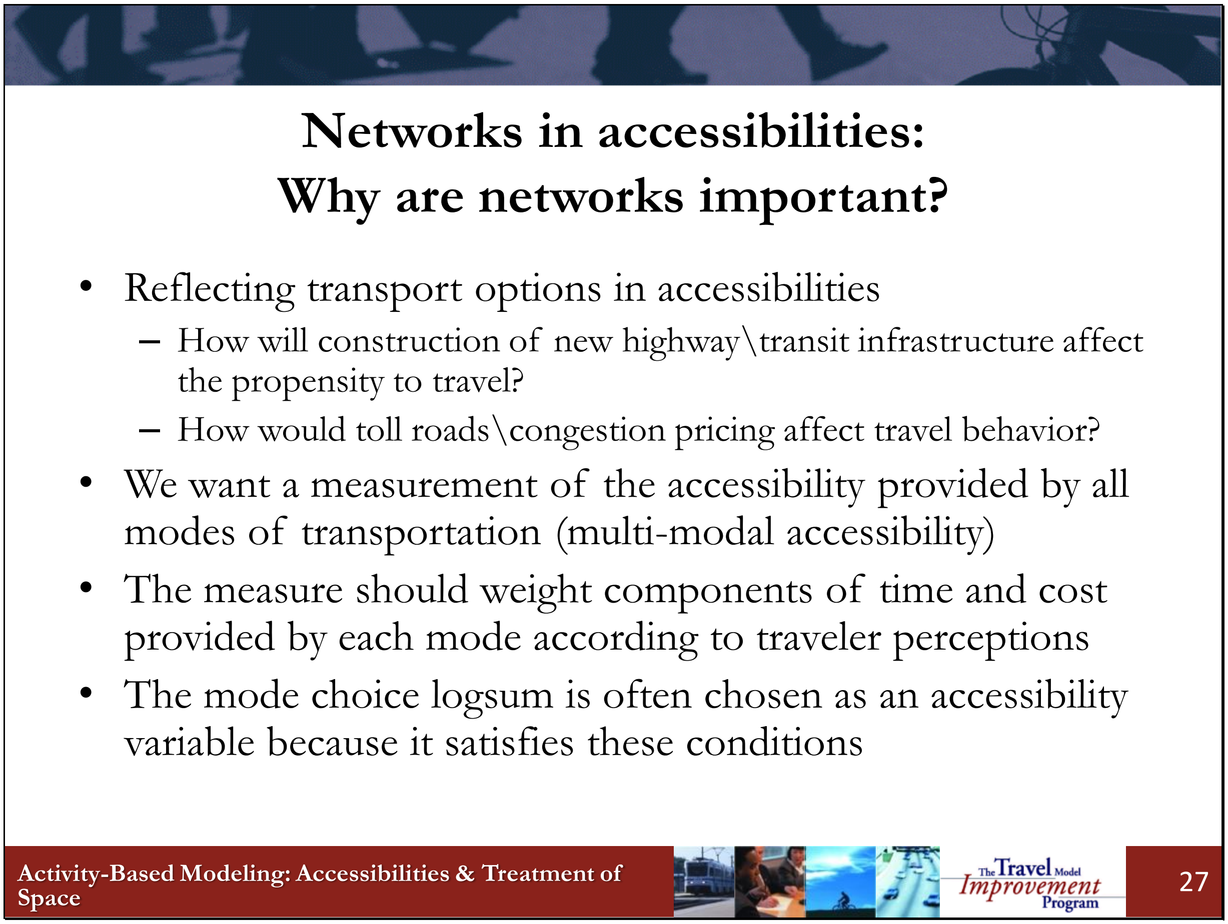
Here is a transit buffer map created for the Pima Association of Governments. This was actually used in the auto ownership model component of the four-step travel model. It uses a threshold of 20 minutes travel time by transit and is strongly correlated with transit service in the urban core and radiating out from the core along major transit corridors. The lumpy effect can be easily seen here, particularly due to the use of relatively large zones. If this variable were to be used in auto ownership, a household on an edge of a zone may have a very different probability of owning 0-vehicles than a household just on the other edge of the zone, as shown.



Network representation is very important in accessibility calculations, since the main goal of travel demand models is to measure the impact of transportation infrastructure on travel behavior. As shown previously, more simplistic accessibility measures only consider density, or only consider one mode of transportation. However, our models should be multi-modal in nature. If a simplistic accessibility measure is used, only changes in the mode that is considered will influence travel behavior. For example, if the model does not explicitly consider toll choice, it is likely that the scheduling of toll trips will not be influenced by the faster travel times in the peak period provided by the toll facility. However, we cannot just average the toll and non-toll travel times, because not all travelers are willing to pay for the toll facility. Similarly, we want to include the influence of transit, but we can't just average the auto times and the transit times. Some travelers may be more or less willing to take transit than other travelers, and there are many attributes of the choice that aren't reflected just in time and cost of each mode.

So the bottom line is that we want a measurement of accessibility that is multi-modal, but takes into account the times and costs of the various alternatives, weighted by the traveler perceptions of those times and costs, as well as traveler characteristics, and all of the other attributes of those modes that aren't explicitly included in time, cost, or other traveler characteristics. That way, we can calculate a true 'average' accessibility across all the modes. The good news is that there is a very convenient measure that does this. It is the mode choice log-sum. We'll now see how this works.

Modal Utilities

- Utility is the weighted sum of the attributes of the mode
  - Weights can vary depending on attributes of traveler, tour\trip purpose
  - Mode-specific constant quantify non-included attributes of mode

$$
\begin{aligned}
\mathrm{Utility}_{auto} = \; & -0.025 * \text{in-vehicle time} \\
+ \; & -0.002 * \text{parking cost + operating cost (cents)} \\
+ \; & -0.050 * \text{access time and egress time} \\
+ \; & 1.500 * \text{autos > drivers}
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{Utility}_{transit} = \; & -0.025 * \text{in-vehicle time} \\
+ \; & -0.050 * \text{access time and egress time} \\
+ \; & -0.050 * \text{first wait time} \\
+ \; & -0.063 * \text{transfer wait time} \\
+ \; & -0.002 * \text{transit fare} \\
+ \; & 0.795 * 16 < \text{age} < 24 \\
+ \; & -1.708
\end{aligned}
$$

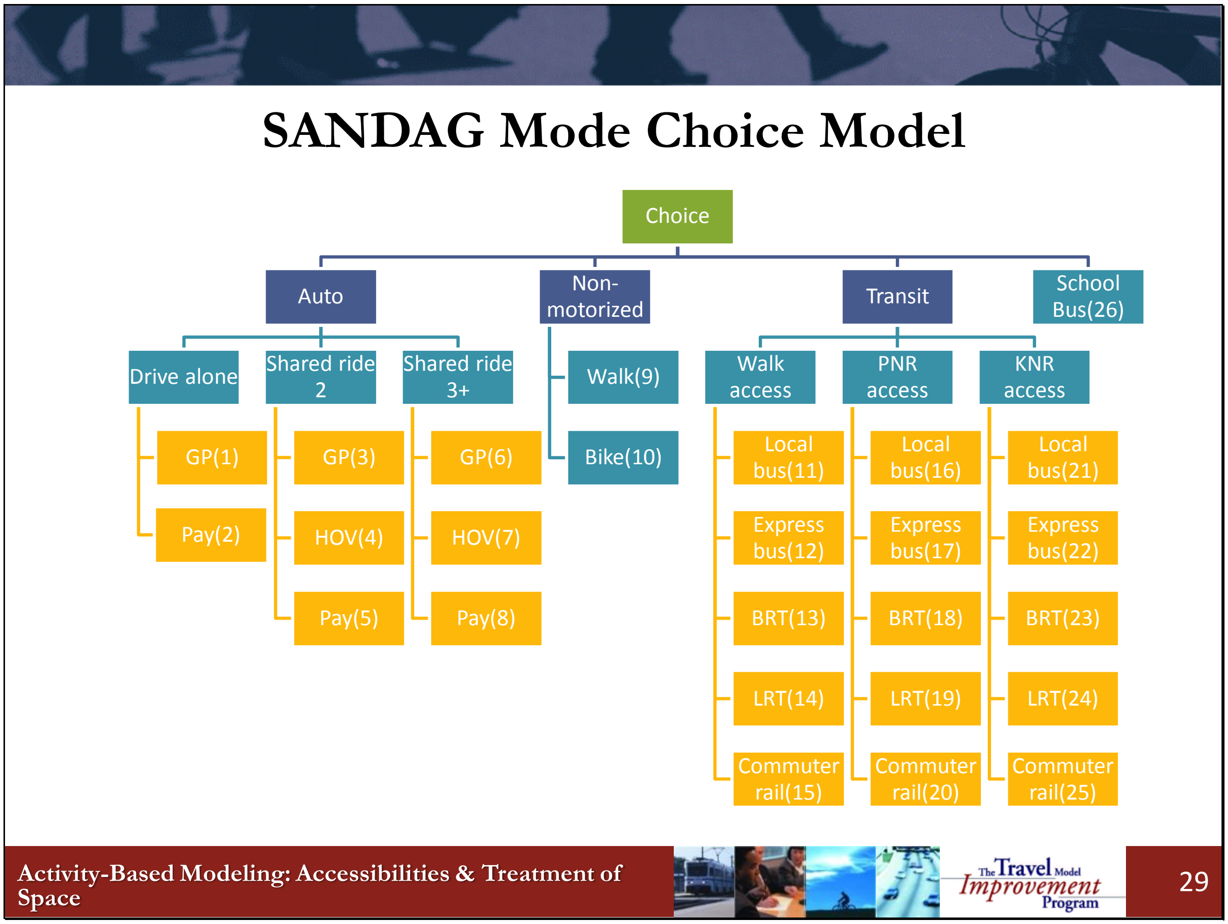
In a mode choice model, a utility is calculated as the weighted sum of the attributes of each alternative. Utility is a numeric value that is assigned to each alternative that represents how useful the alternative is to the decision-maker. The weights, or parameters, used for each component of time and cost are calculated based upon observed data, typically household survey and transit on-board survey data. The utility equations shown on this slide are based upon models estimated for the San Diego association of governments; however, the alternatives and parameters shown are a subset of the actual models, for the sake of simplicity. A few things to note about the utility equation:

- Some of the variables are based upon the origin and destination of the trip (such as in-vehicle time, walk time, wait time, and fare)
- Some of the variables are based upon either the origin or the destination of the trip (such as parking cost)
- Some of the variables are based upon the characteristics of the traveler, such as the number of autos chosen for the household compared to the number of drivers in the

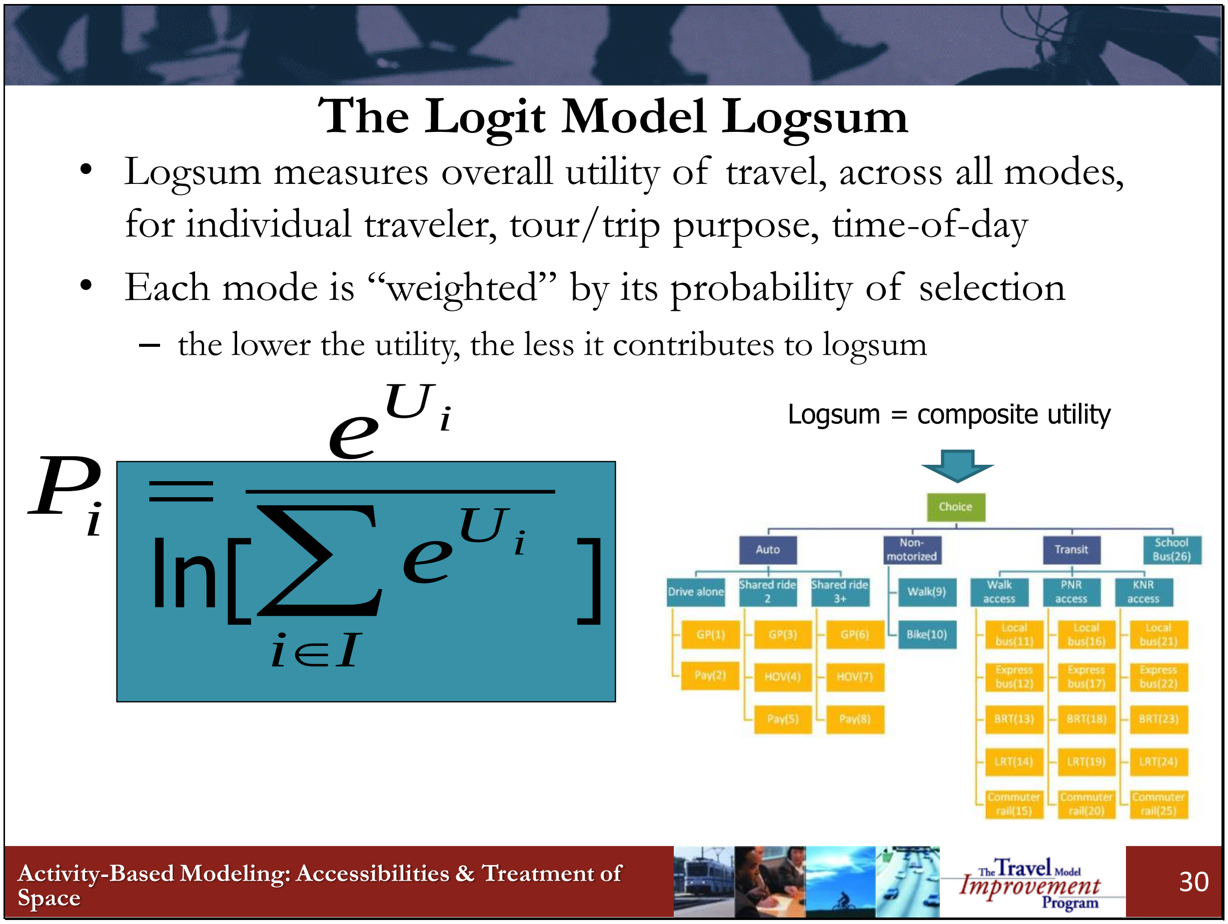
household in the auto utility, as well as the age of the traveler in the transit utility. Further note that the number of autos for the household is the outcome of a previous model, while the number of drivers in the household is a field in the synthetic population. One of the critical advantages of an activity-based model is that the utility equations can take into account the specific characteristics of the traveler including person and household characteristics.

- Alternative-specific constants reflect the non-included attributes of the mode. They reflect the probability of choosing the mode, all else being equal. In other words, they reflect the probability of the mode if the times and costs of the alternatives were exactly the same.

So, here we can see that the mode choice model takes into account times and costs of the modes, weighted by the perceptions of the travelers, as well as the characteristics of those travelers, and the influence of land-use characteristics, such as parking cost, on the mode choice. This is exactly what we want for a good accessibility measure.



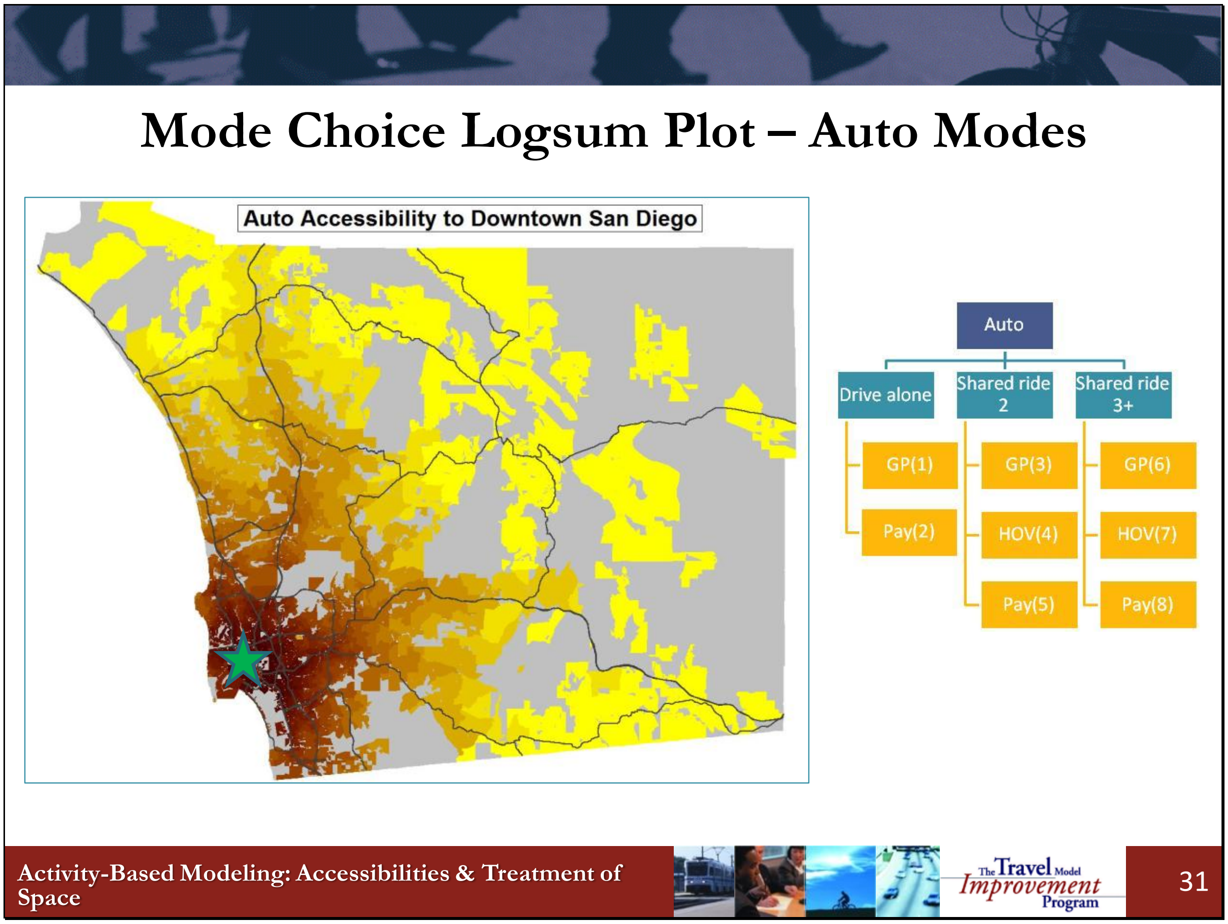
Here we see all of the modes represented in the San Diego mode choice model. Auto modes include drive-alone, shared-2 and shared 3+, with sub-options of general purpose, high-occupancy vehicle, and pay (toll) alternatives. Walk and bike are both represented explicitly, as well as five separate transit line-haul modes (local bus, express bus, bus rapid transit, light-rail transit, and commuter rail) and three access modes (walk, park-and-ride, and kiss-and-ride). School bus is also an option for school tours. This diagram will help you understand the plots on the next few slides. We will discuss various mode choice formulations and advantages\disadvantages of the various options in webinar 10 on August 9.



The way that we convert these utilities into a single accessibility is to take the log-sum of the mode choice model. The denominator of the mode choice model is the sum of the exponentiated utilities of the model. If we calculate the natural log of the denominator of the model, we are essentially converting this sum back into a utility, but it is a utility across all modes of travel. In other words, it is a multi-modal accessibility, taking into account the times and costs of all the modes, weighted by traveler perceptions, and traveler characteristics, and non-included attributes.

A log-sum can be representative of certain conditions. For example, a non-motorized log-sum can be created, where only walk and bike modes are available, or a walk-transit log-sum can be created where only transit modes are available. Log-sums can also be created for a specific decision-maker; for example, a mode choice log-sum for persons in 0-auto households would reflect transit modes to a greater extent than a mode choice log-sum for 1+ auto households.

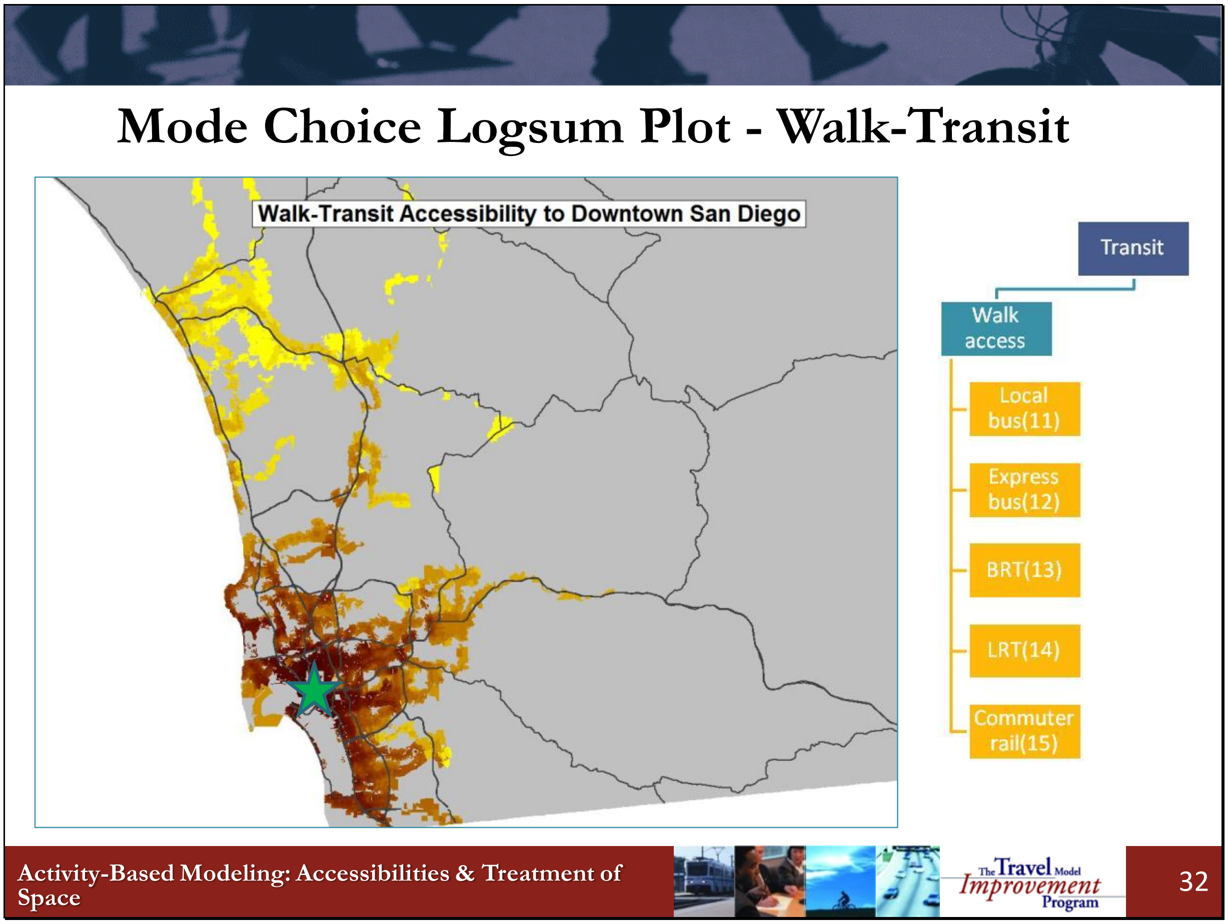
Log-sums are often used as variables in models to ensure “upward integrity” of the model system; for example, the impact of accessibilities by all modes of travel on destination choice is reflected through the use of the mode choice model log-sum in the destination choice model. This will be explained further in the webinar on destination choice.



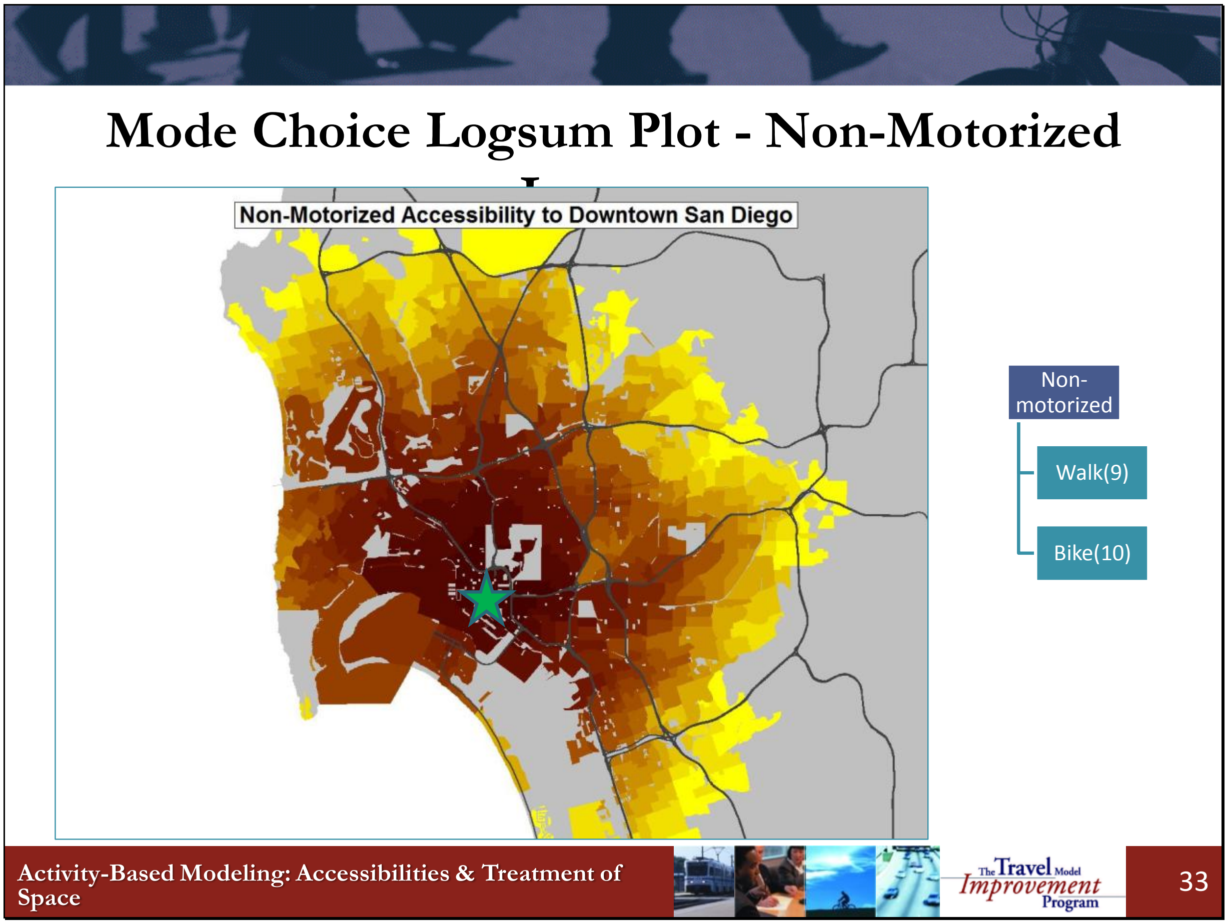
Mode choice log-sums are inherently spatial. That is, they are relevant for specific origin-destination pairs. When mode choice log-sums are created for an entire region, they are typically stored in matrices. In order to visualize them, one must select either a row of the matrix (a set of log-sums from a given origin to all destinations) or a column of the matrix (a set of log-sums from all origins to a given destination). Here we see a plot of mode choice log-sums for San Diego, where a column of the log-sum matrix was selected – the column selected corresponds to a micro-zone in downtown San Diego, as denoted by the green asterisk. These log-sums focus only on auto modes – in other words, only the auto modes were active in the mode choice model that created this map, as shown on the right. You can see that the darker shaded areas of the map are closer to downtown – e.g., more accessible. And the lighter areas are less accessible to downtown. Also, there are dark bands around freeways, indicating the accessibility that these faster facilities provide to downtown.

Areas in grey are micro-zones that do not have any population or households in them. For the sake of computation efficiency, log-sums were not calculated from these micro-zones.

Computational efficiency of the software implementation is an important practical aspect of accessibility calculations. Skipping calculations for zones without households can greatly increase the speed of the calculations, particularly when geography is very small.

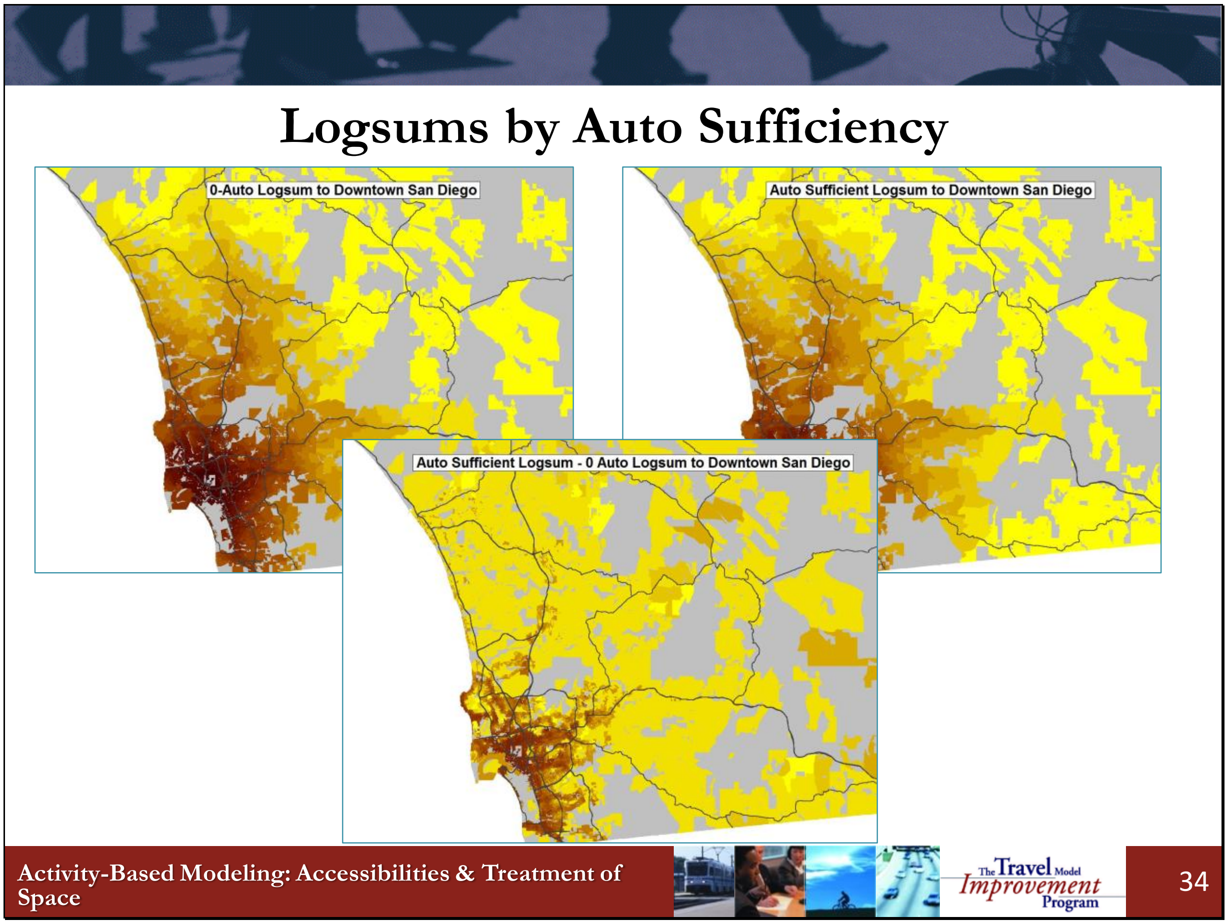


This plot shows the mode choice log-sum taken across walk-transit modes, for all micro-zones to downtown. Contrast this plot with the auto accessibility plot, and notice that the walk-transit log-sums are quite different from the auto accessibilities. The walk-transit accessibilities closely follow transit routes. There is also considerable variation in accessibilities as one moves away from the main routes, reflecting greater walk access and egress times required to use the routes (as per the utility equations shown on the previous slides). Households located close to transit routes will have increased accessibility as a function of the accessibility provided by transit. This is a useful variable in measuring the impact of transit accessibility on household auto ownership, and the walk-transit mode choice log-sum is often used as an explanatory variable in auto ownership for this reason.



Here is a close-up of the non-motorized mode choice log-sum from all micro-zones to a downtown San Diego micro-zone. Note that the accessibility calculations include both walk and bicycle modes. The inclusion of bicycle mode tends to flatten the accessibility calculation up to the maximum bicycle distance. In this model, the maximum bicycle distance was set to 8 miles, so the micro-zones that are further than 8 miles from the downtown zone are shown in grey. The maximum walk distance was set as 3 miles, so micro-zones that are within 3 miles of the downtown zone are much darker, reflecting the influence of the availability of walking as a modal option.

This points out another important aspect of accessibility calculations, and models in general – the use of thresholds can have significant impacts on the explanatory variables, and therefore have significant impacts on the predictions of the model system. It isn't really true that a micro-zone that is 3.0001 miles from downtown has no walk-accessibility while a micro-zone that is 2.9999 miles from downtown does. One of the important aspects of model development is exploring the impact of such thresholds. In the case of San Diego, the utility of walking 3 miles is already quite low – an hour of walking time is required; therefore, it was decided that setting a threshold of 3 miles would not be detrimental in the model system.



The maps above show how certain modes can be turned on or off to calculate mode choice accessibilities by a sub-set of modes. Another technique is to calculate log-sums by market segment. This slide shows log-sums for 0-auto households versus auto sufficient households. Again, it is for the San Diego region, from all micro-zones to the downtown zone. The plot on the top left is for 0-auto households. These log-sums are influenced more by transit and non-motorized modes. Why? Because in the mode choice model, the alternative-specific constants for 0-auto households are higher for transit and non-motorized modes and more negative for auto modes (since they don't have a personal vehicle available). The plot on the top right shows the mode choice log-sums for auto sufficient households to downtown. Auto sufficient households are those households who have at least one vehicle for every driving age household member. At first glance, it doesn't appear that the log-sums are very different for 0-auto households and auto sufficient households. However, if you subtract the 0-auto log-sums from the auto-sufficient log-sums, and plot the results (advance to show animation), then you will see that the difference is the influence of the transit accessibilities. In other words, the difference plot follows the walk-transit accessibility plot closely.

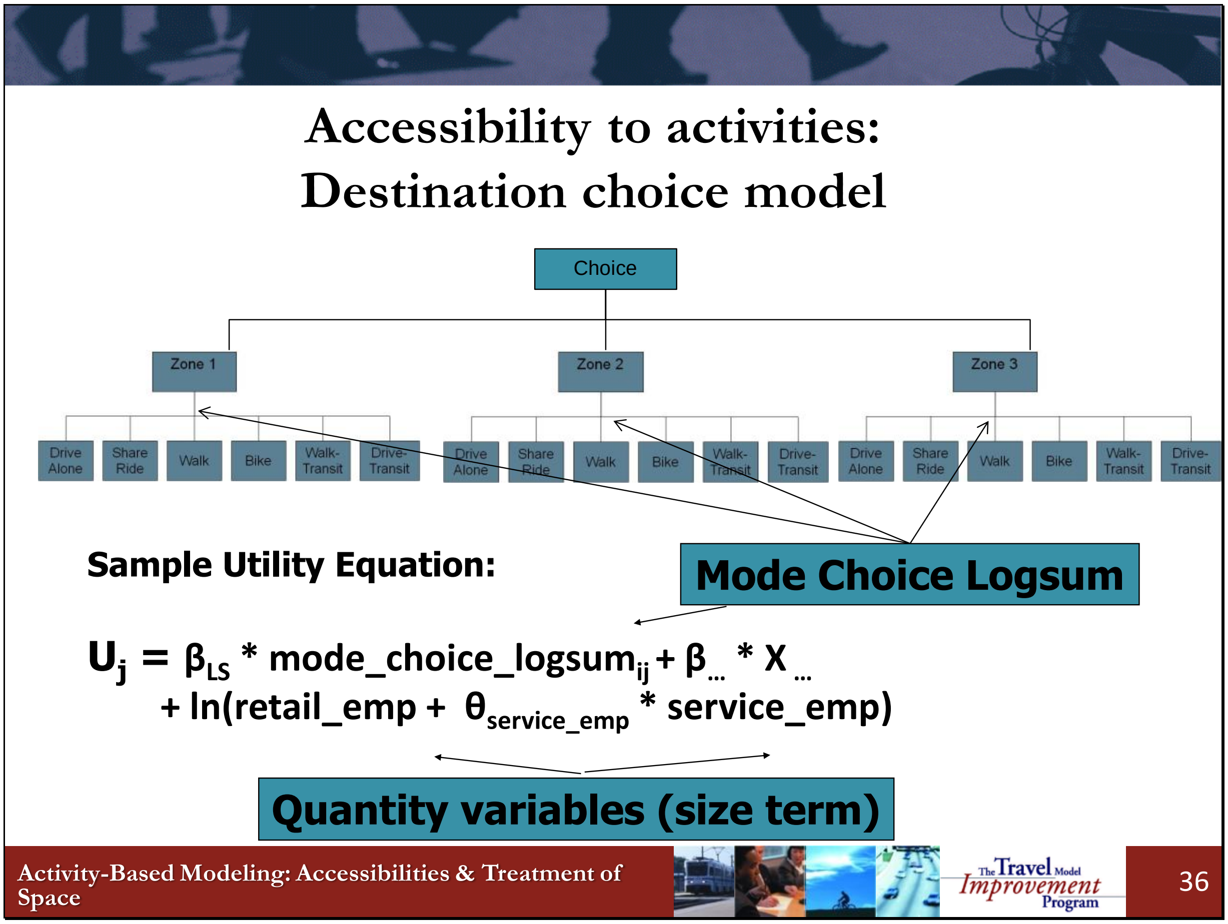
Another practical technique in activity-based models is to pre-calculate accessibilities for relevant market segments, such as auto sufficiency and/or household income, and then refer to them in the main model system software at the appropriate times. In some cases, it may be computationally efficient to do this. However, this computational efficiency comes at a disadvantage. The markets may not capture important differences of between traveler preferences within each market. For example, the slide shows segmentation by auto sufficiency. However, we saw in the mode choice utility equation that traveler age was also an important explanatory variable in the mode choice model. If we lump all traveler age groups together, we'll miss the influence of traveler age on transit preference. An important design consideration in the design and development of activity-based models is when to use accessibilities that are calculated for each traveler separately (and therefore able to take into account all traveler-specific variables) and when to use pre-calculated accessibilities that lump together travelers across specific dimensions like auto sufficiency. Any discussion of model runtime really needs to include consideration of the use of pre-calculated accessibilities versus traveler-specific accessibilities.

Dimensions of accessibilities: Tour/trip purpose

- Different tour & trip purposes are attracted to different types of land-uses
  - Work – total employment, or by occupation\industry type
  - University – university enrollment
  - School – K-8 enrollment
  - Escort – schools & households
  - Shop – retail
  - Maintenance – retail, health, and financial services employment
  - Eating out – restaurant employment
  - Social\Recreational – households, service\retail employment
  - Work-related – restaurant and other employment

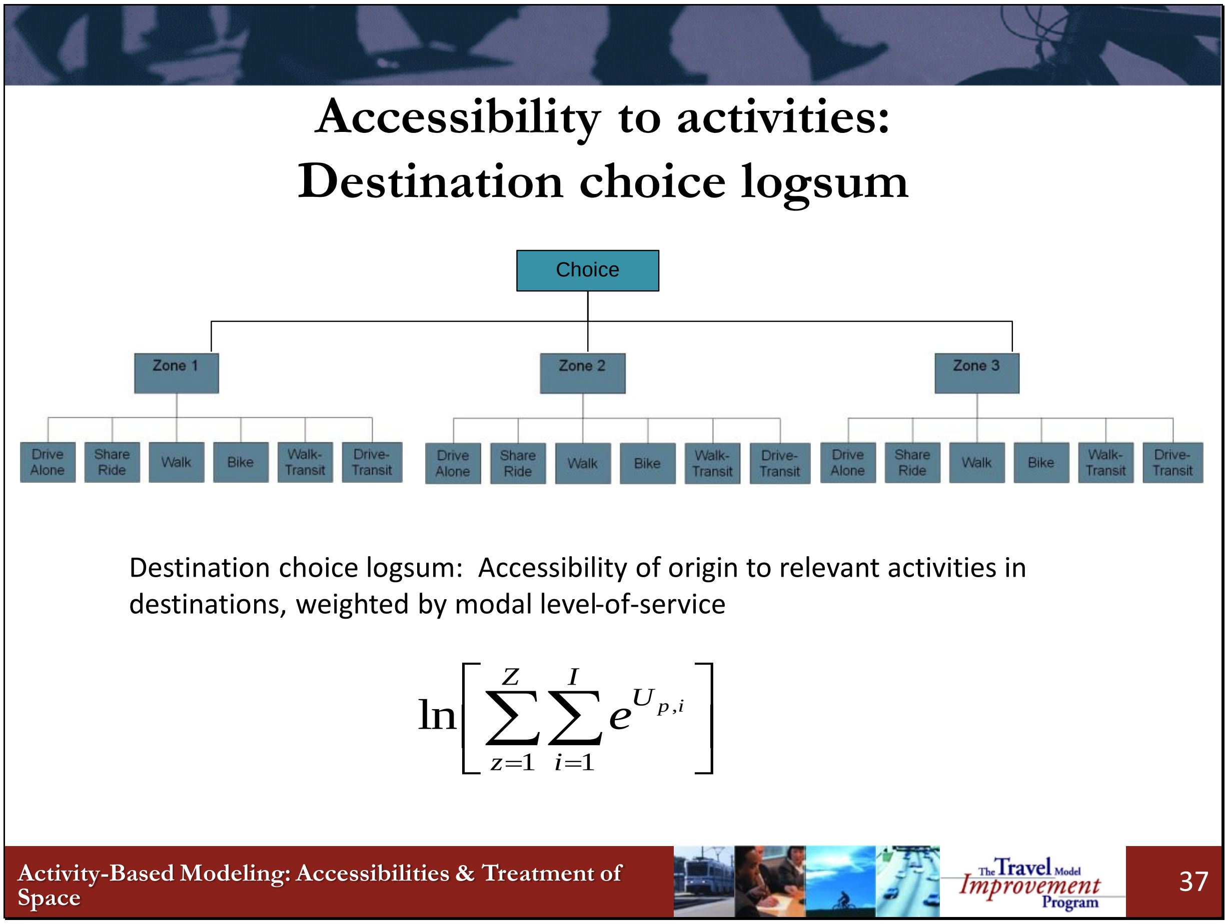
So far we've covered the treatment of space in terms of the zoning system used, and different ways to measure accessibility in terms of network characteristics such as auto, non-motorized, and transit mode alternatives and their characteristics. Now let's look at how accessibilities can take into account the purpose of travel.

Obviously different types of travel are attracted to different types of land-uses. For example, workers are attracted to employment, either total employment or industry type depending on the worker's occupation. So an accessibility measure that is going to be used for a residential location choice model might want to consider accessibility to the types of jobs that workers can work in based upon their occupation. Shopping trips are attracted to retail space or employment. Eating out trips are attracted to restaurant employment. And so on. The possibilities are only limited by the availability of good base-year data on the location of different types of employment, and the ability of the agency to forecast the location of the employment by type into the future. But the bottom line is that we want to have the access to those types of activities represented in our measure of accessibility.

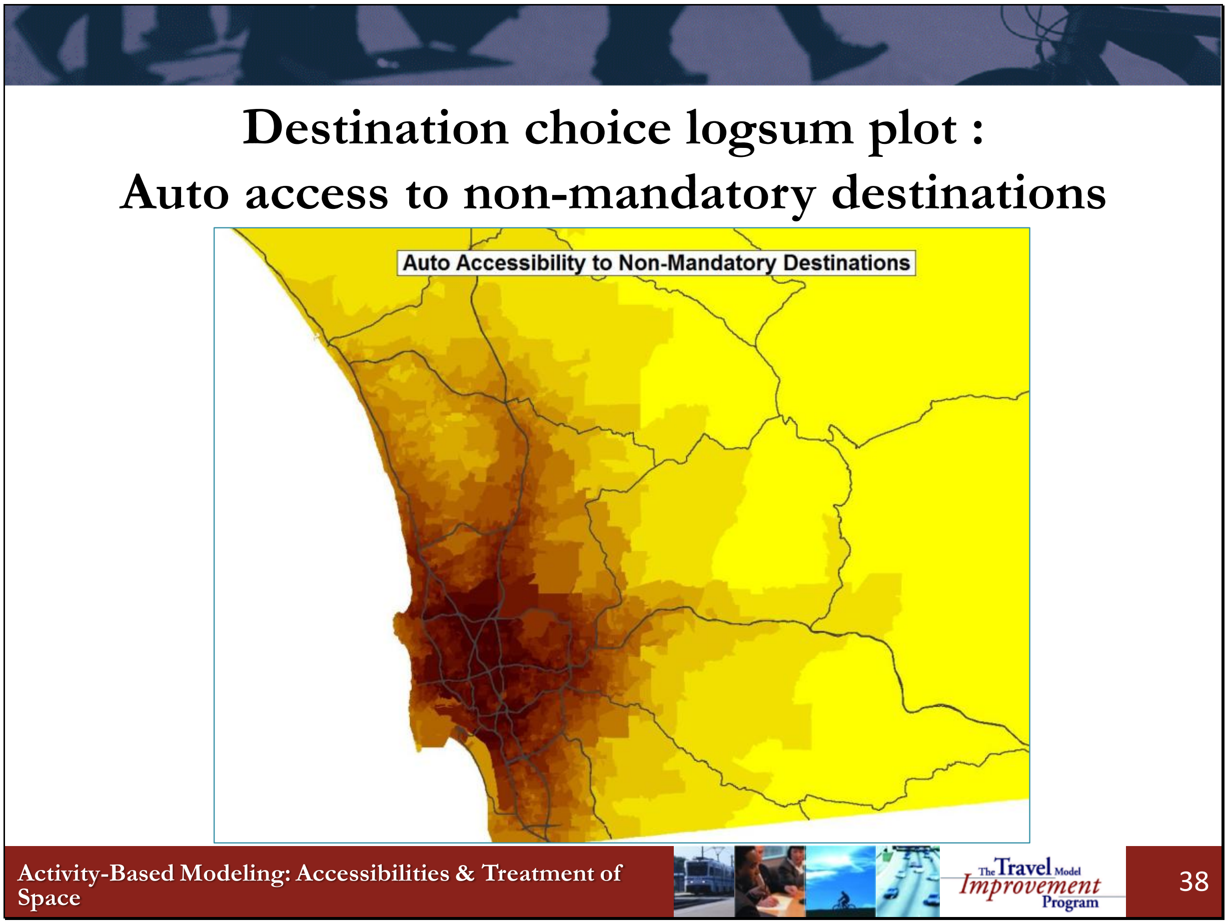


The model that is used to determine the location of out-of-home activities in an activity-based model system is the destination choice model. This slide shows the model form. Each zone (or micro-zone, or parcel) is a potential activity location. In most activity-based models, the measure of accessibility or impedance between the origin zone and potential destination zones is the mode choice log-sum, as described in previous slides. The mode choice log-sum used in the model is based upon the traveler making the decision of where to go, as well as the purpose and time of travel. The attractiveness of each potential destination is based upon its size, as shown in the logged expression. In this case, the example utility is for shopping. So, the relevant variables of zonal attractiveness are retail and service employment. The reason why these terms are logged is so that all else being equal, the number of tours or trips attracted to the zone will be proportional to its size. When a probability is computed, the utility is exponentiated, so logging the size term makes the probability of selection proportional to the size of the zone.

One can think of the destination choice model as a nested, or simultaneous, destination and mode choice model.

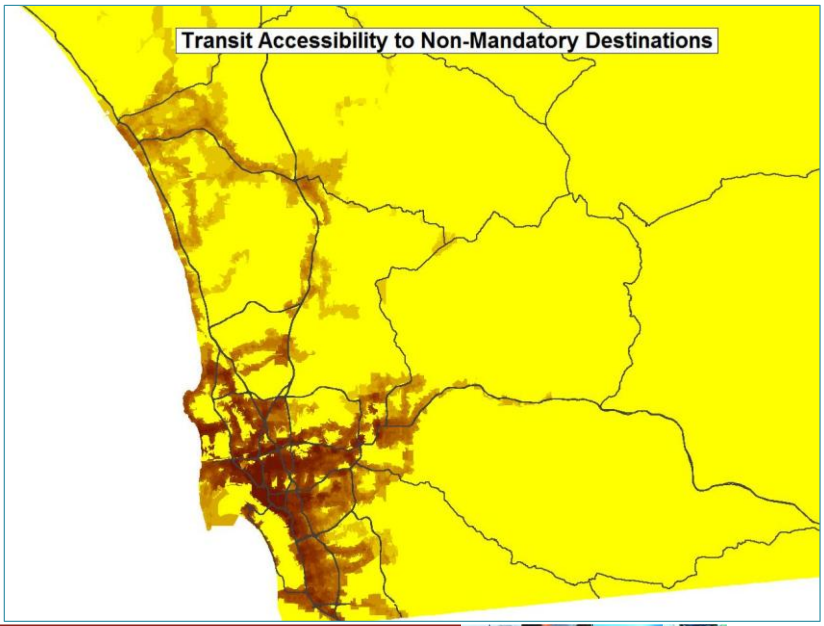


Because the destination choice model takes into account the modal alternatives between the origin and all potential destinations, as well as the land-use or activity opportunities available in each destination, it is a great way to calculate accessibility. In this case, the log-sum of the denominator of the destination choice model is taken. Another way to write the destination choice accessibility is shown on this slide. This accessibility measure is origin-zone based. It is the accessibility to all potential activities, weighted by the impedance to the activity. It is often computed for each specific activity purpose separately; for example, shopping, eating out or other discretionary – just as there are different destination choice models for each activity purpose.



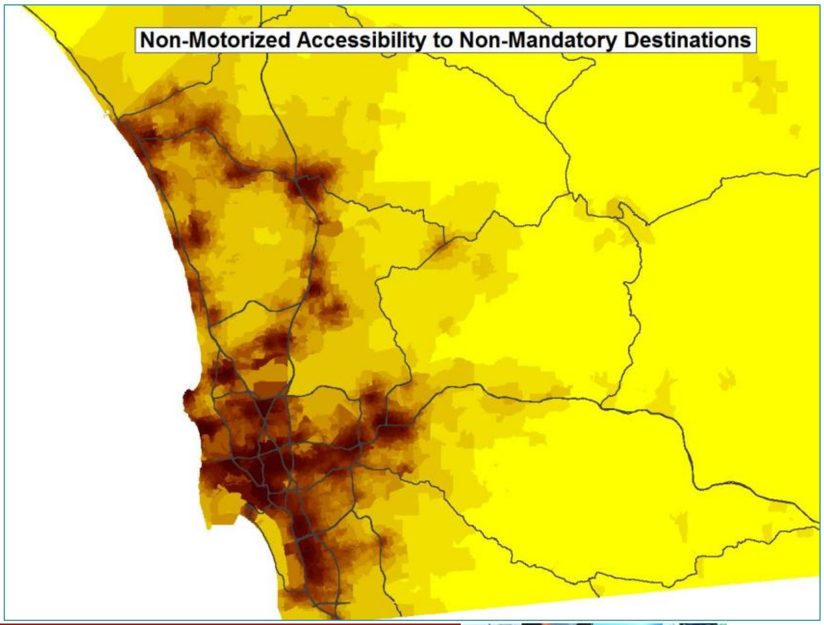
Destination choice log-sums are origin-based, because they are computed across all destinations. In other words, origin-based log-sums are represented as vectors of data, which can be stored in a table with one value for each origin zone. Each vector can be easily plotted, as shown here. This plot shows auto access to non-mandatory destinations. This uses the auto mode as the measure of impedance, and non-mandatory purpose for the size term in the destination choice model. Areas that are close to the main employment hubs in San Diego are darker, because they are more accessible. Think of this plot as showing how many non-mandatory destinations can I get to by car from my zone compared to some other zone.

Destination choice logsum plot: Transit access to non-mandatory destinations

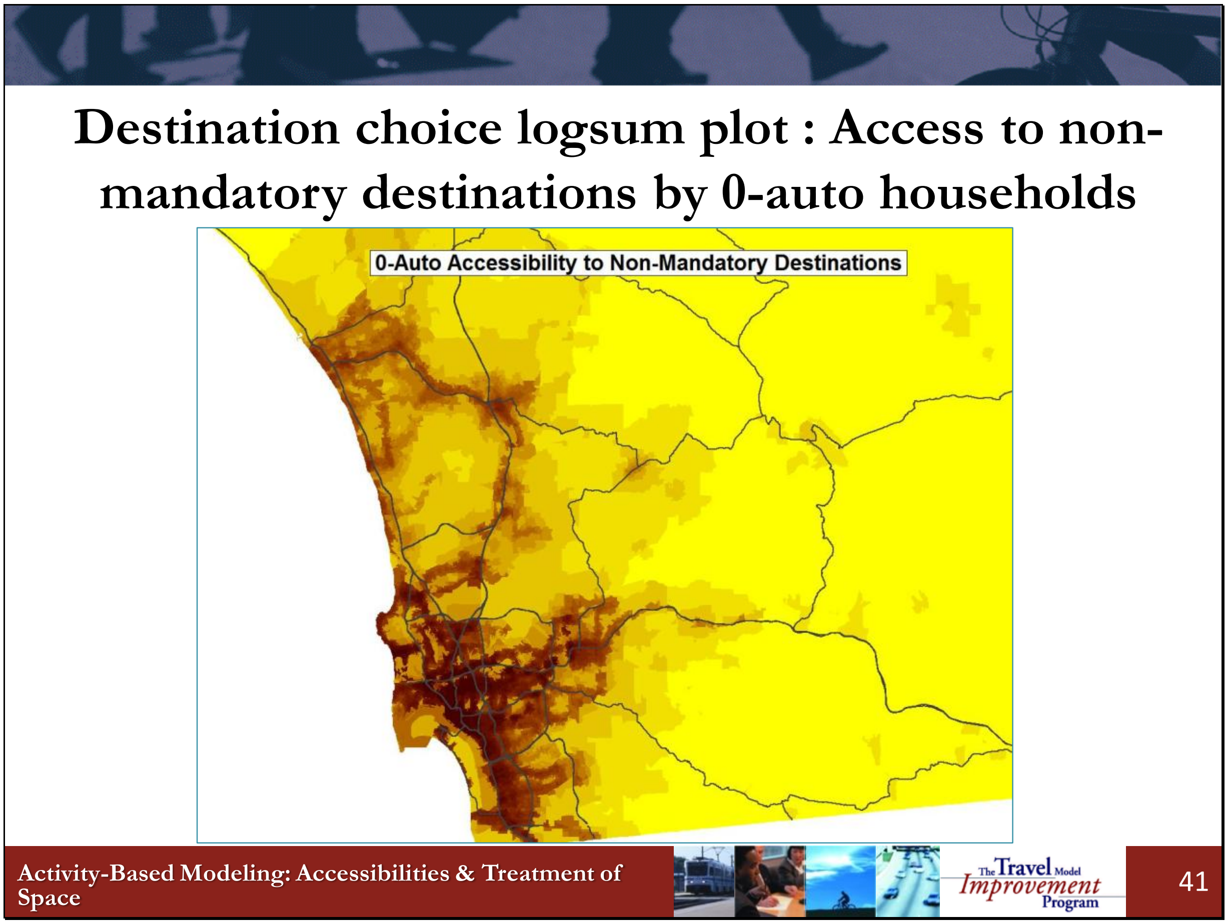


This plot shows transit access to non-mandatory destinations. This uses the transit mode as the measure of impedance, and non-mandatory purpose for the size term in the destination choice model. Areas that are close to transit lines are darker, because they are more accessible. Think of this plot as showing how many non-mandatory destinations can I get to by transit from my zone compared to some other zone. Transit accessibility to non-mandatory destinations often shows up in auto ownership models. Households that are in darker areas tend to own fewer cars because their transit accessibility is much better than lighter areas. So from a policy sensitivity perspective, a model that has such a variable in it will predict changes in auto ownership due to changes in transit accessibility.

Destination choice logsum plot : Non-motorized access non-mandatory destinations



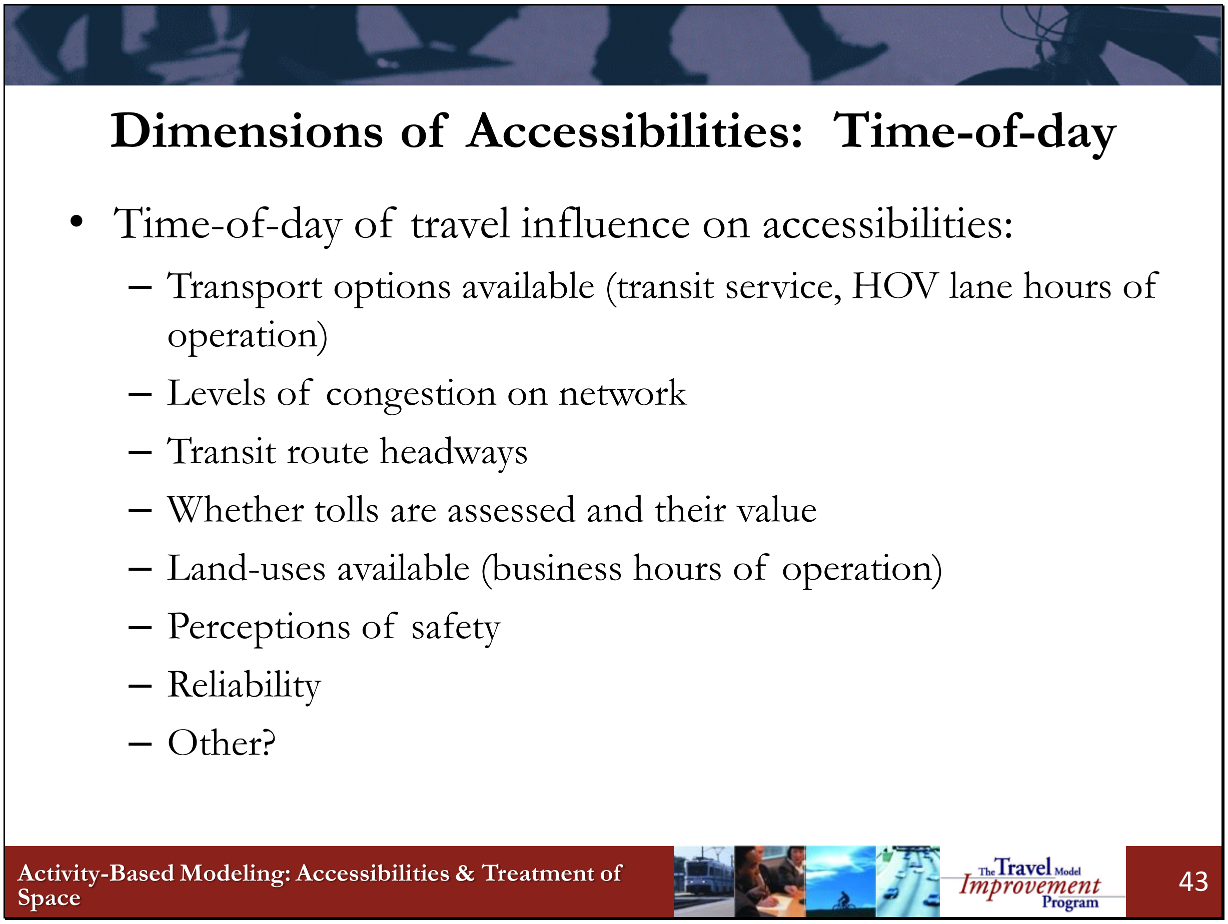
This plot shows transit access to non-mandatory destinations. This uses the walk and bike modes as the measure of impedance, and non-mandatory purpose for the size term in the destination choice model. Think of this plot as showing how many non-mandatory destinations can I get to by walking and/or biking from my zone compared to some other zone. More compact, dense communities with close proximity to retail and service employment show up darker on this map. Non-motorized accessibility to non-mandatory destination variables also often shows up in auto ownership models. Households that are in darker areas tend to own fewer cars because their non-motorized accessibility is much better than lighter areas. Again, a model with such variables in it will show sensitivity to mixed-use and density-oriented land-use policies.



This plot shows access to non-mandatory destinations specifically for 0-auto households. This variables takes into account all modes of travel – auto, walk\bike, and transit. However, the modes are based upon the mode choice model for someone without access to their own automobile. Therefore, non-motorized and transit modes influences the accessibility much more than auto (though auto still influences the accessibility due to ride-sharing with non-household members). Sometimes auto ownership models use a number-of-autos specific destination choice log-sum instead of different mode-specific log-sums. The drawback to the use of a auto-ownership-specific log-sum is that the calibration of the mode choice model can affect the log-sum (since alternative-specific constants for each mode are changing). And, changes in the log-sum can affect auto ownership, which affects mode choice shares. Therefore the calibration process must be iterative and can be time-consuming. For this reason often mode-specific log-sums are used as explanatory variables in upper-level models such as auto ownership and tour generation.

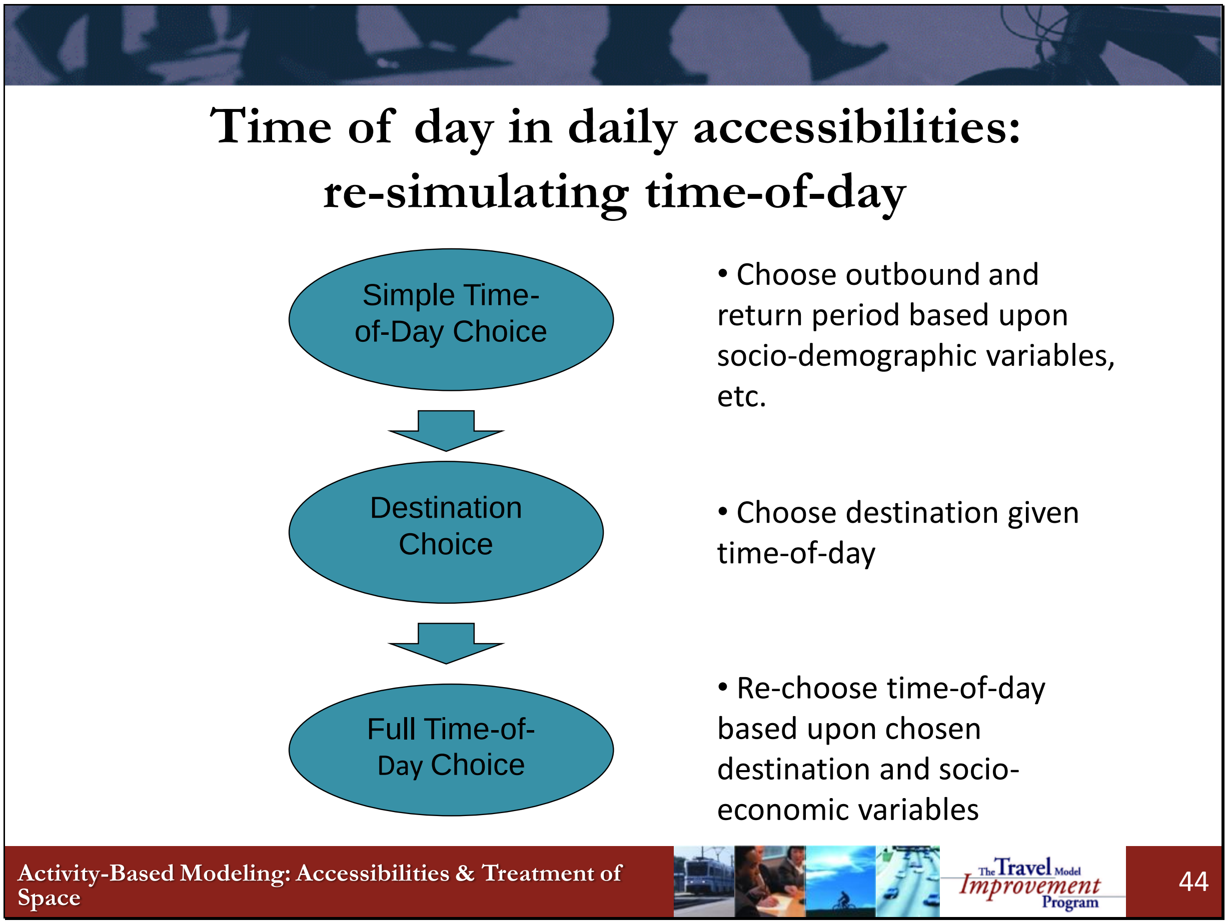
Questions and Answers

The Travel Model Improvement Program



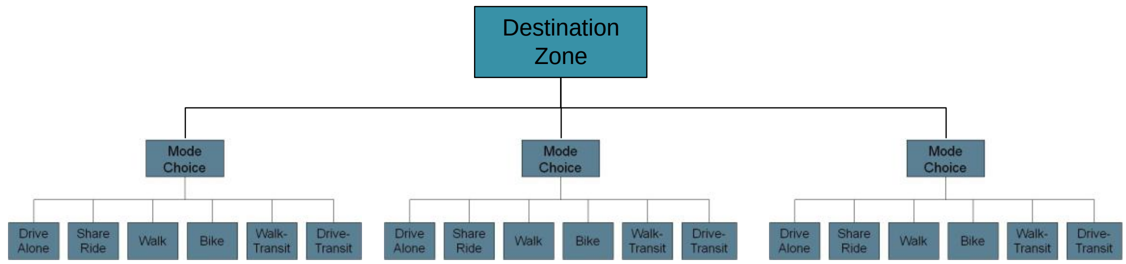
OK, so far we've talked about the influence of mode and traveler characteristics on accessibilities. Now let's talk about differences in time-of-day. It is clear that one of the key advantages of an activity-based model is consideration of multiple time periods in travel decisions. For example, levels of congestion experienced in the PM peak, on my way home from work, can and should influence when I leave for work in the morning. Many aspects of the transportation network vary throughout the day, including the modes available, the levels of congestion, the availability and service frequency of transit, whether tolls are assessed and their value, the land-uses available, perceptions of safety, reliability, and so forth.

In addition, land-usage varies by time-of-day. Stores, doctor's offices, and other business establishments are only open during certain times of day. We will now explore how accessibilities can be calculated throughout the day.



One method of account for time-of-day effects in daily accessibilities is to re-simulate the choice. This is akin to the feedback process used in models where skims are fed back to demand models and the models are re-run until the travel times output from the models are consistent with those input to the models. In the example shown, a simplified time-of-day choice model is applied in which the destination of the tour is unknown. The time periods assigned from this simple model are used to calculate the probability of choosing a destination. Once the destination is chosen, the time-of-day choice model is re-run to choose the final time period. The disadvantage of this approach is that the initial choice of time-of-day will be inconsistent from the full time-of-day choice for a number of observations, and it is unclear what effects this might have on model outcomes.

Time of day in daily accessibilities: "logit averaging"

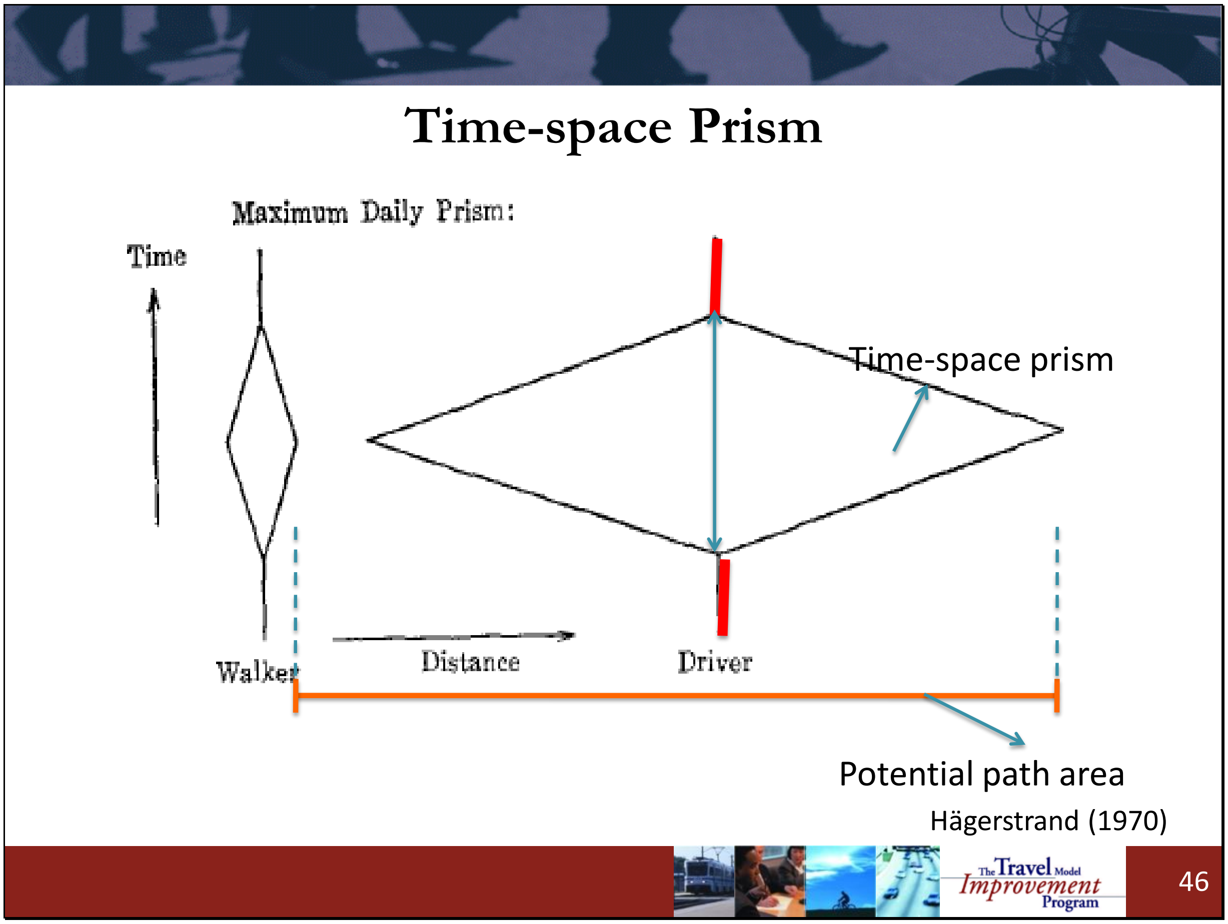


Period (p) = AM Outbound/ PM Return	Periods (p) = Midday Outbound/ PM Return	Periods (p) = PM Outbound/ Evening Return

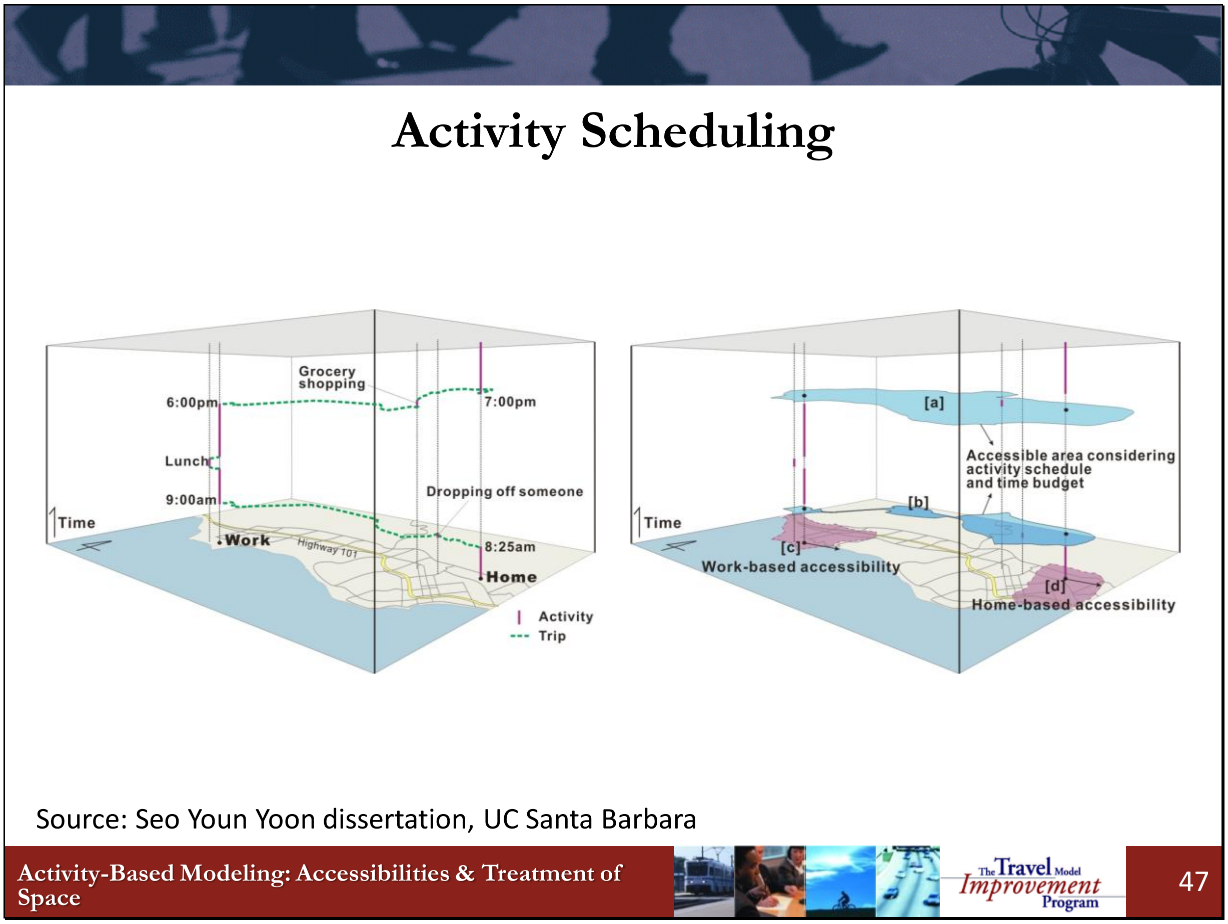
Logit Average: Mode choice logsums are averaged (with constants) across several (or all) time period combinations *p,* for zones *z* and modes *i*

$$\ln\left[\sum_{z=1}^{Z}\sum_{p=1}^{P}\sum_{i=1}^{I}e^{U_{z,p,i}}\right]$$

A logit average of all relevant time-of-day period combinations can be taken, in order to ensure proper representation of the effects of network level-of-service across the entire day in a daily average accessibility. This is the mathematically correct way to represent multiple lower level choices in an upper level logit model, but also imposes the most computational burden.



One way to think about accessibility is to consider the Time-Space prism that Geographers defined 40 years ago. This sketch shows a driver in space (horizontal axis) and time (vertical axis). The prism shows the amount of time available between departure from an origin and return to the same origin. The orange color line is the one dimensional space a person can reach within the available time and this is named the potential path area. If we add some more realism to this representation we get the next figure.



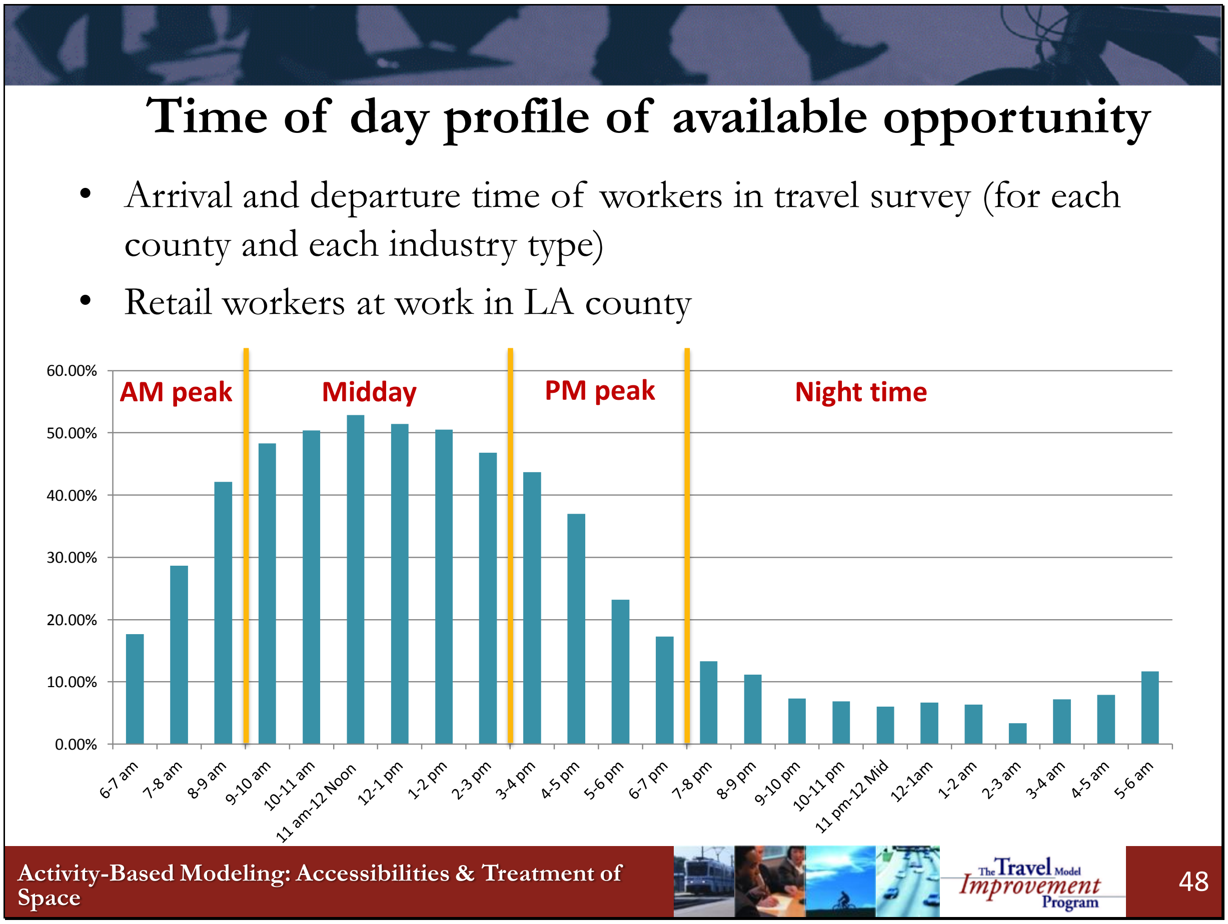
This time we added the activity schedule of a person and represent space in two dimensions. We also added two major anchor points in the schedule that are home and work.

The shaded areas around home and work are potential path areas centered at anchor points. This is the type of accessibility that we compute around destinations. For example, around work assuming we have 15 minutes available time our accessibility will be the amount of stores we can reach and/or the amount of restaurants or any other type of activity locations.

This figure also shows another type of accessibility (the blue shaded areas). We show here an area that can be reached during the morning commute and during the evening commute. These look more like a corridor accessibility – in essence an area of the urban environment that can be reached on the way to work and another area that can be reached on the way back from work to home. We call these time-space based, and they depend heavily on the available time from one place to another and on the activity schedule of an individual.

Note that there are many places which a person cannot reach within the available time and even when the person can reach them – there may be no activity location available (these areas are called urban desserts)

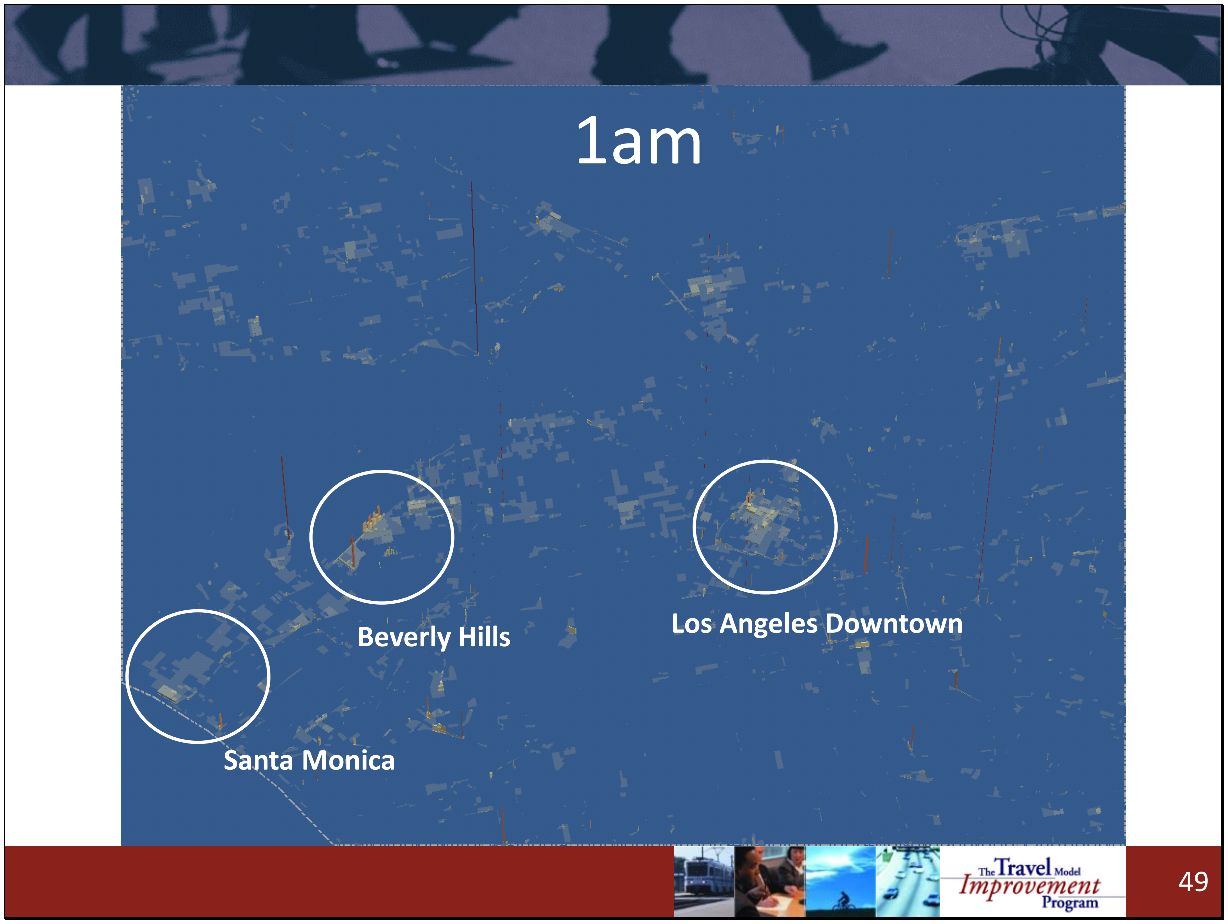
In this webinar we will discuss both types of accessibility - anchor-based and time-space based.



So far we looked at the impact on accessibility of travel time (and speed on the network). But, we also know there is another temporal aspect that we need to account for – time of day. There are dramatic differences in the amount of opportunities a person has for activity participation at different times of a day. Just think of post offices at 6:00 am and at 11:00 am.

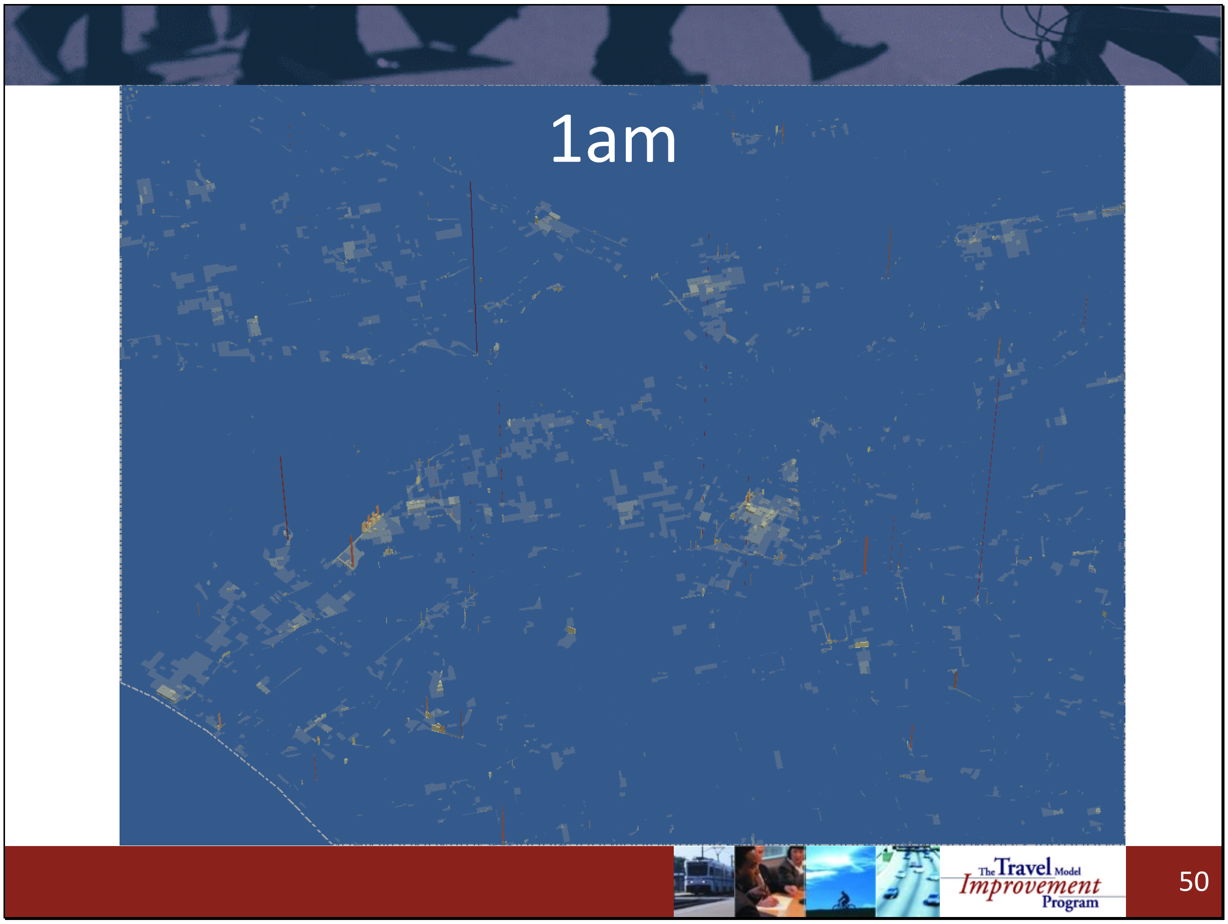
One way to show this in accessibility indicators is to label every stores by opening and closing hours and then do some post-processing. Unfortunately this information is not readily available. Another option is to se information from a travel survey that also asks the industry in which every person works using standardized codes of industries. Then, based on weighted data (to represent the population) of the survey develop time of day profiles of percent of people present at work at different times of a day. This can represent the amount of opportunity available to people to pursue an activity.

The next few slides show hour by hour the number of persons employed in retail in one portion for the Southern California region.



We show the location of Santa Monica at the Pacific Ocean, further northeast of Santa Monica is Beverly Hills and further east is downtown LA. This also happens to be the most popular and crowded corridor in the greater Los Angeles area.

Areas in blue have no opportunities; light blue have a few; yellow indicates more opportunities; the orange color shows there are even more; and red is used for a very high-opportunity location.



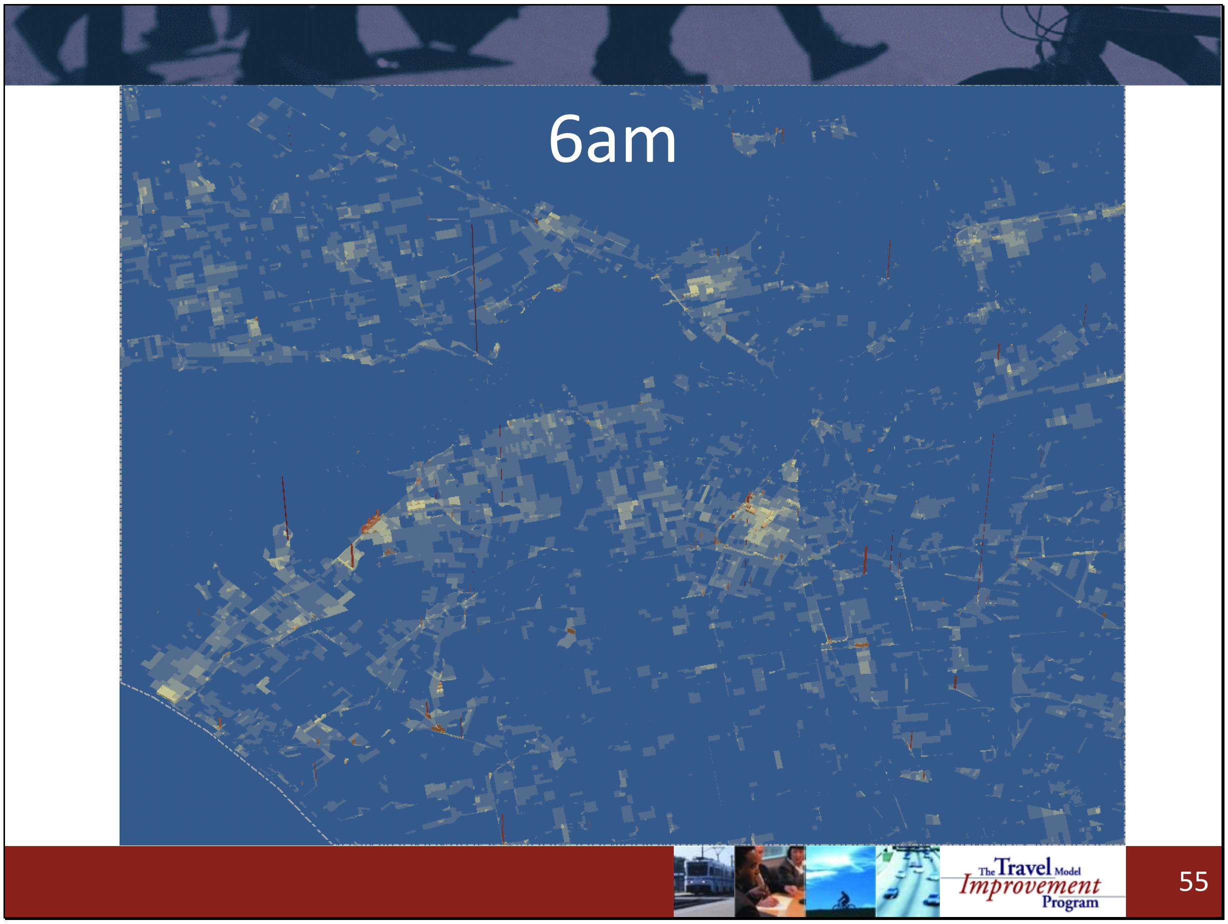
At 1 am there are still some people working in retail along major freeways.

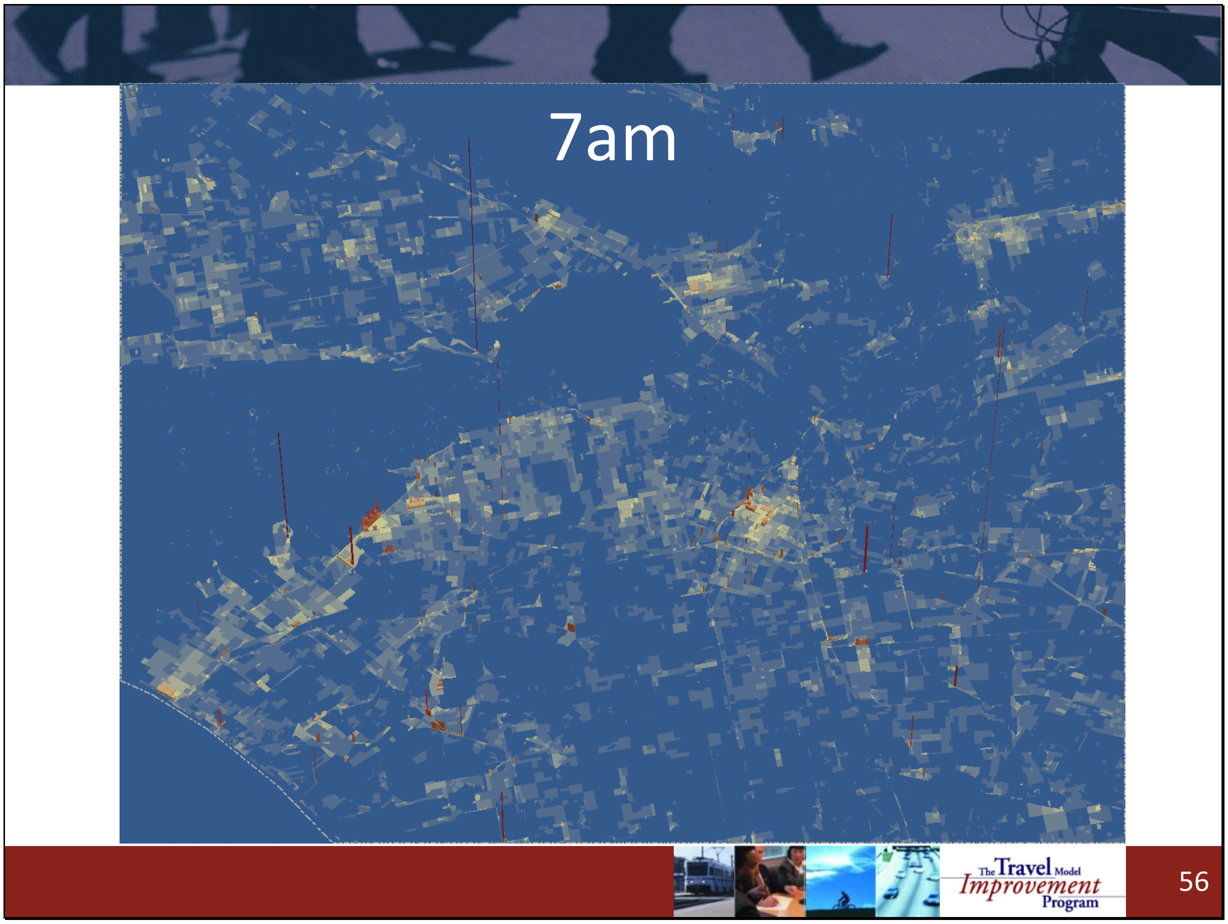
At 2 am most people have gone home, with just a few pockets of retail still available.

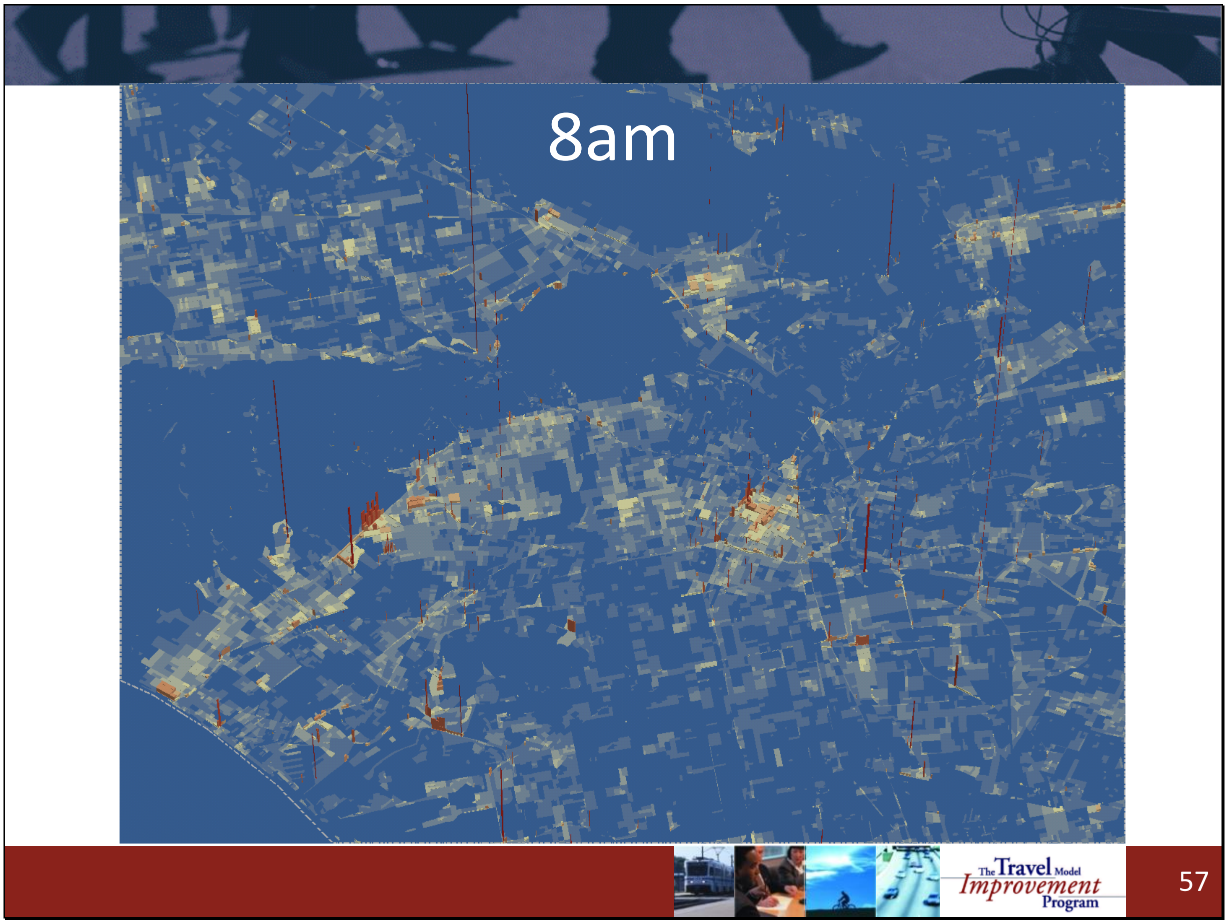
At 3 am we see a slight increase in retail opportunities.

At 4 am a slight increase and then gradually…

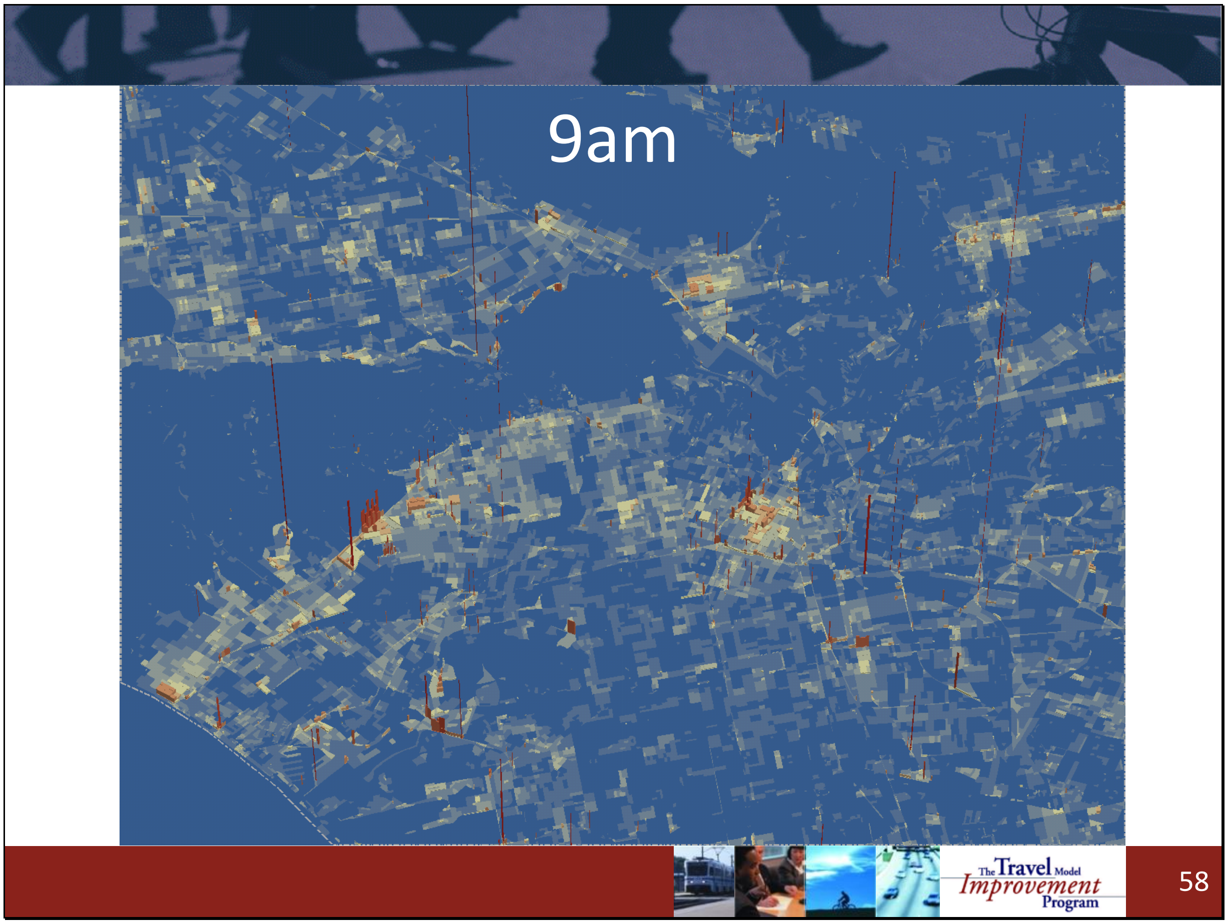
… More and more people arrive at retail locations. For this reason, there is an increase in the number of person in retail per square mile.


6am
The Travel Model Improvement Program
55

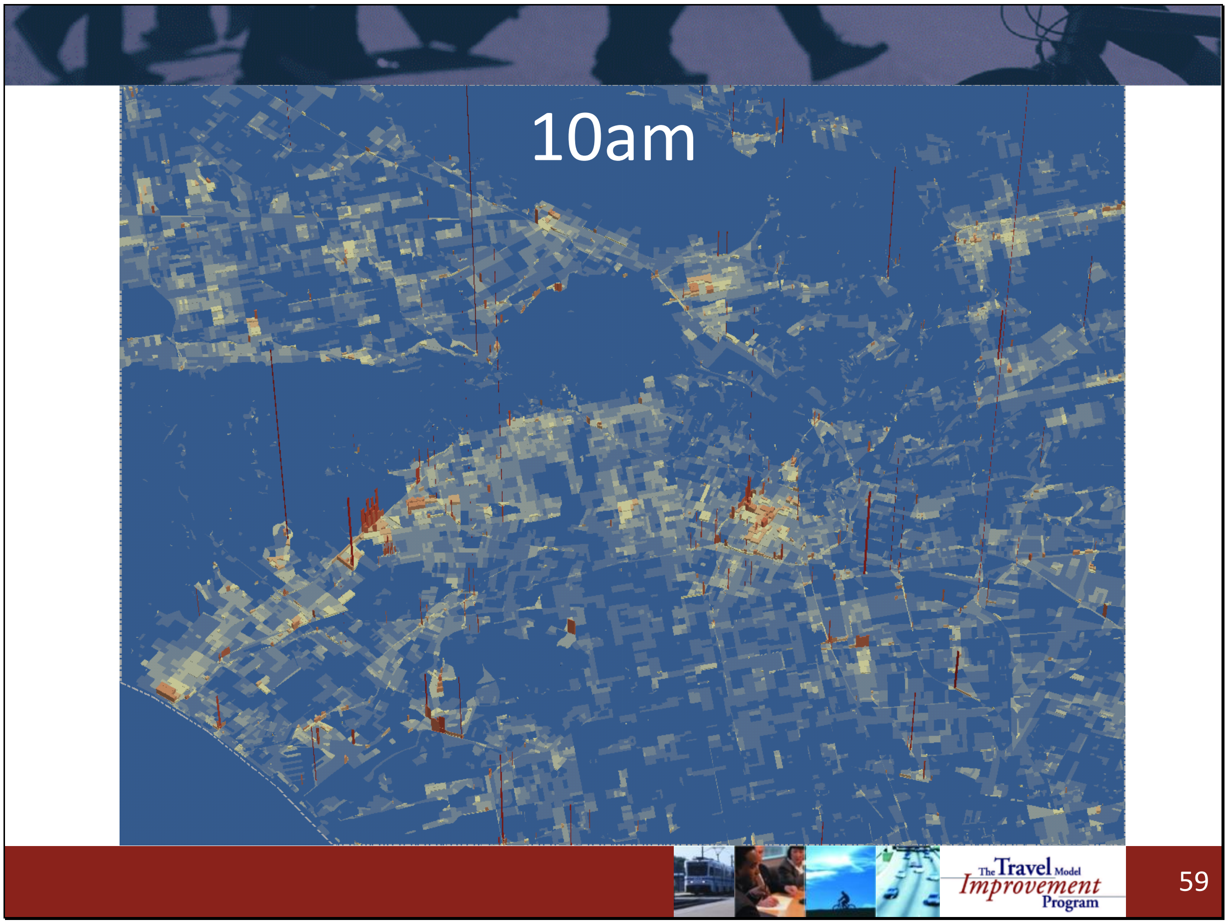

7am
The Travel Model Improvement Program
56

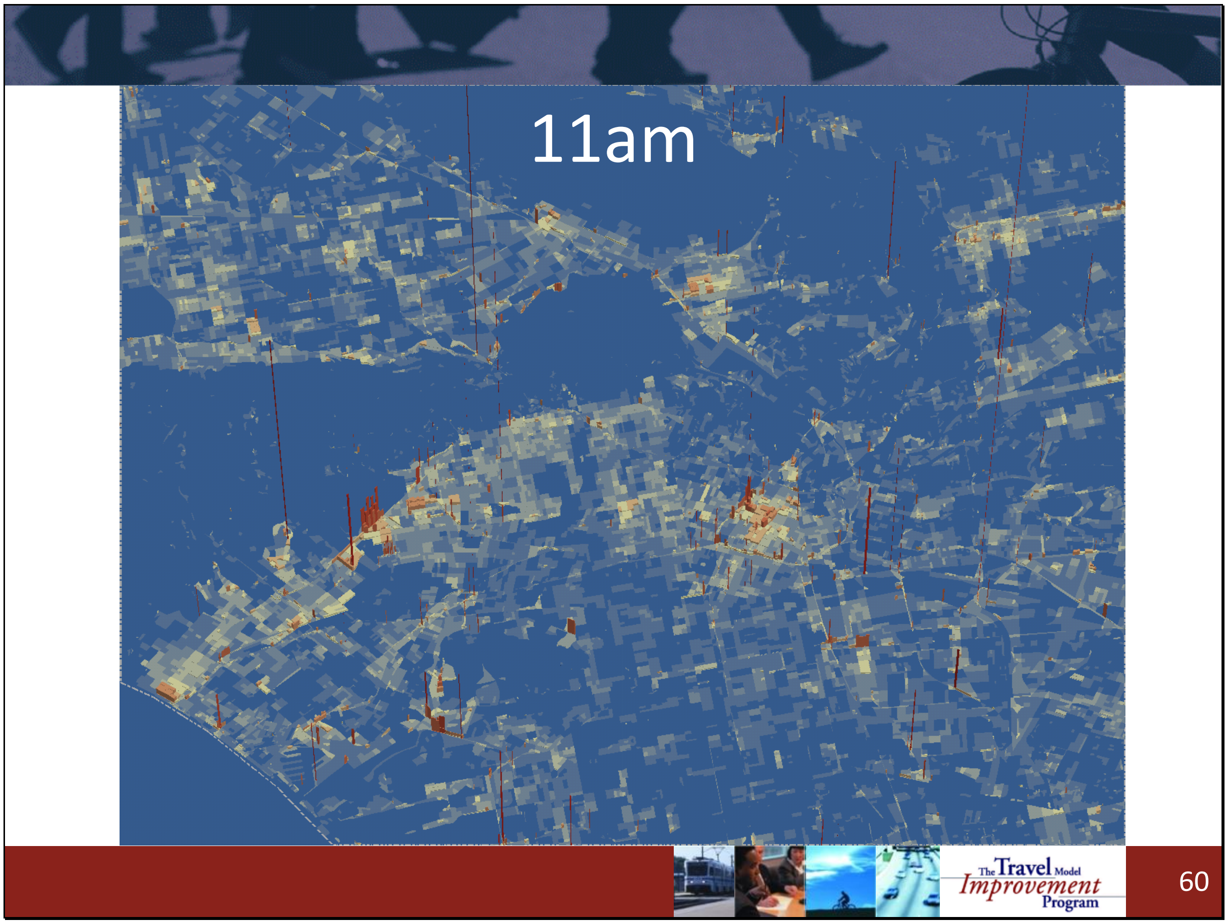


By 8 am, the majority of the areas seems to have reached a high number of retail employees. Note the corridor from Santa Monica to Beverly Hills and then Downtown LA has high numbers, and a few blocks show very high peaks in red.

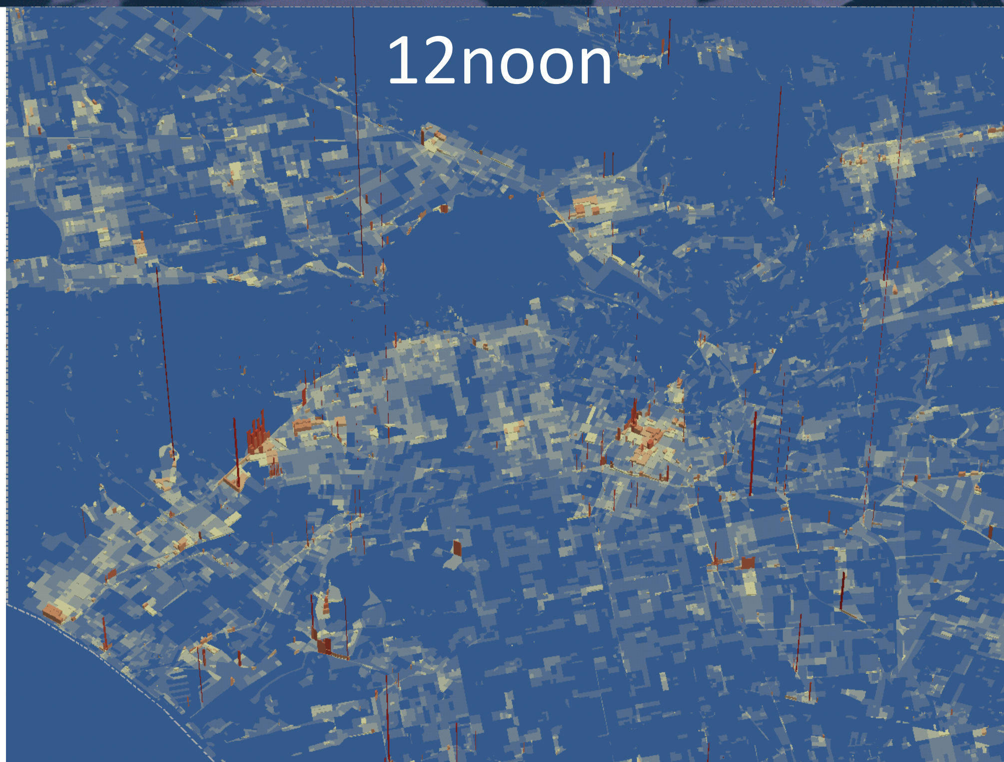


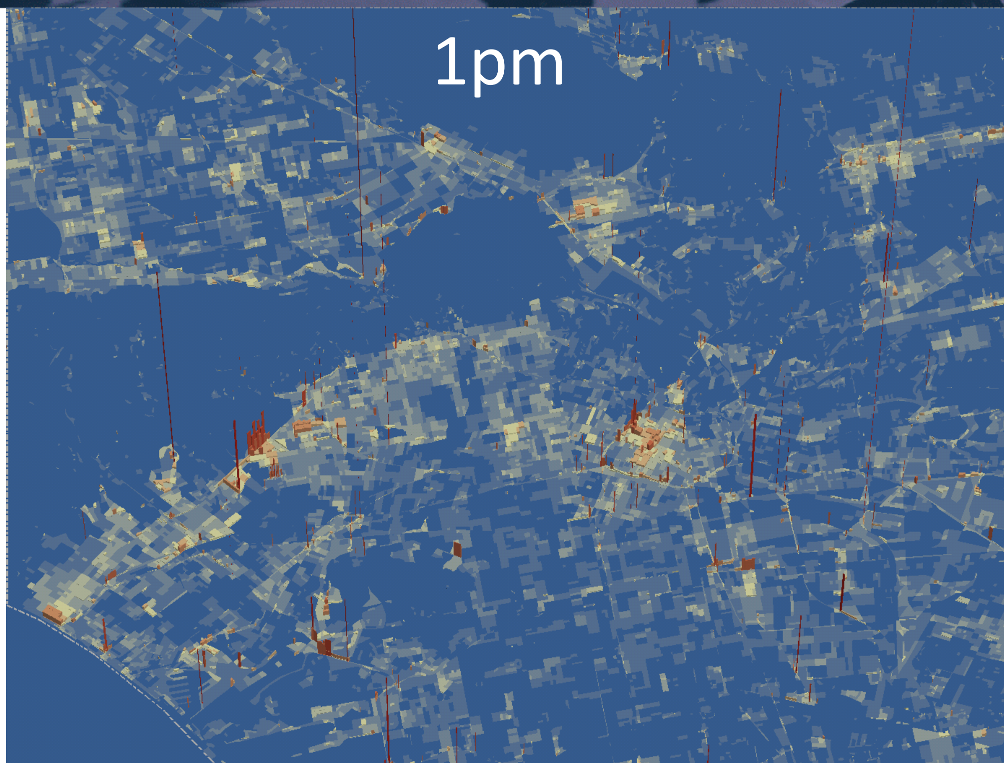
Similarly at 9 am

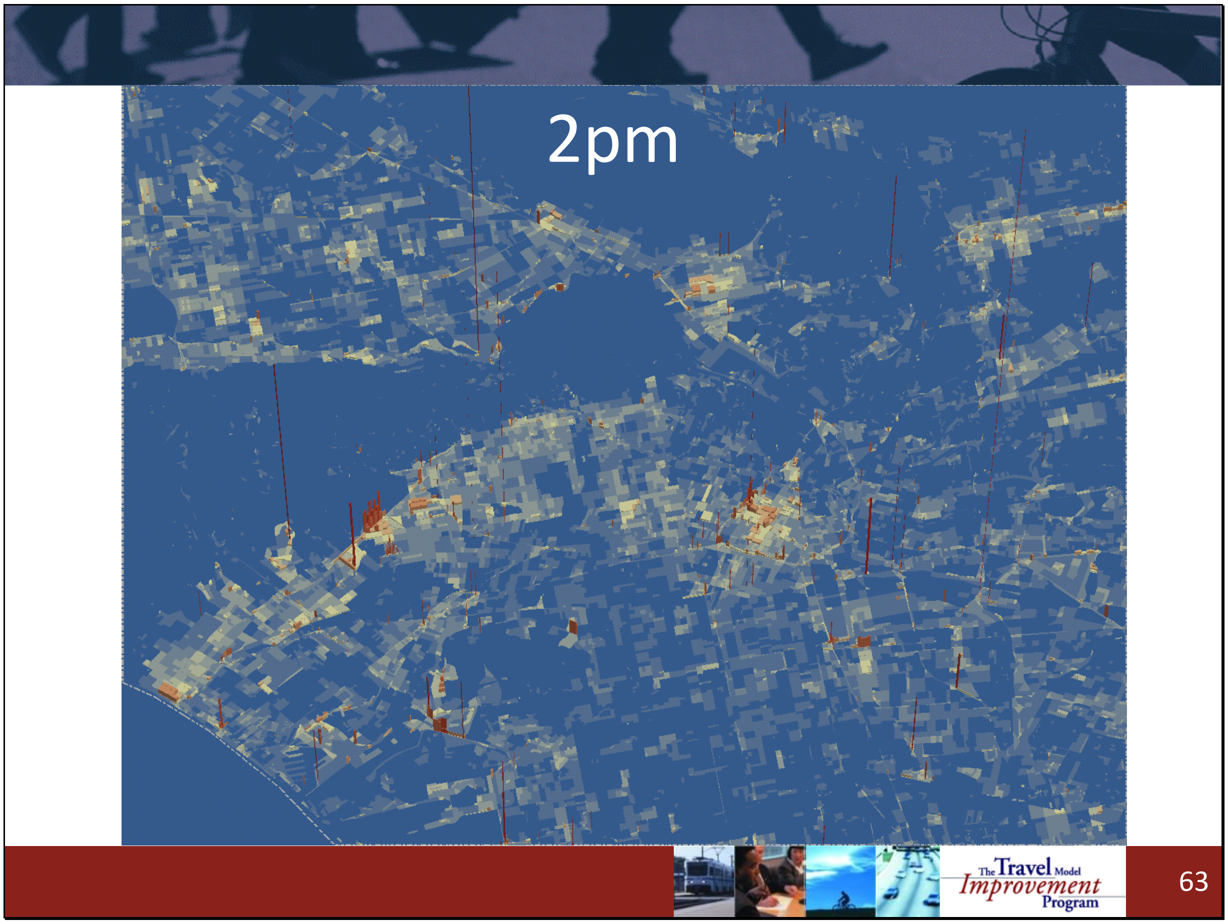

10am
The Travel Model Improvement Program
59

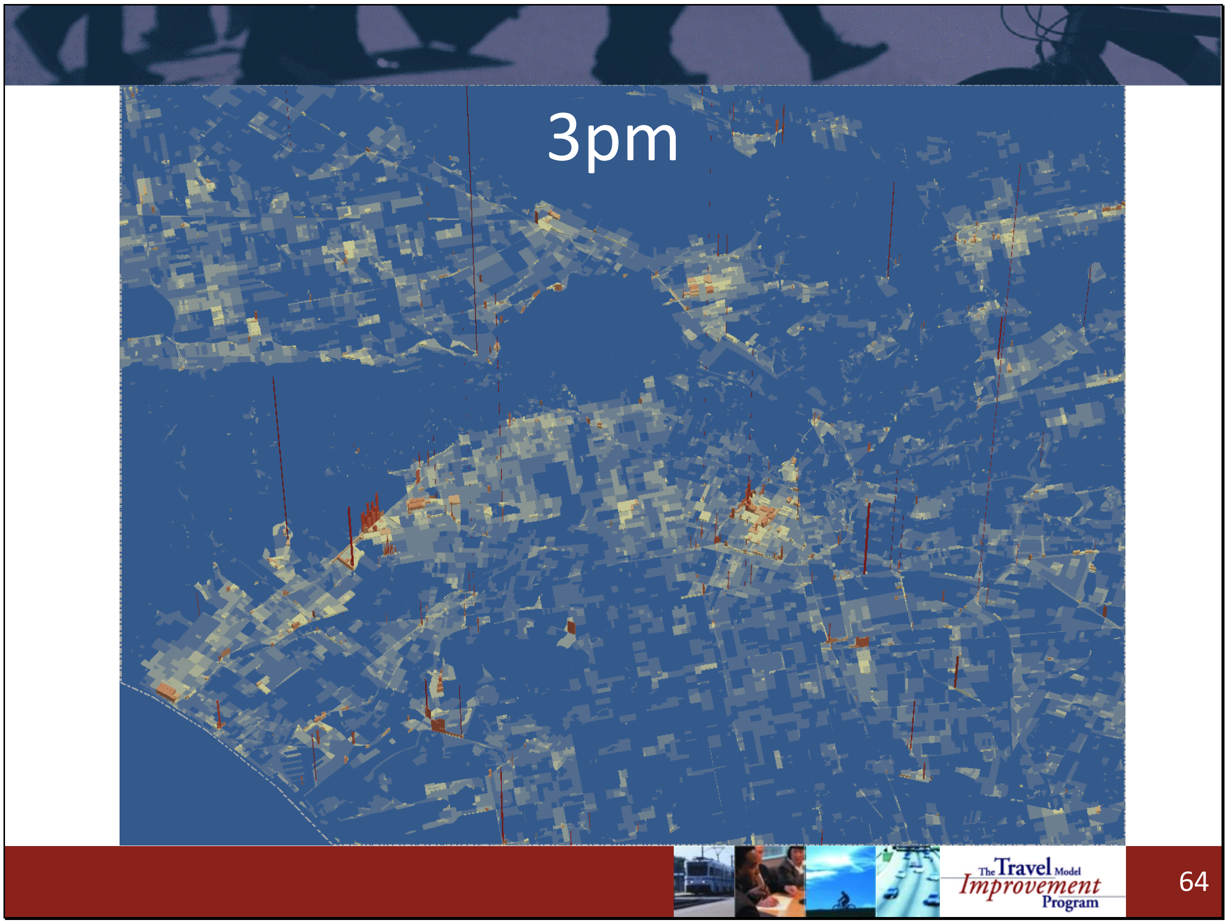

11am
The Travel Model Improvement Program
60

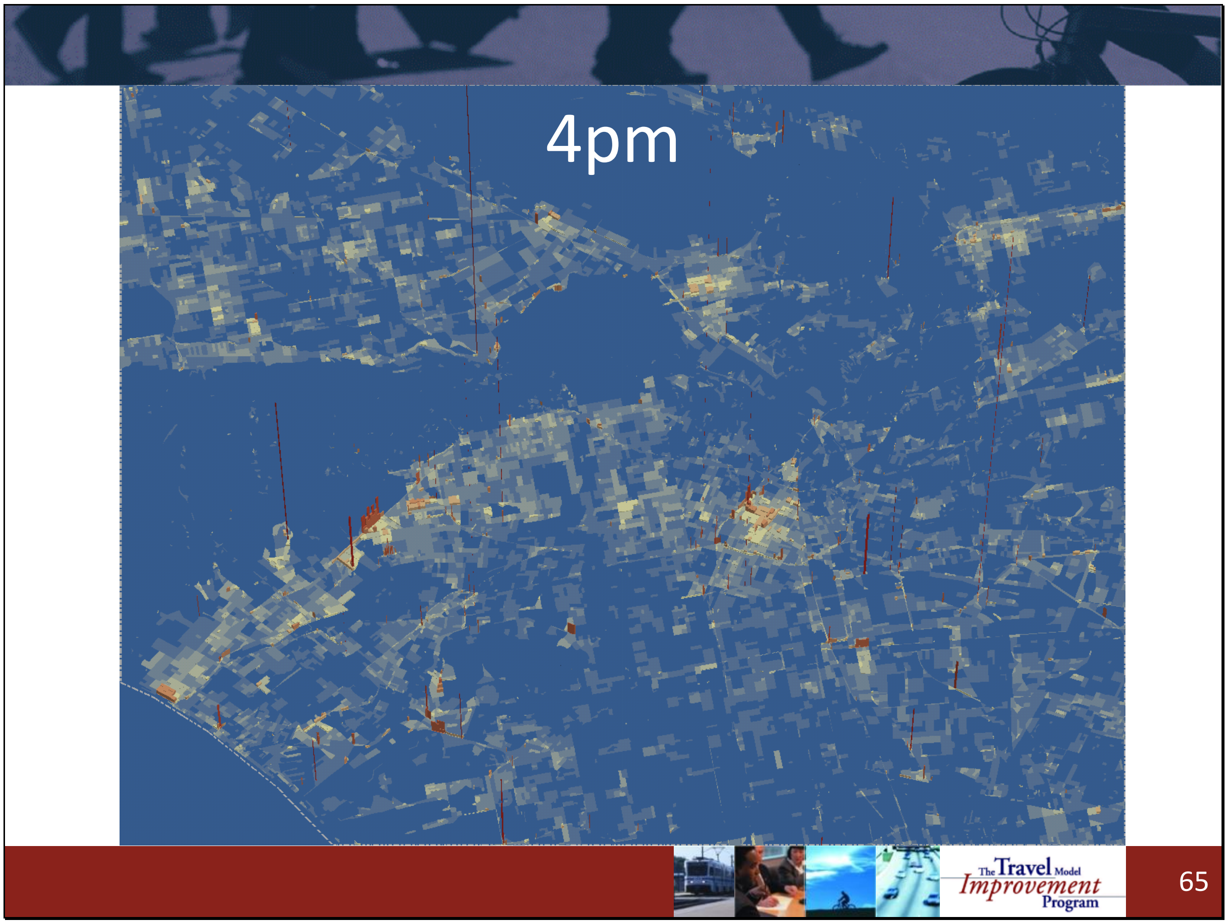
12noon

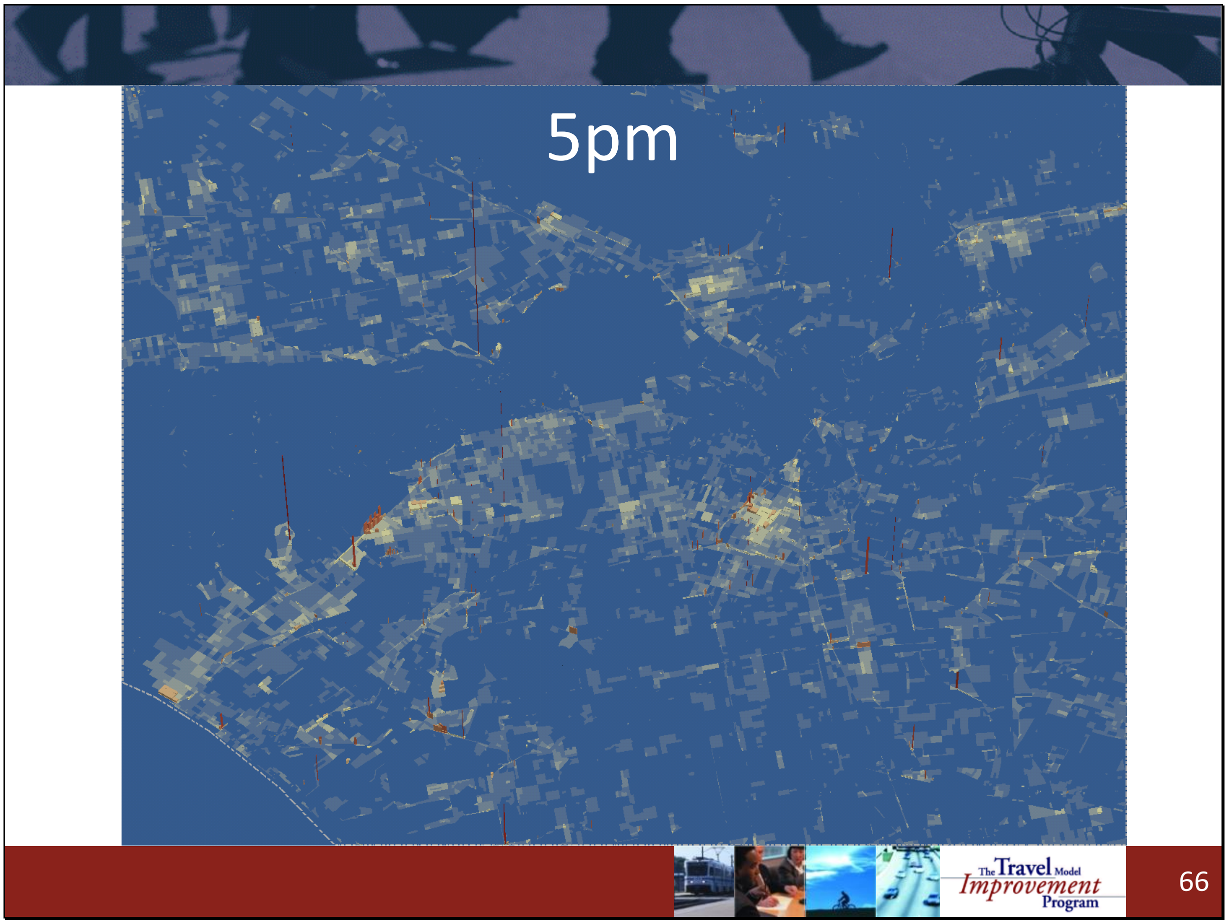



1pm

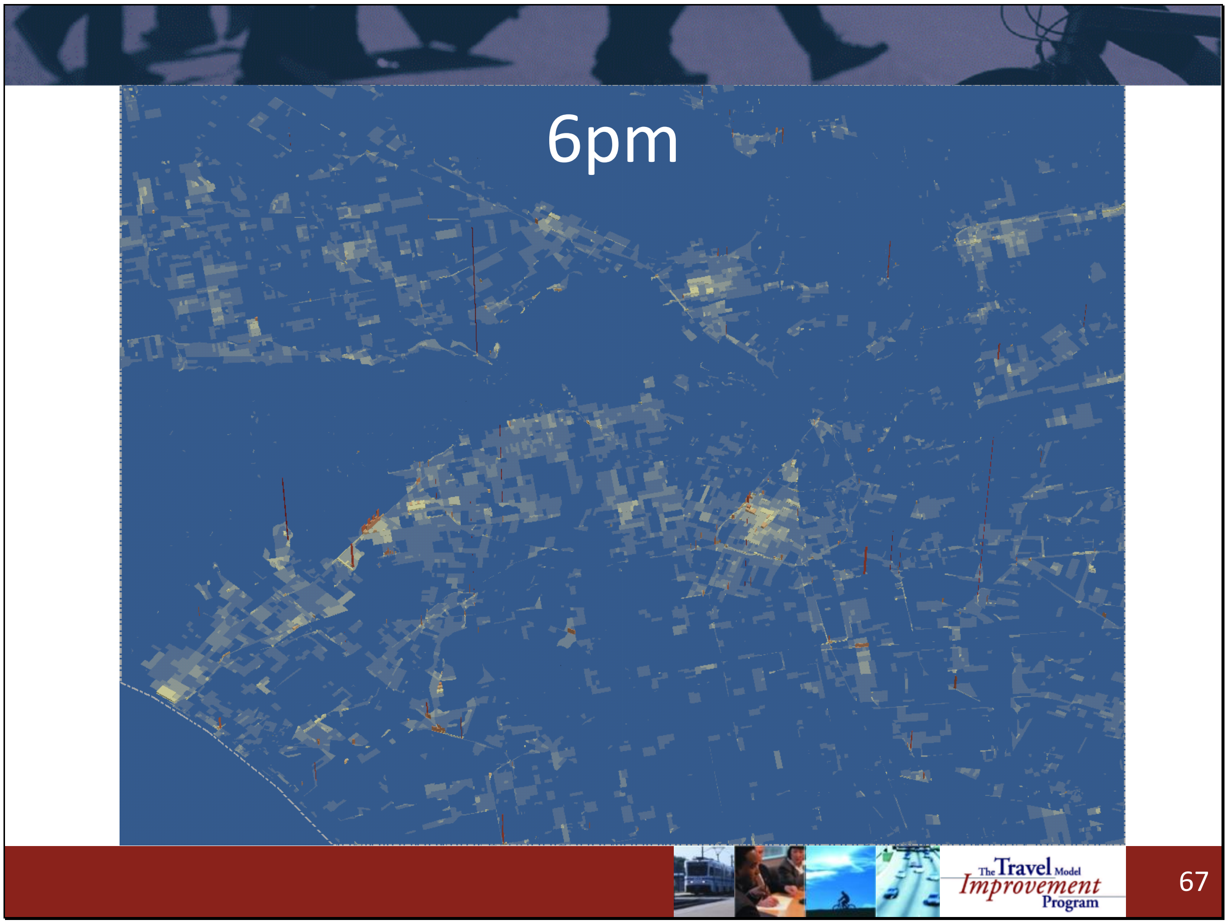

2pm
The Travel Model Improvement Program
63


3pm
The Travel Model Improvement Program
64


4pm
The Travel Model Improvement Program
65



At 5pm we start to see rapid decreases in retail availability.



Similarly for 6 pm.

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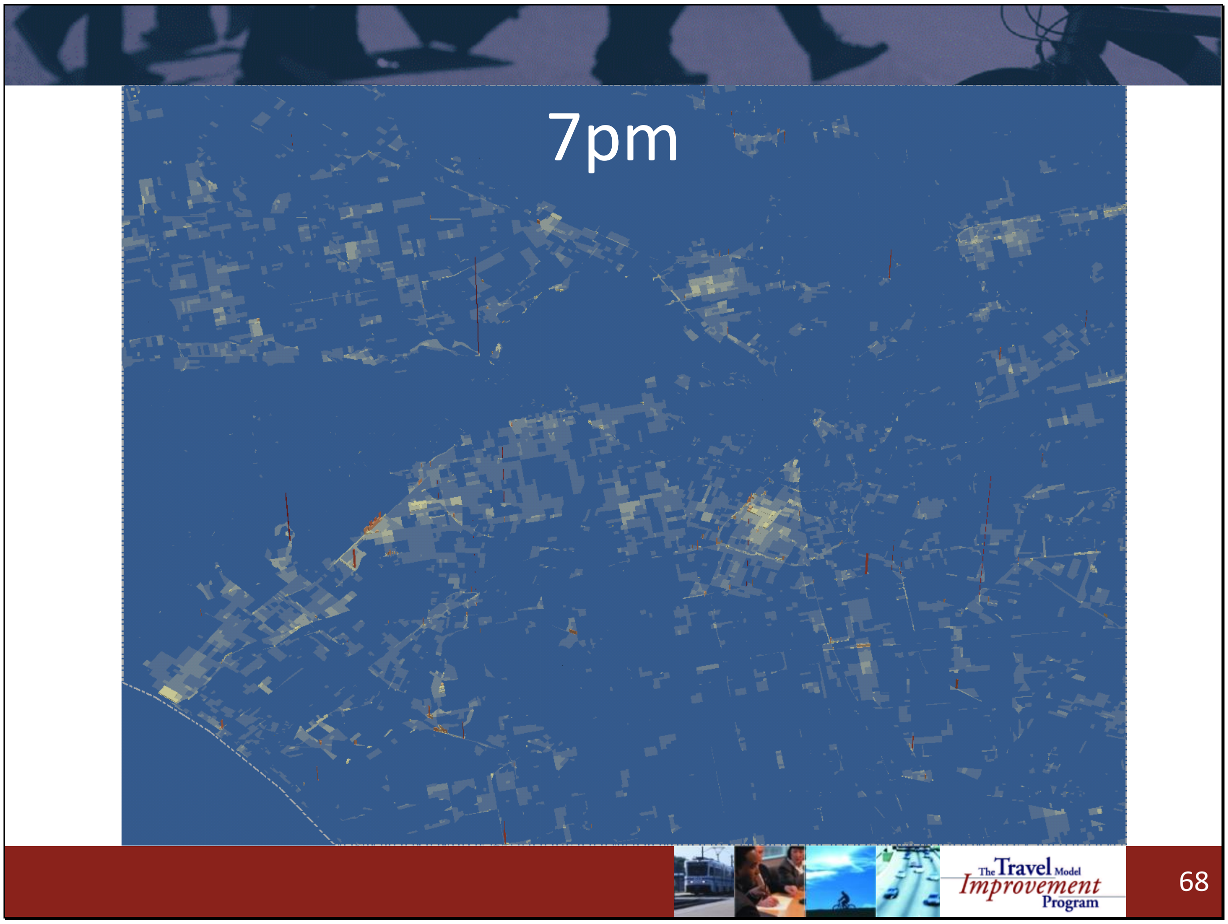
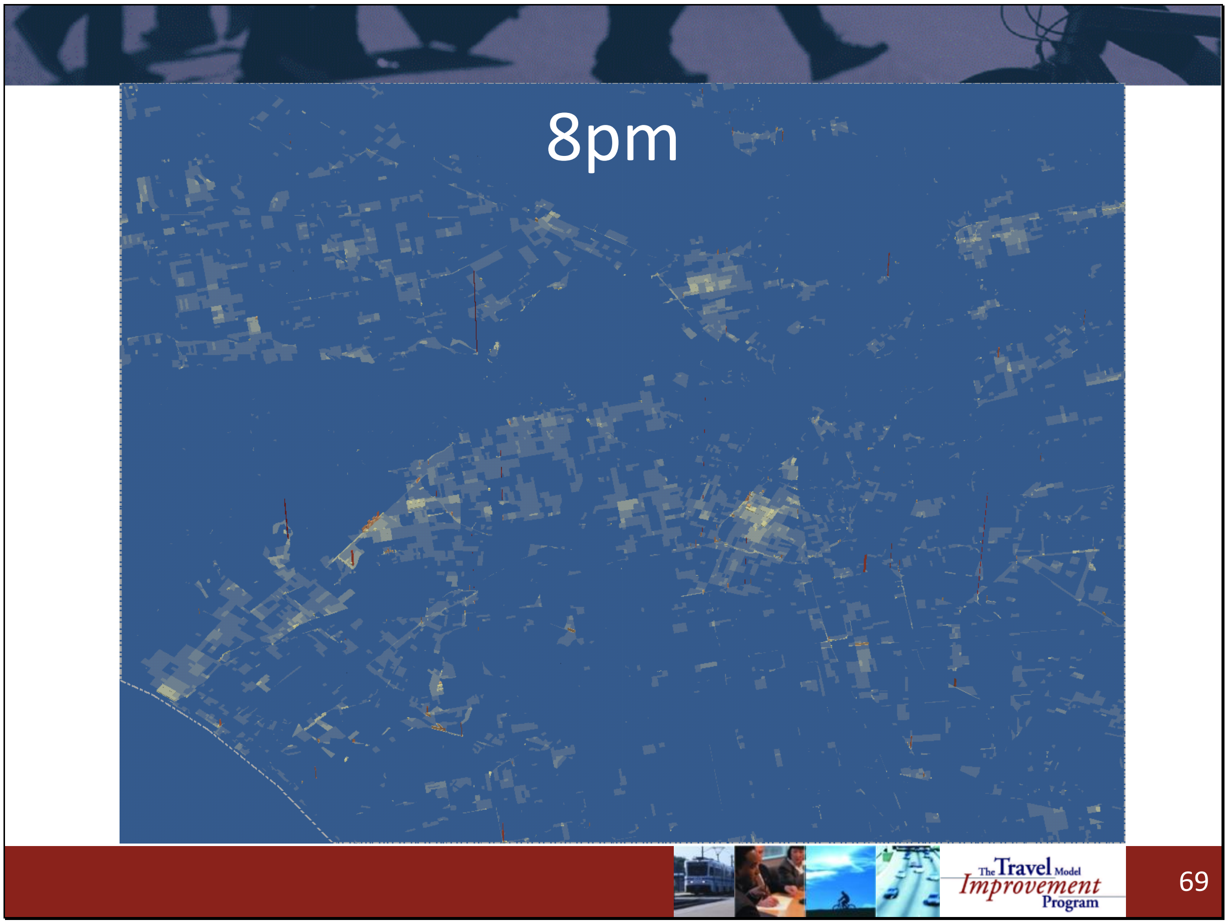
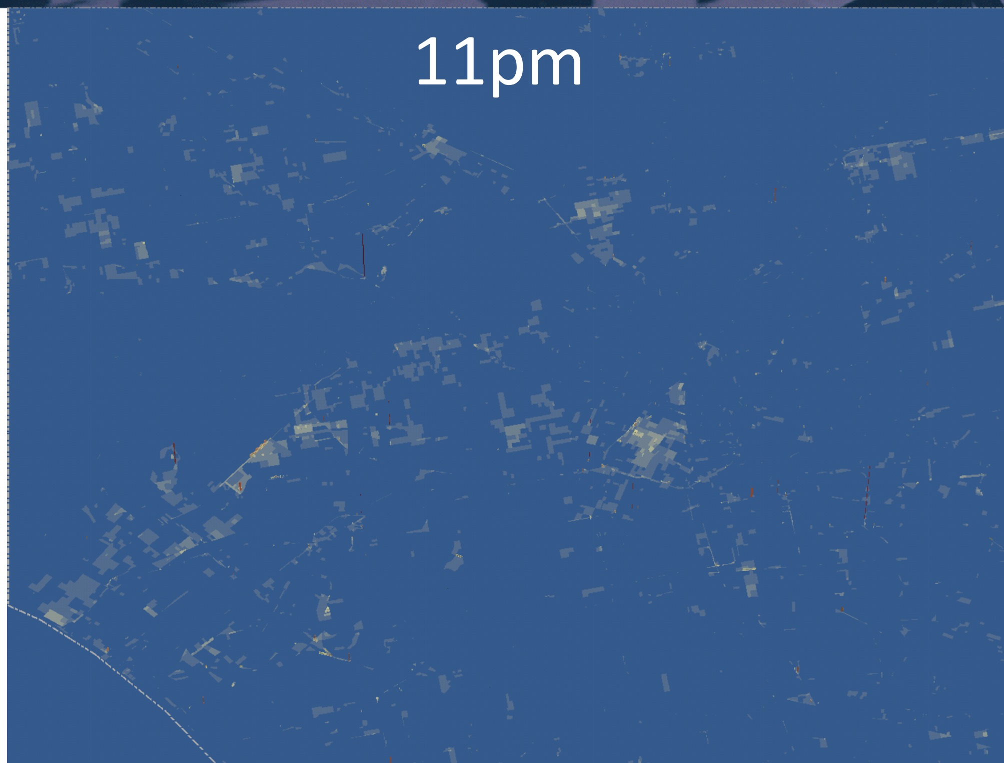



8pm
The Travel Model Improvement Program
69


9pm
The Travel Model Improvement Program
70

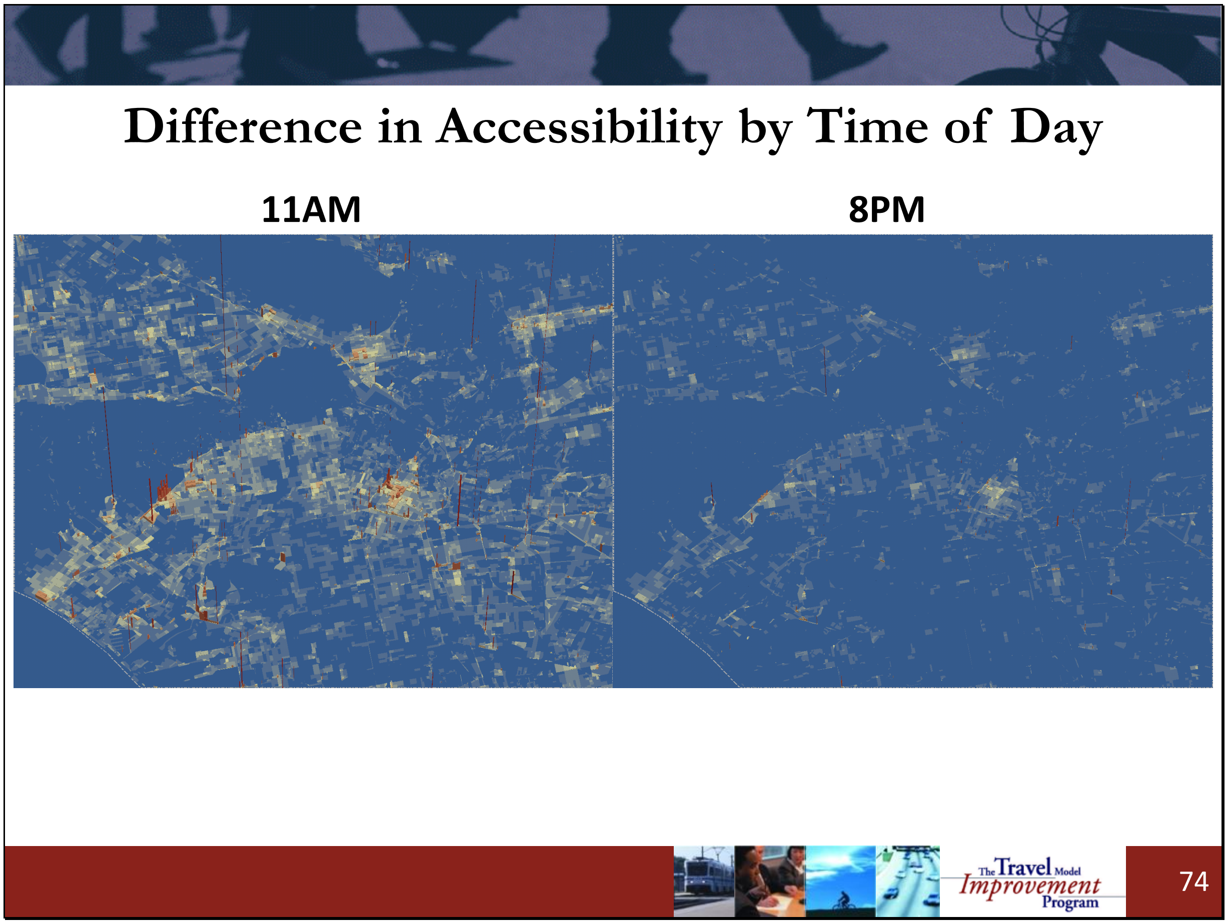
10pm

11pm

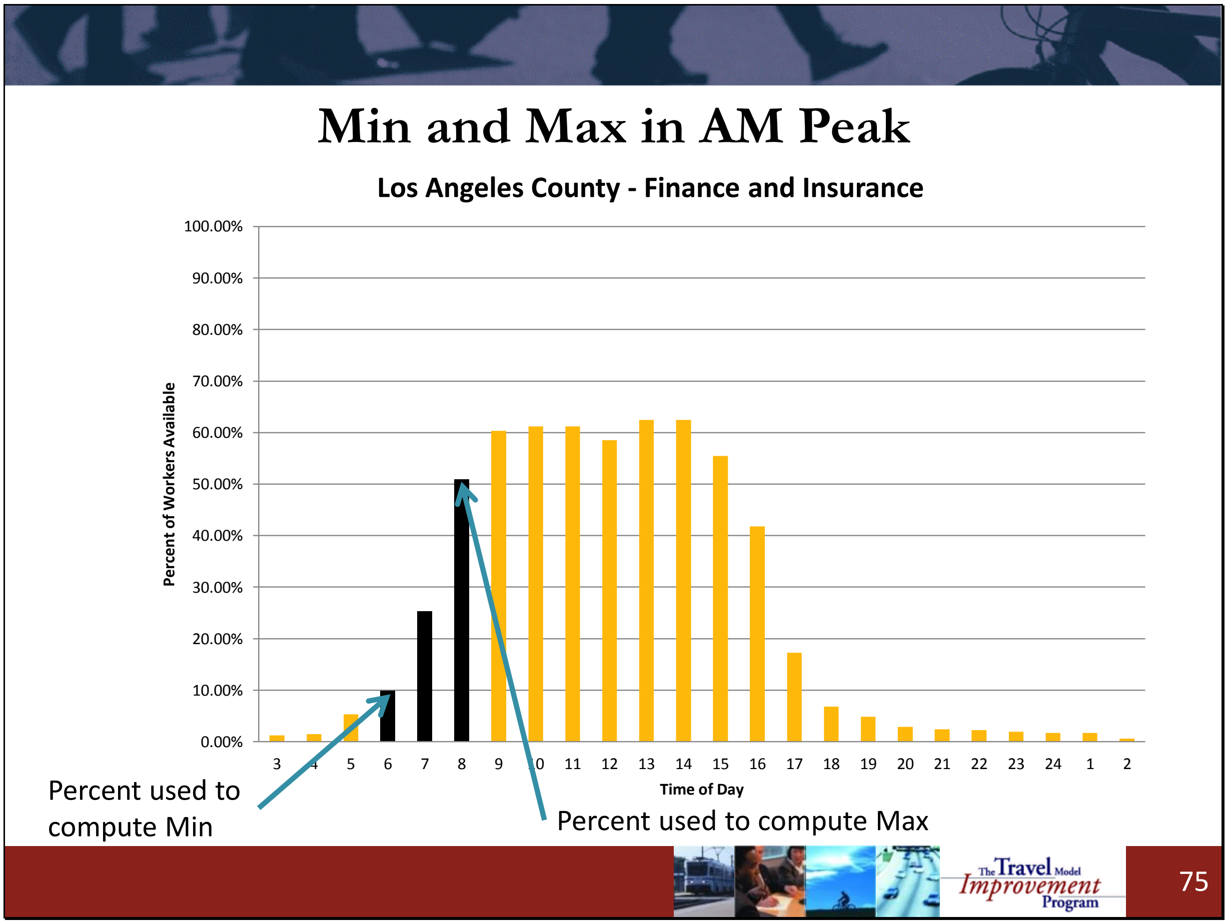


The Travel Model Improvement Program


12midnight
The Travel Model Improvement Program
73

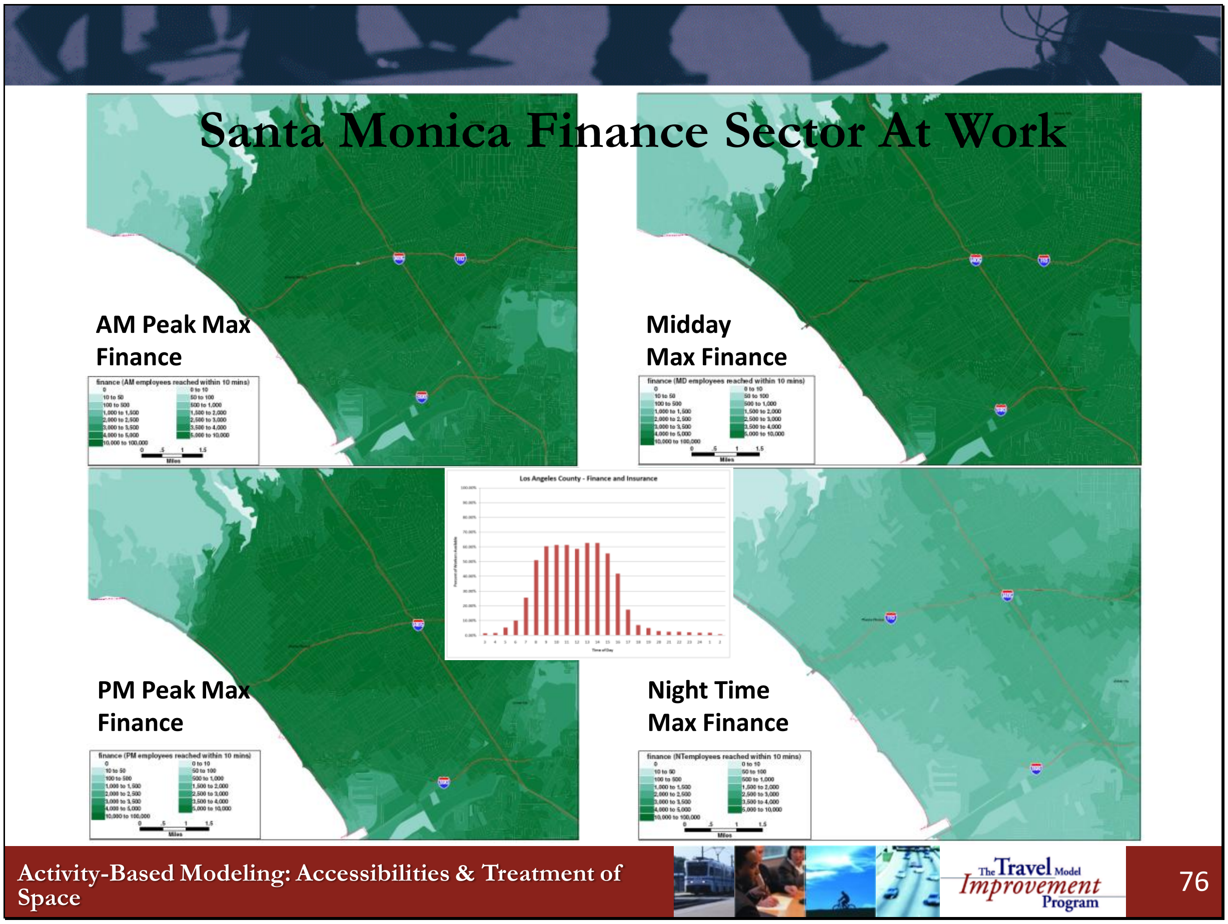


In this slide we see a clear difference between the presence of retail employee at 11 AM and at 8 pm. These differences in accessibility at different times during a day can be used as explanatory variables in activity and travel participation model components of activity-based travel models.

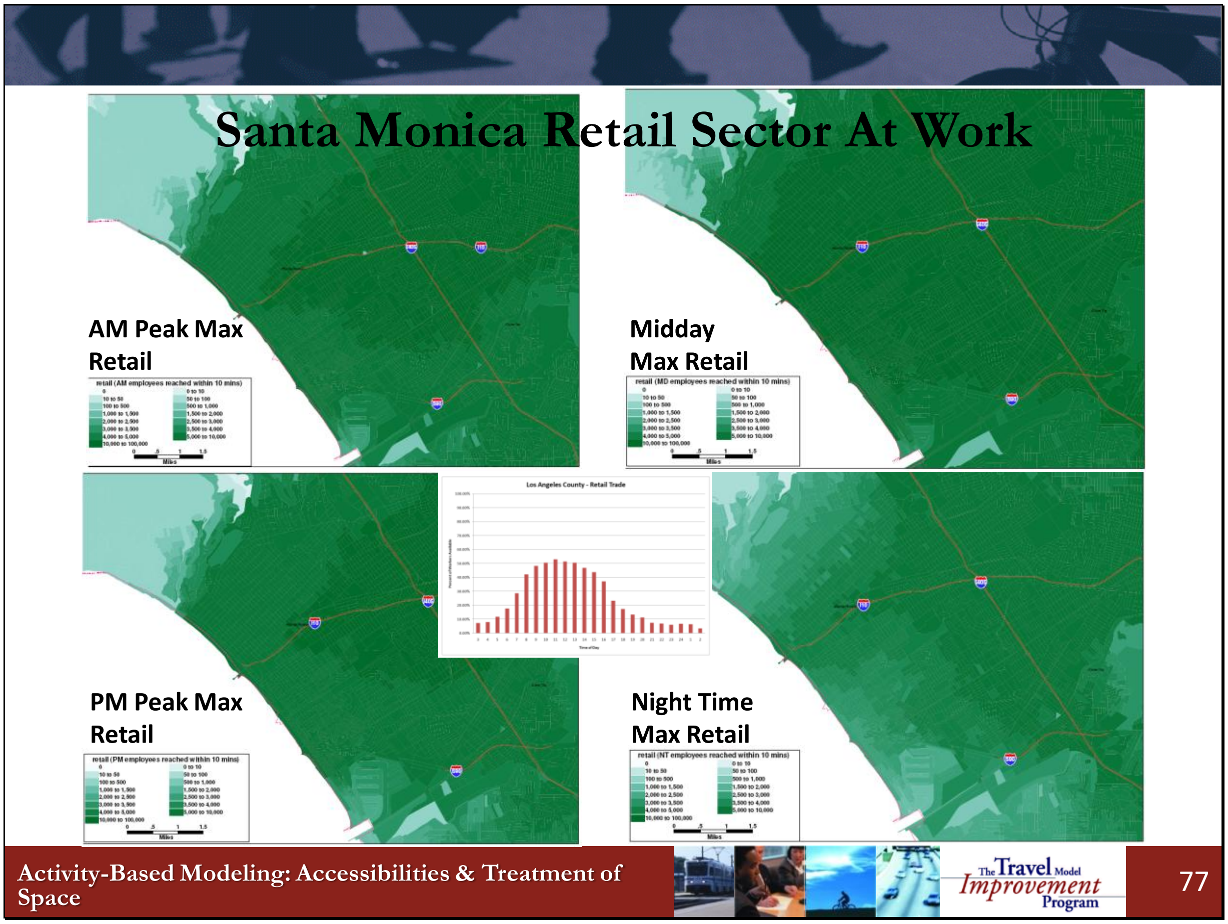


Most traffic assignment four step models either provide peak period travel times that for our purposes contain “extreme” differences in available opportunities as we can see in this image. During the AM peak period we could be reaching 10% or 50% of the employees in this specific industry. Nevertheless, the four step model provides just one set of travel times on the roadways. For this reason we compute the minimum and maximum within this period in an attempt to capture this variation.

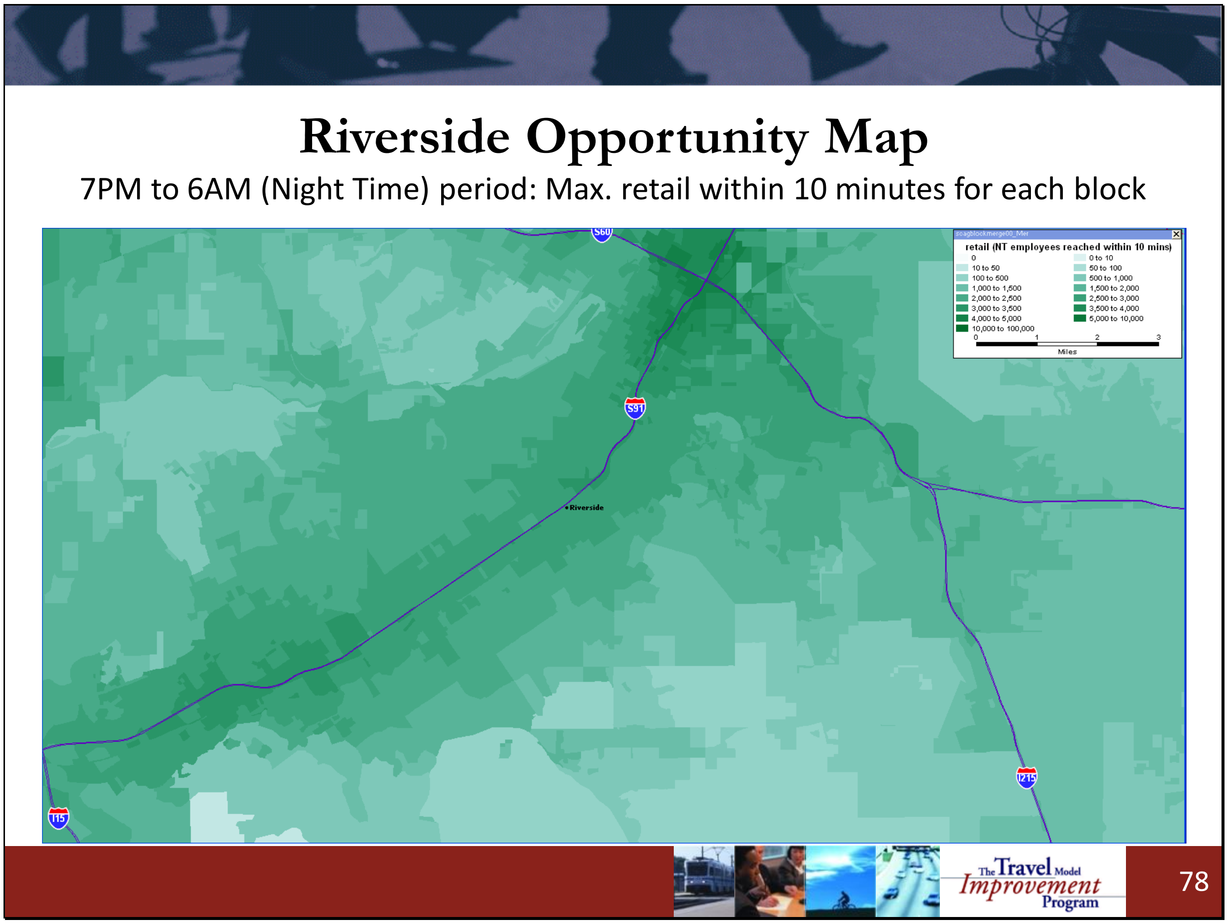
In other applications, and when hour-by-hour travel times are made available instead of the min-max computation, we can calculate accessibility at each hour of the day.



Combining the availability of opportunities in space and time that we reviewed before with the information about travel time on the network, we obtain similar accessibility indicators for the number of employees of an industry that can be reached with ten minutes from each origin point (in this example the block centroid). This slide shows the accessibility within ten minutes to finance employees at different periods in a day. As expected at night time (after 7:00 pm) very few finance opportunities are available, although the travel times are shorter and the network is not as congested as during the pm peak period.

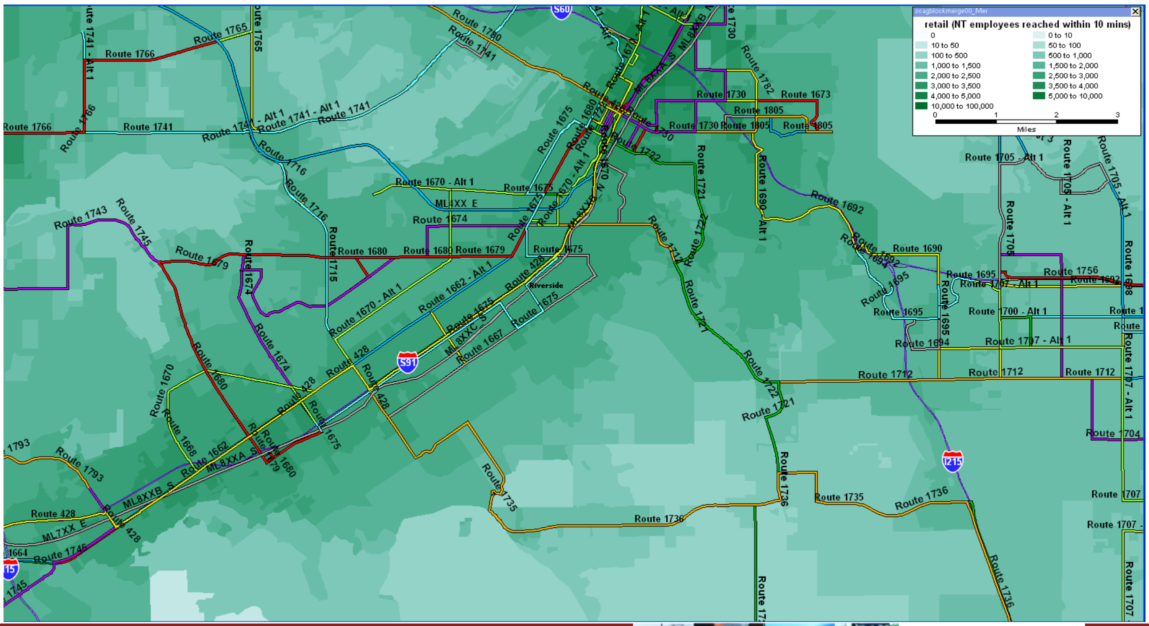


Similarly on this slide we see the accessibility by time of day of the retail employee. This time, however, retail is far higher than finance in the late evening hours. In activity models we should expect this time of day pattern when we model activity types.



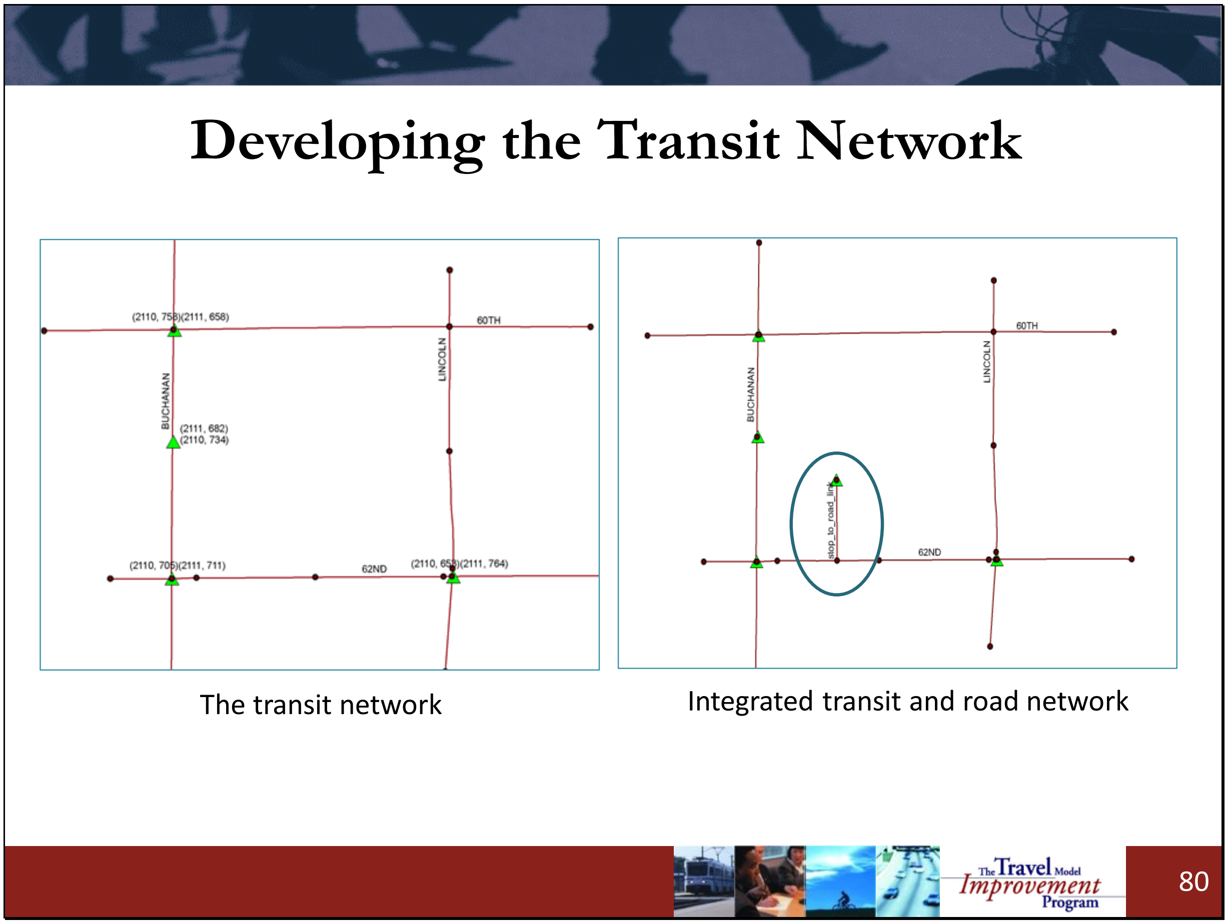
It is also interesting to map accessibility in correspondence of major freeways. This slide shows the clear impact on accessibility of intersecting freeways in the evening. These are the locations of gas stations and convenience stores.

Superimposing Transit Routes



Just superimposing transit routes over the accessibility maps we can see clearly patterns of multiple routes over higher-density environments.

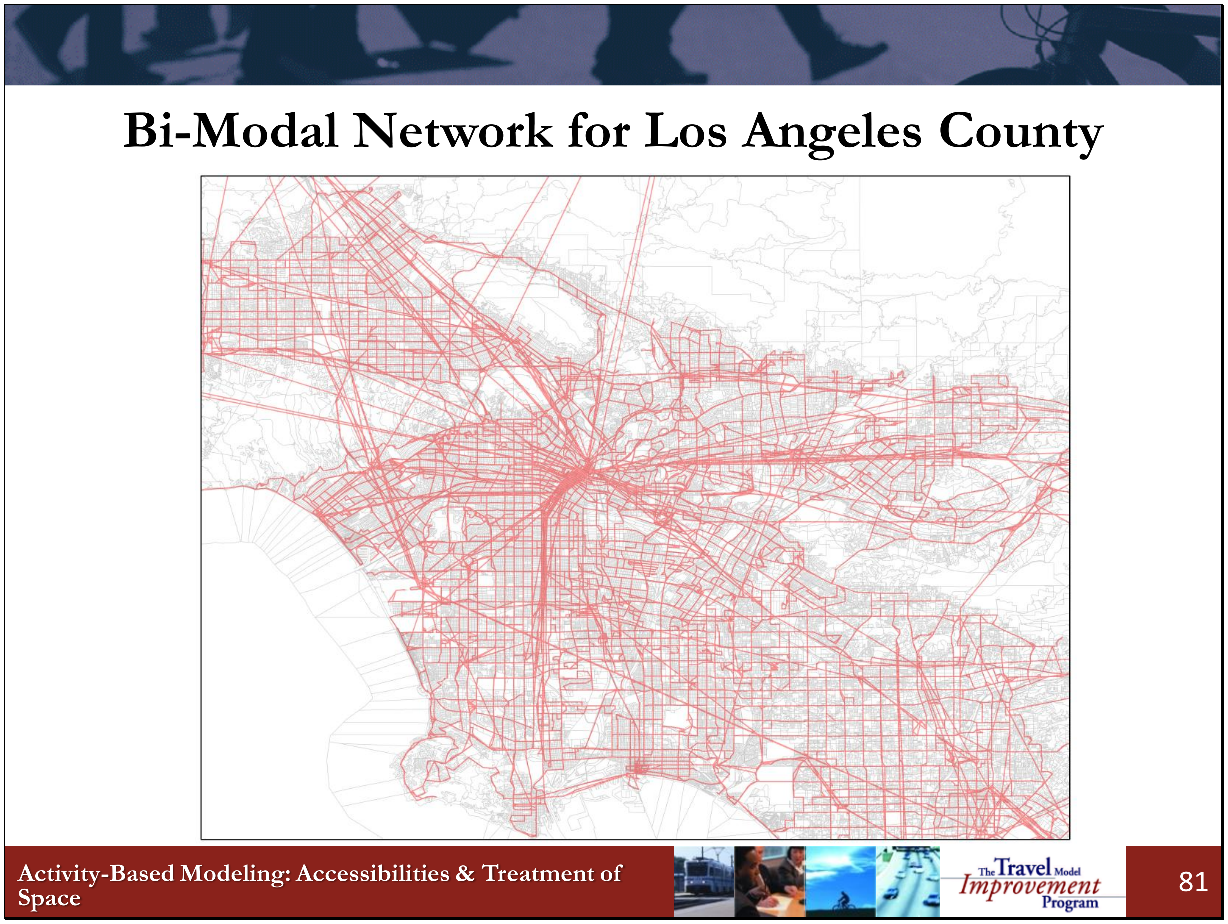
Computation of accessibility using transit information can be done using more detail. We have done this using time tables of transit agencies in Southern California. The key difference from roadway accessibility is that in transit we need to account for walking time to and from bus stops and to develop an algorithm that accounts for vehicles headways and overlapping routes. You can find more details in a TRB paper with first author Ting Lei.



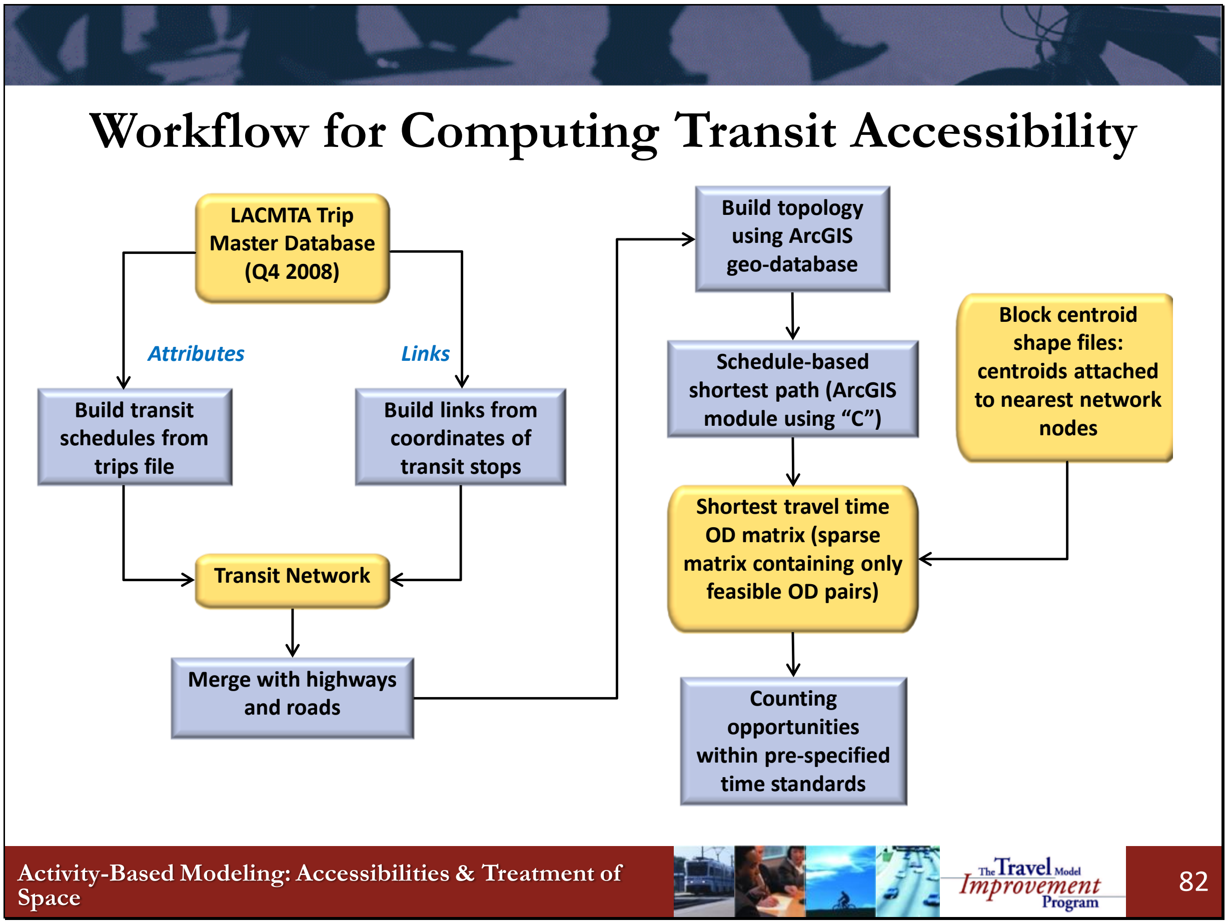
Travel by transit is bi-modal in nature. Both the transit network and the pedestrian network define possible routes of a transit trip. Therefore, the first step for modeling transit travel is to develop an integrated network containing both transit and regular road links. In practice, the network for regular roads are often readily available in a Geographic Information System. The transit network (with schedules) seldom exists in GIS. Instead, they are often provided in tabular format in terms of the schedules and coordinates of transit stops or timed points.

The first task to make the analysis work is to build a transit network from tabular data. It is typical in practice for transit authorities to publish schedules only for a subset of points of any given route called its “timed points”. They may or may not be actual stops. Therefore, the schedules for the rest of the stops in a route need to be inferred from the schedule-building program, e.g. based on their (linear referencing) distances to the immediate neighboring timed points. Once the schedules are generated, they are aggregated and stored as attributes of transit links.

The next step is to merge transit network with the regular road network. This is required because the positions of transit stops from the transit database will not typically match the road network since they come from different sources. Discrepancies between the two networks are shown in the figure below; and they are removed using GIS functions.



The combined bi-modal network thus obtained contains routes for all transit modes in the LACMTA database and it consists of 1,748 routes and 89,980 stops.



The overall workflow for computing transit accessibility is shown here. After the bimodal network is constructed, connectivity (topology) relations among transit and road links are compiled using GIS software. In this application, we used ESRI's ArcGIS. This makes the bimodal network a graph in the sense of graph theory, except that our network contains schedules in addition to the lengths of arcs in regular graphs.

A key component of this research is a shortest time path algorithm that can take advantage of the schedule information stored in the augmented network. Considering the large number of origins and destinations and the need to compute routes for all pairs of them, we implemented the schedule-based shortest path algorithm reported in a previous paper (Lei and Church, 2010) by means of adapting an efficient open source C++ library for graph algorithms.

The basic procedure is based on augmenting the well-known Dijkstra algorithm as follows:

1. Set the label for the source node to zero and the labels for all other nodes to infinity. Mark all nodes as unvisited.

2. Set the source node as the current node.

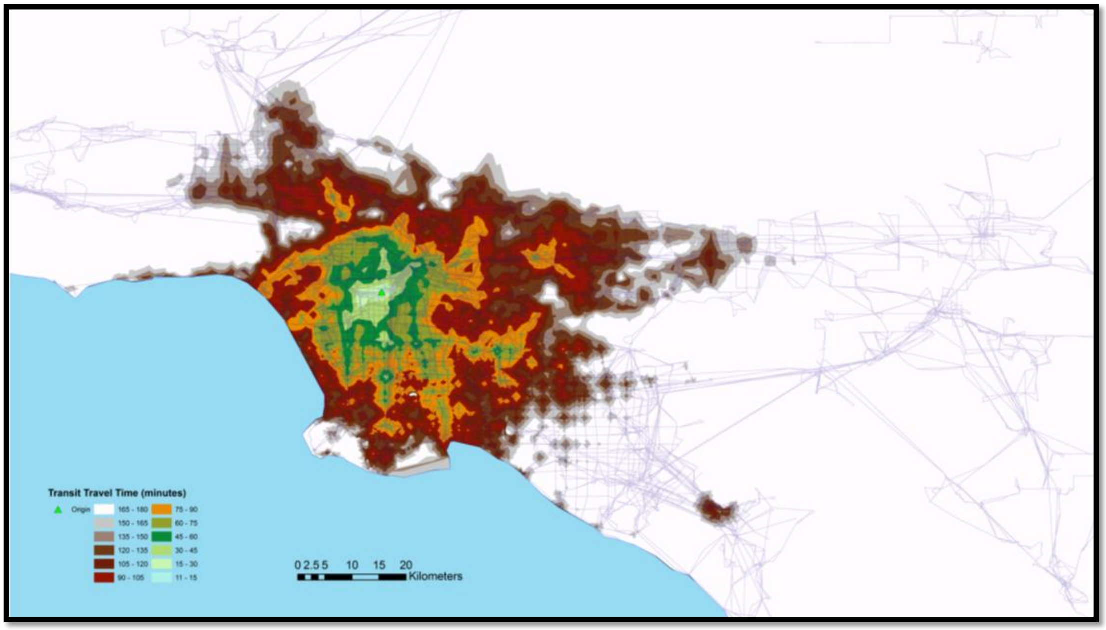
3. For the current node, calculate a tentative label for each one of its neighboring nodes by adding the label of the current node and the cost to traverse the arc connecting the current node and the neighboring node. Update the label for the neighboring node if the tentative label for the neighbor is less than its current value.

3.1. If the link connecting the current node and a neighboring node is a regular road link, then the cost to traverse the link is the length of the link divided by the traveling/walking speed.

3.2. If the connection link is a transit link, then look up the array of departure times and find the earliest departure time after the arrival time at the current node. The arrival time at the current node is just the sum of the departure time for the entire trip plus its label.

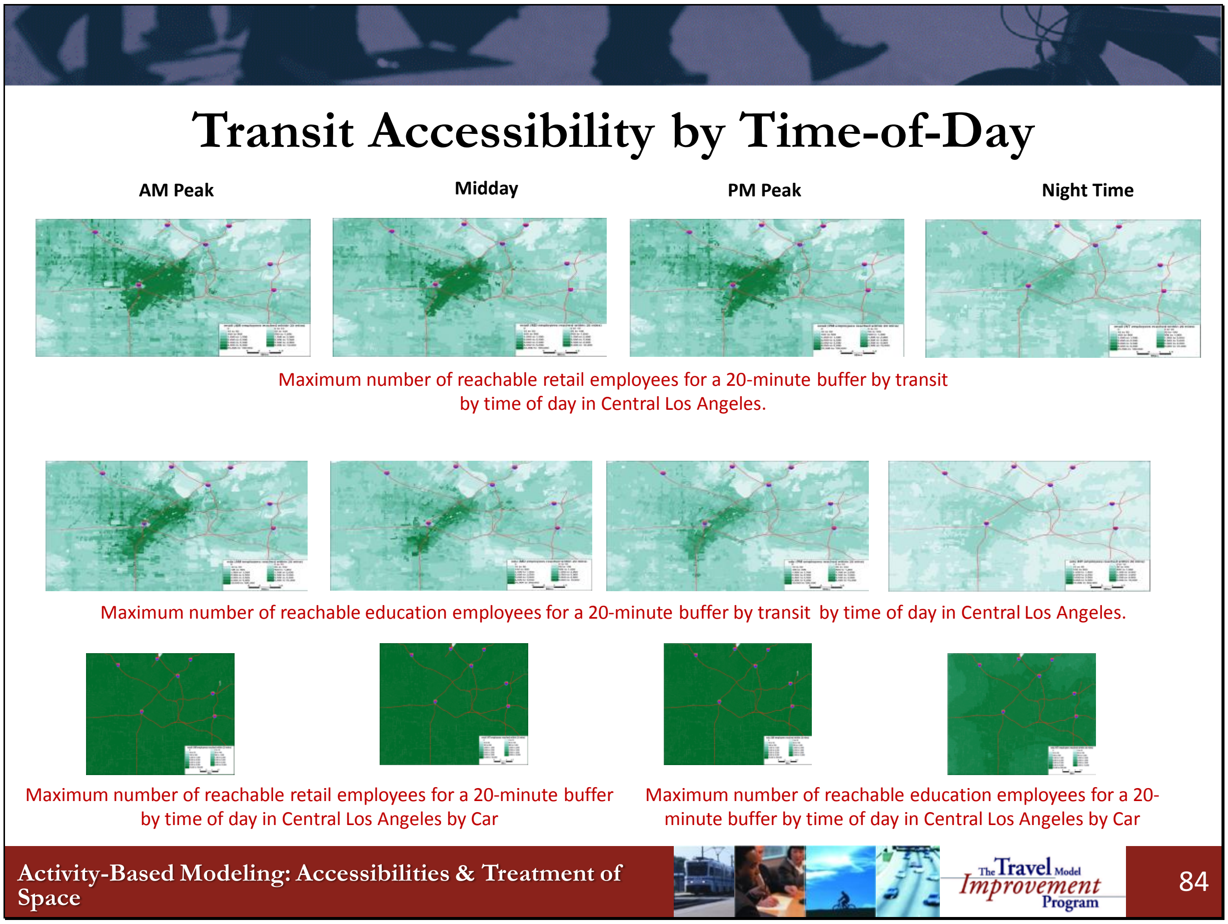
4. When all the neighbors of the current node are updated, mark the current node as visited (and its distance is now permanent). Mark the unvisited node with the lowest tentative distances as the current node repeat Step 3 until the set of unvisited nodes is empty.

Space-time Prism of Travel by Public Transit



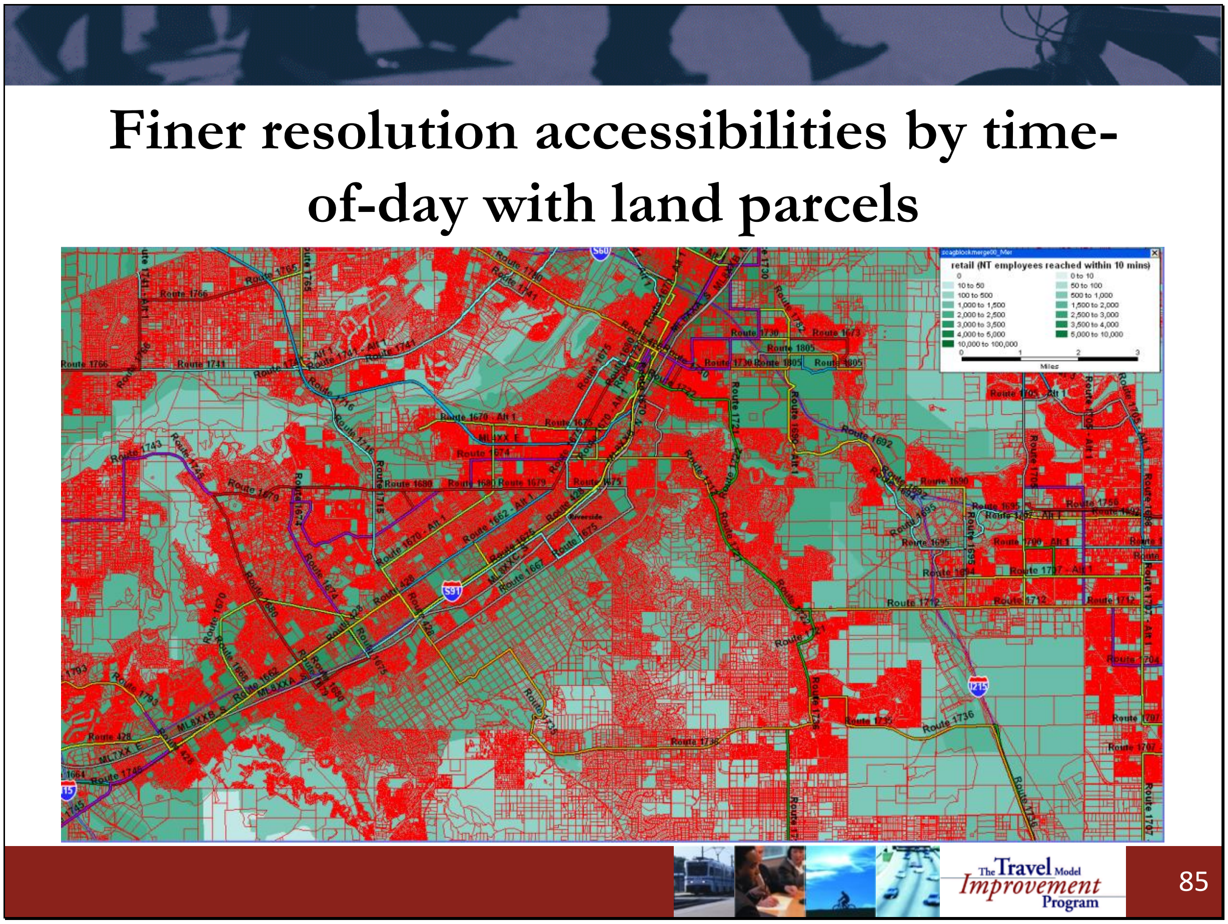
Data Source: LACMTA master trip database, Ting Lei, Jan. 2012

This isochronic map shows the space-time prism of travel by transit, starting from a given location. The distorted shape of the space-time prism footprint which follows transit routes and stops distinguishes travel by transit from travel by other modes, such as the automobile.

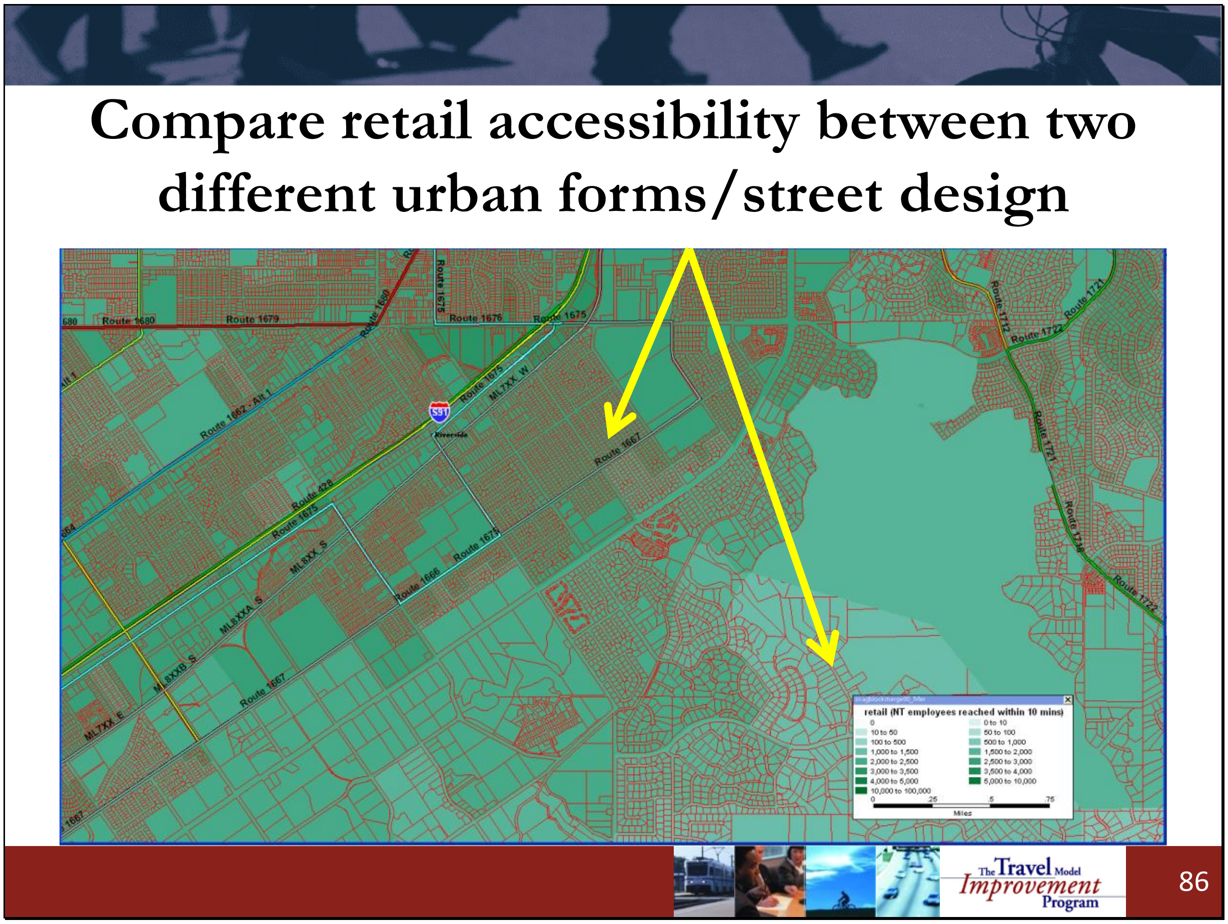


The figures in this slide show transit accessibility indicators for the retail and education type and 20 minute time buffers for four periods in a day.

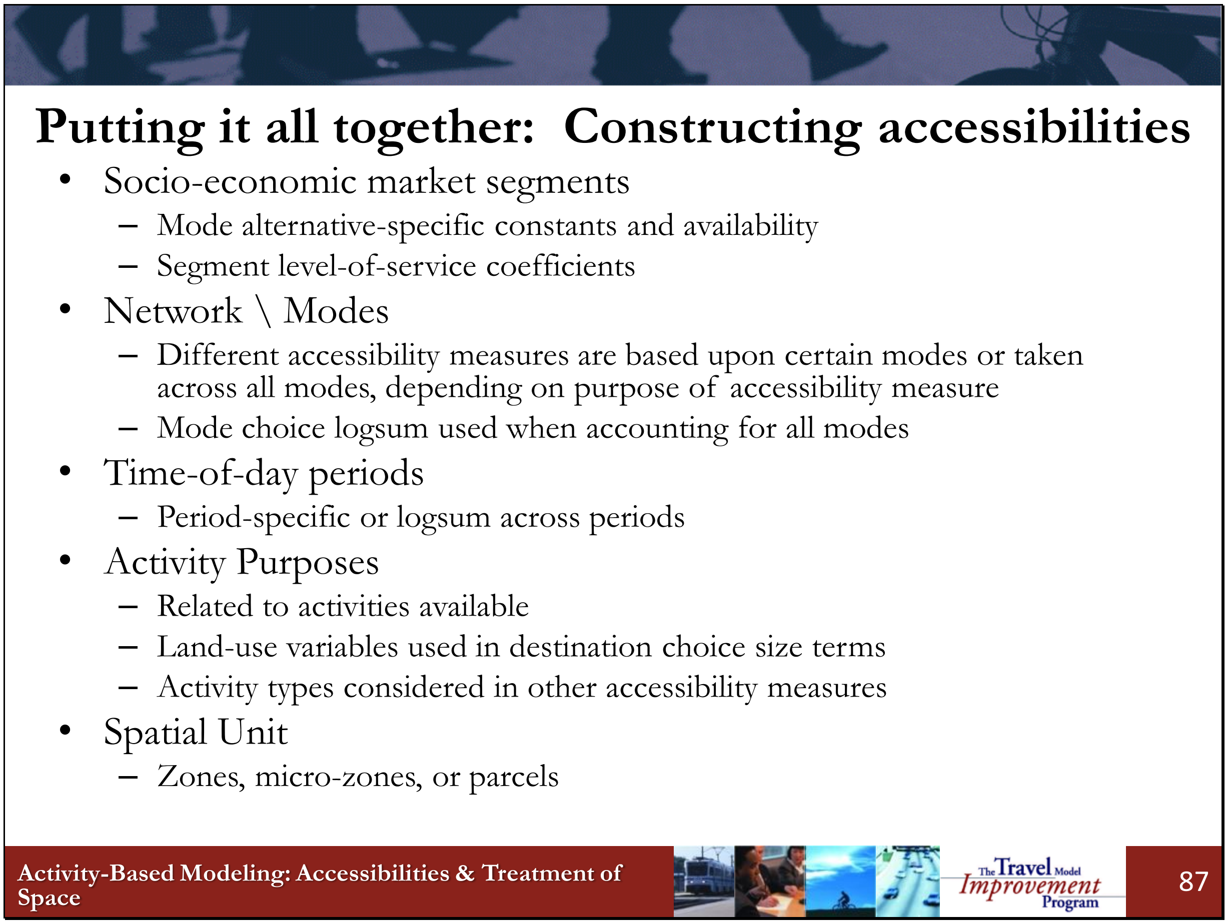
For comparison, we also show automobile accessibility indicators computed for the same region. From these figures, we can see the difference of accessibility for different types of opportunity, different times of day, and different modes of transportation.



Fine resolution accessibility indicators can also be used in activity-based models, via parcel-based data. This plot shows number of employees reached within 10 minutes by each parcel. Such information can be useful to measure the attractiveness of parcels for residential location choice models.



Fine resolution accessibility indicators can also be used to explain in a visually clear manner why we want land use policies that promote higher density and mix of activities and why cul-de-sac type of developments provide low levels of accessibility and motivate people to use their car to reach locations of greater opportunity. This slide shows the difference in accessibility enjoyed by different urban forms. The small parcels coupled with a grid street system in the middle of the map lead to better accessibility than the larger parcels located in the cul-de-sac neighborhood in the lower right portion of the map.



Now we've discussed all of the major elements of accessibilities. How do we put it all together to calculate accessibility measures? One way is to define the various combinations of each element. This includes:

Socio-economic markets: The socio-economic category is important to know the value-of-time (and therefore determine the cost coefficients to apply to tolls, transit fares and other out-of-pocket costs), and also can be used to determine alternative-specific constants for modes.

Network\mode: Accessibilities can be mode-specific. They can be calculated taking into account groups of modes (such as all transit line-haul modes), or they can be calculated across all modes.

Time-of-day periods: Accessibilities can be calculated for specific times of day, such as 9:30 A.M., or calculated across multiple time periods, reflecting a daily accessibility.

Activity purposes: Accessibilities are typically based upon travel for a specific activity purpose, such as shopping or eating out. The activity purpose relates to the size term that is considered in the destination choice model. An accessibility for shopping would typically be influenced by retail employment, for example.

Spatial unit: The treatment of space is an important consideration, and often imposes the most computational burden.

For example, a parcel-based approach to calculating accessibilities imposes substantial computational overhead, as accessibilities would need to be calculated for parcels^2 cells, times the number of markets, modes, time-of-day, and activity purposes. Assuming 1 million parcels and time in 30 minute increments, this might amount to more than 1 trillion calculations! For this reason, often trade-offs have to be made in terms of the representation of space and the temporal dimension when constructing accessibilities.

Example of Accessibility Combinations

SANDAG Activity-based Model

No	Description	Model where used	Attraction size variable	Travel Cost
1	Access to non-mandatory attractions by SOV in off-peak	Car ownership	Total weighted employment for all purposes	Generalized SOV time
2	Access to non-mandatory attractions by transit in off peak	Car ownership	Total weighted employment for all purposes	Generalized best path walk-to-transit time
4-9	Access to non-mandatory attractions by all modes	Daily Activity Pattern Model	Total weighted employment for all purposes	Off-peak mode choice logsums segmented by 3 auto sufficiency groups
16-18	Access to eating-out attractions by all modes except SOV	Joint tour frequency	Weighted employment for eating out	Off-peak mode choice logsum (HOV skims) segmented by 3 adult HH car-availability groups
43-44	Access to at-work attractions by all modes except HOV	Individual sub-tour frequency	Weighted employment for at work	Off-peak mode choice logsum segmented by adult 2 car-availability groups

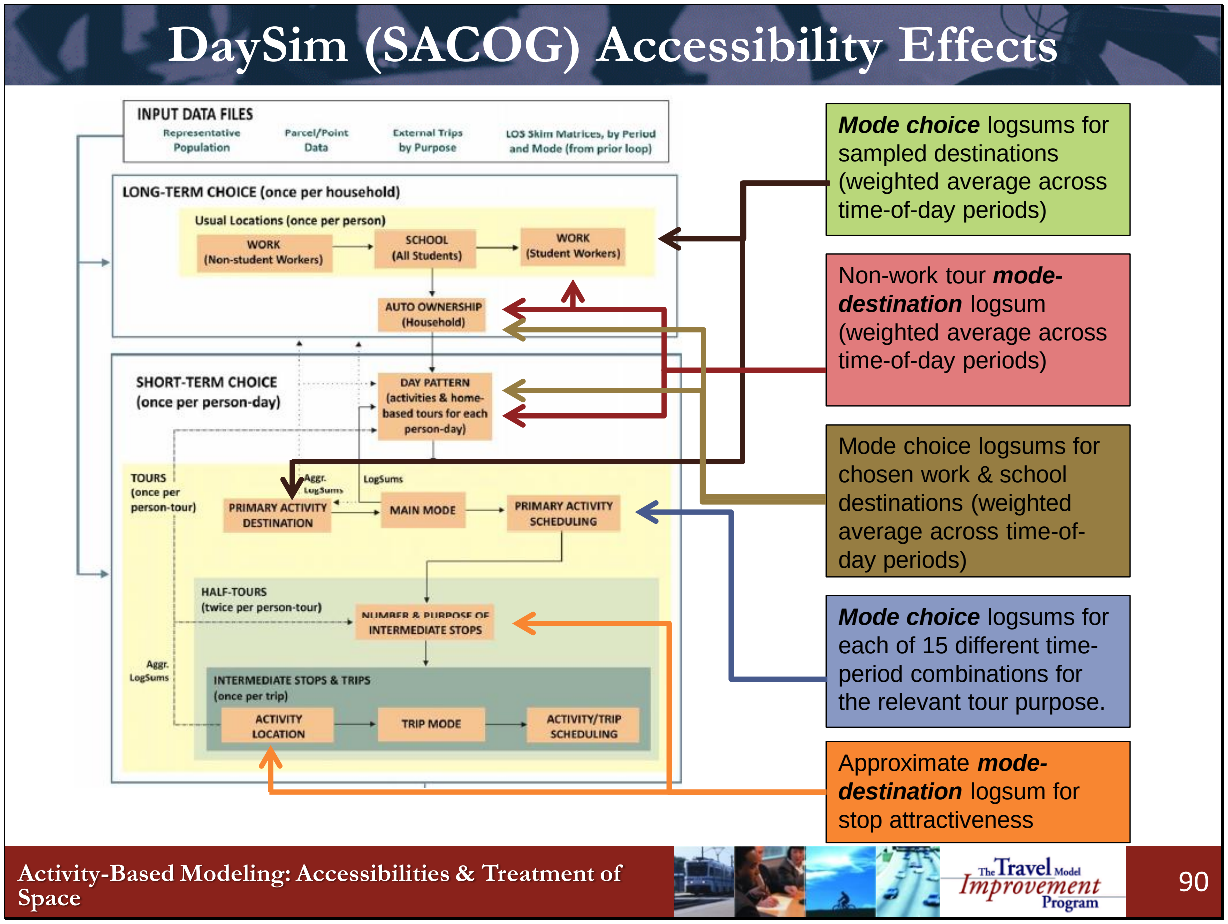
Here is an example of how the accessibilities for the SANDAG model were defined. There are a total of 50 different origin-based accessibility measures. They are defined based upon the period of travel considered, the modes considered, the market segmentation considered, and the activity purposes considered. The spatial system used is the micro-zone. Software is optimized so that various elements of accessibilities, such as the travel cost variables or the size term variables, are re-used to the maximum extent possible. This results in accessibilities that can be calculated in less than 10 minutes (for 50 variables, across 22,000 micro-zones).

Here are the data needs required for calculating accessibility variables. Networks are required by time-of-day. They are skimmed for each time period of interest. Since various components of time and cost are saved, this can result in a large number of matrices.

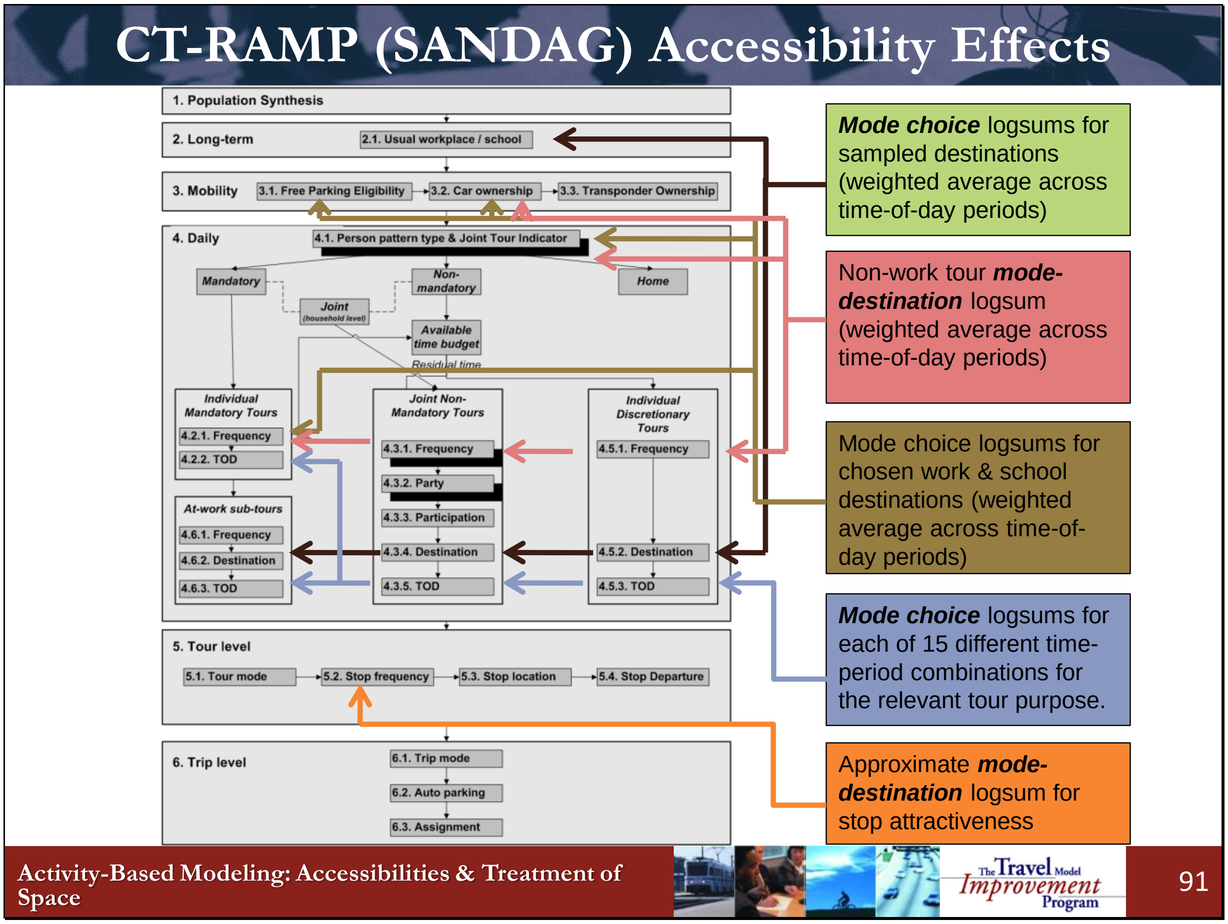
Land-use data is required at the zone, micro-zone, and/or parcel level. This typically includes households and population by type (which must be consistent with the synthetic population) and employment by type. Land-use design and density information is also required.

Household survey data (and transit on-board survey data) is used to determine the coefficients on in-vehicle and out-of-vehicle time and cost, socio-demographic variables, and size term coefficients which state the relative attractiveness of different types of land-use for different activity purposes. Household and/or transit on-board data is also used to estimate the effect of accessibility variables on travel behavior. For example, how sensitive is auto ownership to retail employment accessibility? How sensitive is the number of tours generated to the accessibility of home and work? We will explore these relationships further in subsequent webinars.

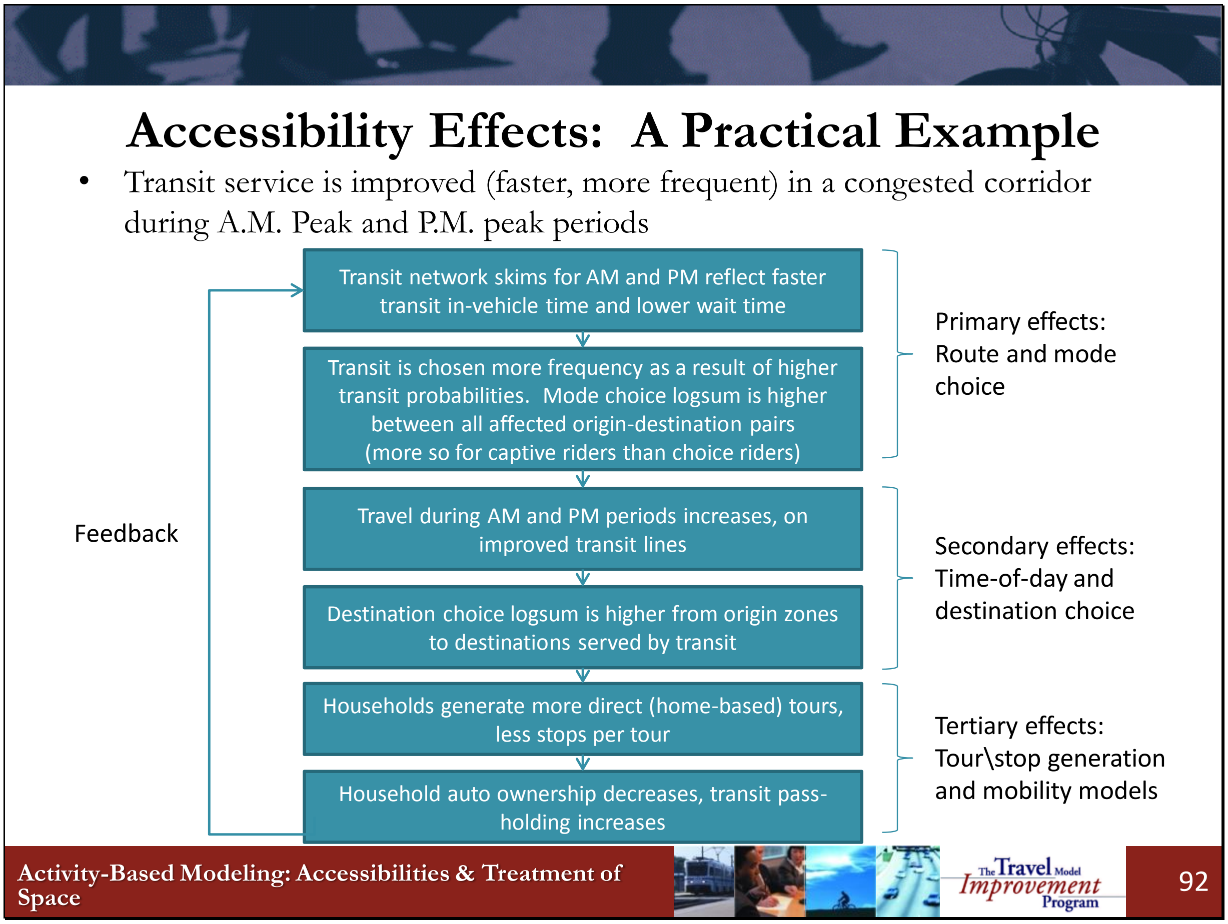
In forecasting, the coefficients are typically held constant, and the input networks and land-use data are changed to reflect forecasted network supply and development patterns (either assumed land-use or predicted from a land-use model). The model system is then run to determine the effect of accessibilities and other changes in the model inputs on travel behavior and network performance.



This slide shows different types of accessibilities and what model components they effect in the Sacramento, California version of the DaySim model. Besides the standard level-of-service matrices (times and costs) that are used in mode and destination choice models, the system relies on two key types of accessibility measures: mode choice log-sums and destination (a.k.a. mode-destination) choice log-sums. The mode choice log-sums vary by whether they are for sampled or chosen destinations, and what purposes and time period(s) are considered, whereas the destination choice log-sums vary by purpose, typically with weighting across periods.



This slide shows the same sorts of accessibilities as the previous slide, and their consideration in the San Diego version of CT-RAMP. There are some differences between the exact purposes and time period definitions between the model systems, but also a good deal of consistency in their general definition and impact on the various model components.



Here is a practical, concrete example of how an activity-based model might respond to network scenario. In this scenario, we are modeling increased transit service in a congested corridor during the AM and PM peak periods. The change is coded into our transit network and the model system is run. 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) and in mode choice (transit will be chosen more frequently for trips and tours in the corridor). These are all primary effects of the transit improvement, and these effects are typically considered in a four-step trip-based model.

An activity-based model will also typically consider secondary and tertiary effects, that the four-step model does not. These include time-of-day and destination choice impacts. The transit improvement will produce a higher-value mode choice log-sum for affected zone pairs. The time-of-day choice model considers the improvement in mode choice log-sum, causing more transit riders to choose to travel in the AM and PM peak periods (as a result of the improvement in log-sums). 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 mode choice log-sum also affects destination choice; more travelers will choose destinations in the improved corridor, since the relative accessibility of this corridor has improved.

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 accessibility variables.

Learning summary

- Describe why accessibilities are important in activity-based models
  - Measure the effects of network and land-use changes on travel behavior
  - Provide linkages from lower level model components, such as mode choice, to upper level components, such as tour generation and auto ownership
- List important dimensions of accessibilities
  - Spatial representation (zones, micro-zones, parcels)
  - Network\modes considered
  - Time period(s) considered
  - Activities considered
- Identify three main types of accessibilities
  - Buffer-type variables
  - Mode choice logsums
  - Destination choice logsums

In today's session, we covered the treatment of space and the calculation of accessibilities in activity-based models.

Accessibilities variables are important because they convert the times and costs provided by the transportation network to the land-use system. They are used to represent the alternatives available in lower level model components, such as mode choice, on upper-level model decisions, such as the number and complexity of tours generated and the number of autos owned.

The important dimensions of accessibilities include the level of detail in the spatial system, the networks and modes considered, the time periods for which accessibilities are calculated, and the activity purposes and/or land-uses considered.

The main types of accessibilities used in activity-based models are buffer-type variables, mode choice log-sums, and destination choice log-sums.

Questions and Answers

The Travel Model Improvement Program

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 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

Once again, here is the schedule for the webinar series. Our next webinar, three weeks from today, will cover long-term choice models such as work and school location choice, and medium-term mobility models such as auto ownership, transit pass-holding, and parking reimbursement.

Thank you!

Continue the discussion online…

The new TMIP Online Community of Practice includes a Discussion Forum where members can post messages, create forums and communicate directly with other members. Simply sign-up as a new member, navigate to http://tmiponline.org/Community/Discussion-Forums.aspx?g=posts&t=523 and begin interacting with other participants from today's webinar session on Activity-Based Modeling.

Session 6 Questions and Answers

Is there any basis for using mode choice log-sums that omit bias constants?

Kostas: There may be a reason for log-sums that omit alternative-specific constants. However, there are problems with using them. The main problem is that the choices may not be consistent. For example, let's assume that transit has a negative constant for riders from auto-sufficient households. Let's further assume that the mode choice log-sum were used as the measure of impedance in destination choice. Finally, let's assume that transit is improved between some zone-pair. The effect of the transit improvement on the mode choice log-sum would be much higher without the negative alternative-specific constant than with it. That would lead to a higher probability of selecting the destination than would otherwise occur, and more travelers would select it as a result. Then those travelers would need to choose a mode, in which (presumably) the utility for transit would include the negative constant. This would mean that the utility of choosing transit would be inconsistently lower than the number of travelers who selected the zone. As a result of improving transit, the model might predict many more travelers choosing to drive to the zone – certainly not a reasonable outcome or prediction. For this reason, consistency between log-sums is very important.

The Green Book (A Policy on Geometric Design of Highways and Streets) states that the typical pedestrian will not walk over 1 mile to work, ½ mile to catch a bus, and about 80% will not travel over 1/2 miles. On slide 33 a distance of 3 miles is used. Is there a reason for this? Is this based on a study of this city?

Joel: First of all, we should be careful not to base our models on policy manuals whose research may be outdated or developed by committee. It is important to design models that reflect local conditions as well as potential effects of future policies. Secondly, the thresholds used for modal availability need to be set at the upper limits of the behavior that is being modeled. It may be that 80% of travelers will not walk over ½ mile, but that is only 80% of a distribution that includes some travelers walking 1.5-3 miles. This distribution is represented in our models by a negative parameter on distance. As distance increases, the utility of walking, and therefore the probability of walking, decreases. We want to set thresholds to cover 95% or more of the distribution. In other words, we want to set the threshold at the point at which the cumulative probability of choosing the alternative is 95% or higher, and let the parameter on distance control for the probability. We do not want to set thresholds based upon the average observed distance (or 50% of the cumulative probability distribution).

Do workers in the LA model choose specific jobs? Is their occupation modeled? Are workplace surveys necessary to inform the calibration of these models?

Kostas: The SCAG ABM does not use occupation in the model. Workers choose zones based upon the employment in the zone. They are then allocated to smaller geography. The model was not developed based upon workplace survey data, but such data may be useful to validate the predictions of workers at specific workplaces or for different types of employment. There are other models that do use occupation type when choosing workplace. Workplace location choice will be covered in detail at the next webinar in 3 weeks.