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

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2012 Activity-Based Modeling Webinar Series

Executive and Management Sessions	
Executive Perspective	February 2
Institutional Topics for Managers	February 23
Technical Issues for Managers	March 15
Technical Sessions	
Activity-Based Model Frameworks and Techniques	April 5
Population Synthesis and Household Evolution	April 26
Accessibility and Treatment of Space	**May 16**
Long-Term and Medium Term Mobility Models	June 7
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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

Learning Outcomes

By the end of this session, you will be able to:

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

Webinar Outline

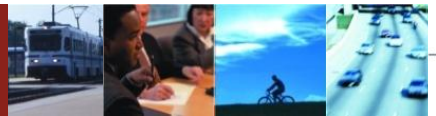
- Basic terminology
- Need for accessibility measures
- Important dimensions of accessibilities
- Data needs
- Types of accessibilities
- Impact of accessibility on activity and travel choices
- On-going research
- Questions and answers

Terminology

- Skims
- Density\Area type classification variables
- Continuous accessibility variables
- Mode choice logsum
- Destination choice logsum

Key Concepts

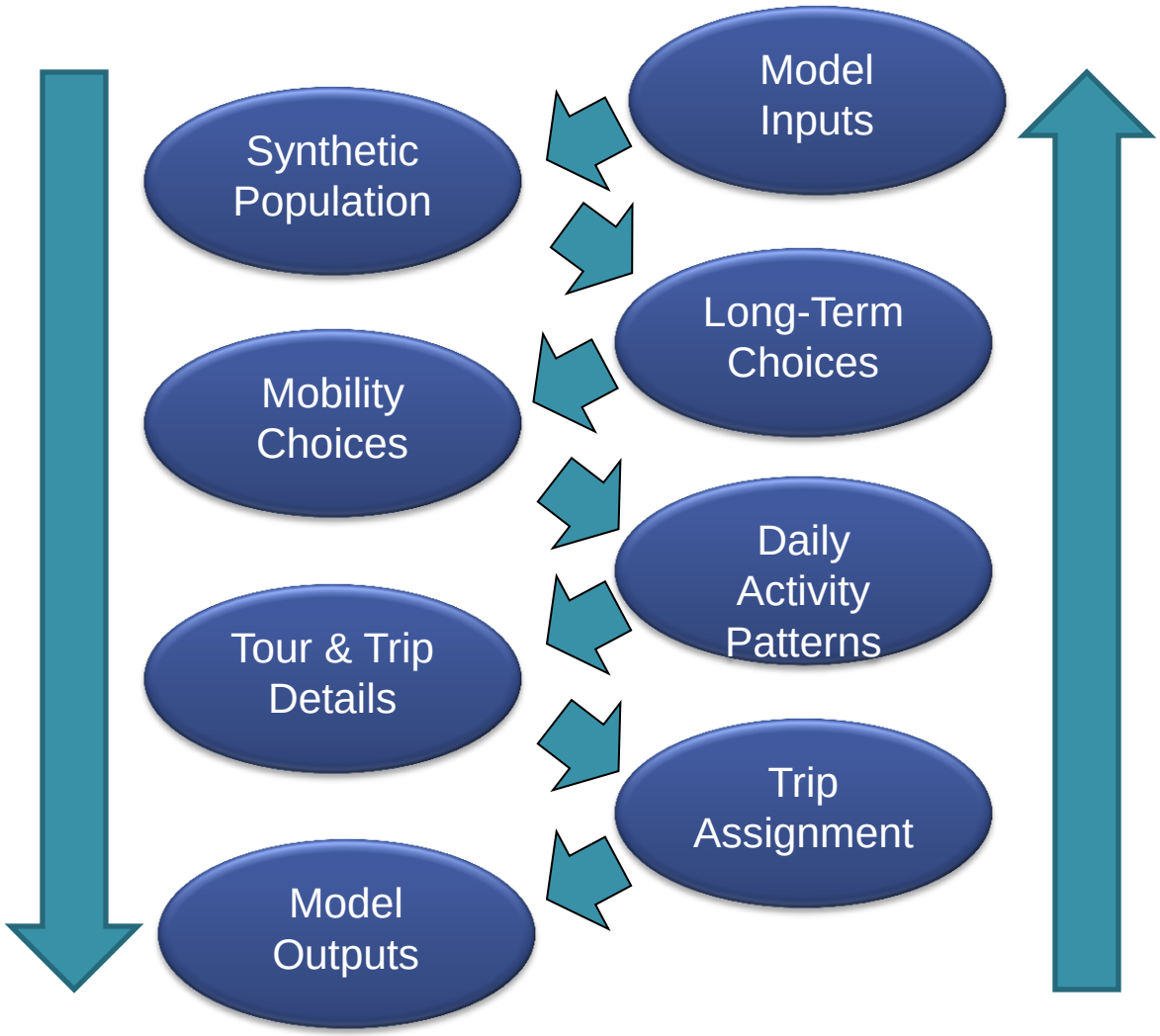
- There is a growing recognition that accessibility affects a wide range of travel dimensions:
  - Route choice
  - Mode choice (including car occupancy)
  - Time-of-day choice
  - Tour and stop destination choice
  - Daily activity pattern generation
  - Car ownership choice
  - Workplace and Residential location choice
- Accessibilities are used to represent the influences of transport policy, land-use policy, development patterns, geographical constraints, and congestion on these choices



Accessibilities

Downward Integrity:

Choices made in higher models affect choices made in lower models



Upward Integrity:

Expected utility of making choices in lower models affect choices made in higher models

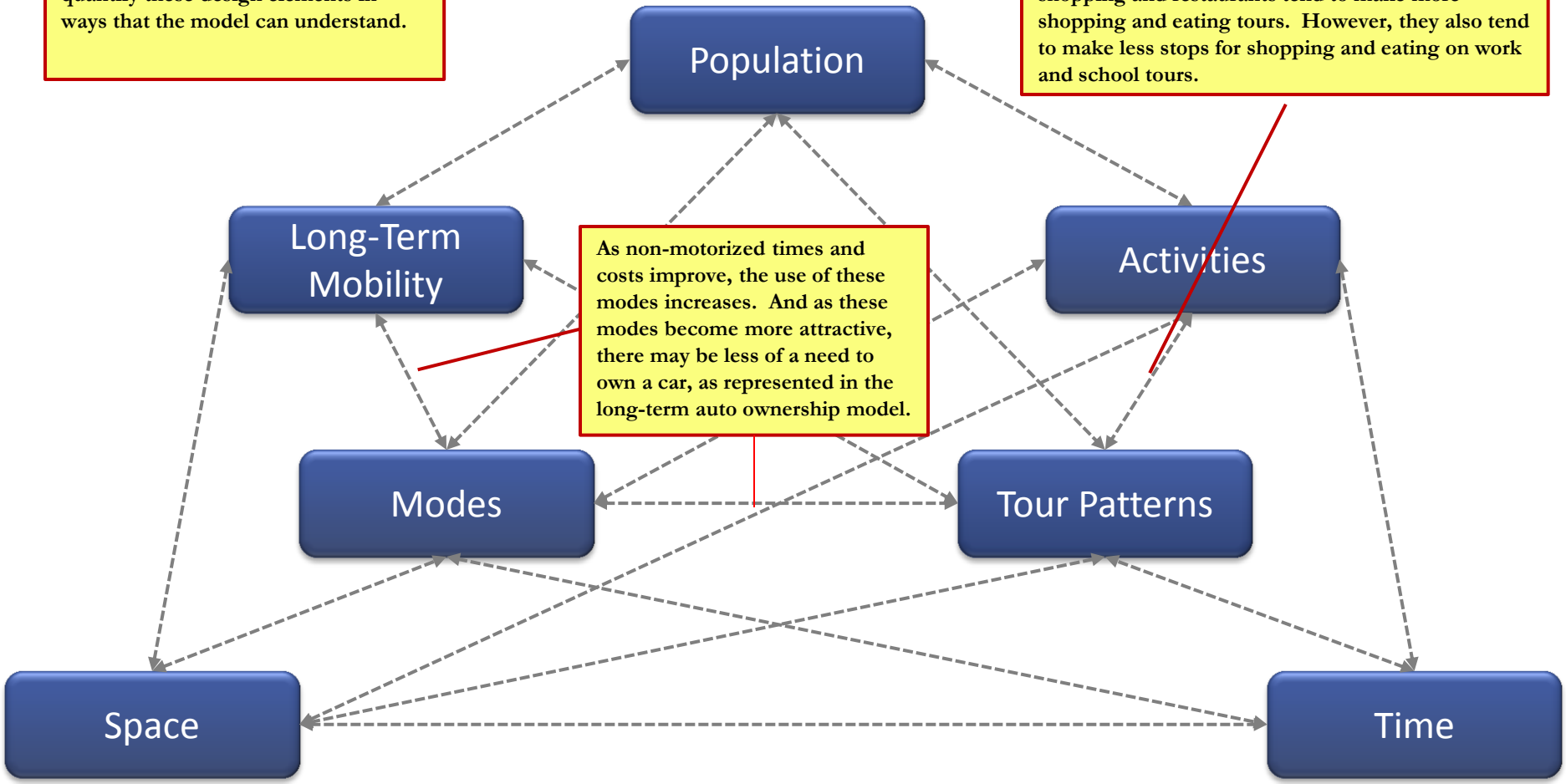
Defining Accessibility

- Origin-Destination Based:
  - How long will it take to get from home to work?
  - How long will it take to get from home to work by transit at 9:30 AM?
  - How accessible is work from home at 9:30 A.M. by all modes of transport?
  - How accessible is work from home throughout the day by all modes of transport?
- Origin-Based
  - How many shopping opportunities can I get to from my home?
  - How many shopping opportunities can I get to from my home by transit at 9:30 A.M.?
  - How accessible is my home to shopping opportunities at 9:30 A.M. by all modes of transport?
  - How accessible is my home to shopping opportunities throughout the day by all modes of transport?

Relations between activity model design elements

Accessibilities relate most to the definition of space, modes, time, and activities. Accessibility measures quantify these design elements in ways that the model can understand.

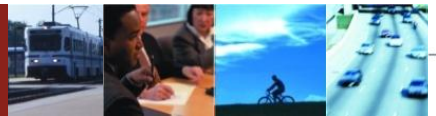
Access to activities influences the types of tours generated and their complexity. For example, people who live in areas that are highly accessible to shopping and restaurants tend to make more shopping and eating tours. However, they also tend to make less stops for shopping and eating on work and school tours.



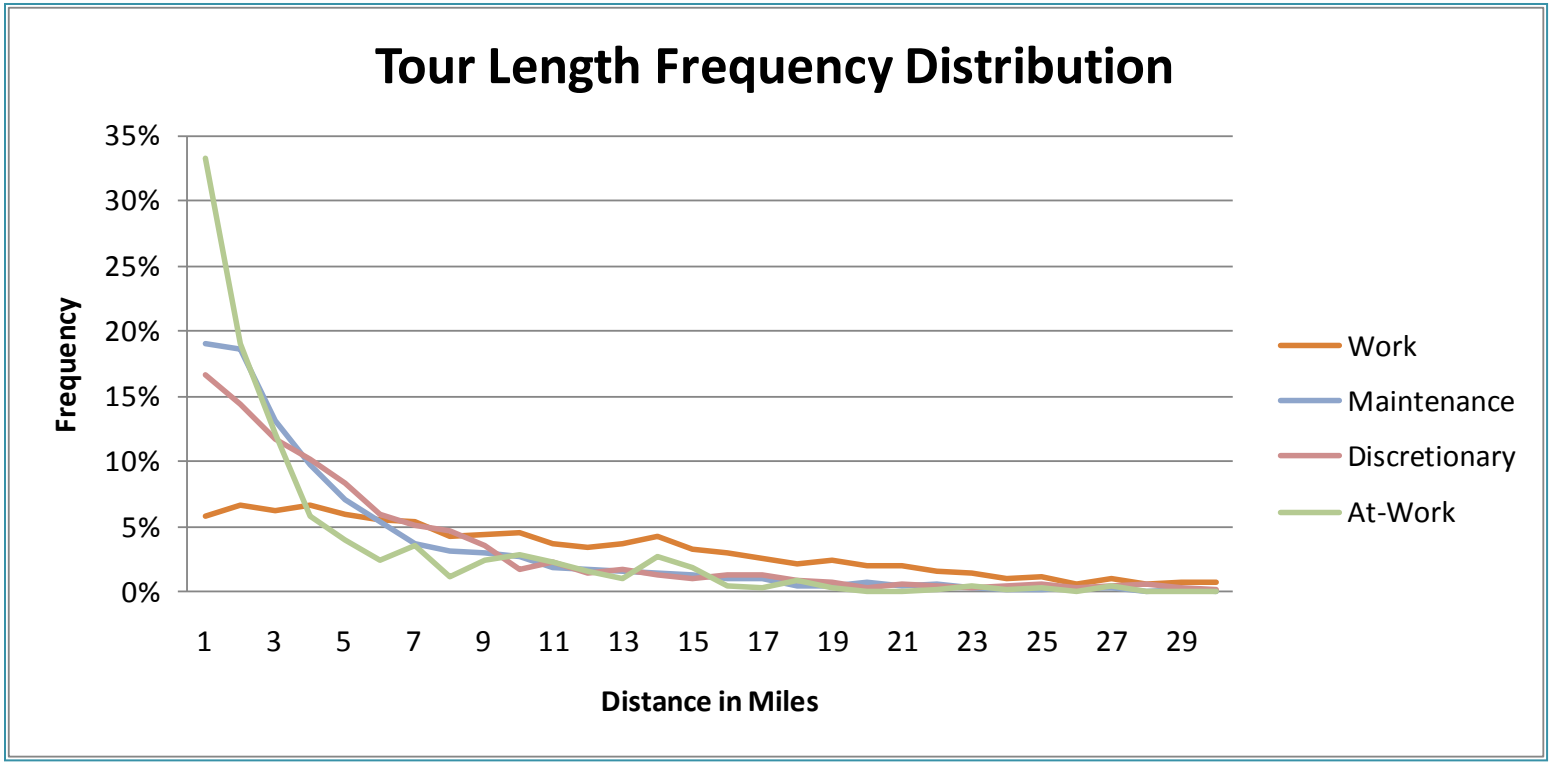
As non-motorized times and costs improve, the use of these modes increases. And as these modes become more attractive, there may be less of a need to own a car, as represented in the long-term auto ownership model.

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



Tour Length Frequency Distributions

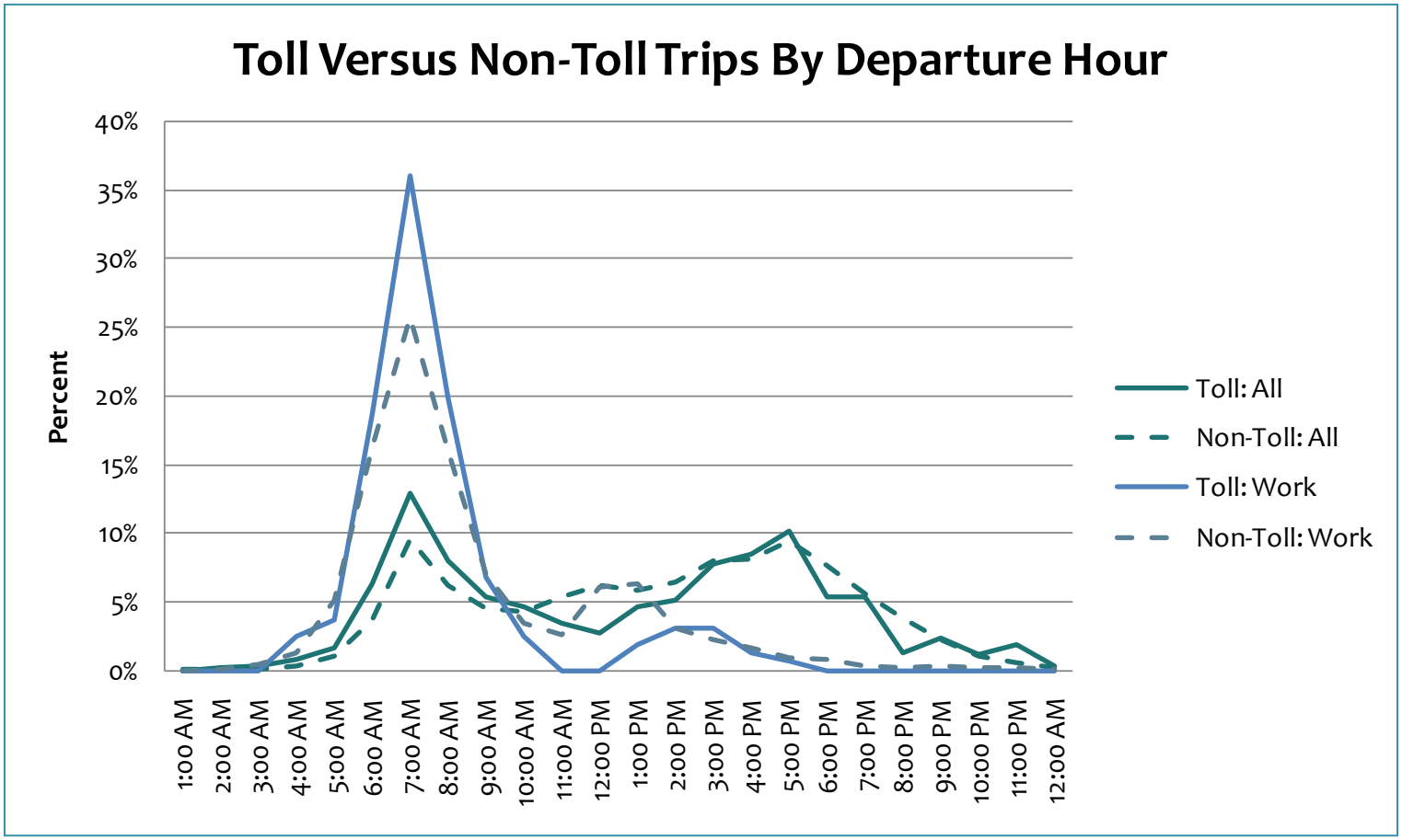


Source: 2005 San Diego Household Survey Data, San Diego Association of Governments

Purpose of tour is an important consideration

- Mandatory travel tends to be longer than maintenance or discretionary
- At-work sub-tours tend to be very short (e.g. travel to lunch\meetings)

Accessibility Impact on Time-of-Day Choice



Source: 2011 Atlanta Regional Commission Household Survey Data, Atlanta Regional Commission

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

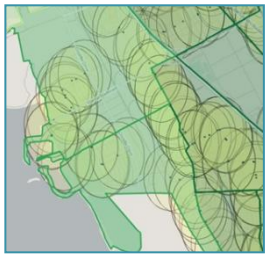
Dimensions of Accessibility Variables

- Spatial system (destinations)
  - Zones, sub-zones, or parcels
- Modes
  - Auto, transit, non-motorized
  - HOV\Toll
  - Proper weighting of in-vehicle, out-of-vehicle, and cost attributes
- Markets (household\person types)
  - Different market segments have different values-of-time, mode shares
  - Typical market segments are auto sufficiency, income, household size
- Time periods
  - To reflect different levels of congestion and supply
  - Peak\off-peak or more fine-grained
- Activity purposes
  - Different land-use types are important for different activity purposes
  - Typical activity purposes have been listed in other presentations (mandatory, maintenance, discretionary)

Data Required for Accessibility Measures

- Zoning system(s)
- Transport networks and associated skims
  - By mode
  - By time-of-day
  - By market? (e.g. income group)
- Land-use data
  - Synthetic population
  - Employment by category
  - Parking supply, cost
  - '4D variables' – intersection density, sidewalks, topology, etc.
- Survey data
  - Household survey data, properly weighted and expanded
  - Required to estimate size term, parameters

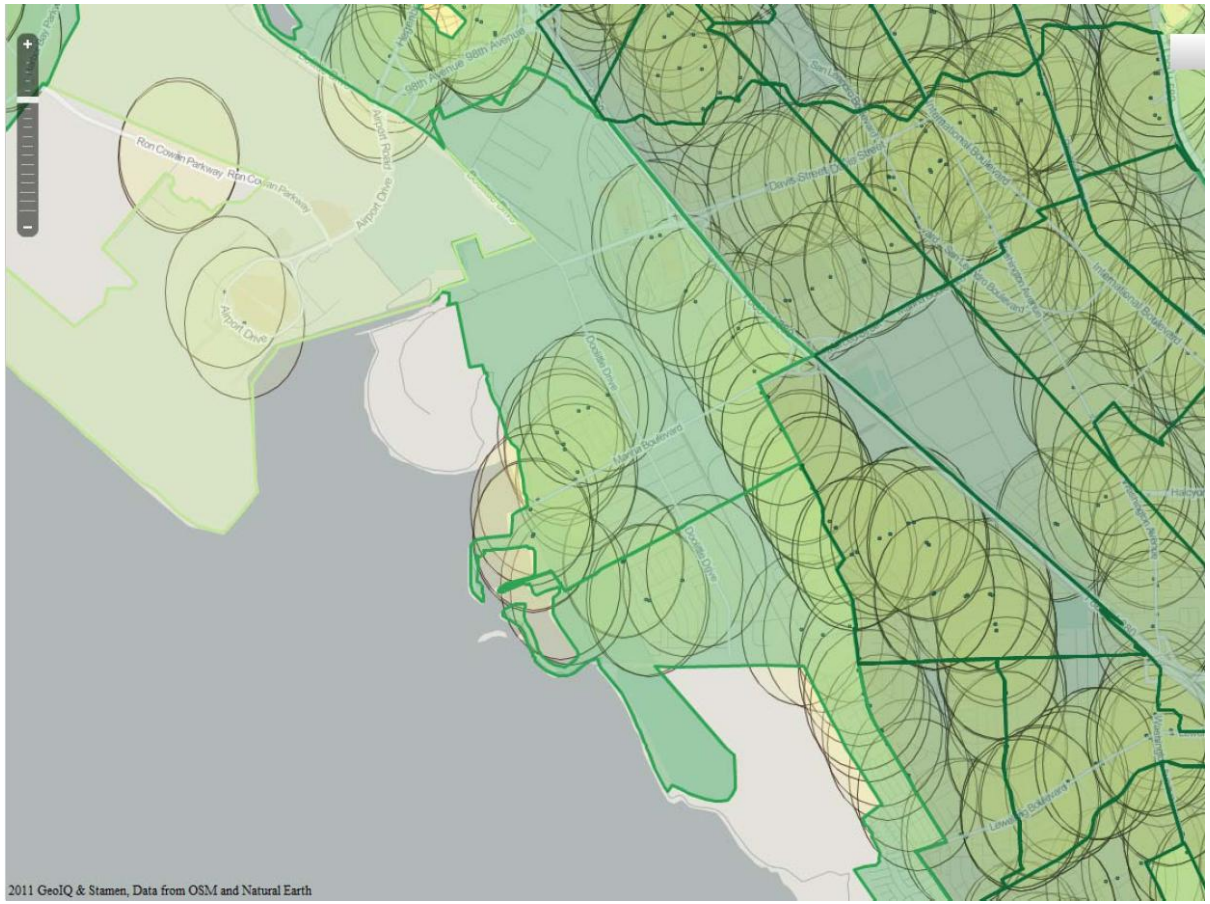
Spatial Systems

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	

Metropolitan Transportation Commission Transportation Analysis Zones

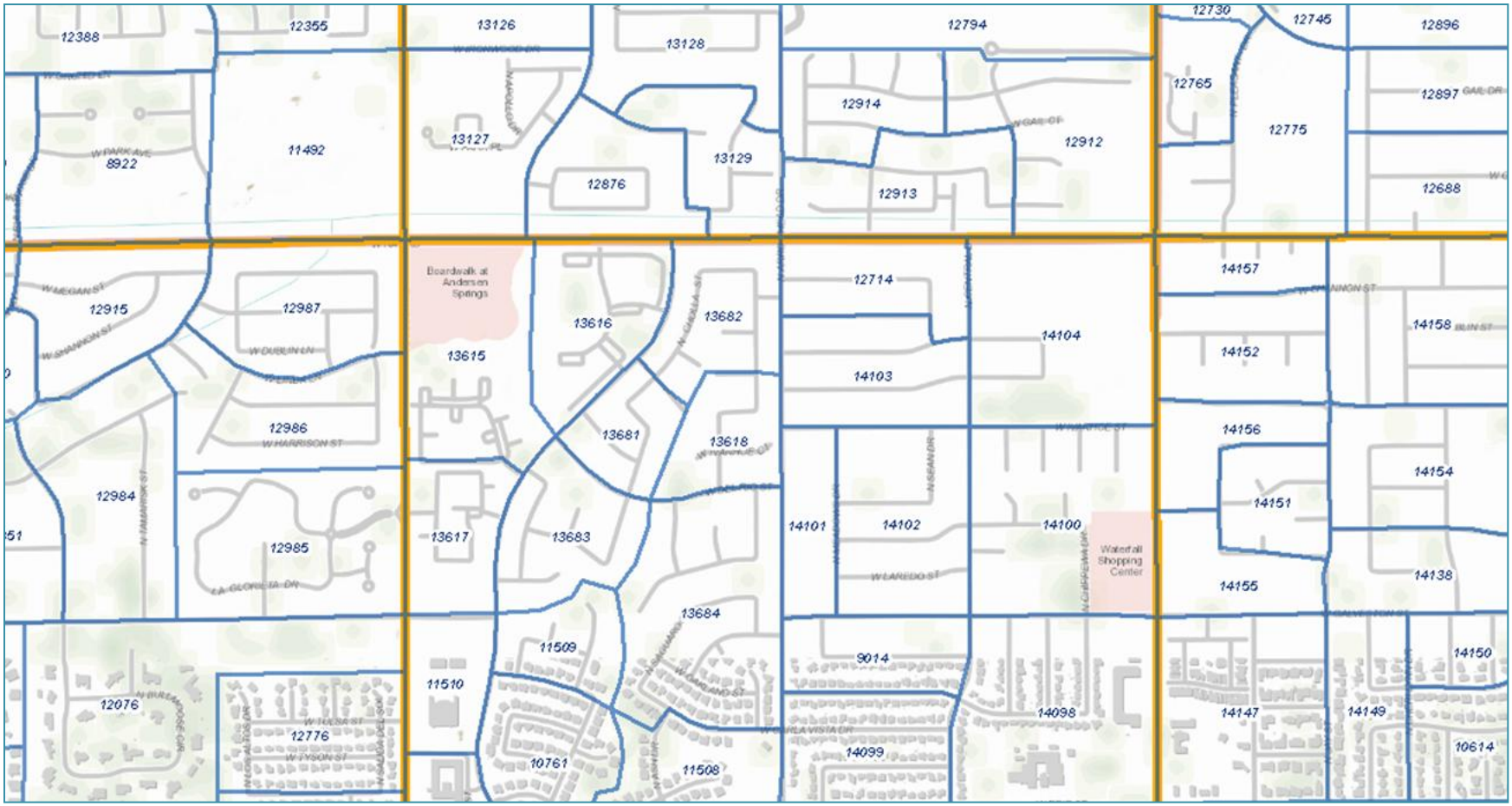
Metropolitan Transportation Commission Sub-zone Map

Walk accessibility defined by area within 1/3 mile of transit stops



Micro-zones

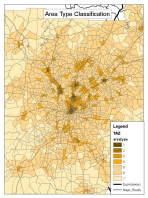
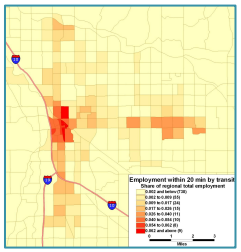
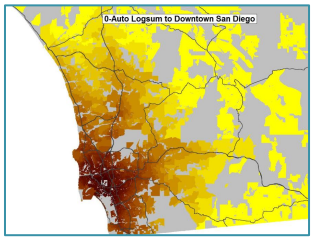
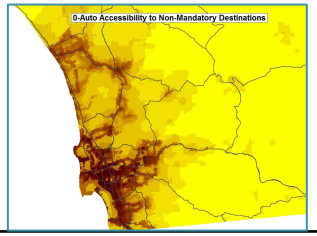
(Maricopa Association of Governments)



Parcels

(Sacramento Area Council of Governments)

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	

Area Type Stratification ("Dummy") Variables

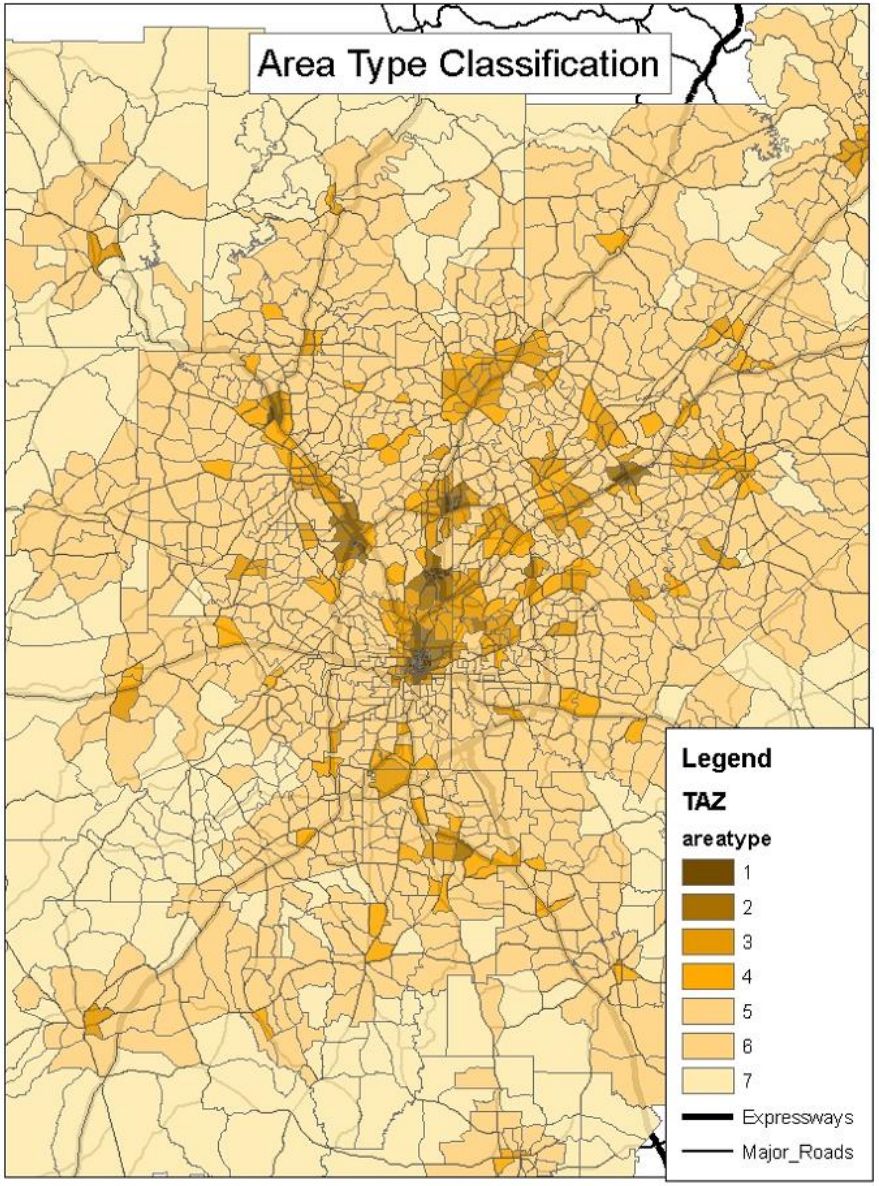
Population Density$_i$ = population$_i$ / acres$_i$ * 0.25

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

Atlanta Regional Commission Area Type Map



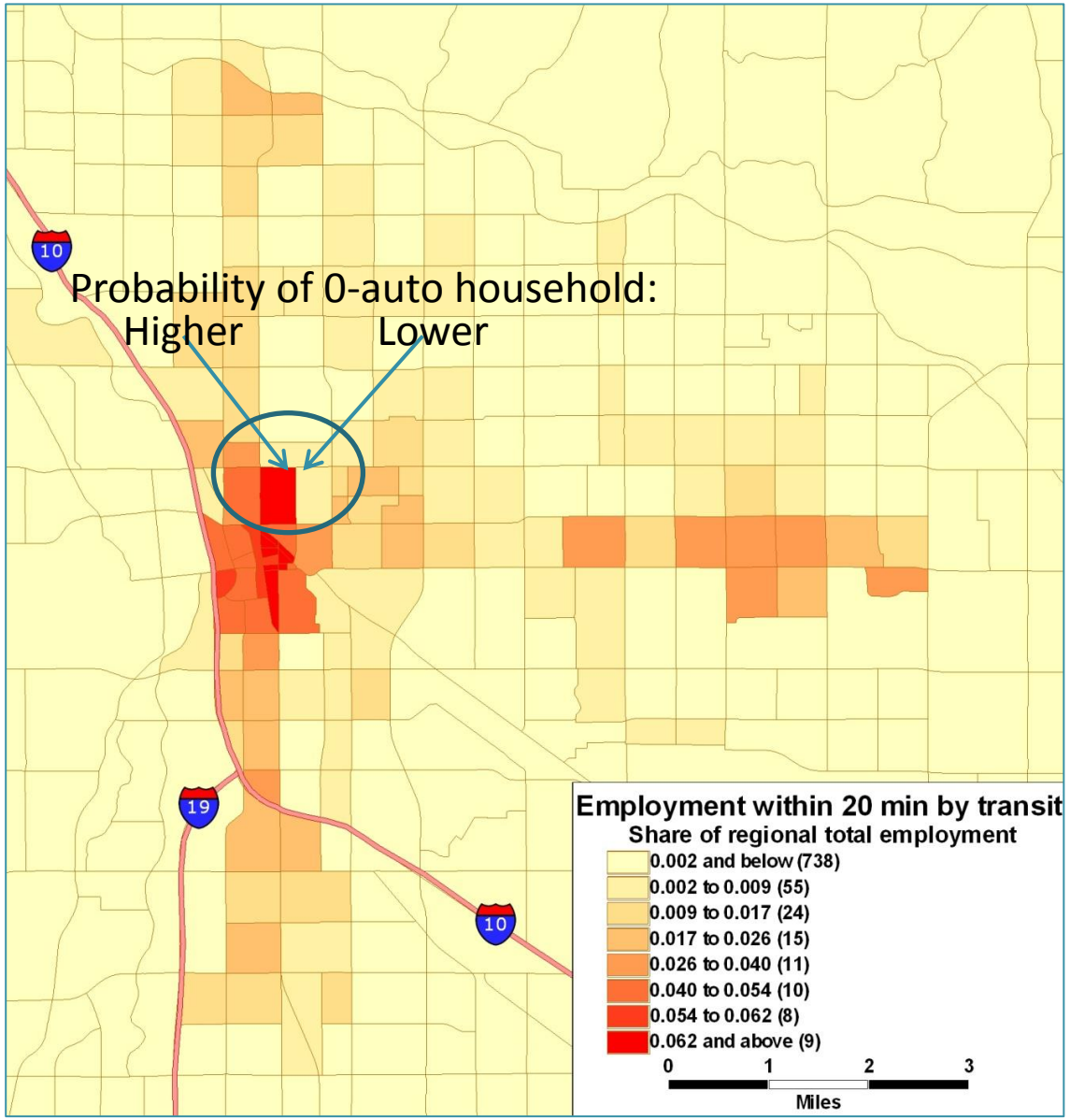
- Easy to calculate and use
- However, does not consider:
  - transport accessibility
  - purpose of travel
  - temporal affects
- And is somewhat 'lumpy'

Buffer Variables

$$Emp_i = \sum_{j=1}^{n} Emp_j * [TransitTime_{ij} \leq 30]$$

- Total retail employment within 30 minutes of transit service
  - Advantages
    - Relatively easy to calculate, interpret
    - Utilizes both network level-of-service and relevant land-use data
  - Disadvantages
    - Cliff effects
    - Proper weighting for in-vehicle\out-vehicle components?
    - Only one mode, time-period, land-use category

Pima Association of Governments Transit Buffer Map



Networks in accessibilities: Why are networks important?

- Reflecting transport options in accessibilities
  - How will construction of new highway\transit infrastructure affect the propensity to travel?
  - How would toll roads\congestion pricing affect travel behavior?
- We want a measurement of the accessibility provided by all modes of transportation (multi-modal accessibility)
- The measure should weight components of time and cost provided by each mode according to traveler perceptions
- The mode choice logsum is often chosen as an accessibility variable because it satisfies these conditions

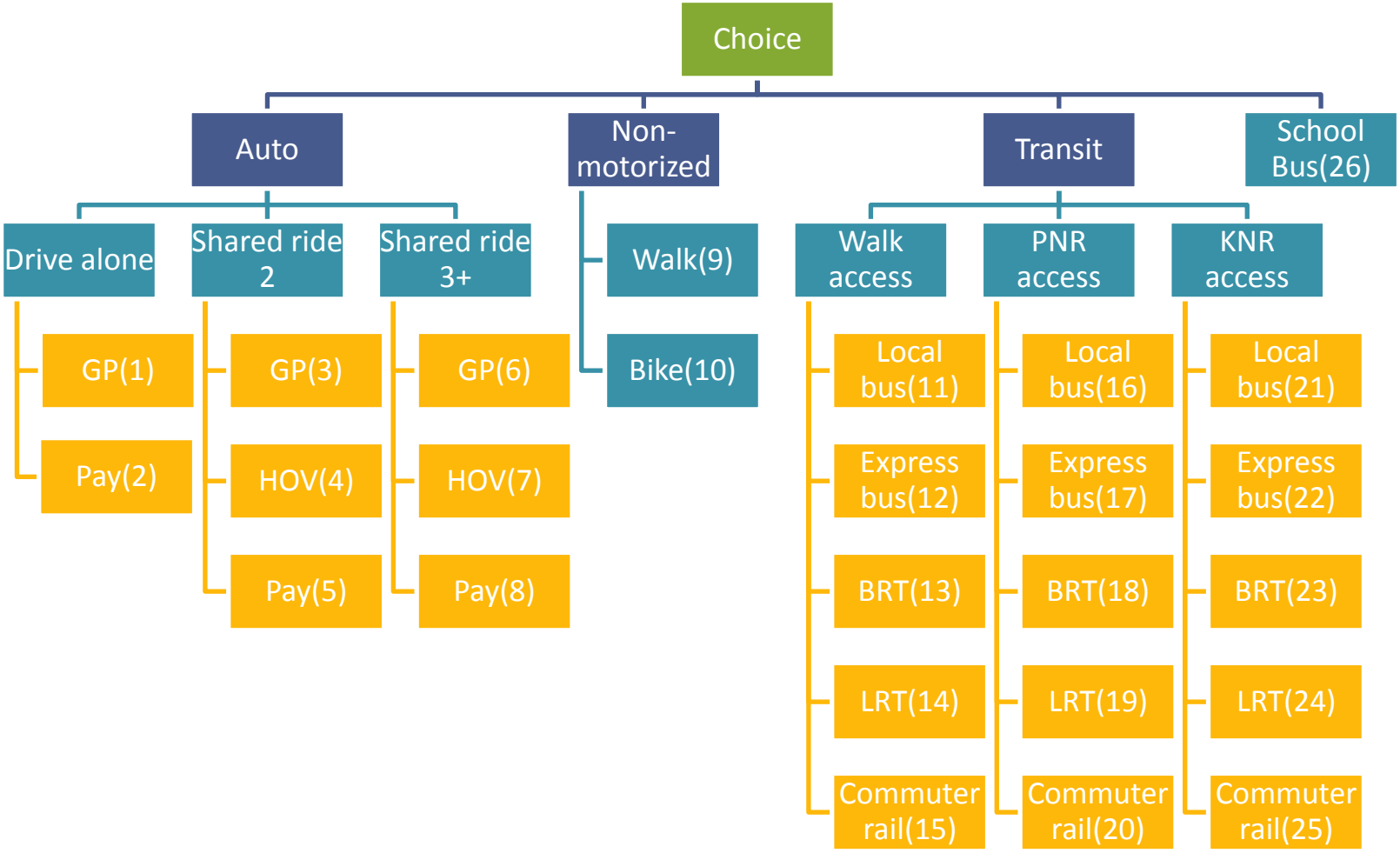
Modal Utilities

- 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

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

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

SANDAG Mode Choice Model

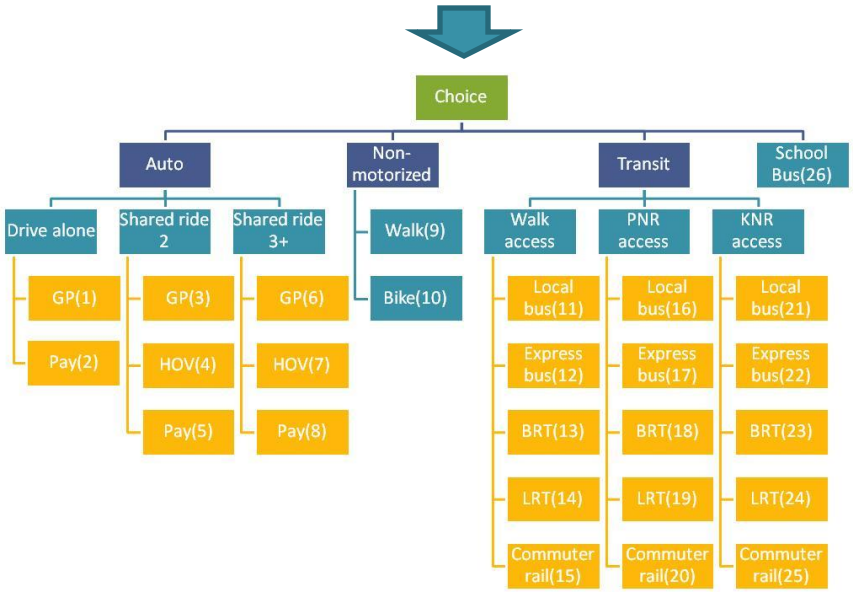


The Logit Model Logsum

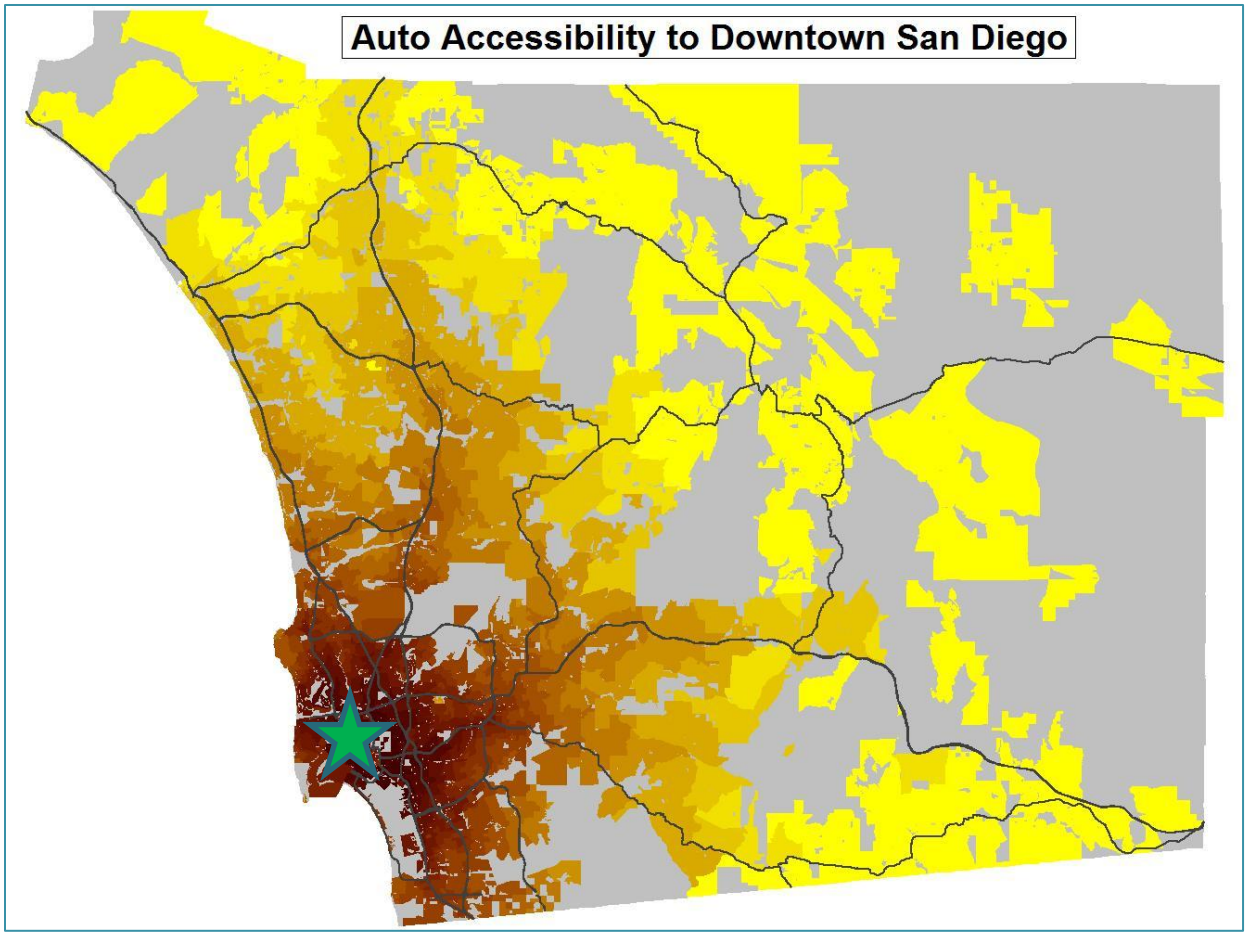
- Logsum measures overall utility of travel, across all modes, for individual traveler, tour/trip purpose, time-of-day
- Each mode is "weighted" by its probability of selection
  - the lower the utility, the less it contributes to logsum

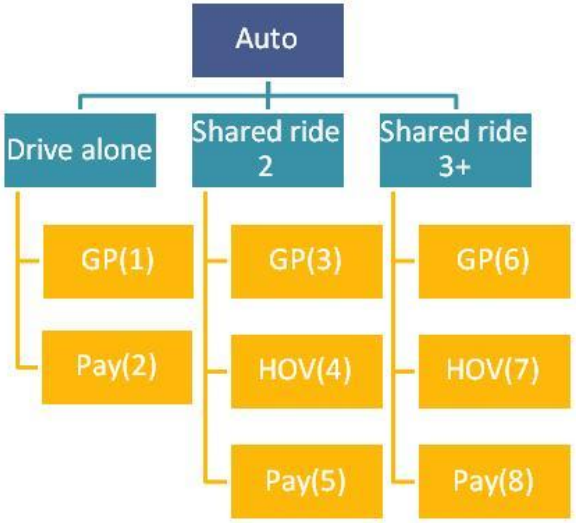
$$P_i = \frac{e^{U_i}}{\ln\left[\sum_{i \in I} e^{U_i}\right]}$$

Logsum = composite utility

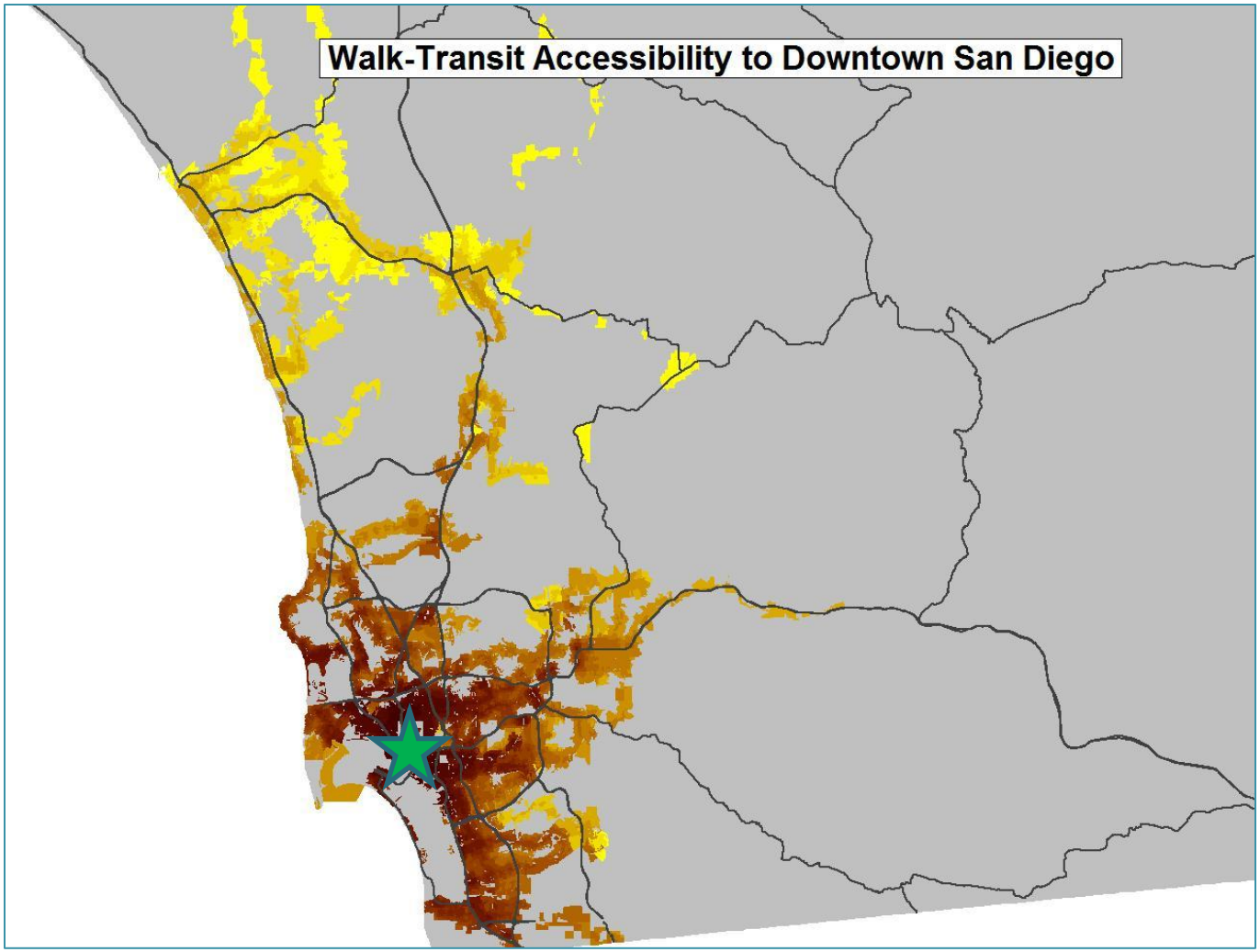


Mode Choice Logsum Plot – Auto Modes



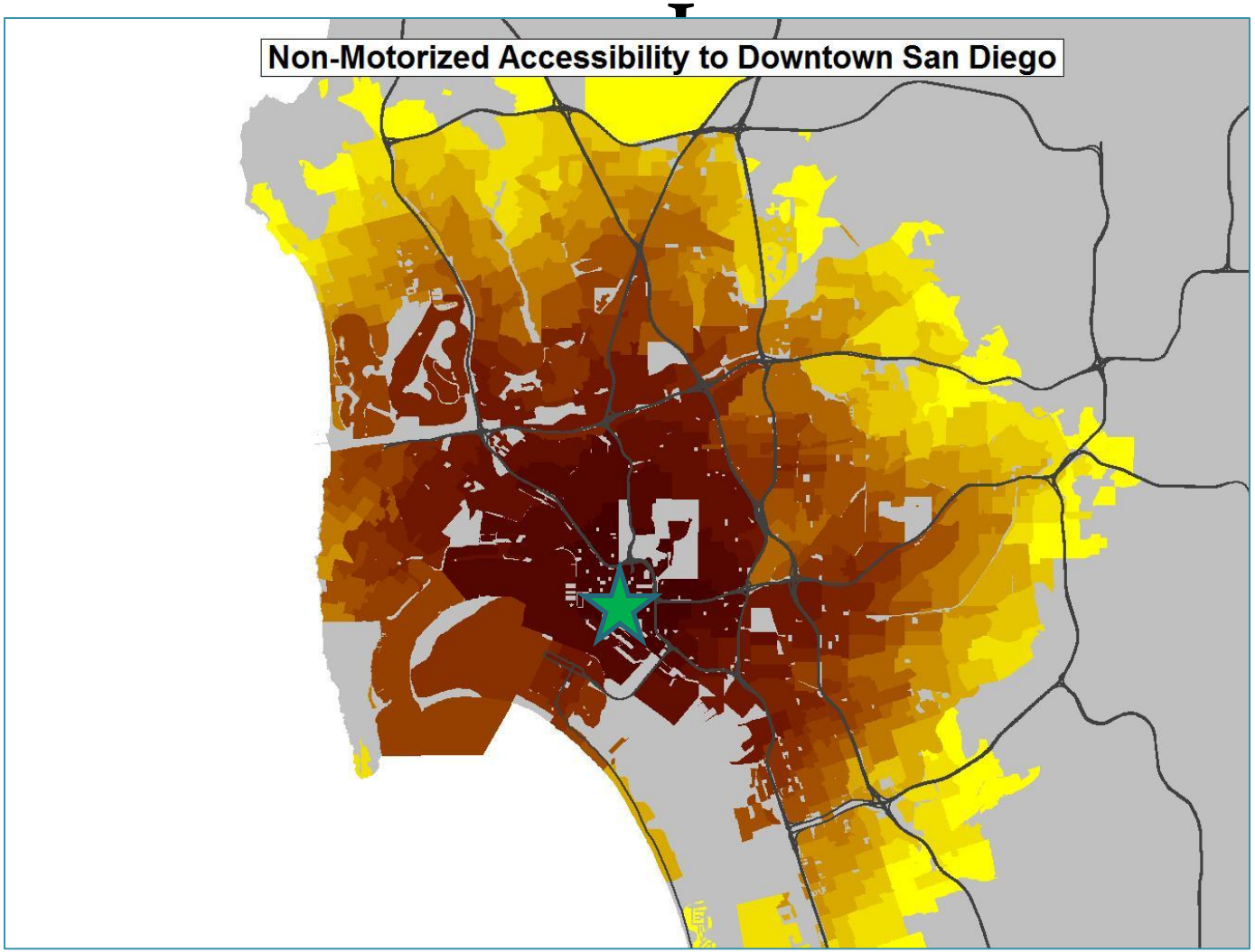


Mode Choice Logsum Plot - Walk-Transit



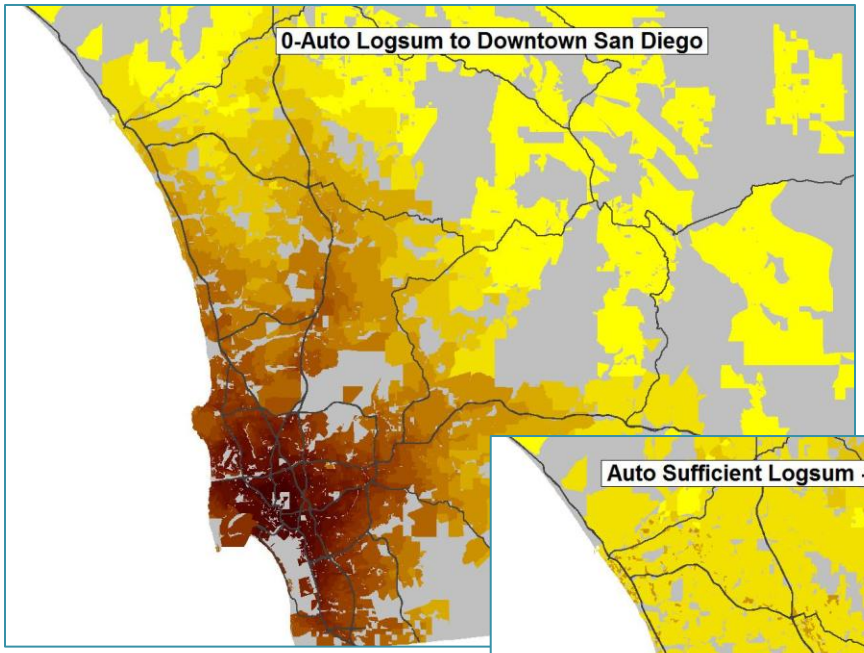
- Transit
  - Walk access
    - Local bus(11)
    - Express bus(12)
    - BRT(13)
    - LRT(14)
    - Commuter rail(15)

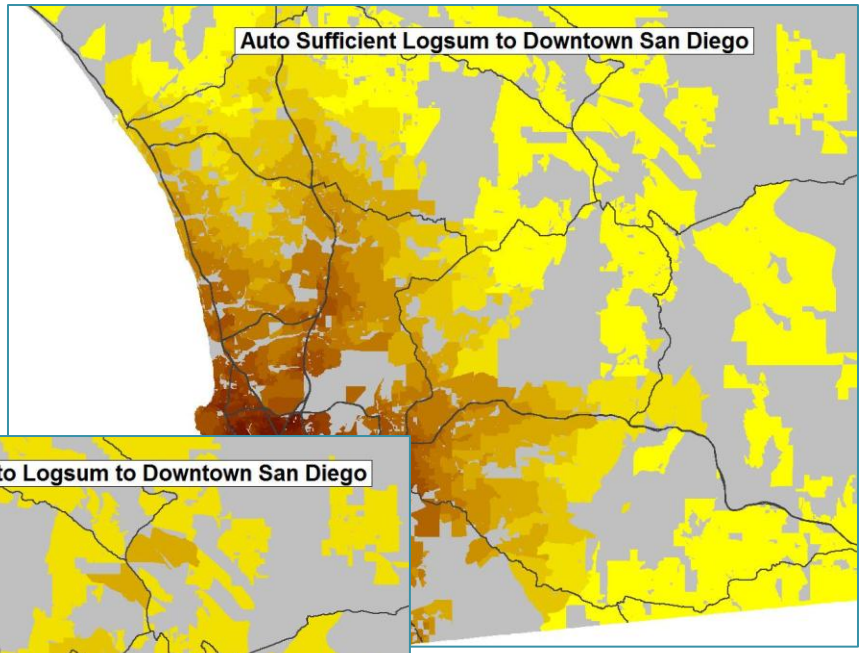
Mode Choice Logsum Plot - Non-Motorized

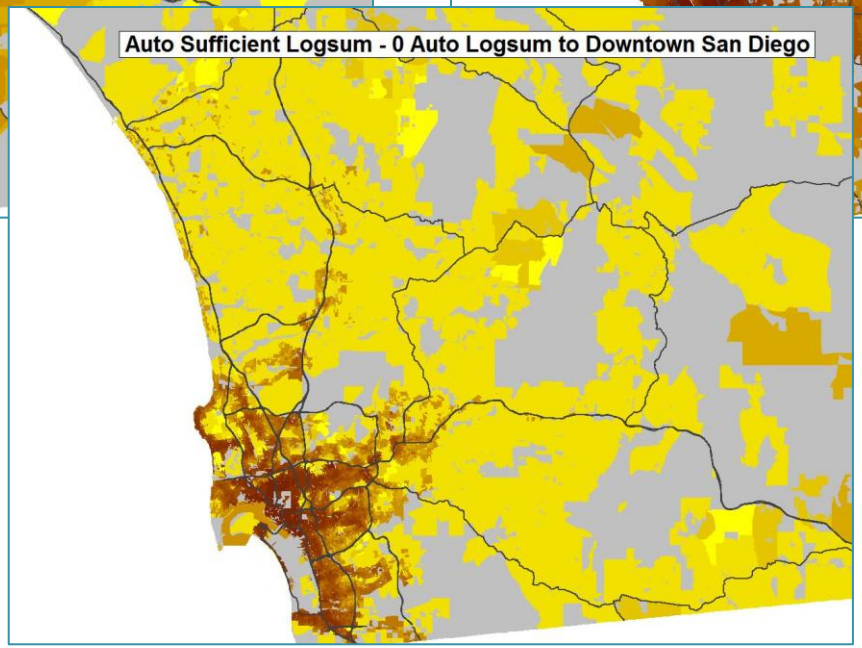


- Non-motorized
  - Walk(9)
  - Bike(10)

Logsums by Auto Sufficiency



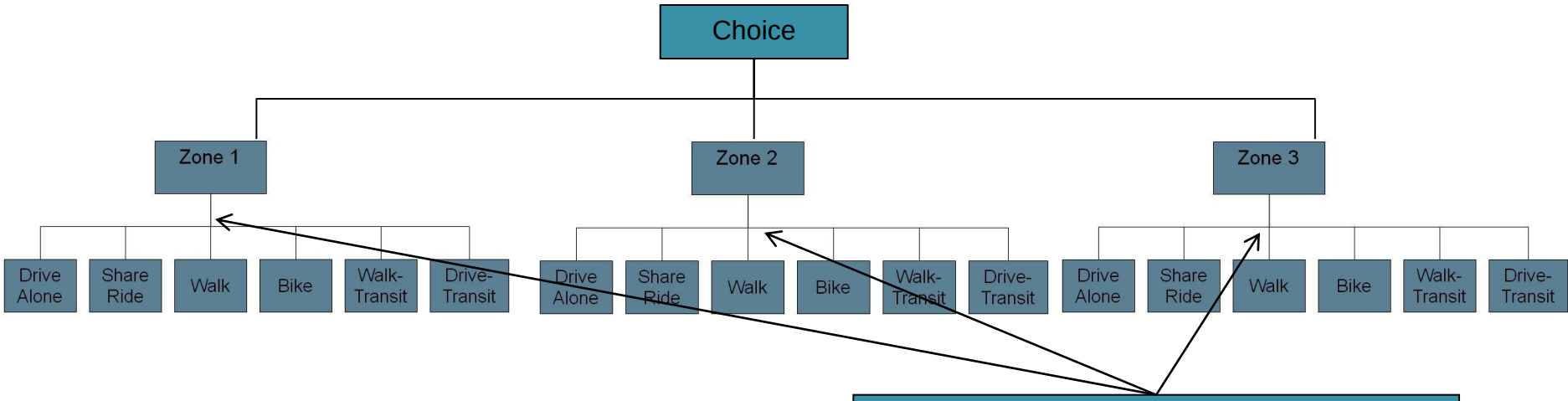




Dimensions of accessibilities: Tour/trip purpose

- 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

Accessibility to activities: Destination choice model



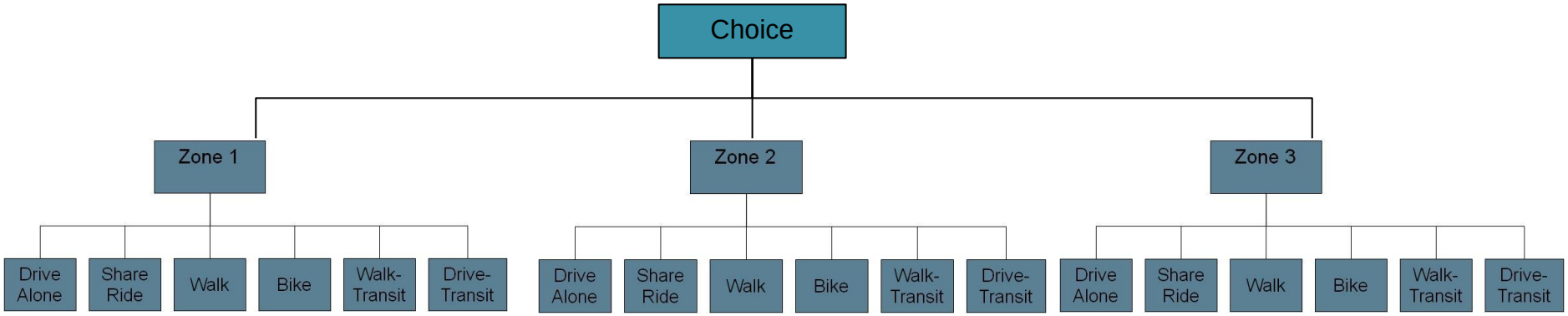
Sample Utility Equation:

Mode Choice Logsum

$$U_j = \beta_{LS} * mode\_choice\_logsum_{ij} + \beta_{...} * X_{...} + ln(retail\_emp + \theta_{service\_emp} * service\_emp)$$

Quantity variables (size term)

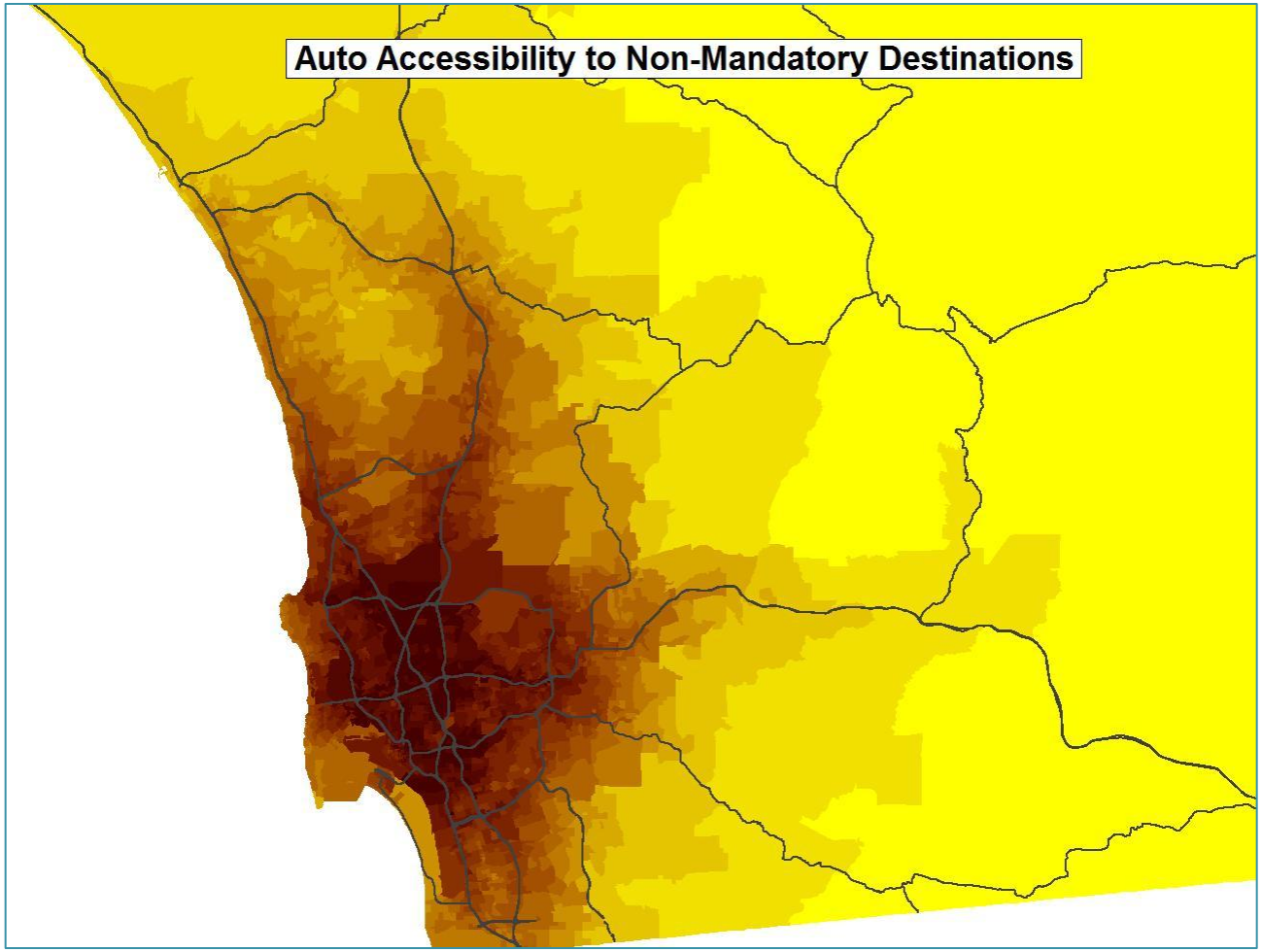
Accessibility to activities: Destination choice logsum



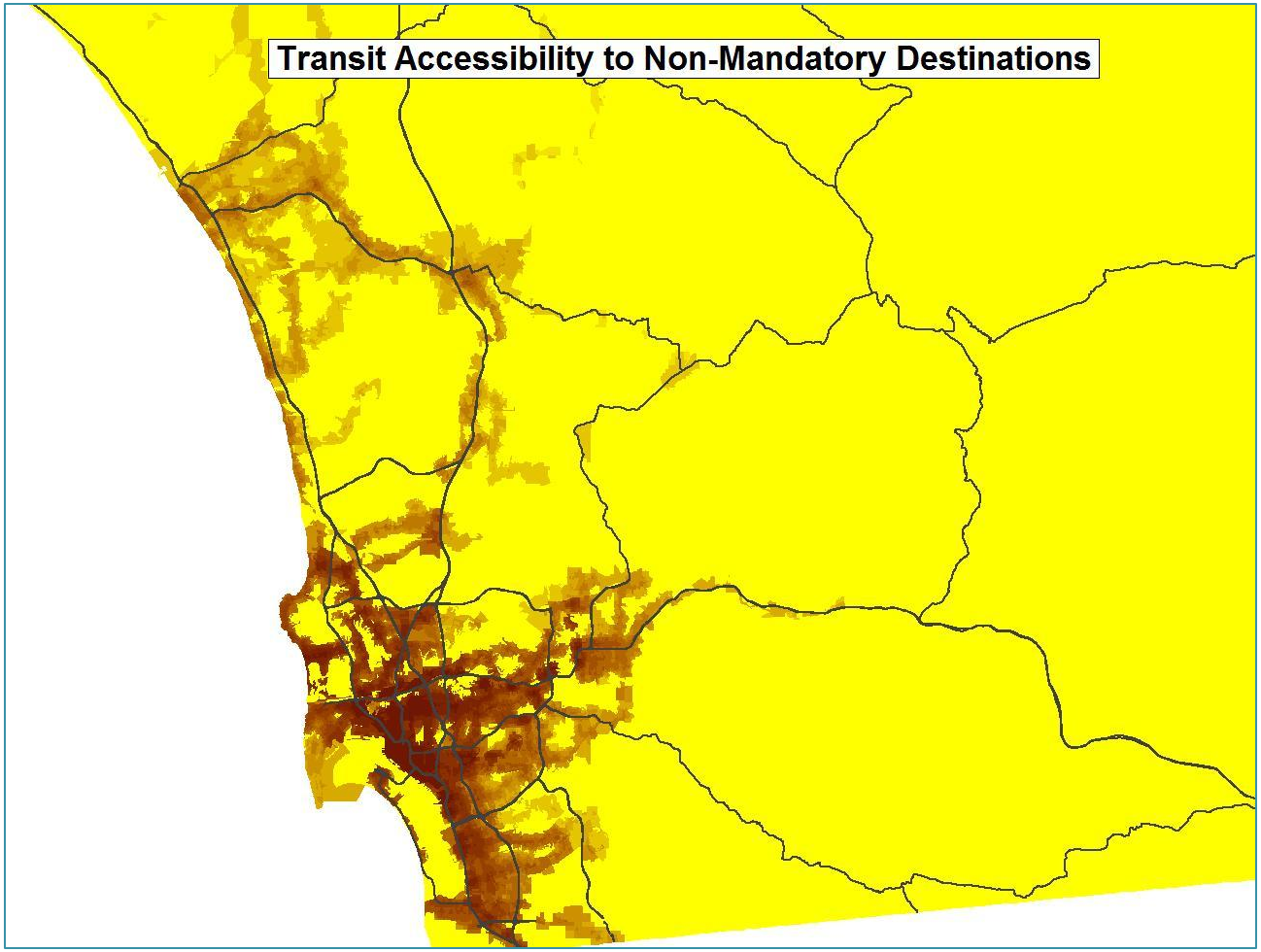
Destination choice logsum: Accessibility of origin to relevant activities in destinations, weighted by modal level-of-service

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

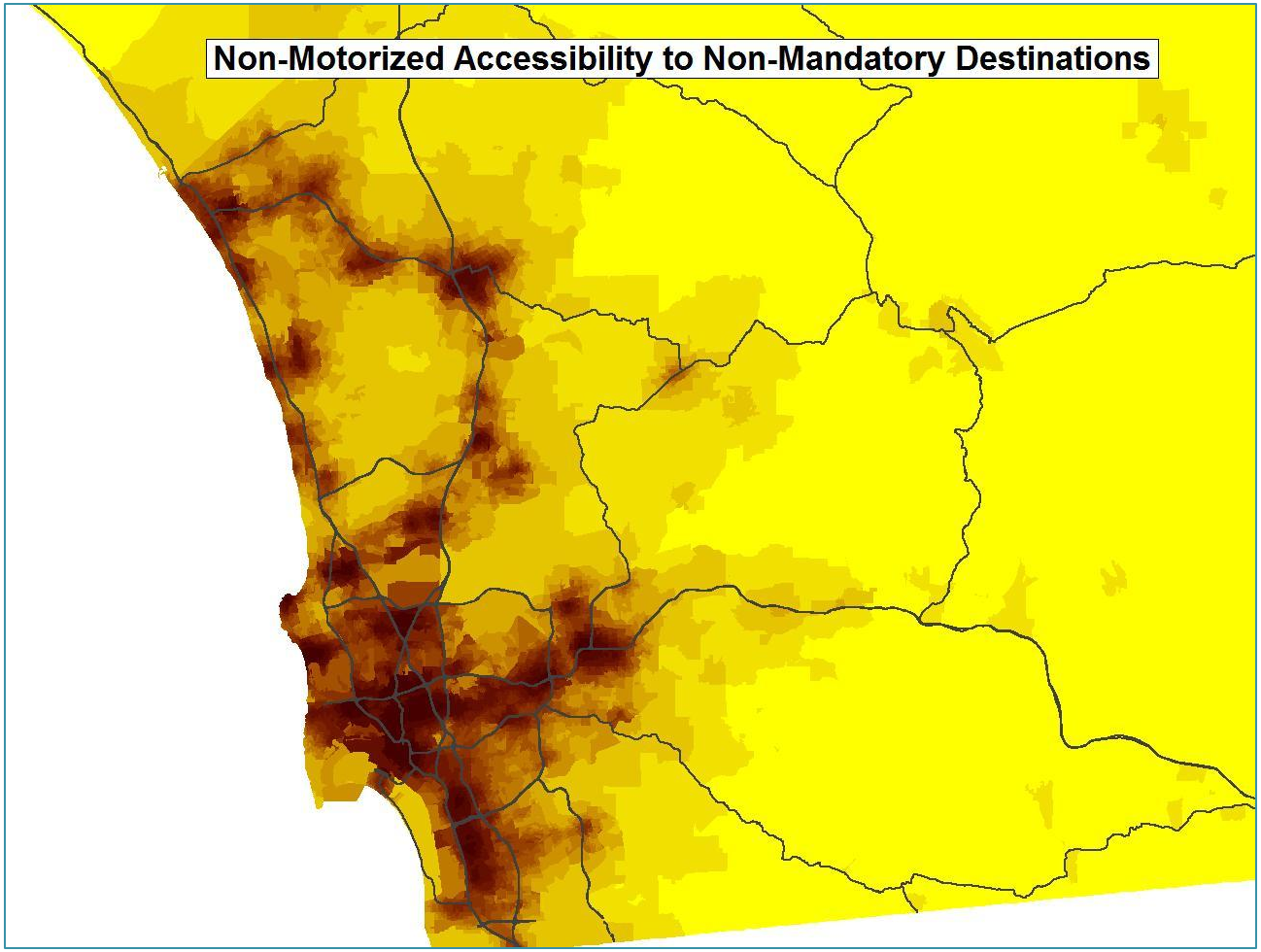
Destination choice logsum plot : Auto access to non-mandatory destinations



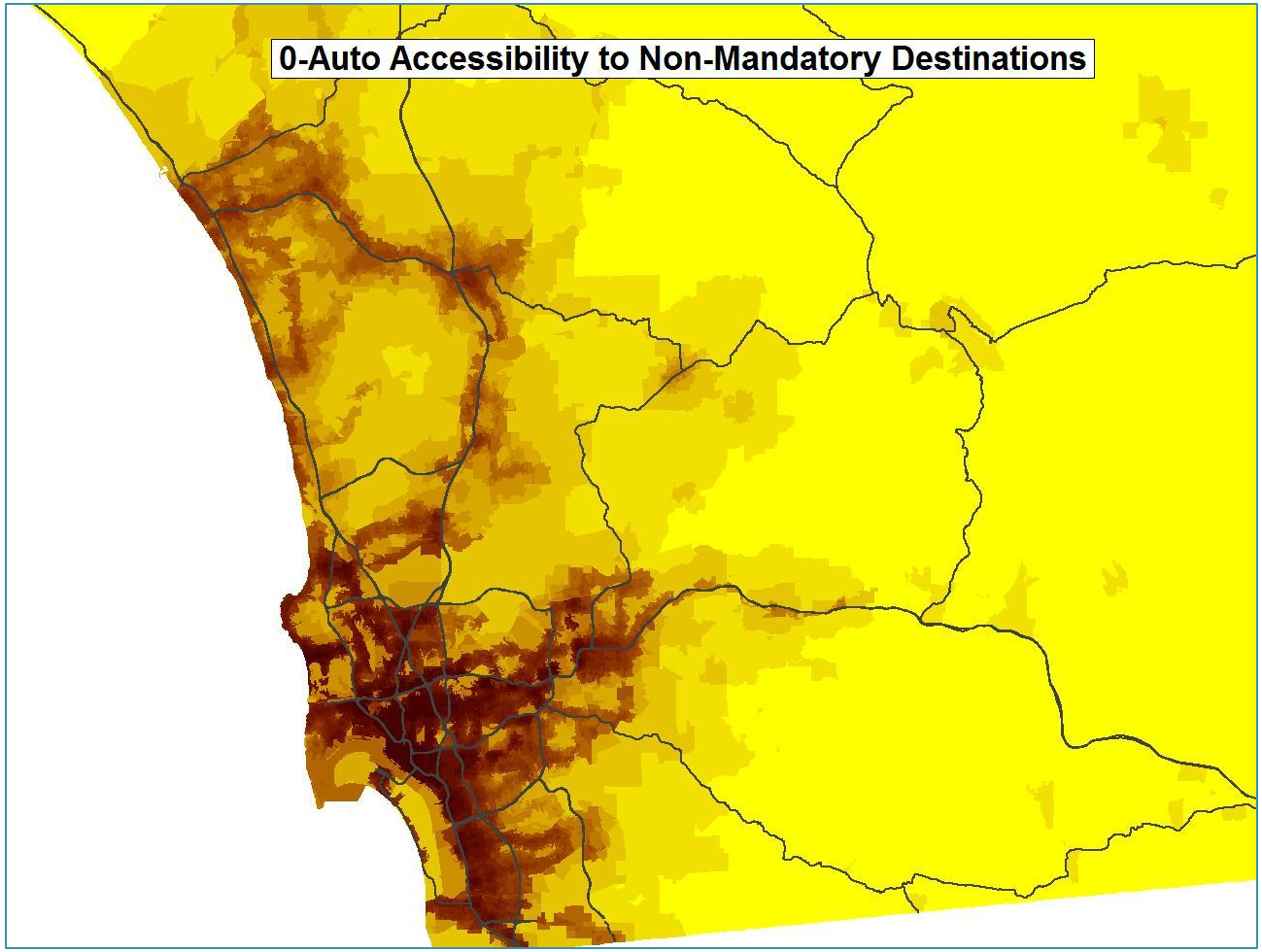
Destination choice logsum plot: Transit access to non-mandatory destinations



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



Destination choice logsum plot : Access to non-mandatory destinations by 0-auto households

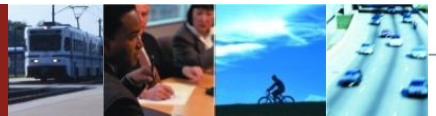


Questions and Answers

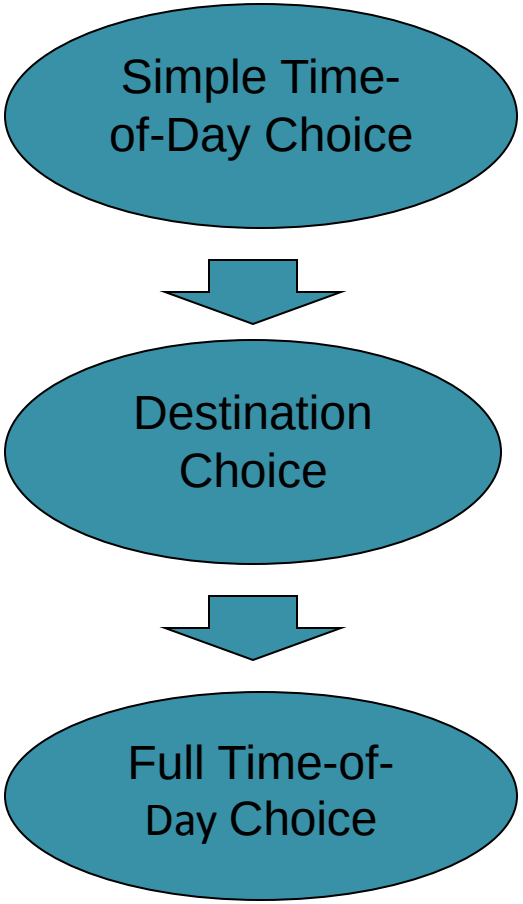
The Travel Model Improvement Program

Dimensions of Accessibilities: Time-of-day

- Time-of-day of travel influence on accessibilities:
  - Transport options available (transit service, HOV lane hours of operation)
  - Levels of congestion on network
  - Transit route headways
  - Whether tolls are assessed and their value
  - Land-uses available (business hours of operation)
  - Perceptions of safety
  - Reliability
  - Other?

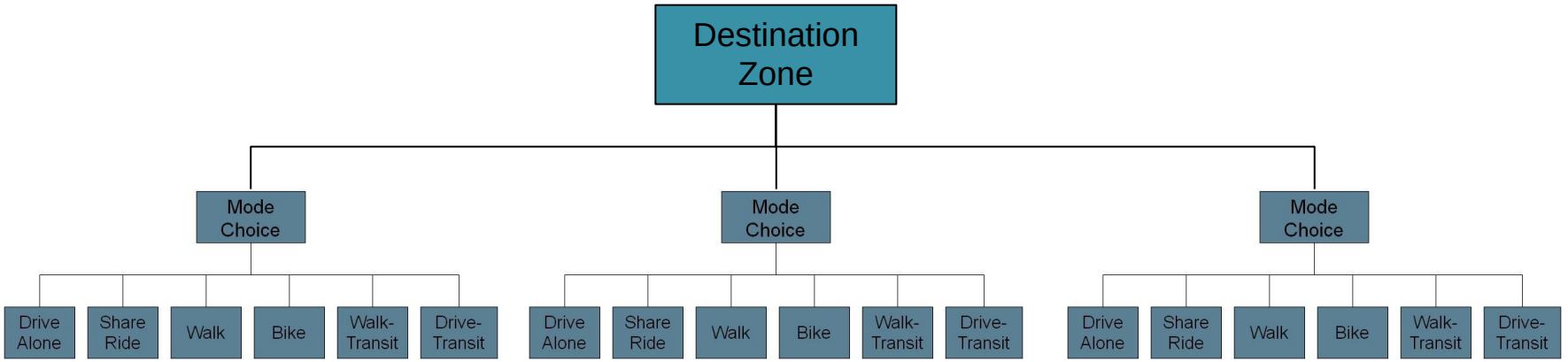


Time of day in daily accessibilities: re-simulating time-of-day



- Choose outbound and return period based upon socio-demographic variables, etc.
- Choose destination given time-of-day
- Re-choose time-of-day based upon chosen destination and socio-economic variables

Time of day in daily accessibilities: "logit averaging"



Period (p) = AM Outbound/ PM Return

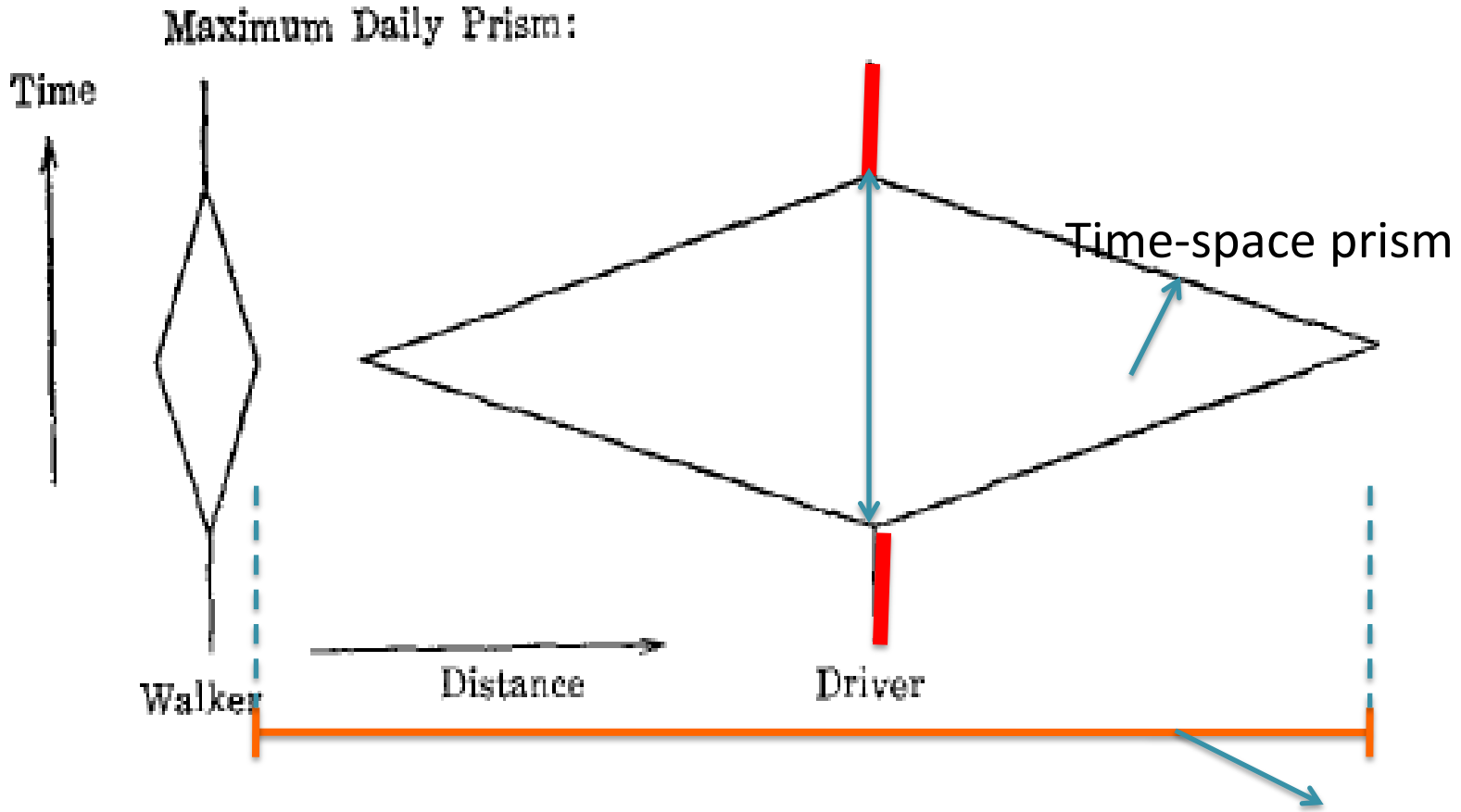
Periods (p) = Midday Outbound/ PM Return

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*

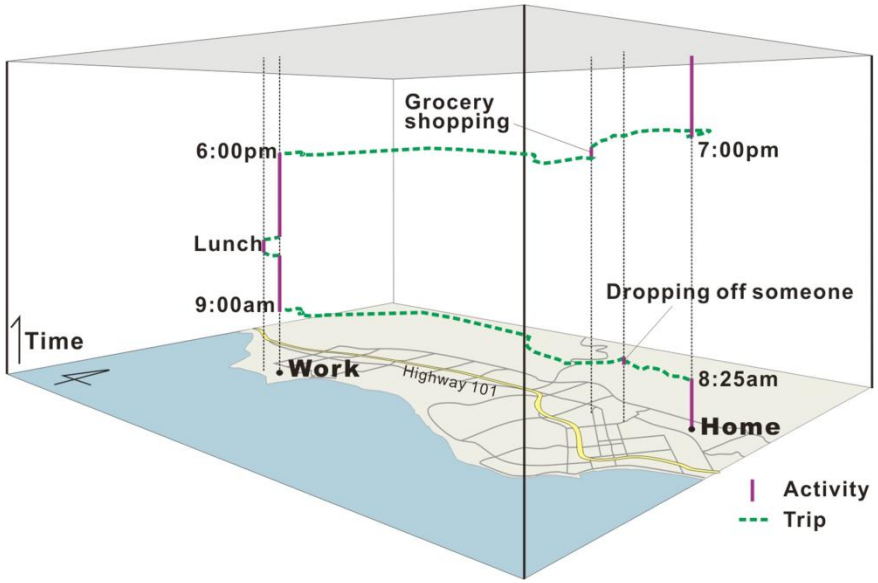
$$\ln\left[\sum_{z=1}^{Z}\sum_{p=1}^{P}\sum_{i=1}^{I} e^{U_{z,p,i}}\right]$$

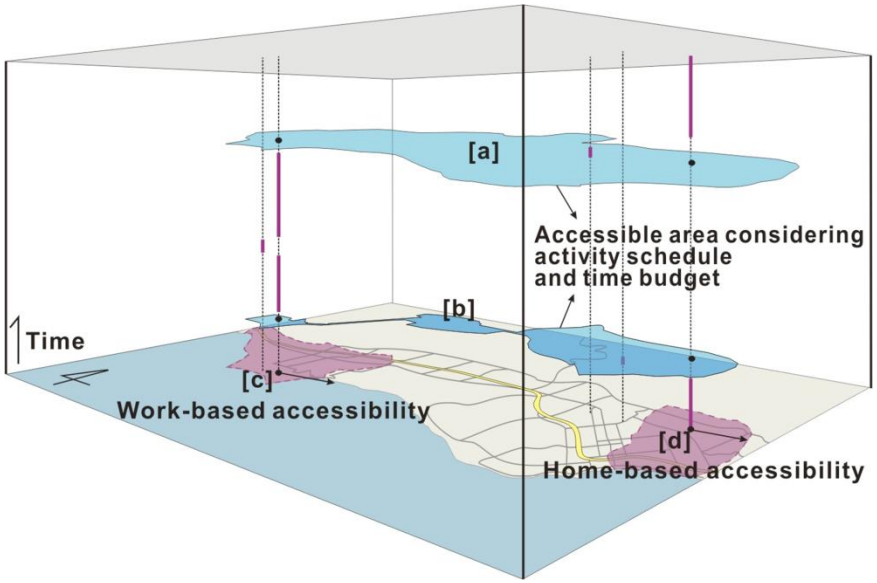
Time-space Prism



Hägerstrand (1970)

Activity Scheduling

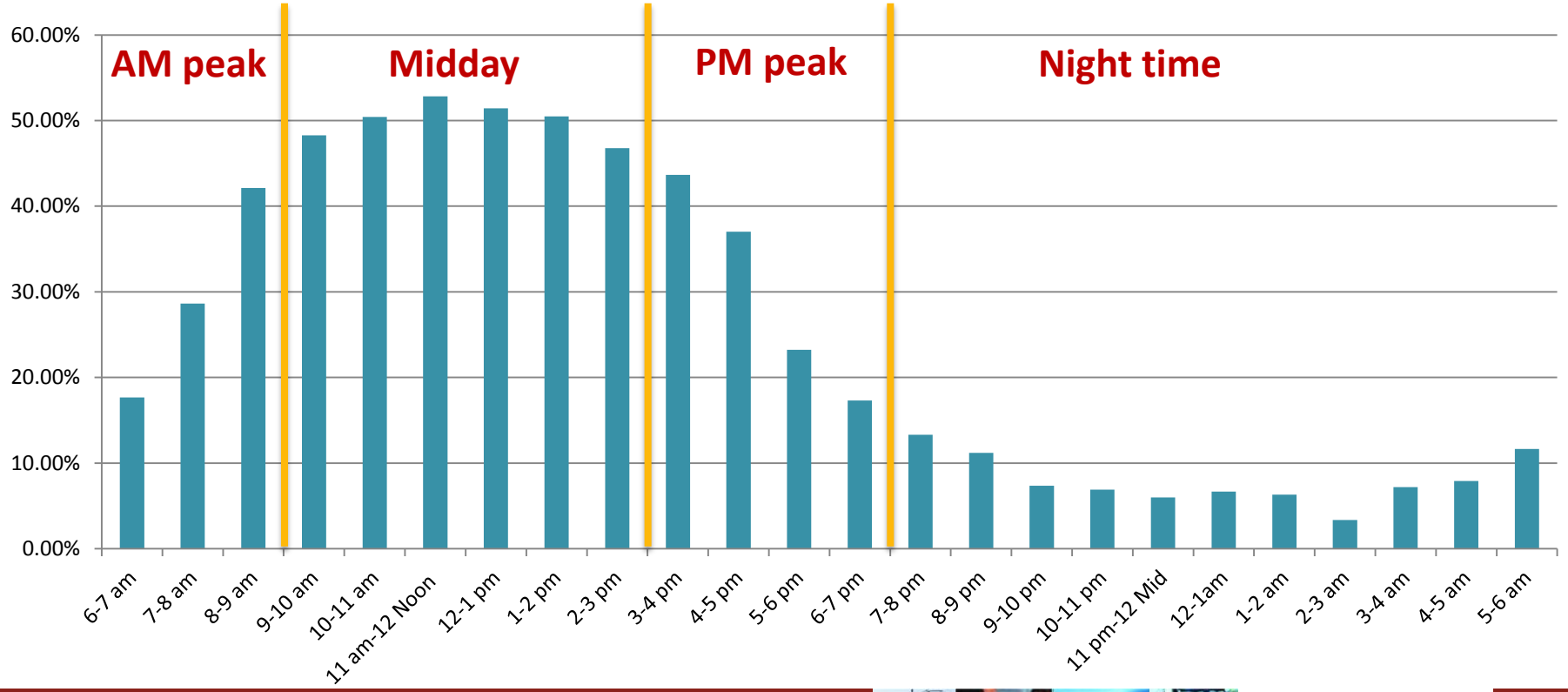


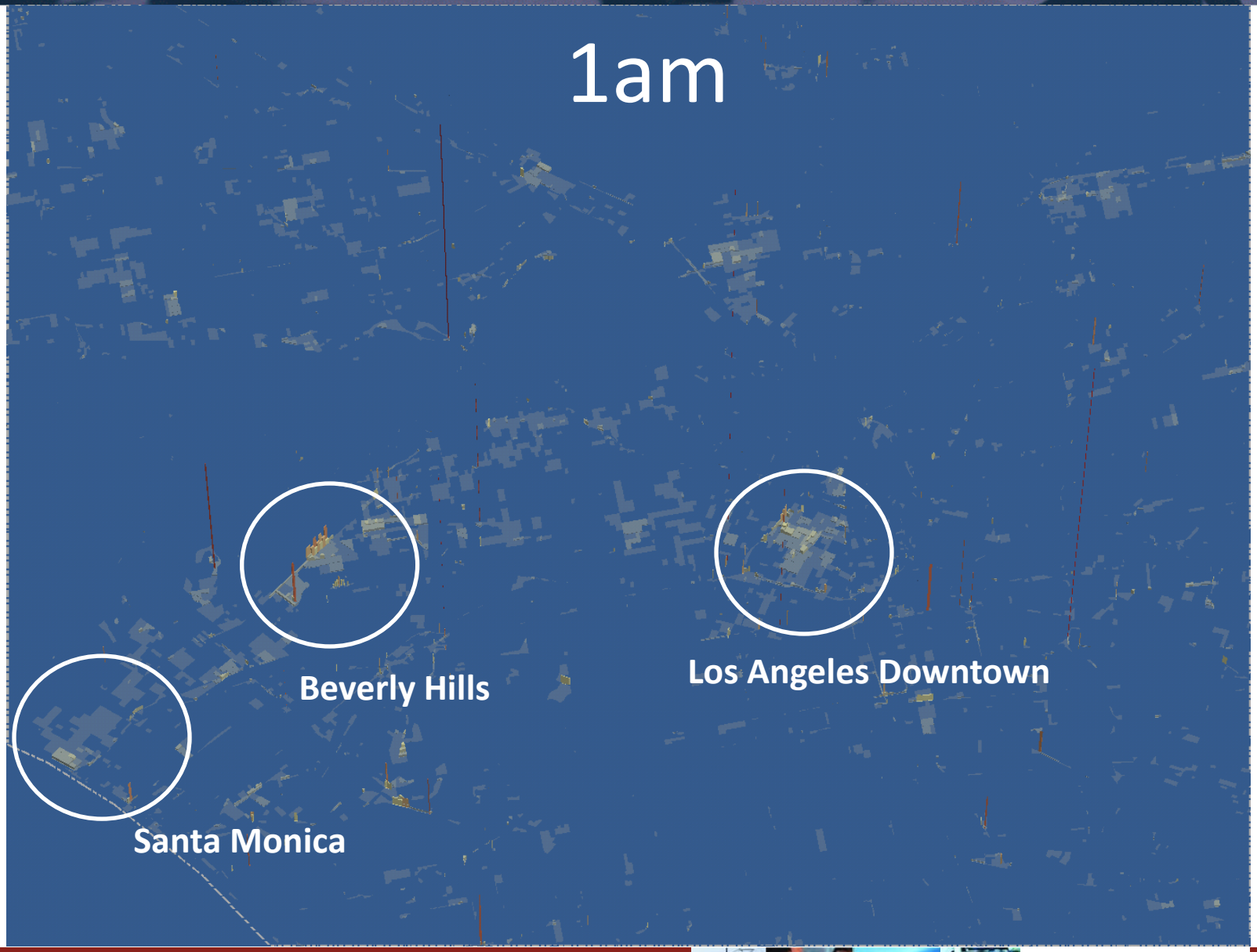


Source: Seo Youn Yoon dissertation, UC Santa Barbara

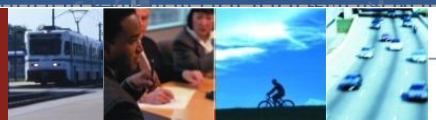
Time of day profile of available opportunity

- Arrival and departure time of workers in travel survey (for each county and each industry type)
- Retail workers at work in LA county



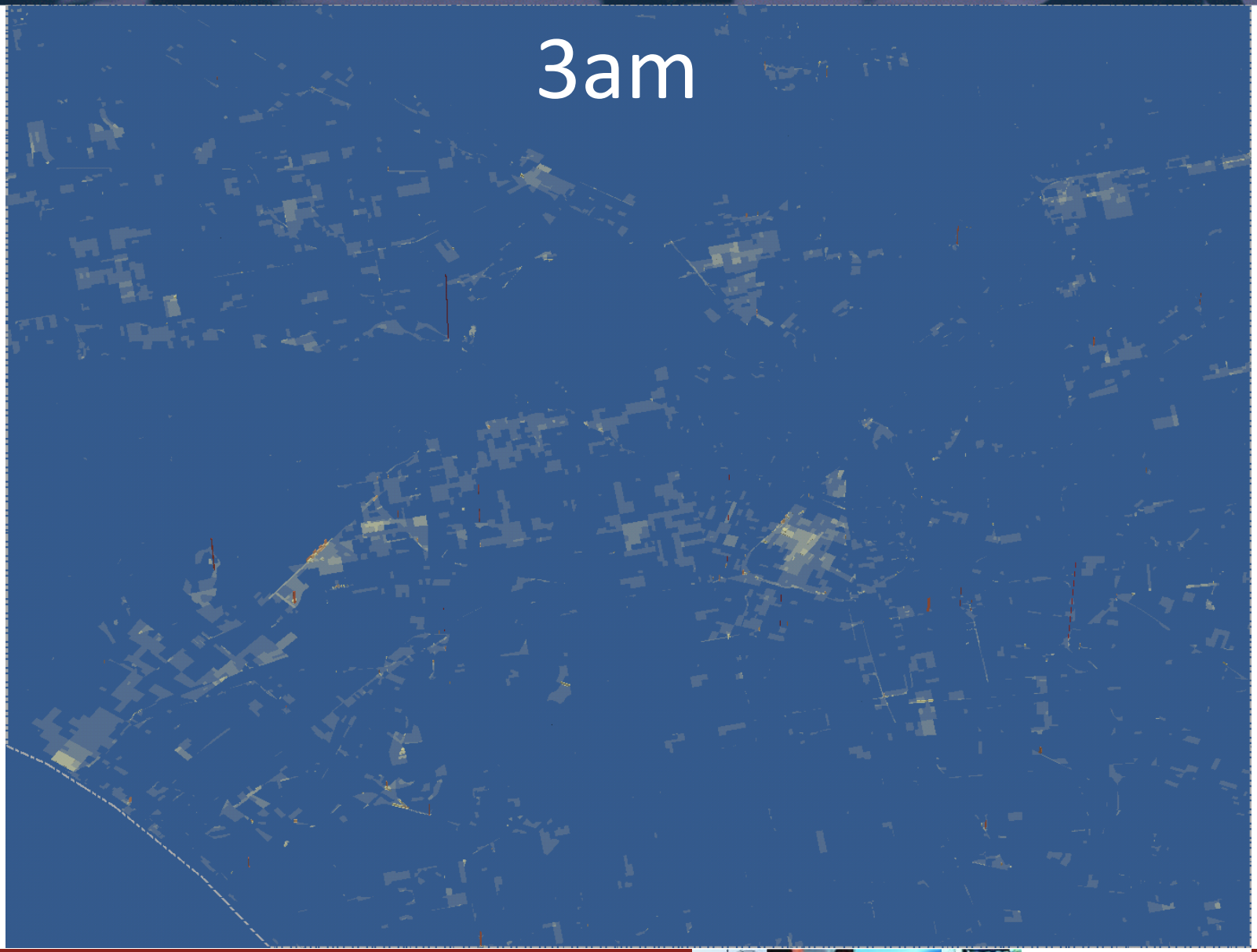

1am
Beverly Hills
Los Angeles Downtown
Santa Monica

1am

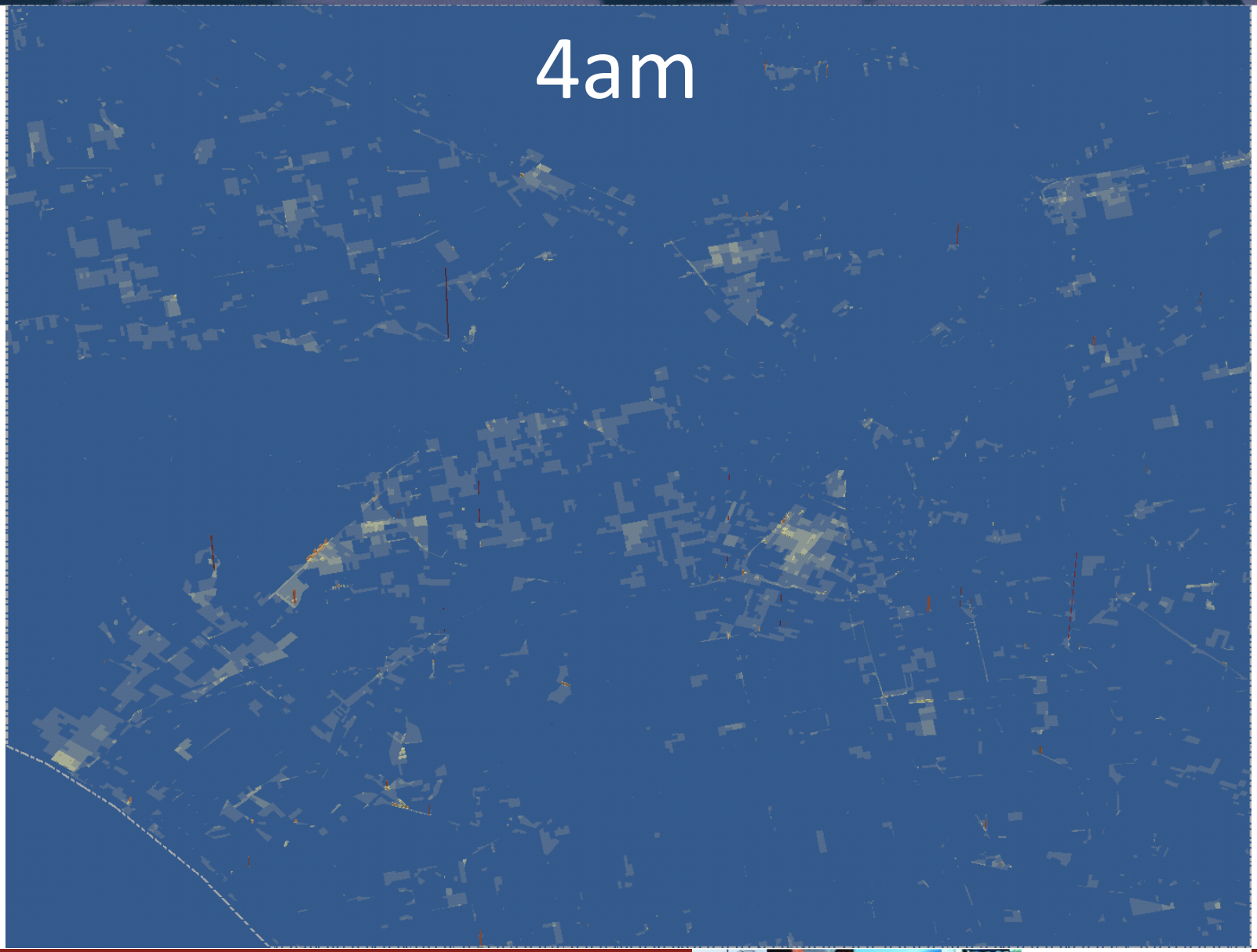


2am

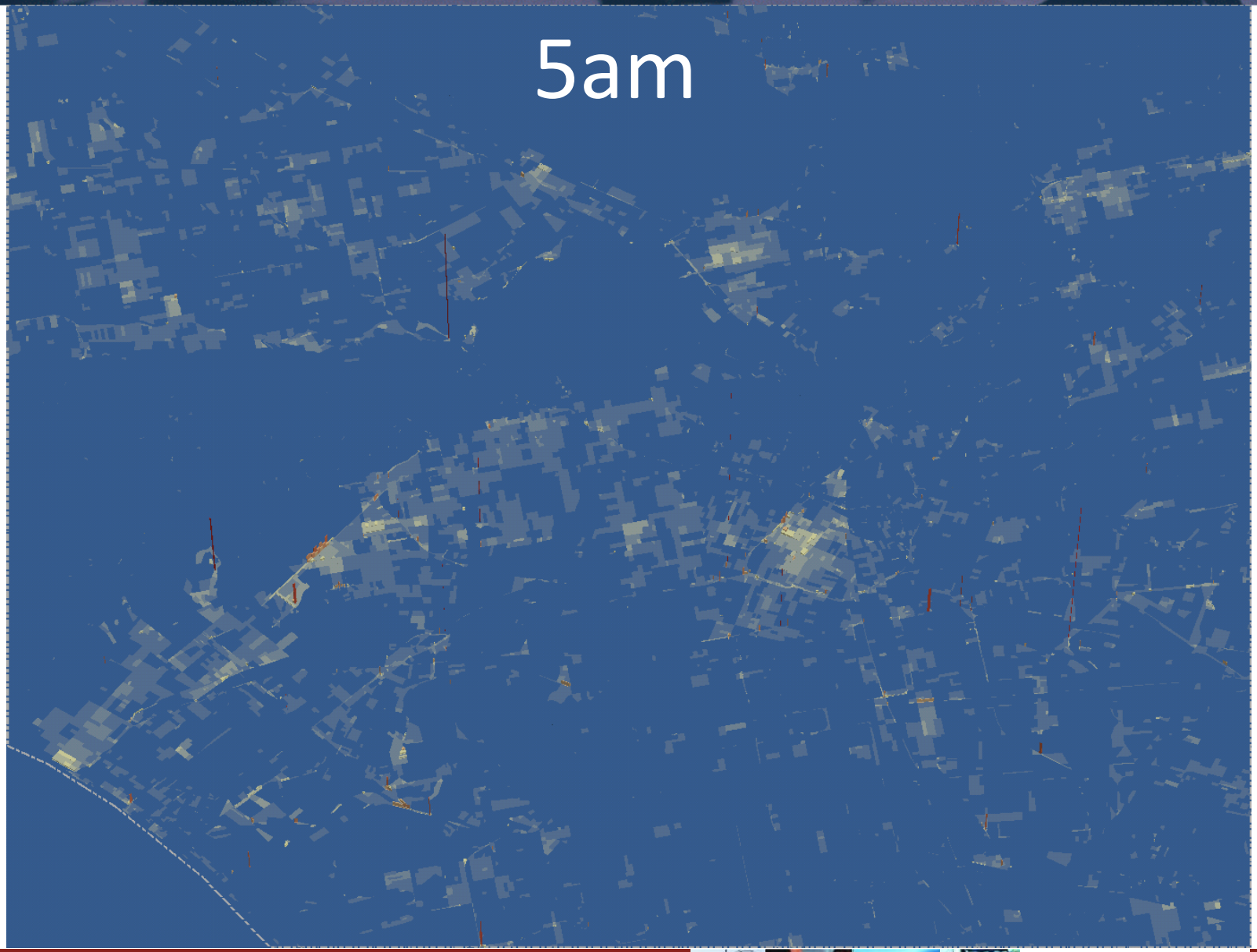
3am



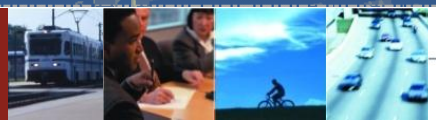
4am

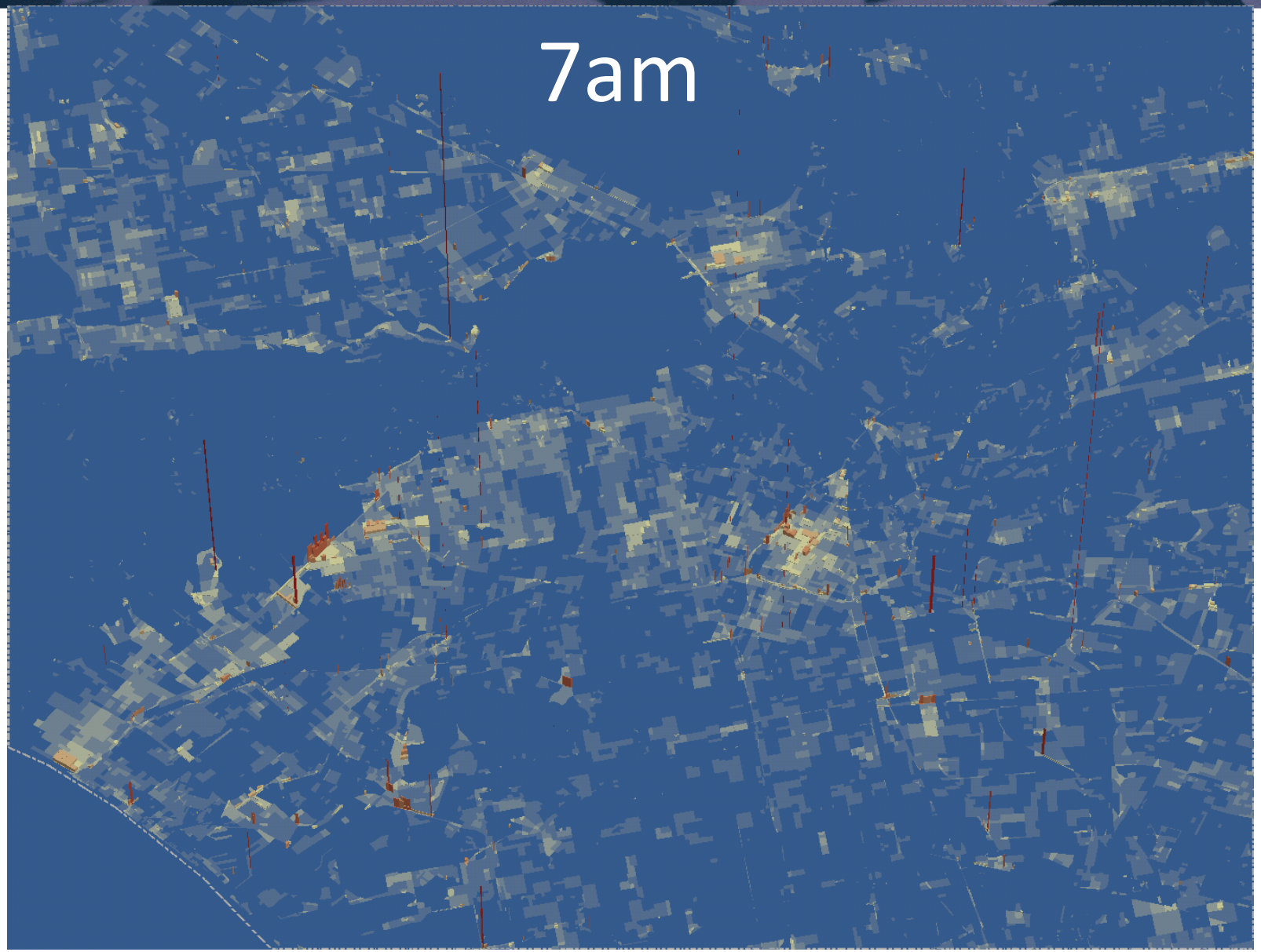


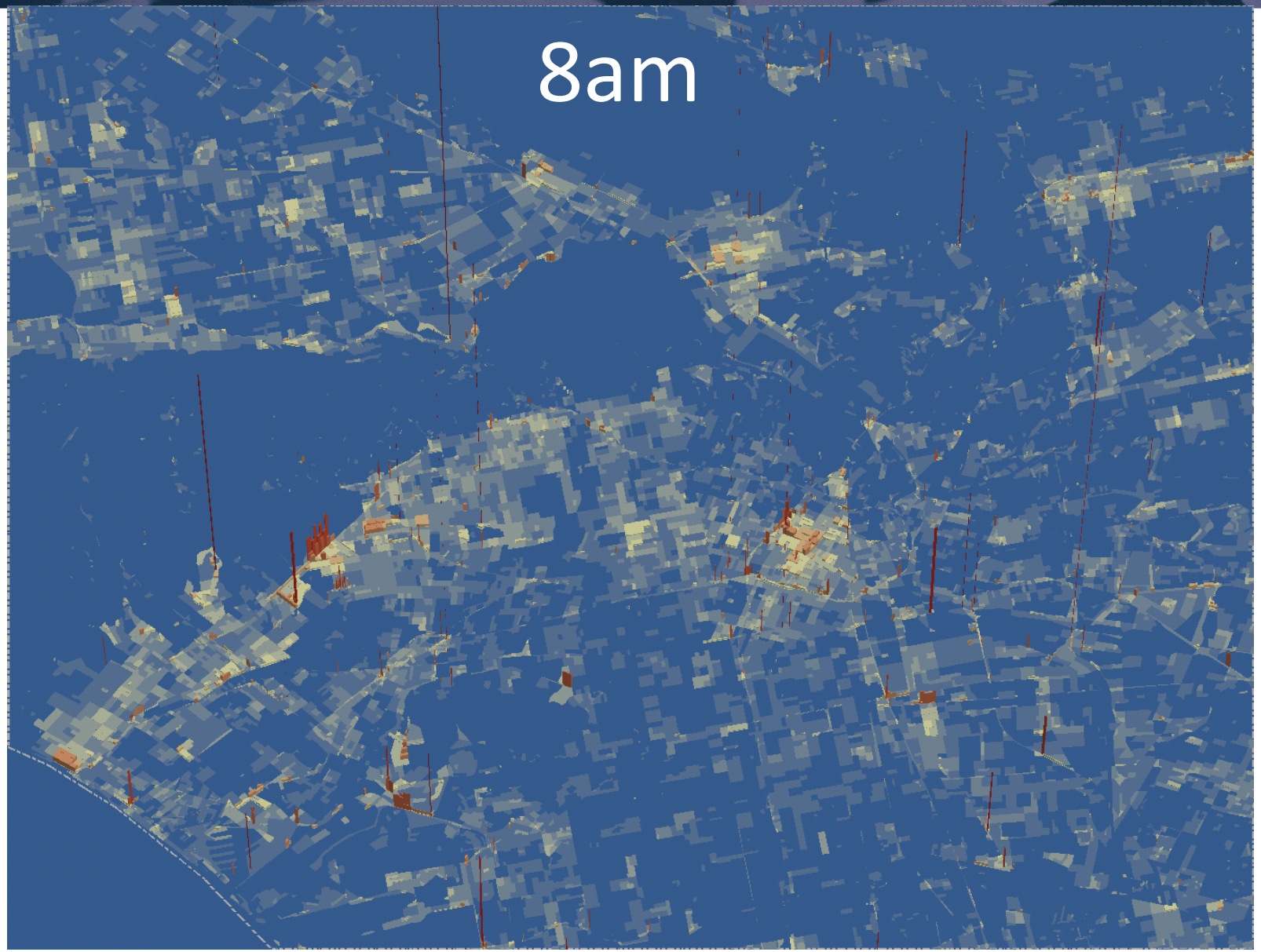
5am

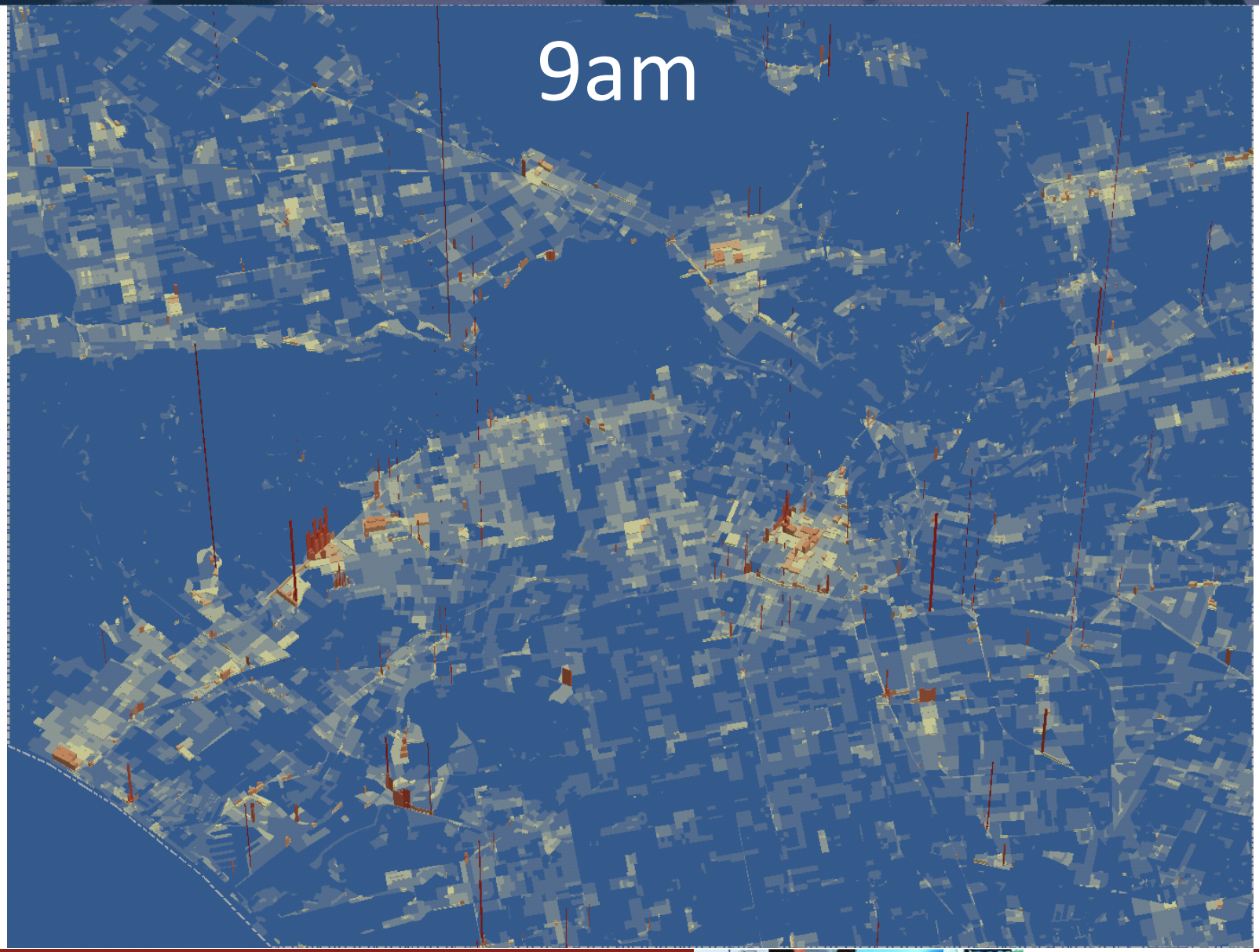


6am

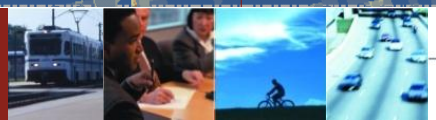



7am


8am

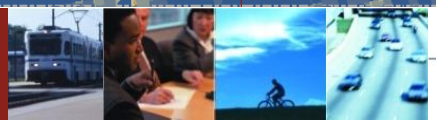

9am

10am

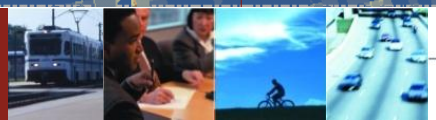


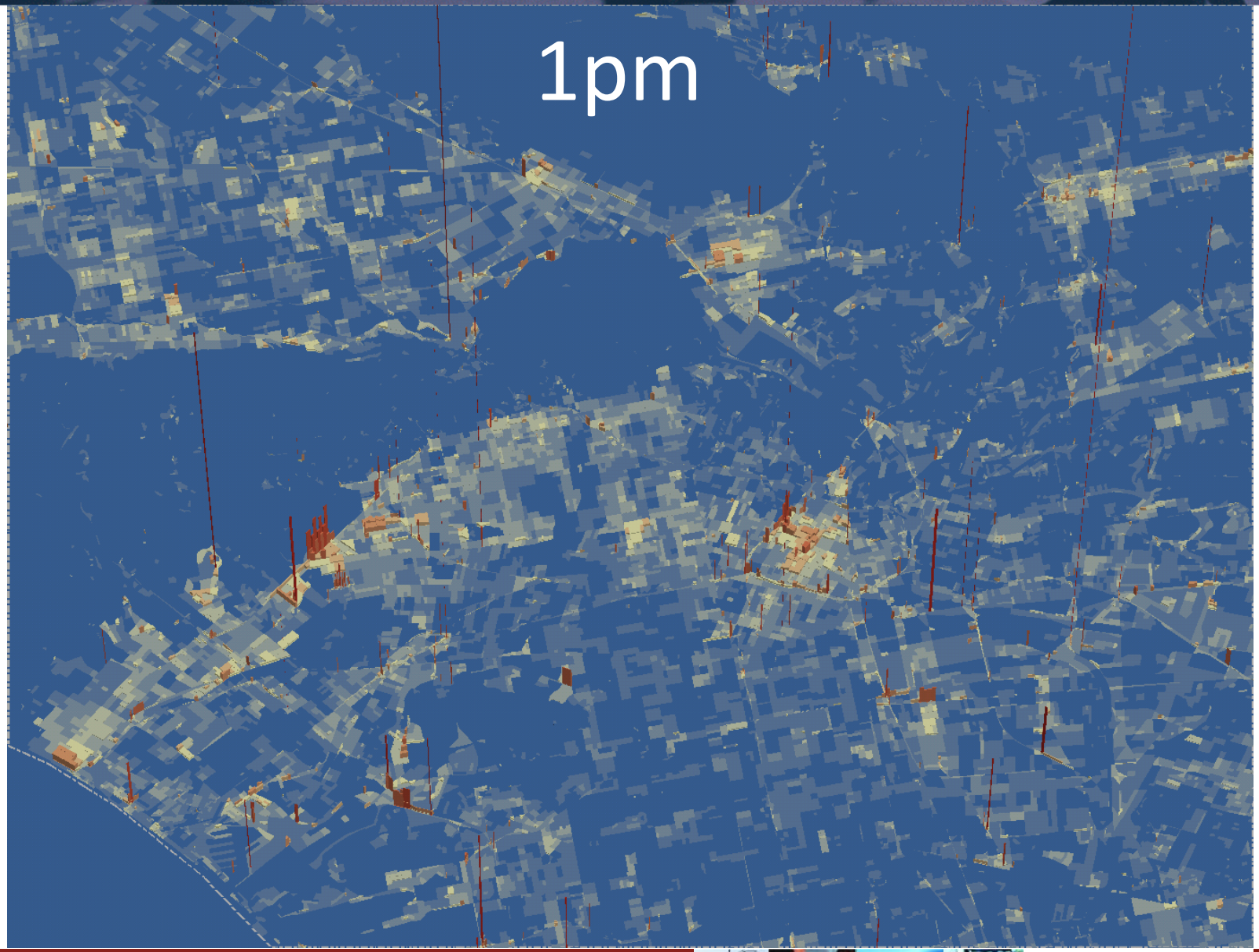
The Travel Model Improvement Program

11am



12noon

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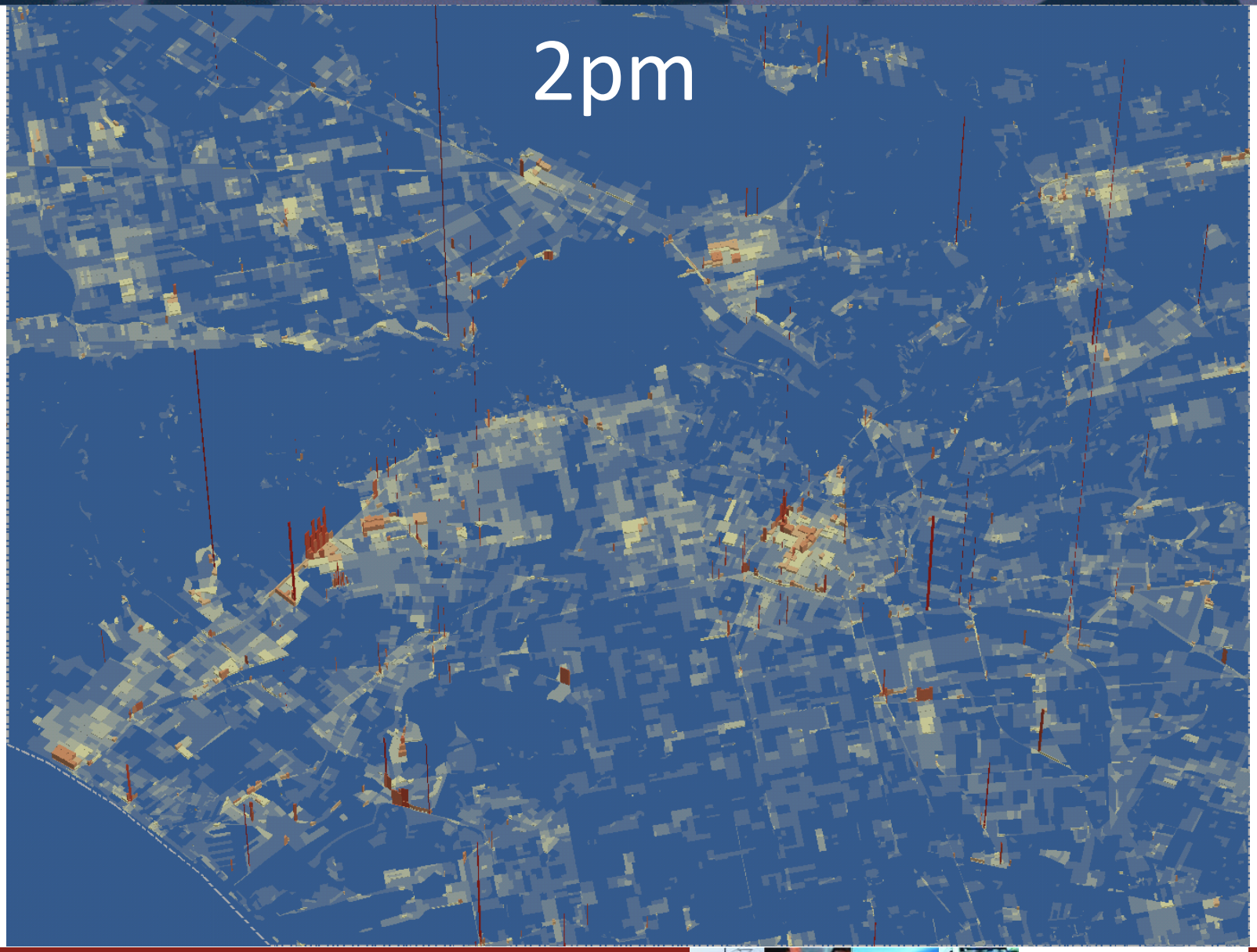
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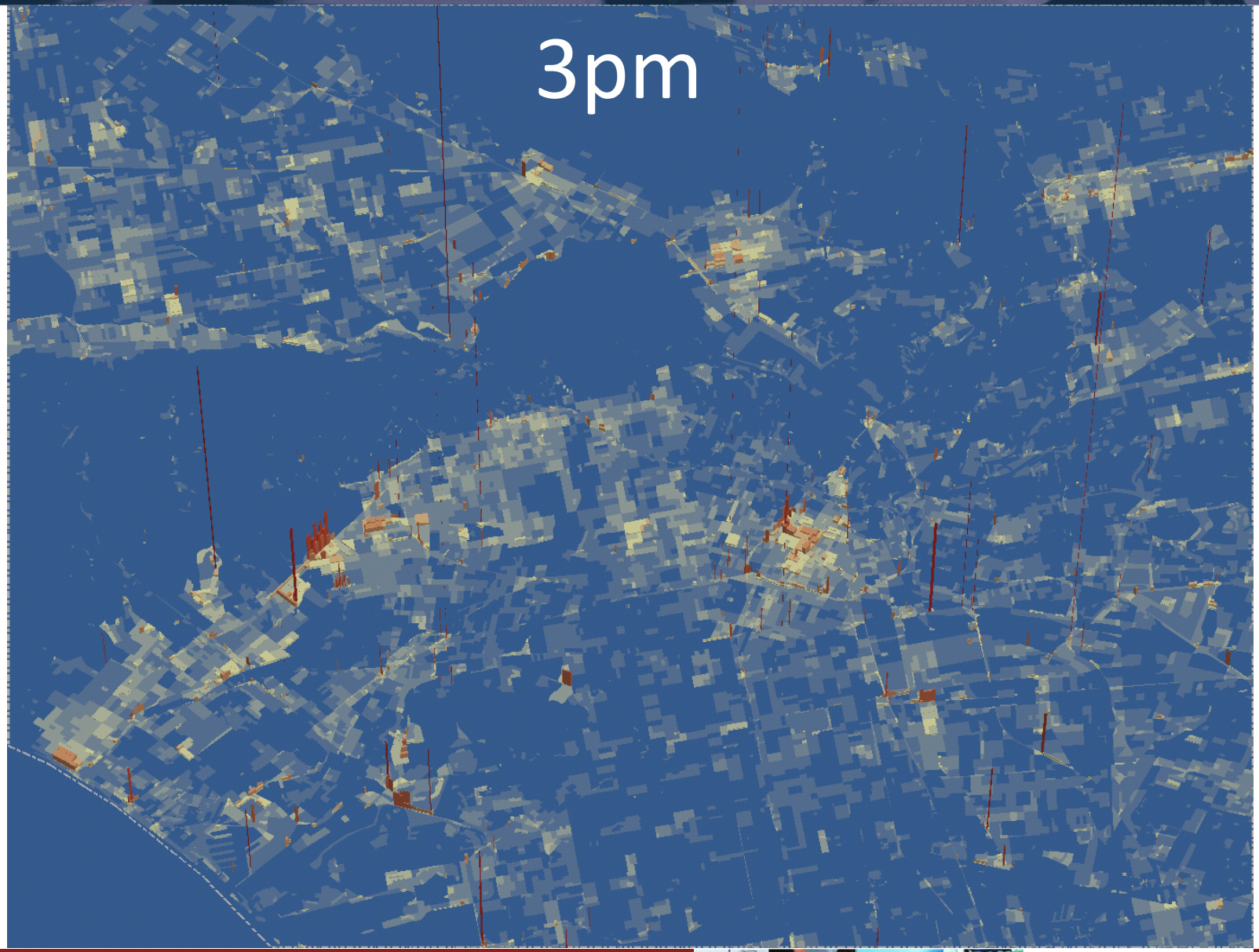
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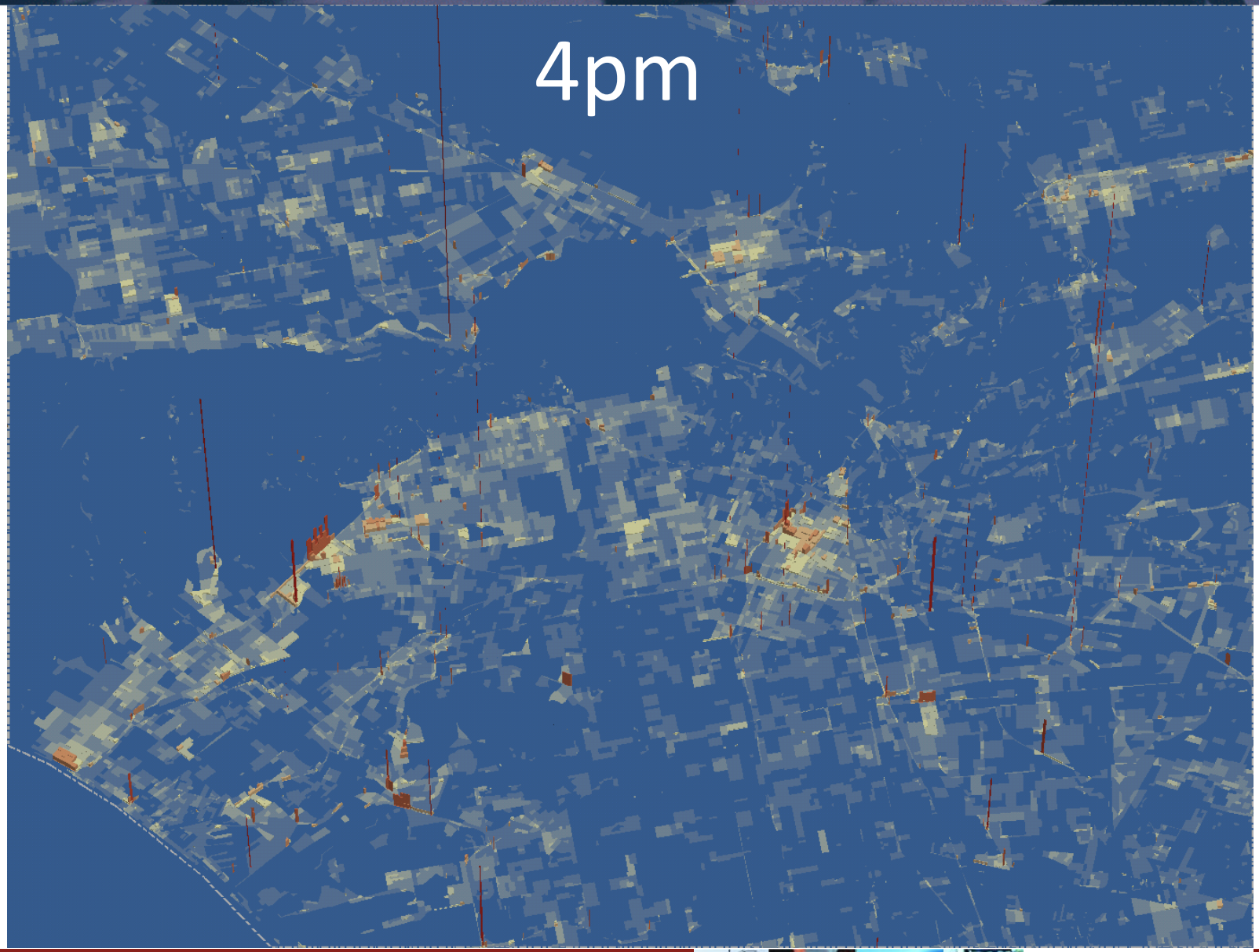
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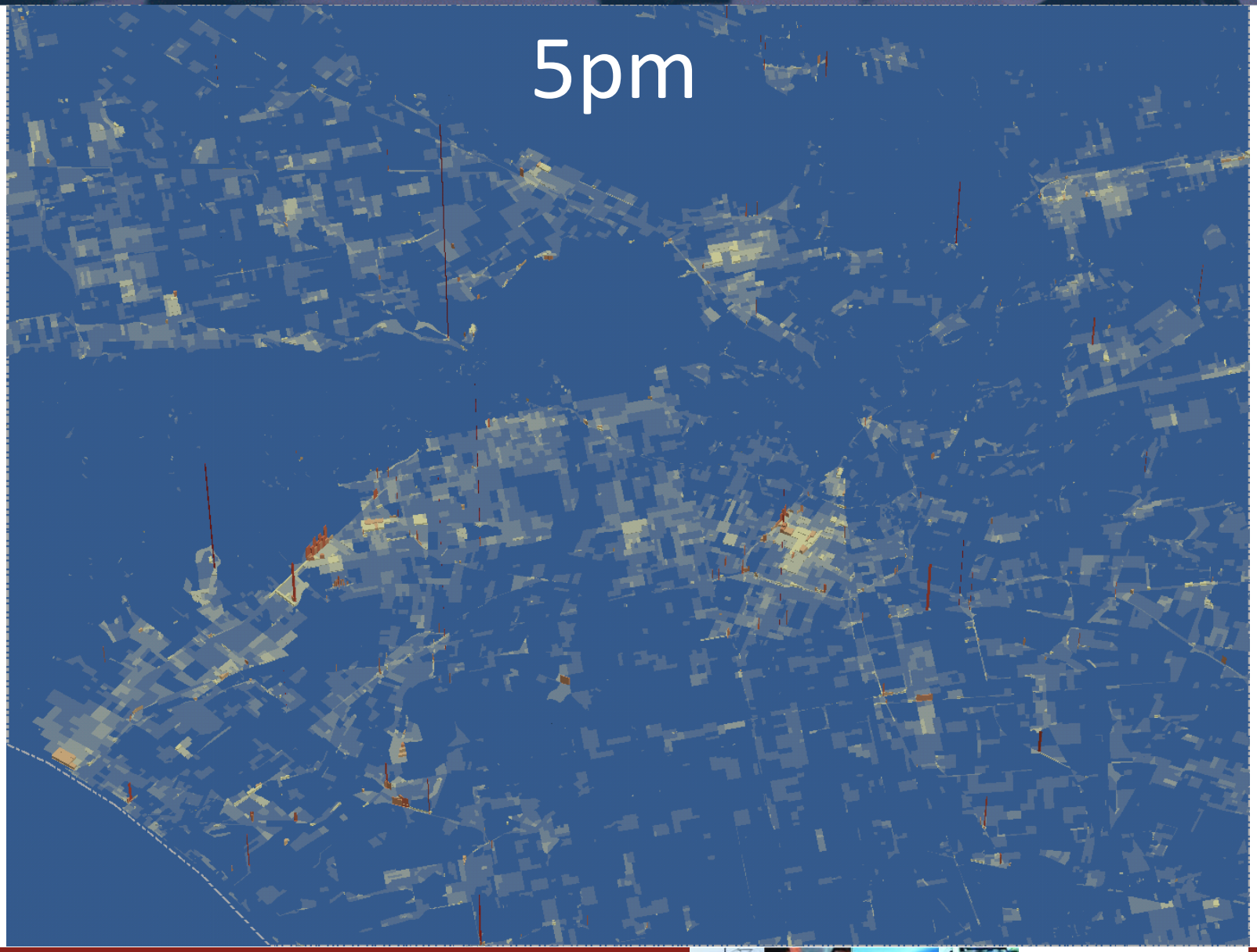
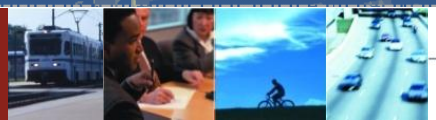
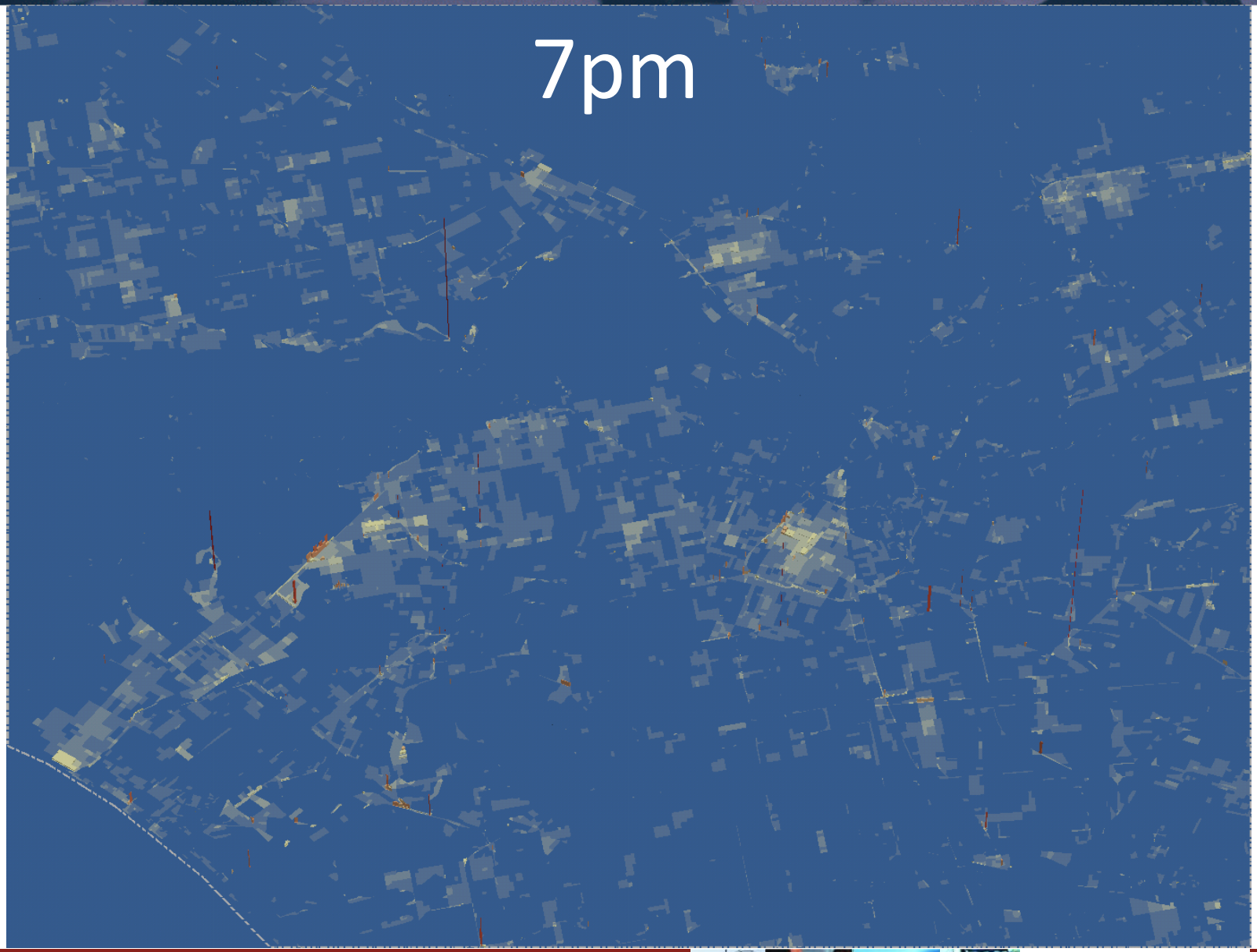

5pm

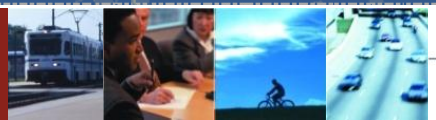
6pm



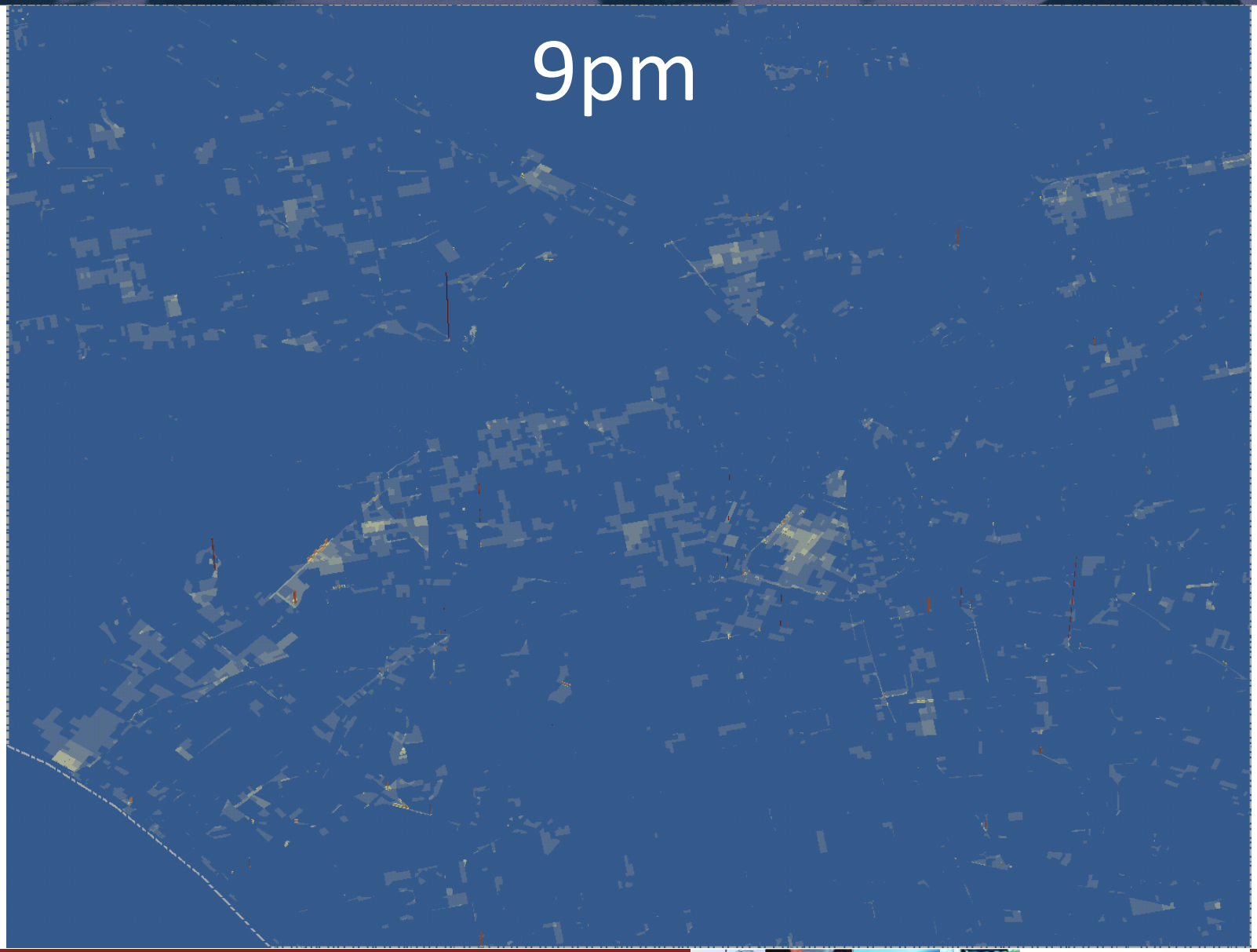
7pm



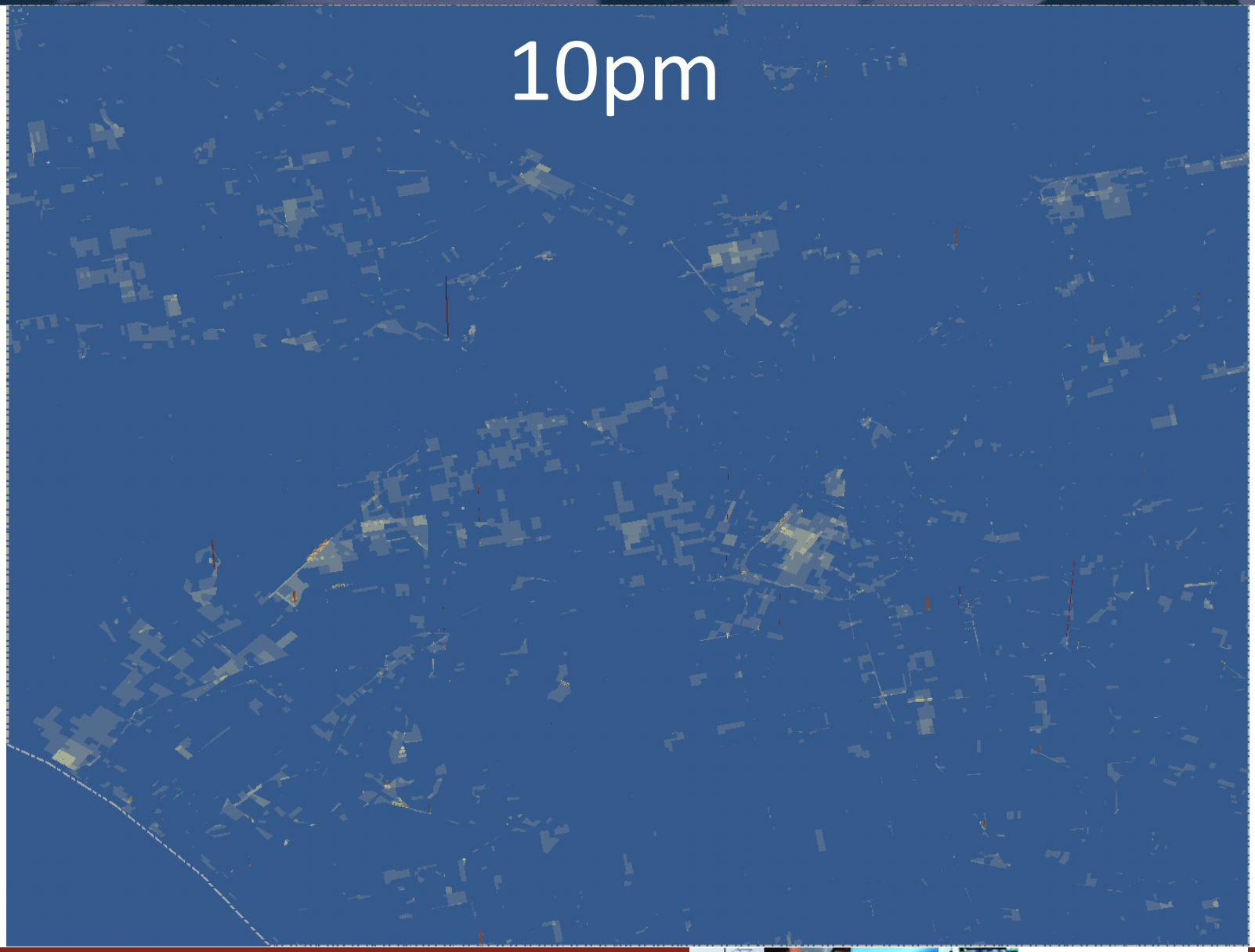
8pm



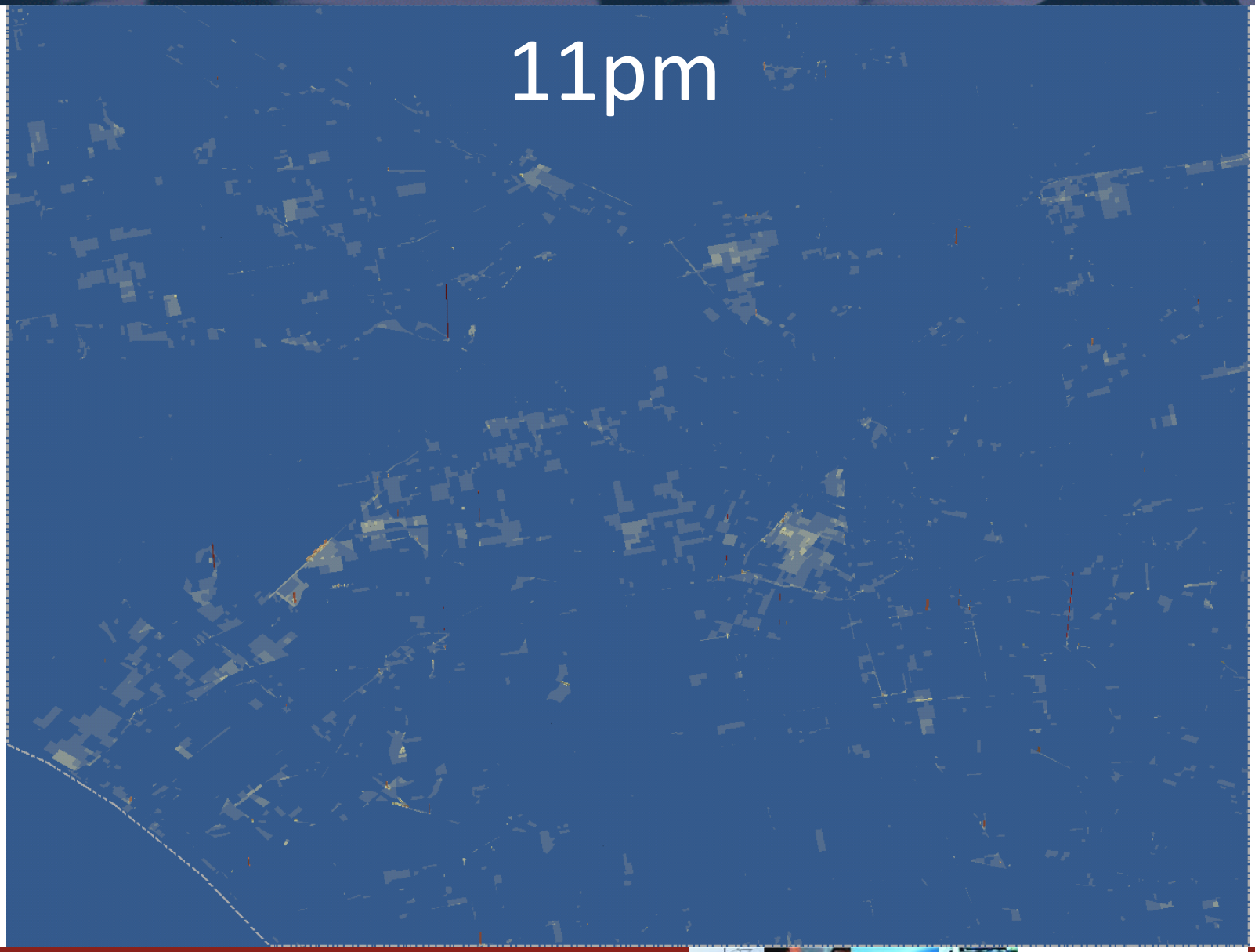
9pm



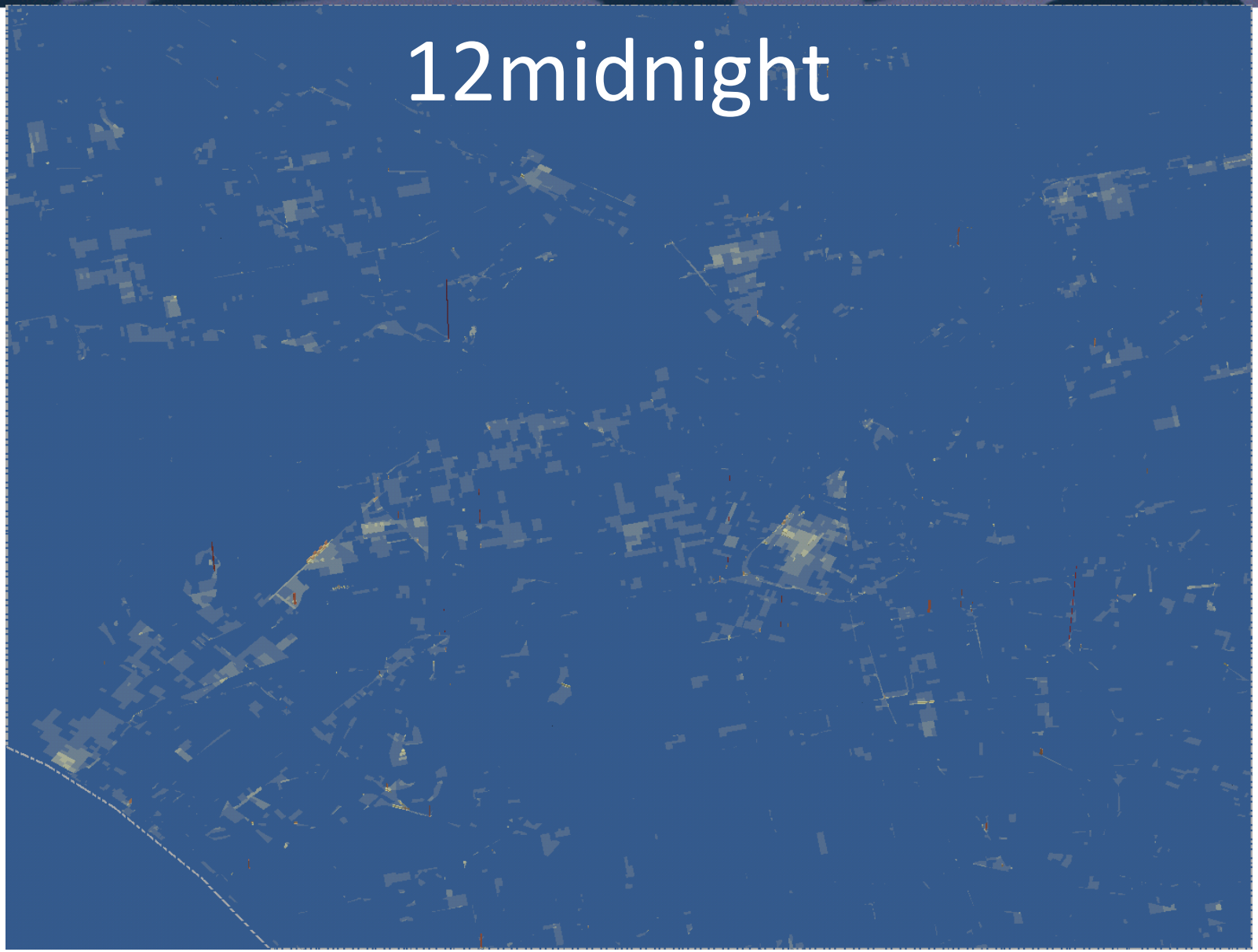
10pm



11pm



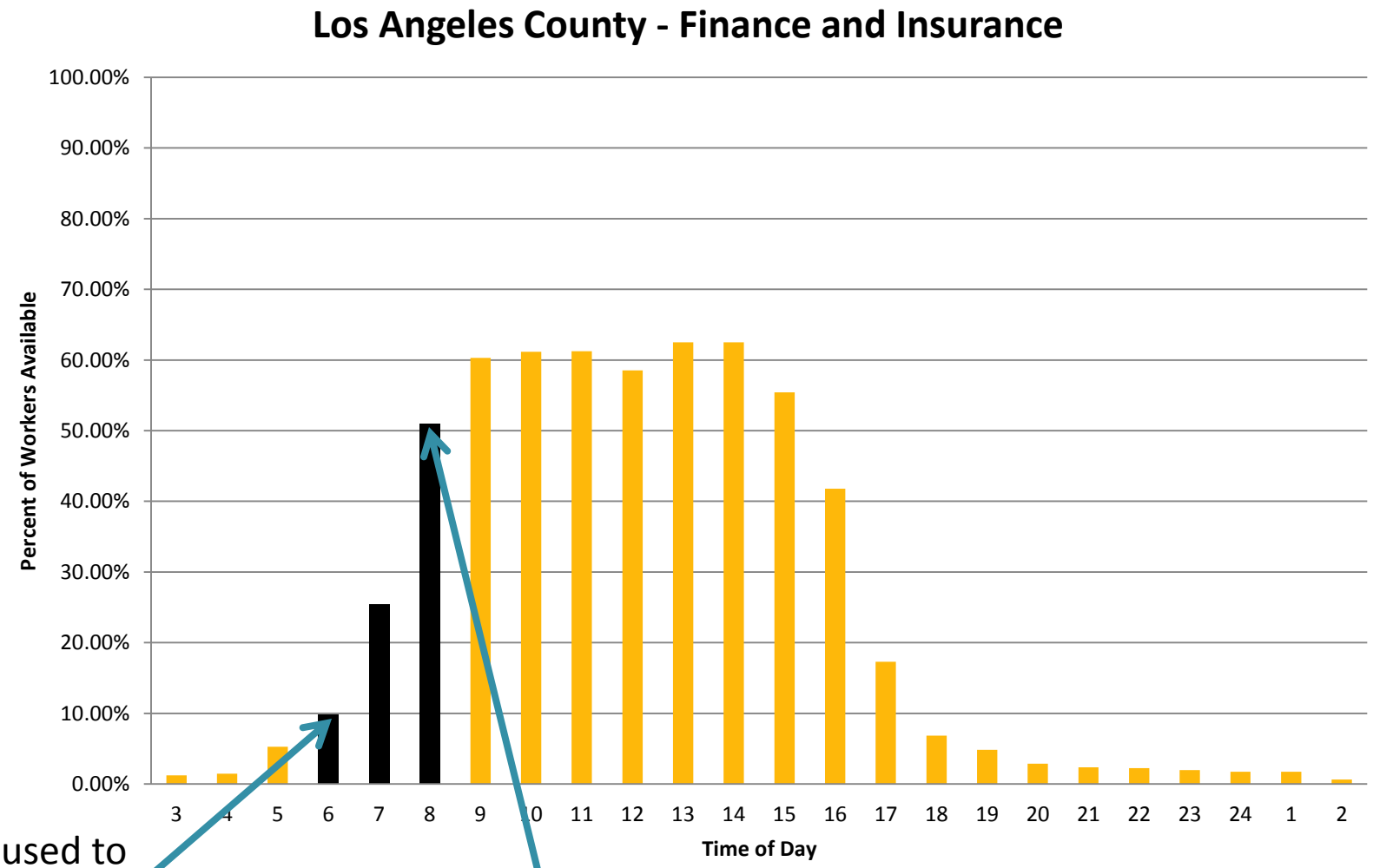
12midnight



Difference in Accessibility by Time of Day

11AM **8PM**

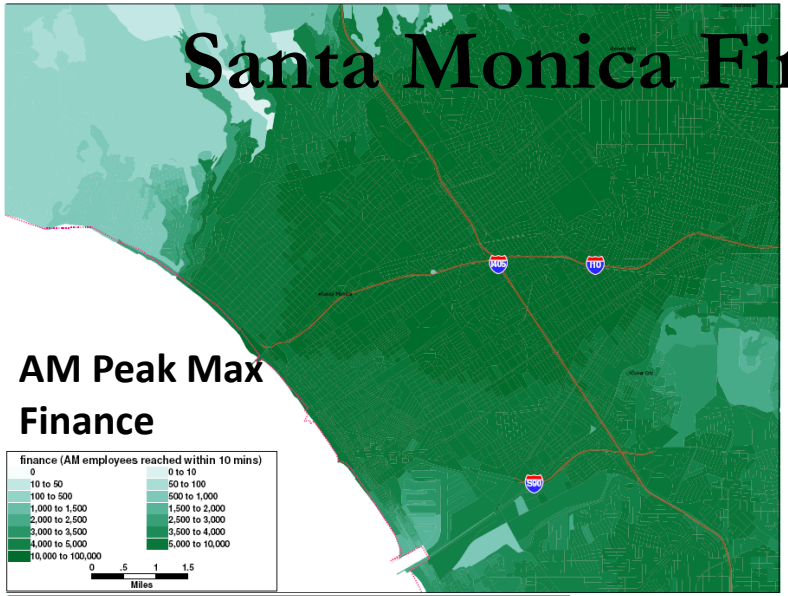
Min and Max in AM Peak

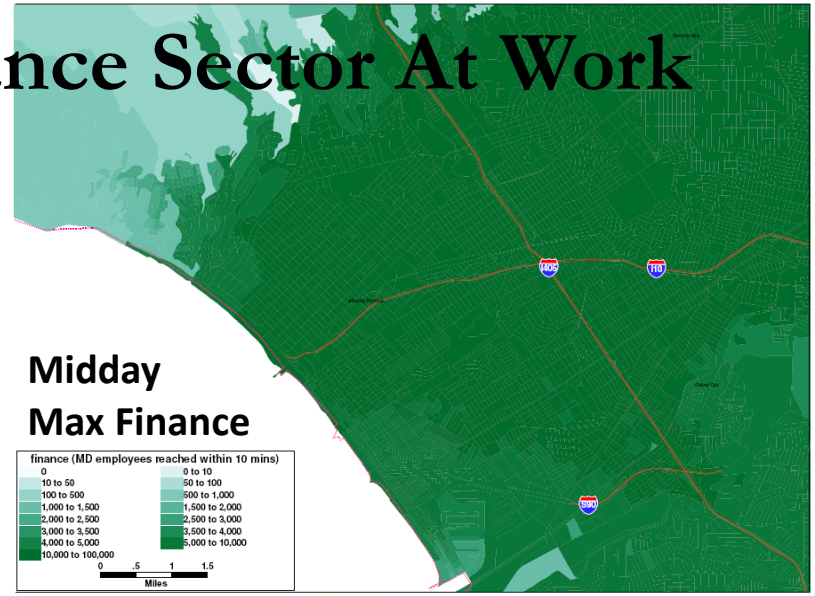


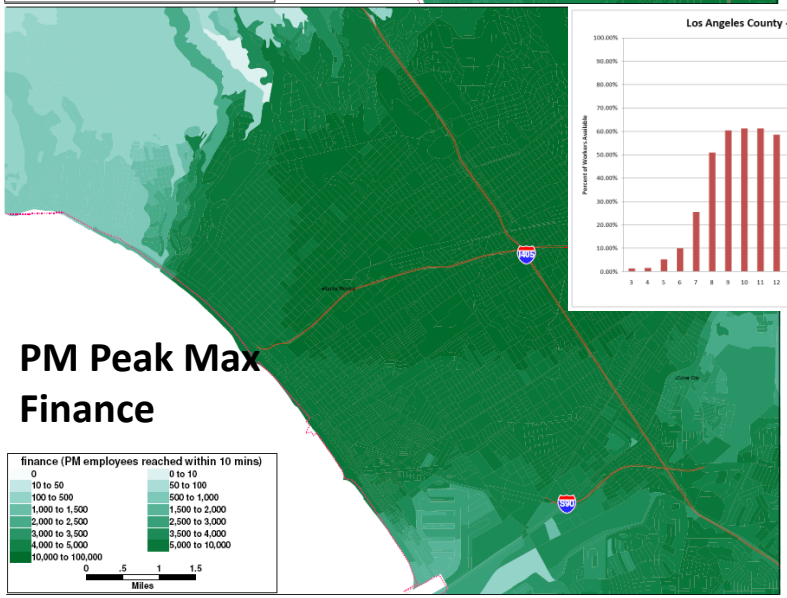
Percent used to compute Min

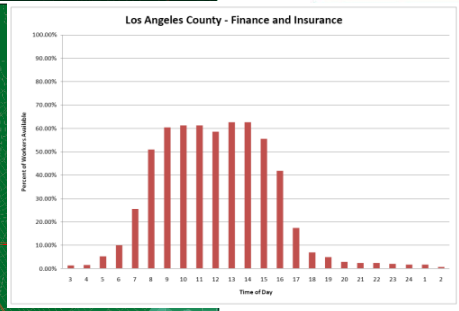
Percent used to compute Max

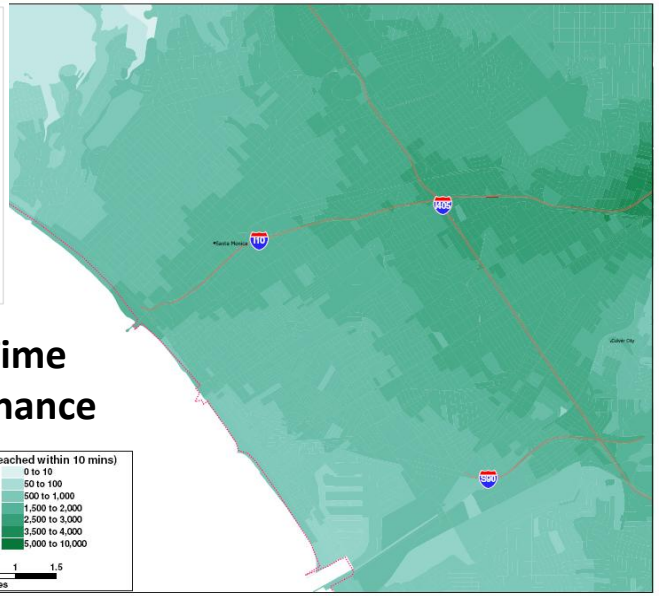
Santa Monica Finance Sector At Work



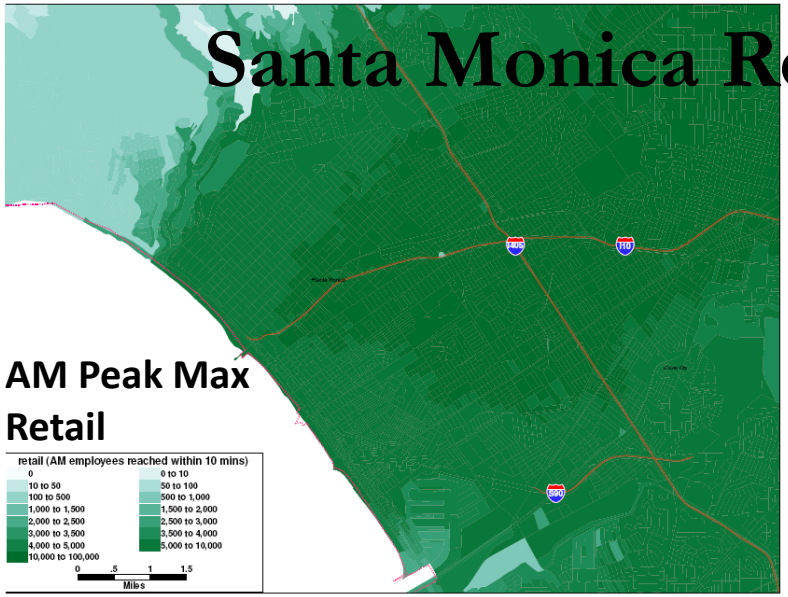


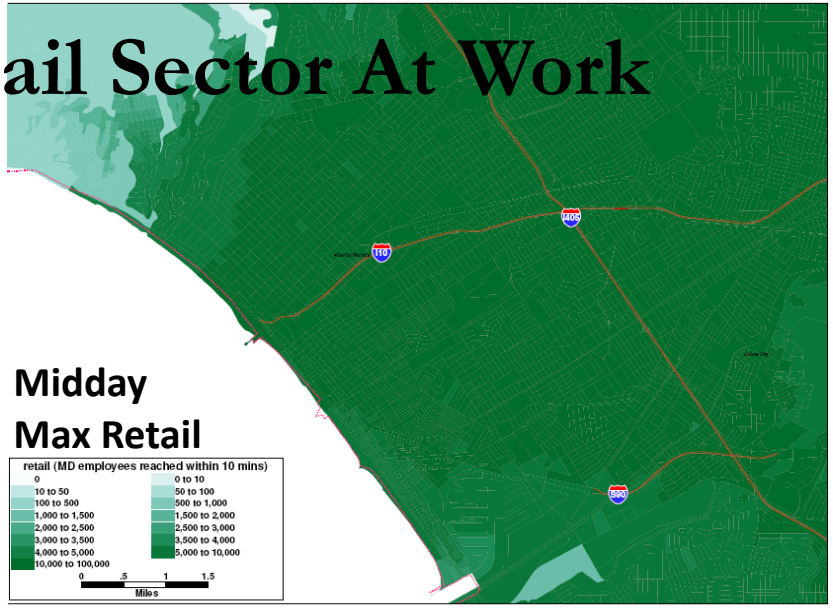


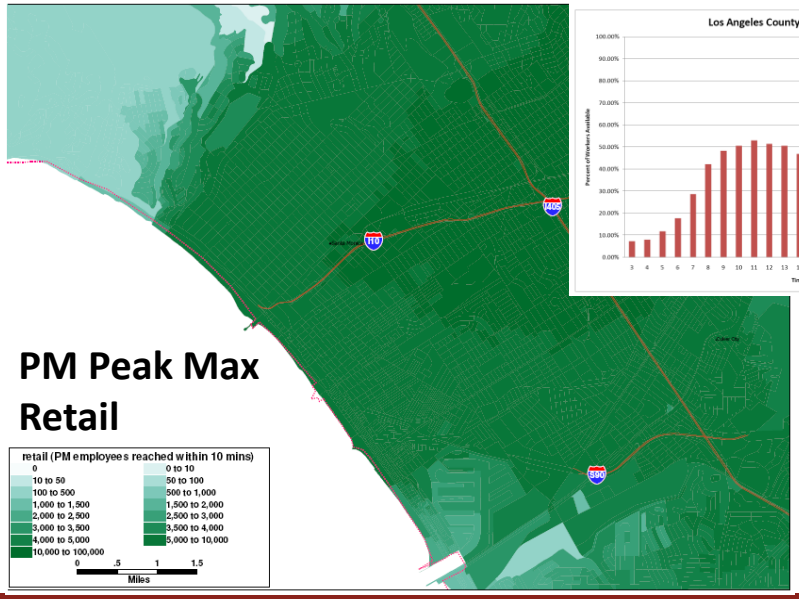


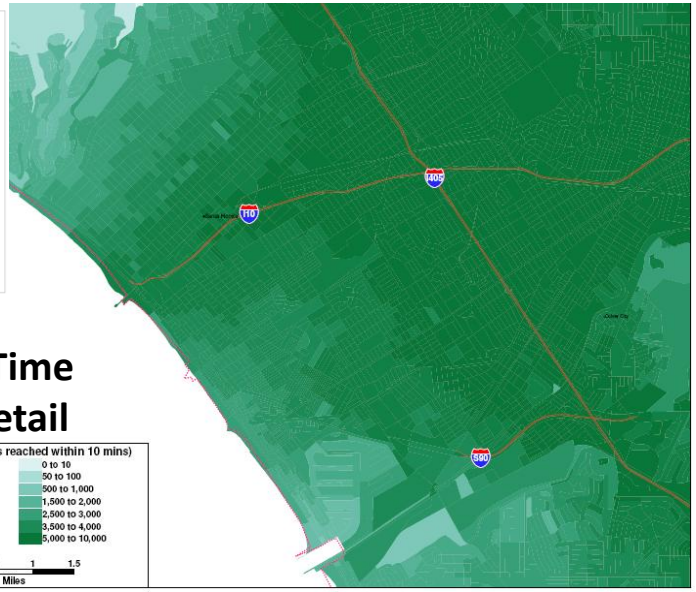


Santa Monica Retail Sector At Work



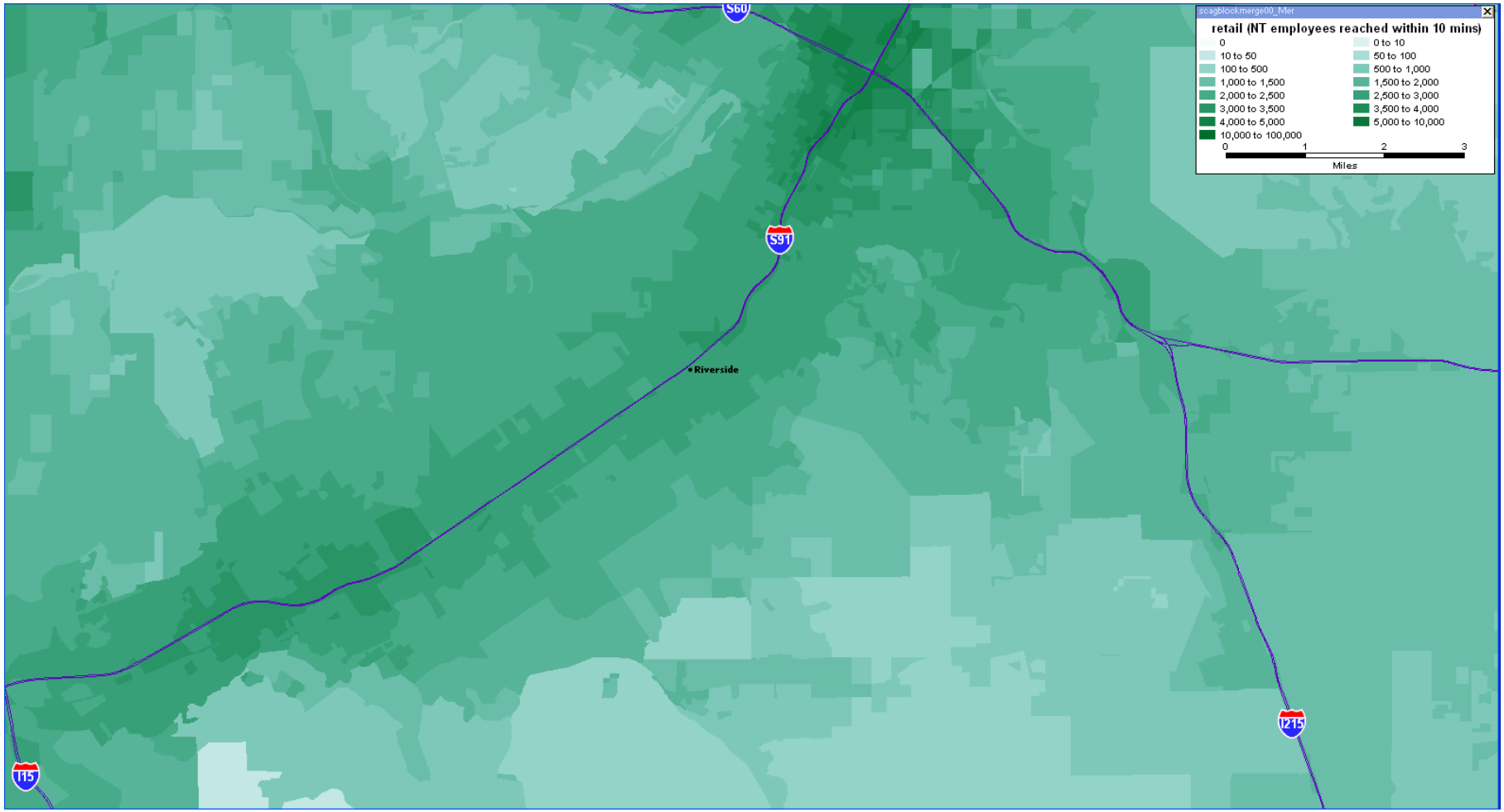




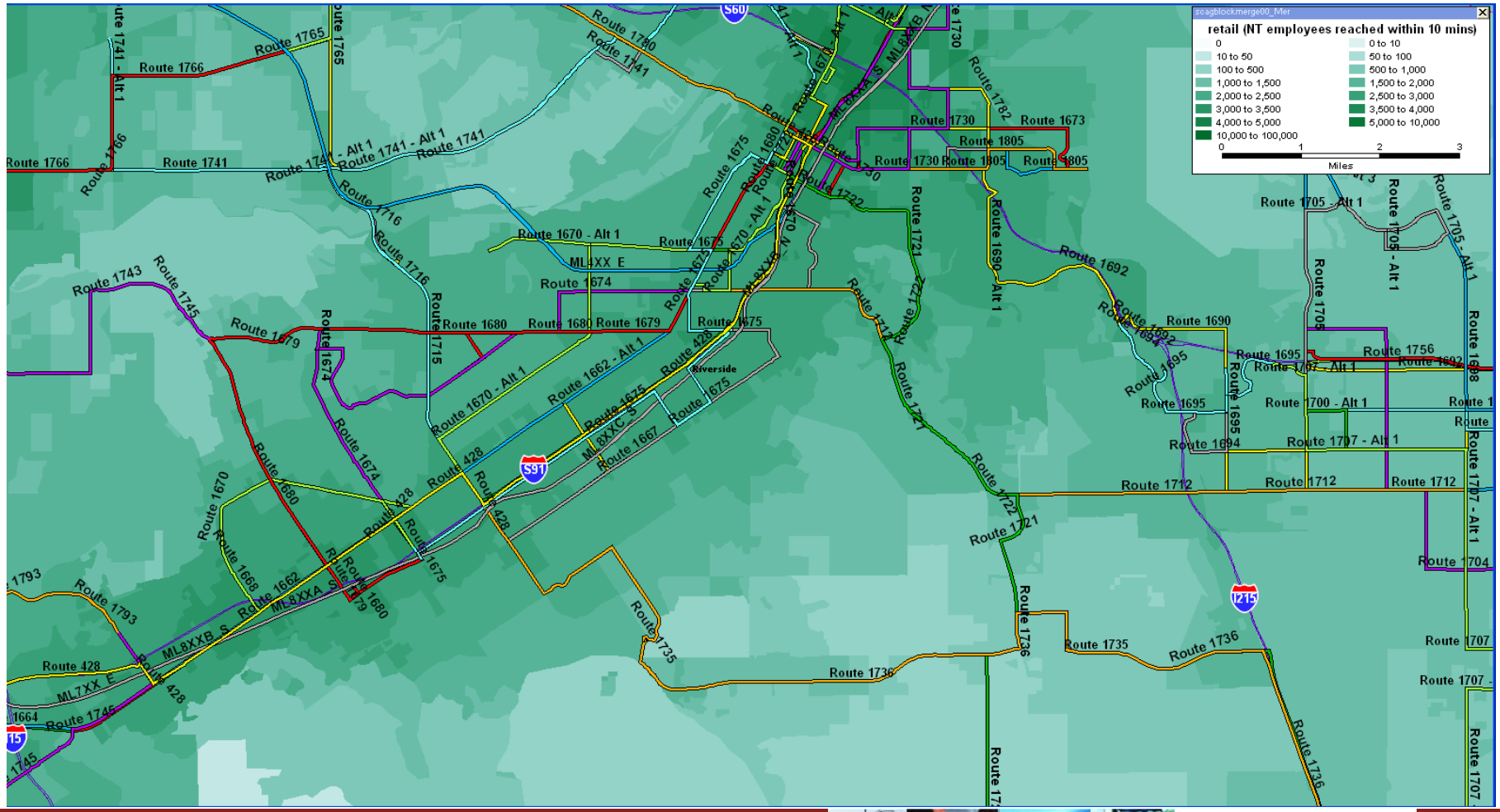


Riverside Opportunity Map

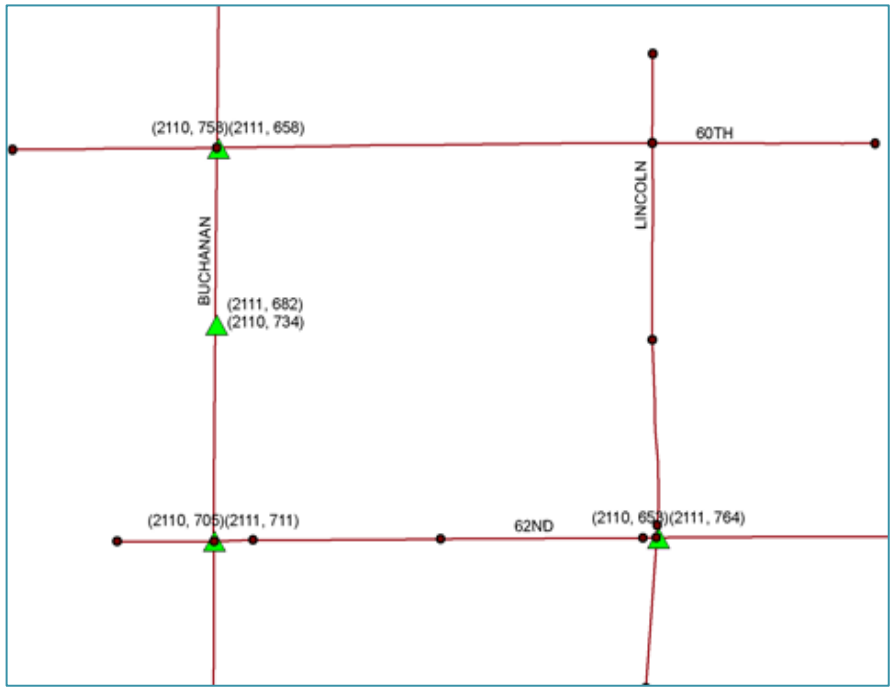
7PM to 6AM (Night Time) period: Max. retail within 10 minutes for each block



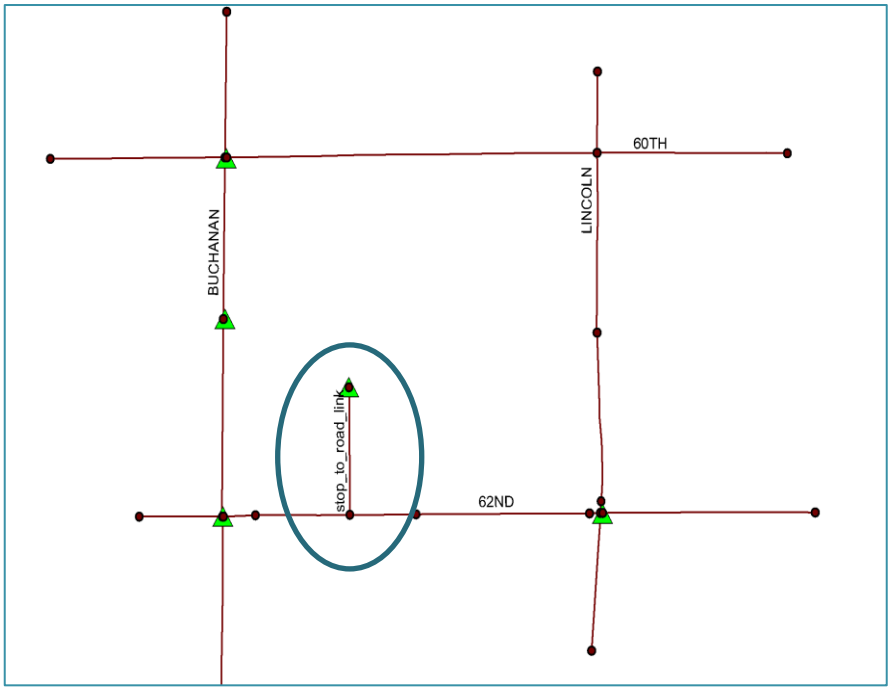
Superimposing Transit Routes



Developing the Transit Network

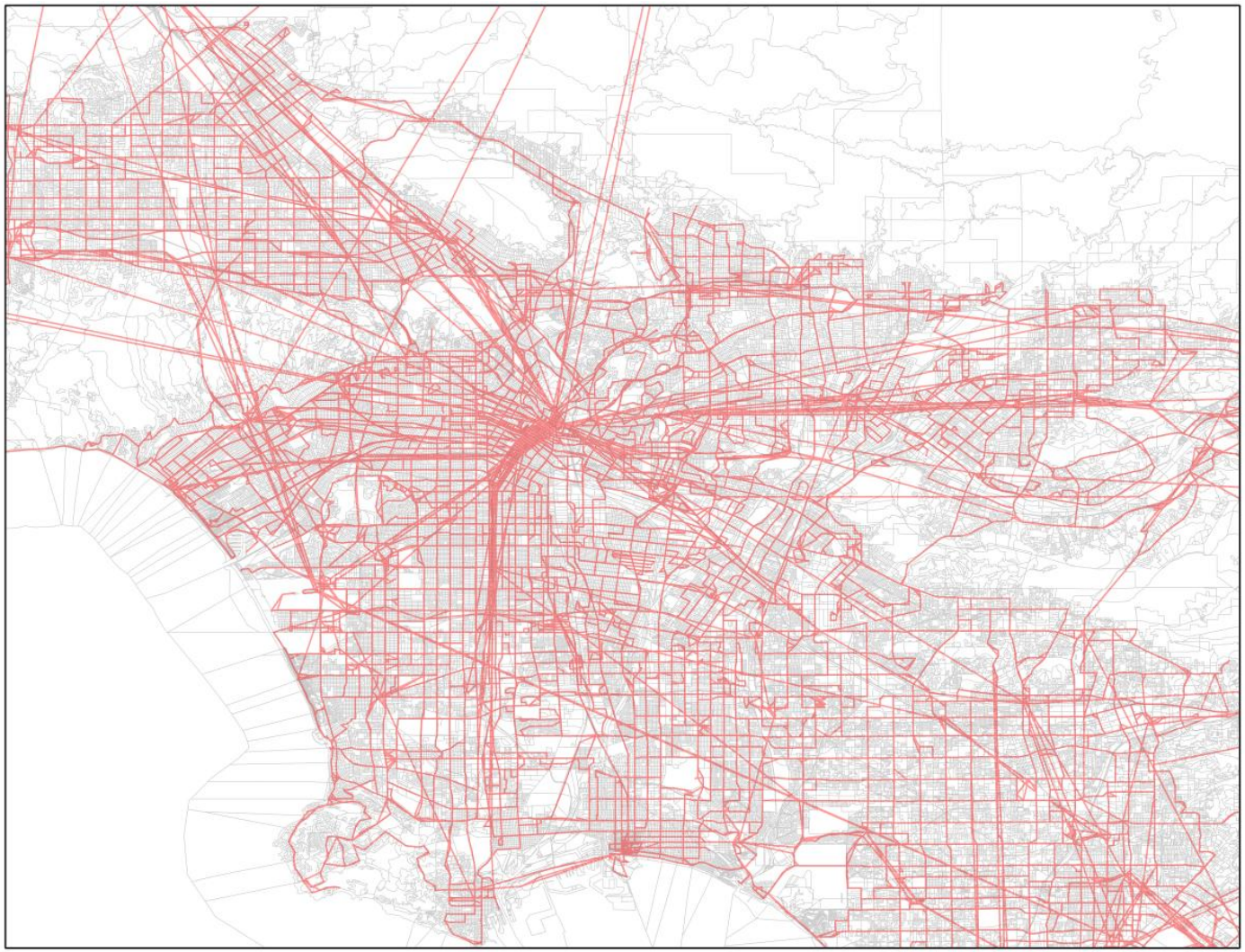


The transit network

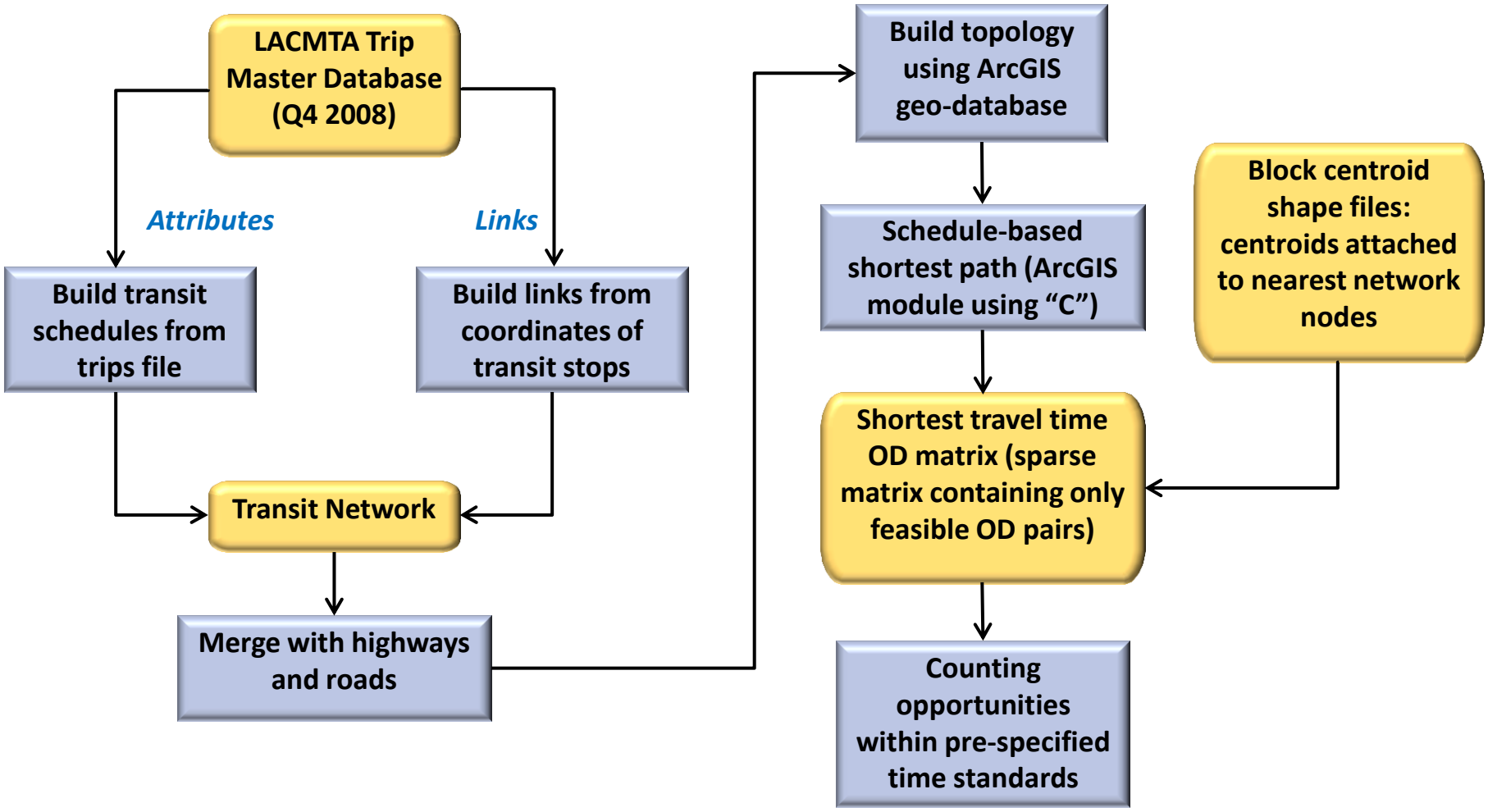


Integrated transit and road network

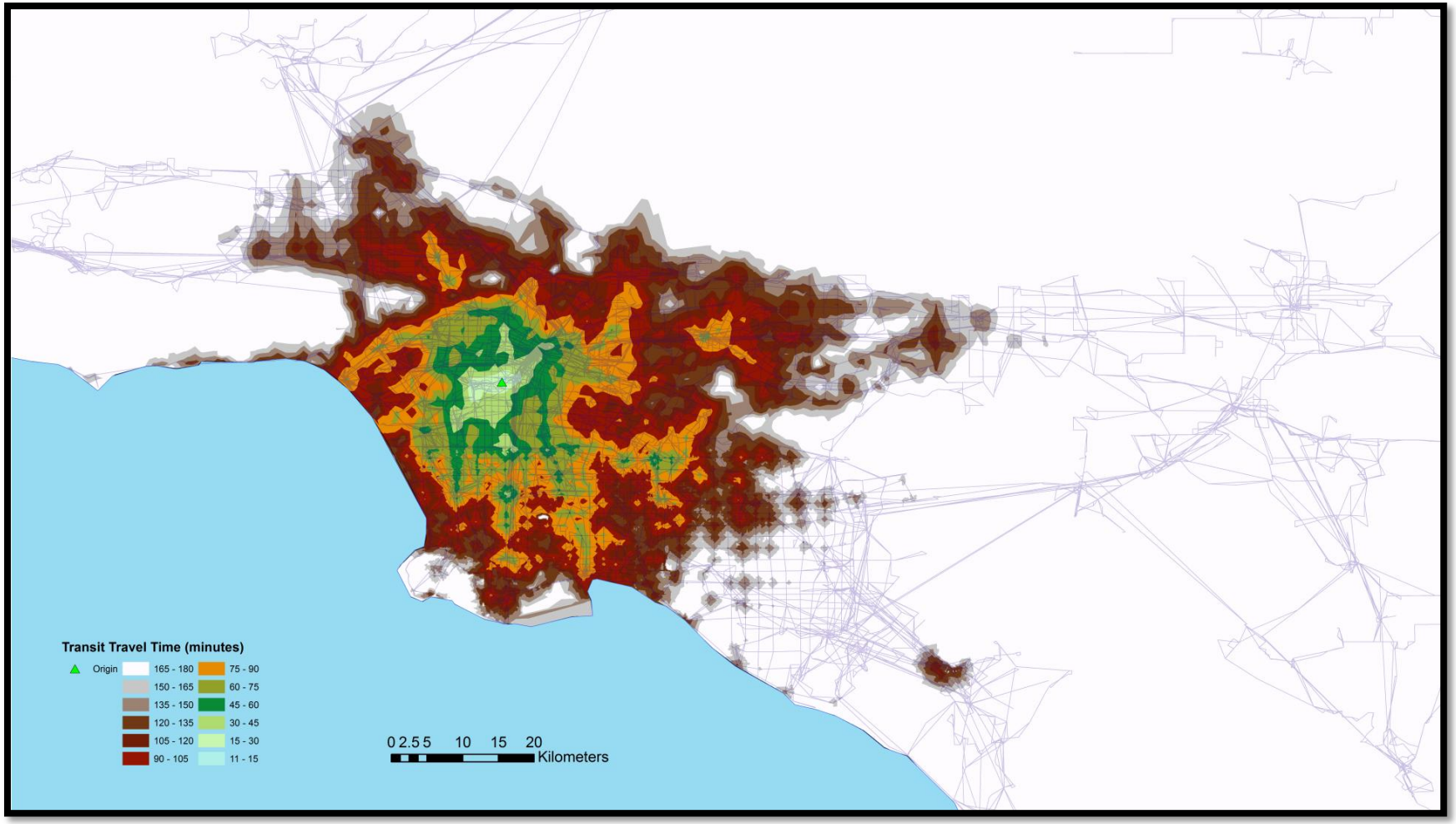
Bi-Modal Network for Los Angeles County



Workflow for Computing Transit Accessibility



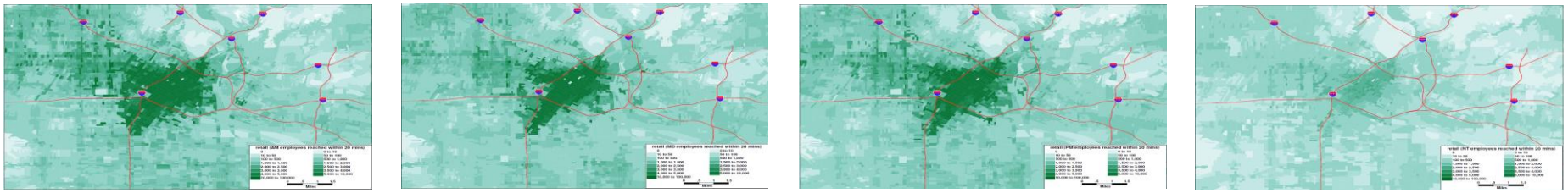
Space-time Prism of Travel by Public Transit



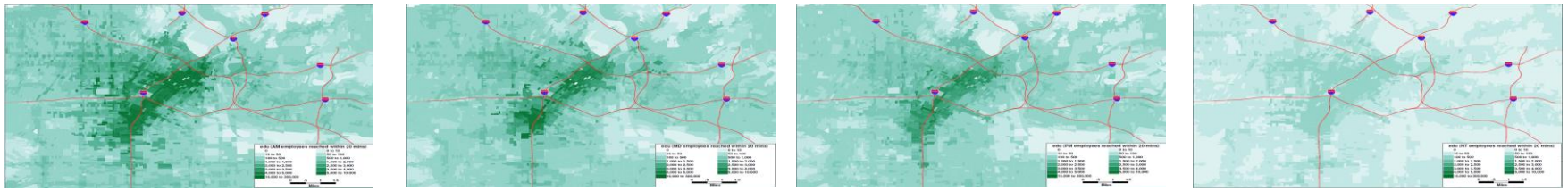
Data Source: LACMTA master trip database, Ting Lei, Jan. 2012

Transit Accessibility by Time-of-Day

AM Peak | Midday | PM Peak | Night Time



Maximum number of reachable retail employees for a 20-minute buffer by transit by time of day in Central Los Angeles.

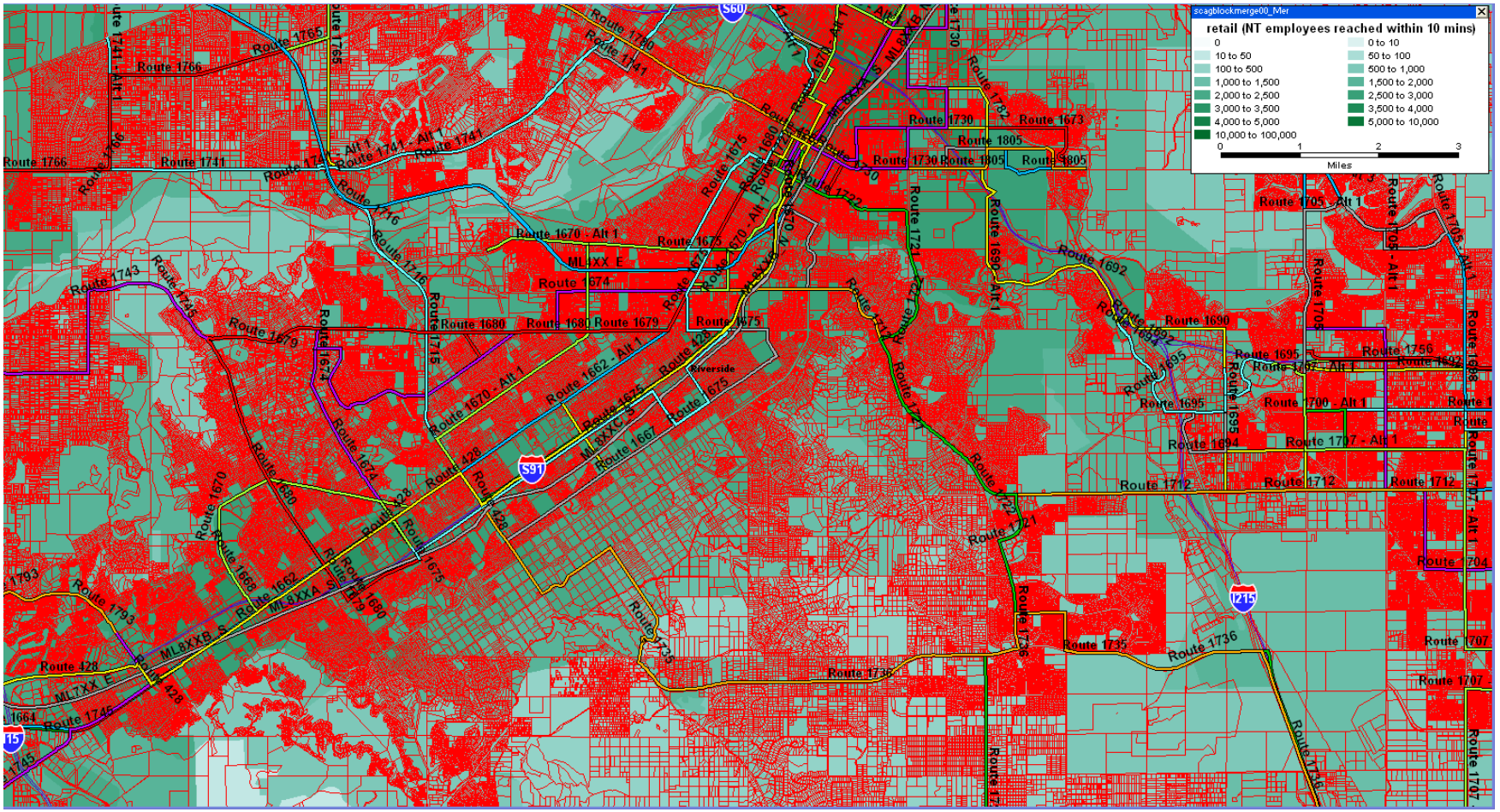


Maximum number of reachable education employees for a 20-minute buffer by transit by time of day in Central Los Angeles.

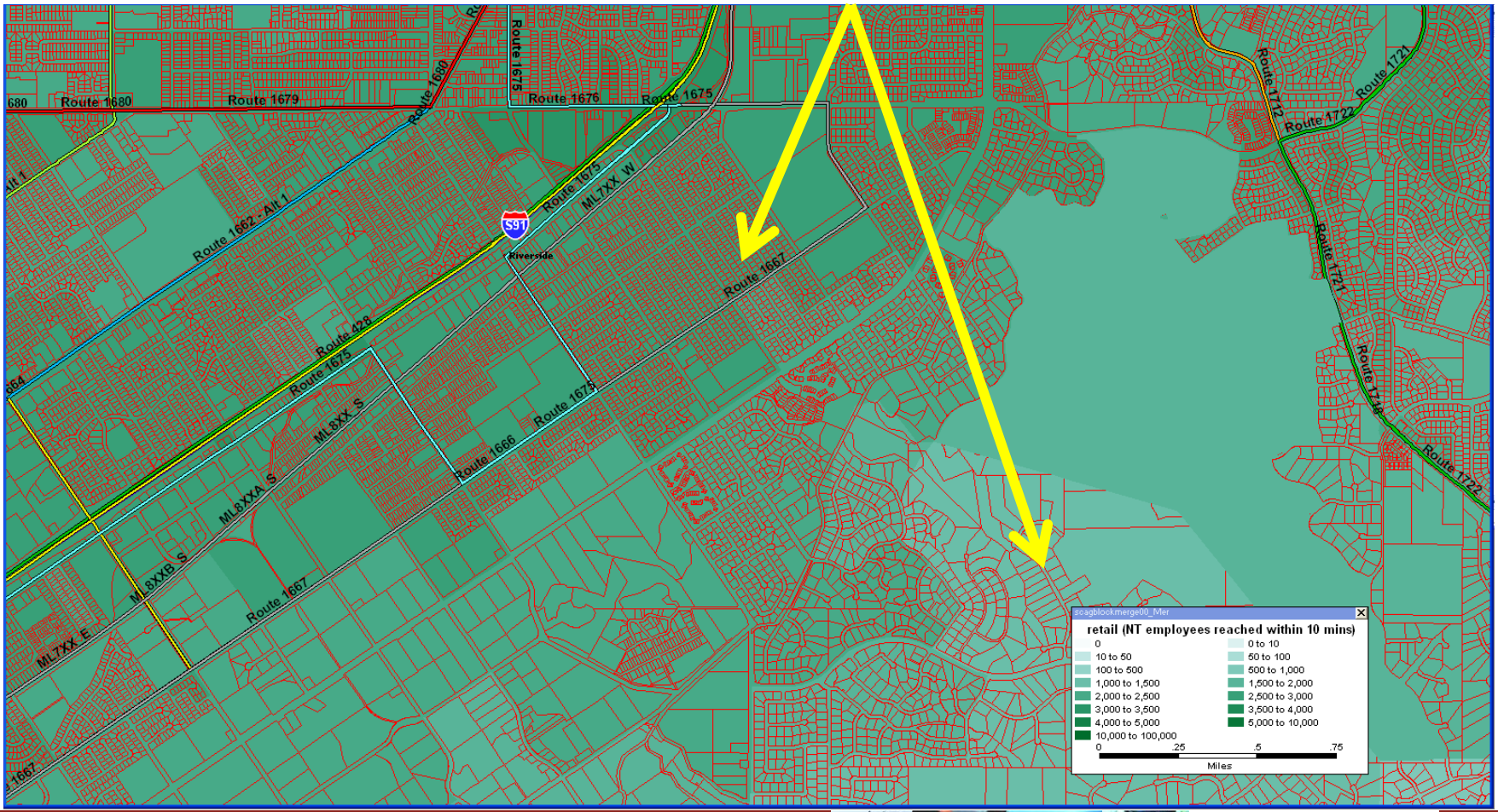
Maximum number of reachable retail employees for a 20-minute buffer by time of day in Central Los Angeles by Car

Maximum number of reachable education employees for a 20-minute buffer by time of day in Central Los Angeles by Car

Finer resolution accessibilities by time-of-day with land parcels



Compare retail accessibility between two different urban forms/street design



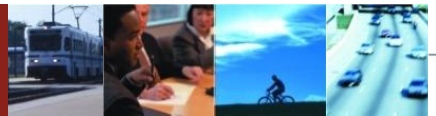
Putting it all together: Constructing accessibilities

- Socio-economic market segments
  - Mode alternative-specific constants and availability
  - Segment level-of-service coefficients
- Network \ Modes
  - Different accessibility measures are based upon certain modes or taken across all modes, depending on purpose of accessibility measure
  - Mode choice logsum used when accounting for all modes
- Time-of-day periods
  - Period-specific or logsum across periods
- Activity Purposes
  - Related to activities available
  - Land-use variables used in destination choice size terms
  - Activity types considered in other accessibility measures
- Spatial Unit
  - Zones, micro-zones, or parcels

Example of Accessibility Combinations

SANDAG Activity-based Model

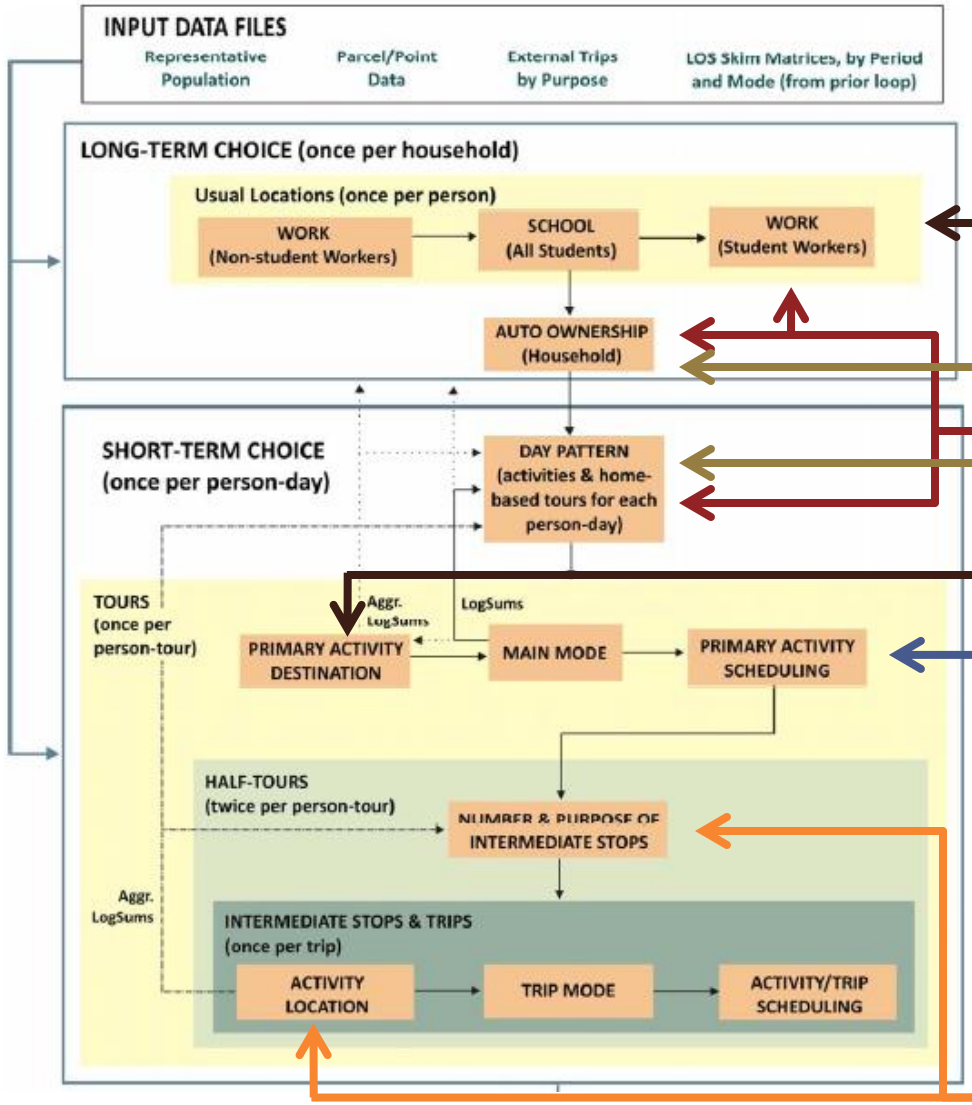
No	Description	Model where used	Attraction size variable	Travel Cost
1	Access to non-mandatory attractions by SOV in off-peak	Car ownership	Total weighted employment for all purposes	Generalized SOV time
2	Access to non-mandatory attractions by transit in off peak	Car ownership	Total weighted employment 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



Putting it all together: data needs

- Networks & Level-of-Service Skims
  - By mode, time-of-day
  - In-vehicle time, out-of-vehicle time, distance, fare, tolls, etc.
- Land-Use Data
  - Zone, micro-zone, and/or parcel level
  - Households, population, employment by type
  - "4D" measures – intersection density, "walkability", mixed-use, etc.
- Household survey data (and transit on-board survey if available)
  - Used to estimate size term, level-of-service, socio-demographic and other coefficients and alternative-specific constants
- Future forecasting
  - Hold coefficients constant, vary input networks and land-use data to measure effects of accessibilities on travel

DaySim (SACOG) Accessibility Effects



Mode choice logsums for sampled destinations (weighted average across time-of-day periods)

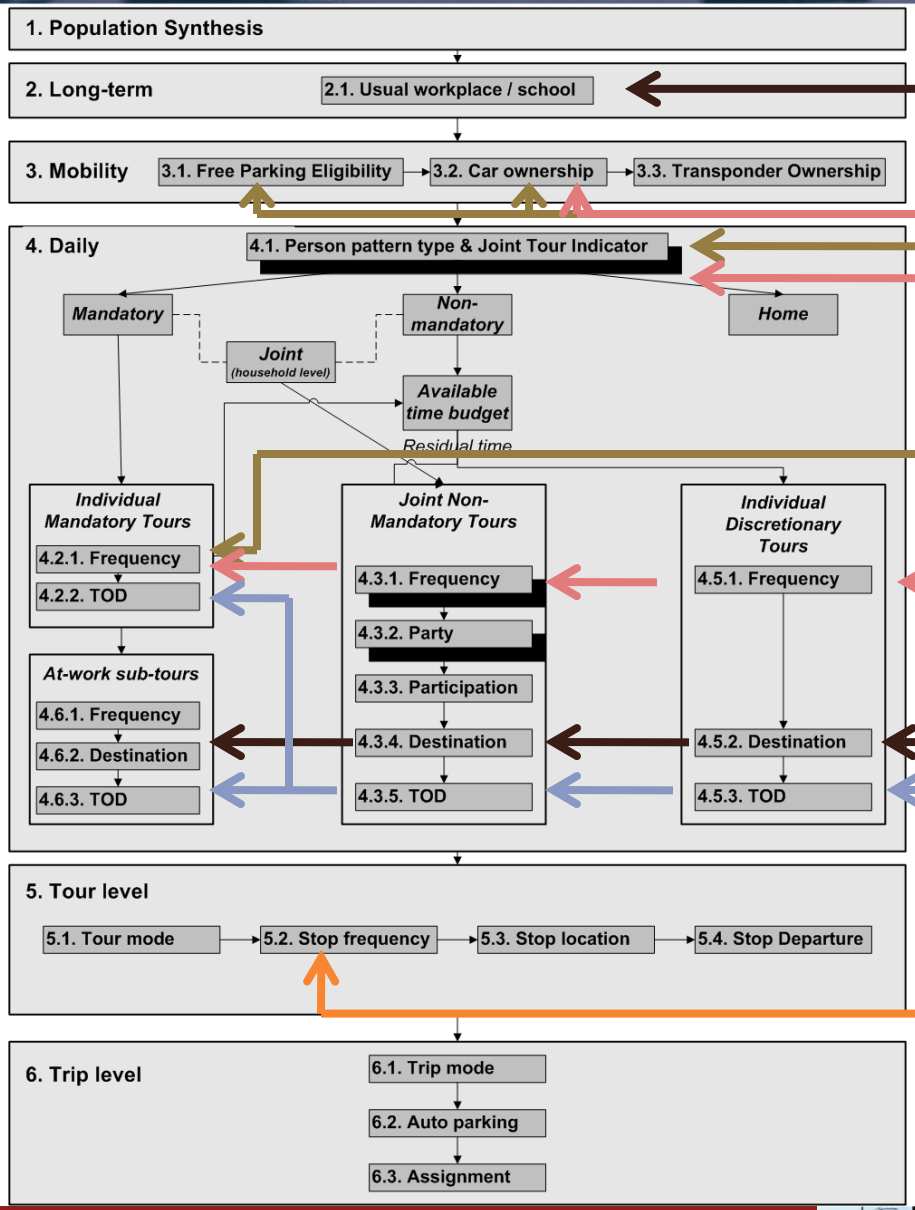
Non-work tour ***mode-destination*** logsum (weighted average across time-of-day periods)

Mode choice logsums for chosen work & school destinations (weighted average across time-of-day periods)

Mode choice logsums for each of 15 different time-period combinations for the relevant tour purpose.

Approximate ***mode-destination*** logsum for stop attractiveness

CT-RAMP (SANDAG) Accessibility Effects



Mode choice logsums for sampled destinations (weighted average across time-of-day periods)

Non-work tour ***mode-destination*** logsum (weighted average across time-of-day periods)

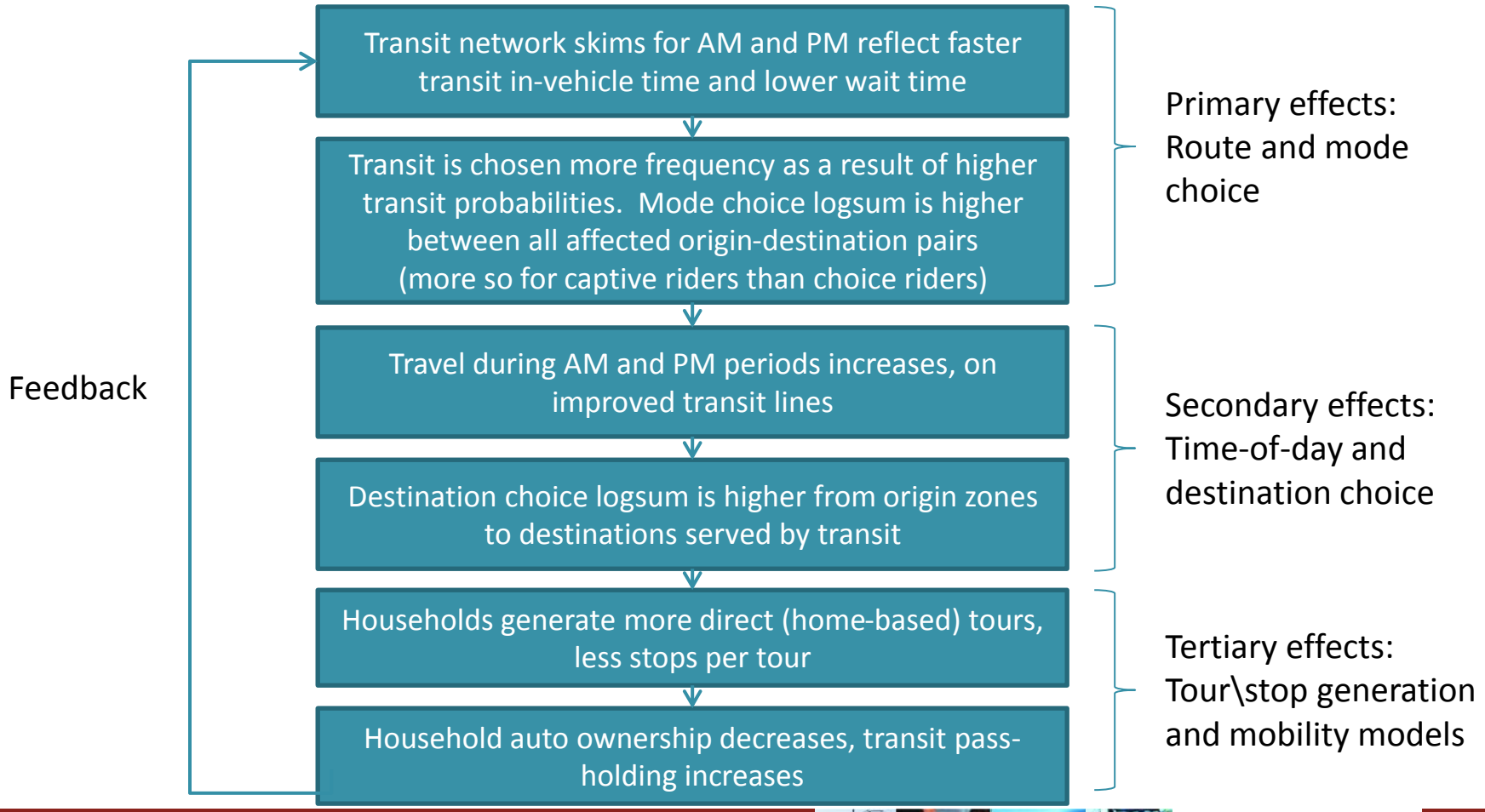
Mode choice logsums for chosen work & school destinations (weighted average across time-of-day periods)

Mode choice logsums for each of 15 different time-period combinations for the relevant tour purpose.

Approximate ***mode-destination*** logsum for stop attractiveness

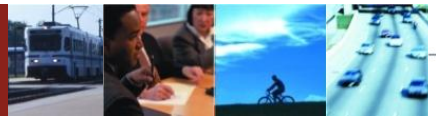
Accessibility Effects: A Practical Example

- Transit service is improved (faster, more frequent) in a congested corridor during A.M. Peak and P.M. peak periods



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



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	
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Accessibility and Treatment of Space	May 16
Long-Term and Medium Term Mobility Models	**June 7**
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