TMIP Webinar Series

Activity-Based Modeling

Session 10: Tour Mode, Primary Destination, Intermediate Stop Location and Trip Mode

The Travel Model Improvement Program

Speakers: Joel Freedman & John Gliebe

August 9, 2012

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2012 Activity-Based Modeling Webinar Series

Executive and Management Sessions	
Executive Perspective	February 2
Institutional Topics for Managers	February 23
Technical Issues for Managers	March 15
Technical Sessions	
Activity-Based Model Frameworks and Techniques	April 5
Population Synthesis and Household Evolution	April 26
Accessibility and Treatment of Space	May 16
Long-Term and Mobility Choice Models	June 7
Activity Pattern Generation	June 28
Scheduling and Time of Day Choice	July 19
Tour and Trip Mode, Intermediate Stop Location	**August 9**
Network Integration	August 30
Forecasting, Performance Measures and Software	September 20

Learning Outcomes

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

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

Webinar Outline

- Tour mode, primary destination, intermediate stop location and trip mode review
- Tour mode choice
- Intermediate stop location choice
- Trip mode choice
- Questions and answers

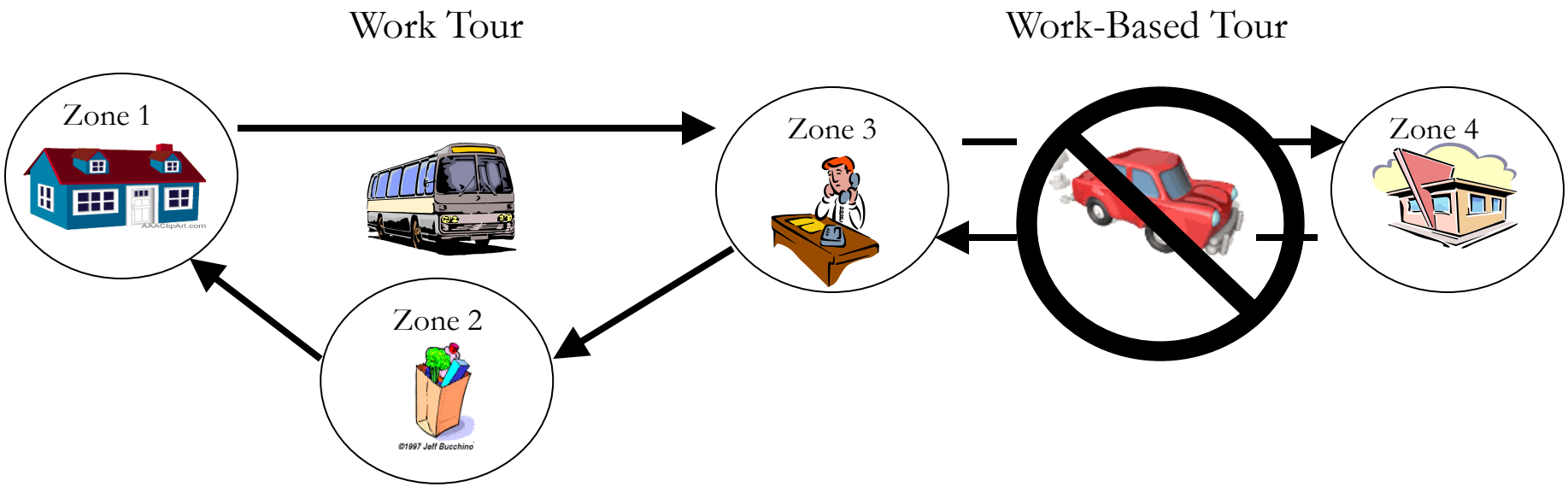
Terminology

- Tour mode
  - Preferred mode or primary mode for the tour
  - Ensures consistency between modes for each trip on tour
- Trip mode
  - The mode for each trip on the tour
- Rubber-banding
  - The use of out-of-direction distance, time, and/or utility to choose intermediate stop location
  - Ensures reasonable locations of stops on tours

Key Concepts

- Consistency across travel dimensions is important
  - Number of stops on tour with mode used (correlations)
  - Tour origin and destination with intermediate stop locations (logic)
  - Intermediate stop locations with tour mode used
  - Trip mode and tour mode
- How can we ensure consistency?
  - Model structure
  - Constraints (alternatives available) and situational variables
  - Log-sums (upward integrity)

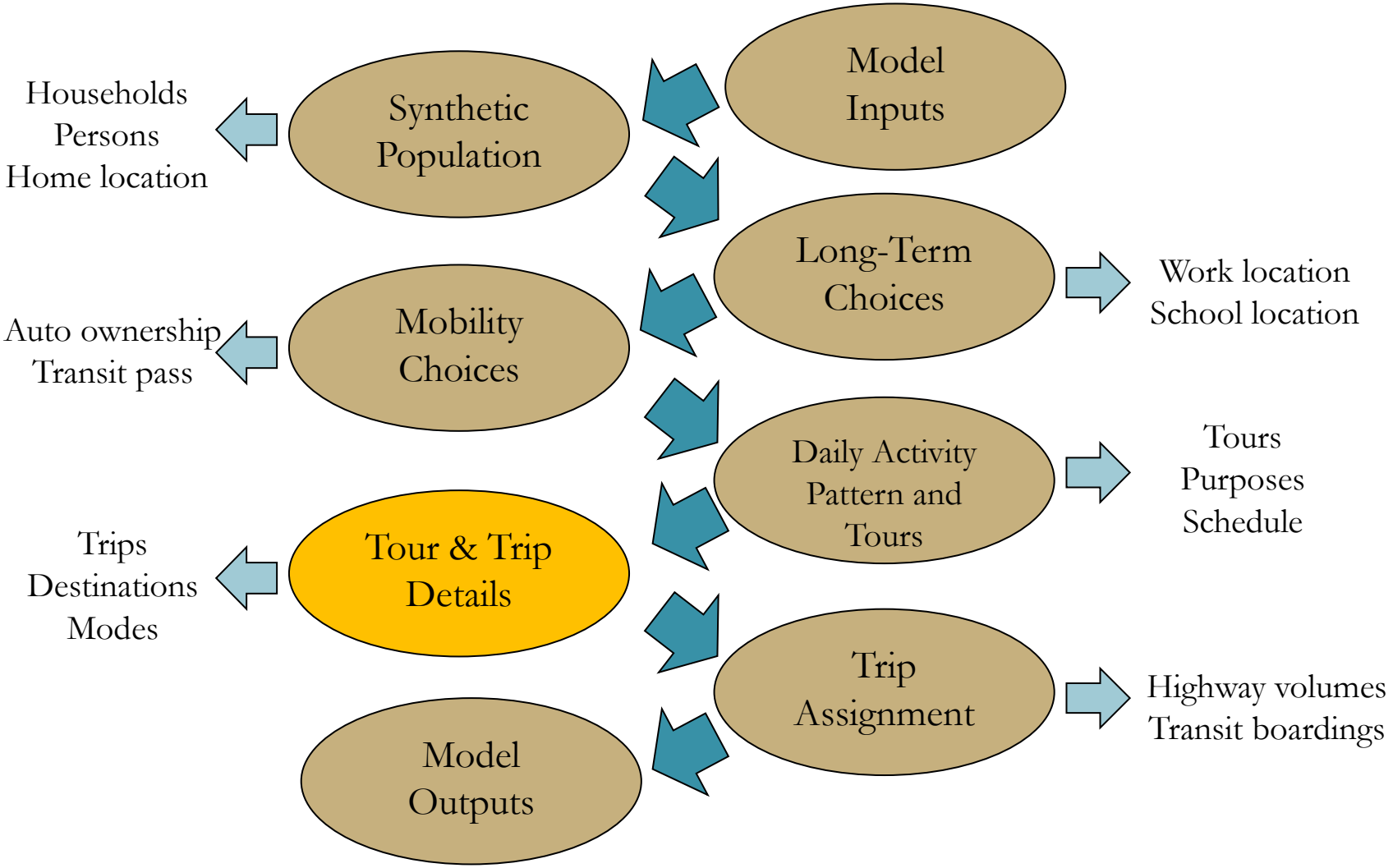
Key Concepts



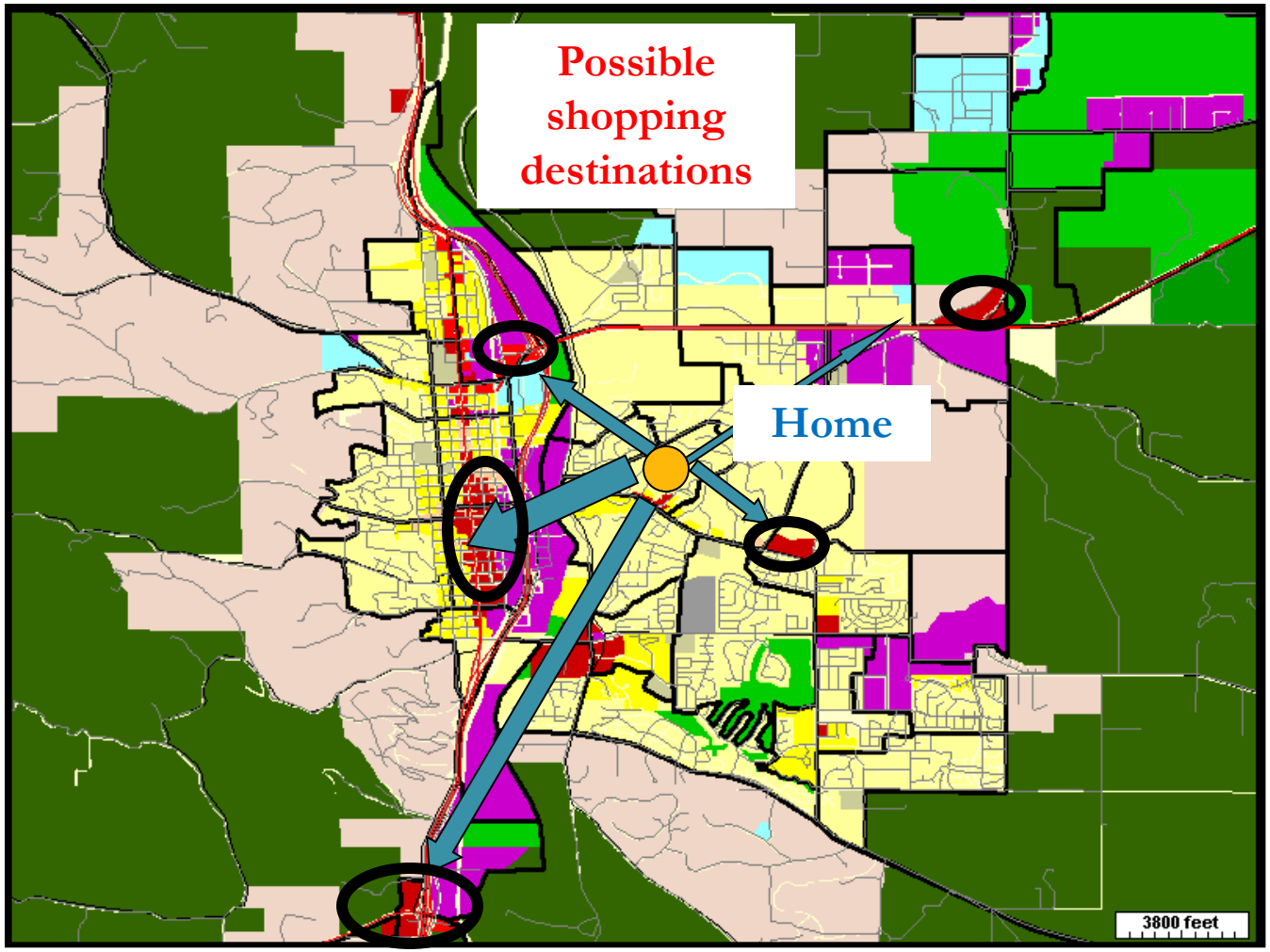
Bus to Work -> Drive alone not available for lunch

Bus to Work -> Likely choose close lunch location

Role and Placement in an ABM

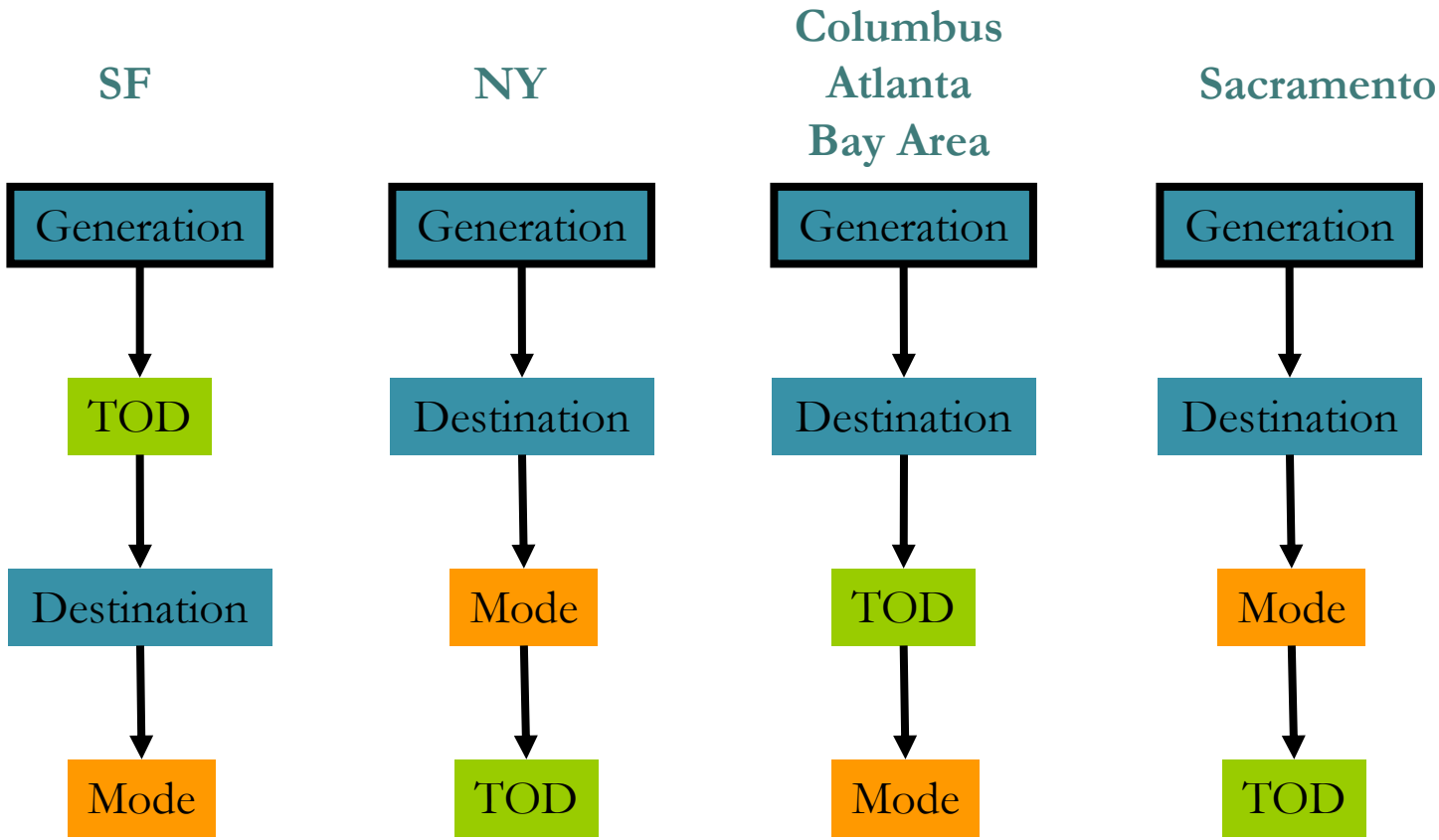


(Non-Mandatory) Tour Destination Choice



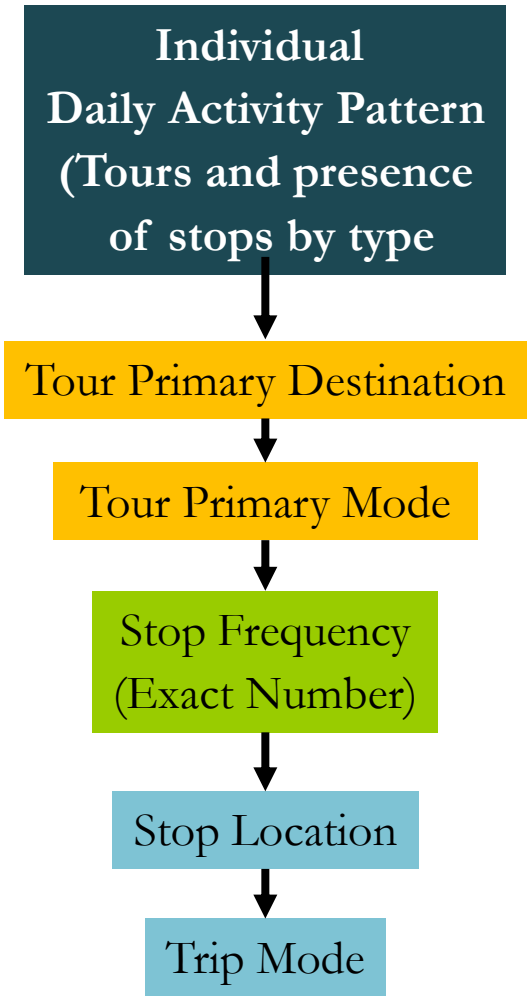
- Similar to mandatory tour destination choice
- Probability depends on a size term, and an impedance to each TAZ
- Singly-constrained or doubly-constrained?

Sequencing (Non-Mandatory) Tour Level Models



- Should destination choice or time-of-day choice happen first?
- If destination choice happens first, which time period should be used for level-of-service?

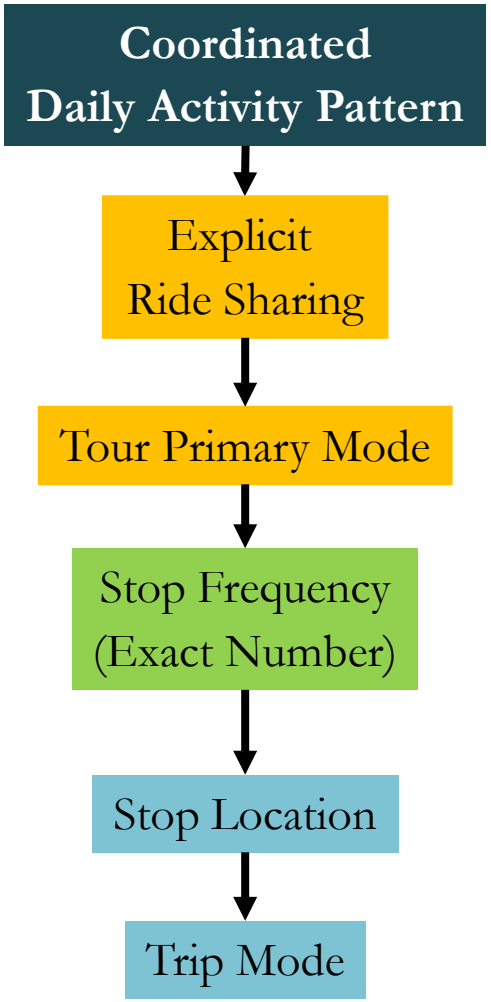
Model Structures I



DaySim Structure

- Daily activity pattern models predict 0 vs. 1+ stops on outbound and inbound portions of tours
- Tours with intermediate stops are more likely to choose auto modes

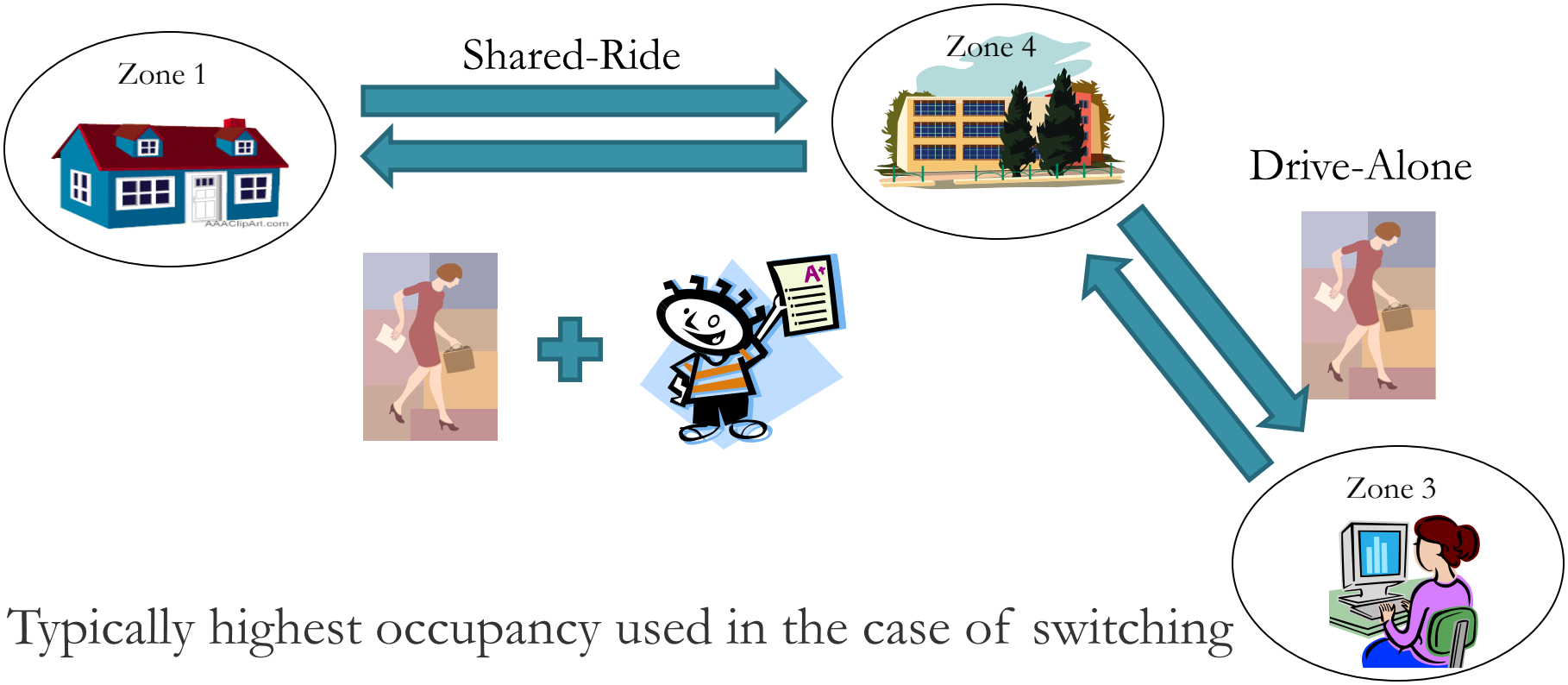
Model Structures II



CT-RAMP Structure

- Tour mode choice occurs before stop frequency
- Auto tours are more likely to have intermediate stops than walk-transit tours (drive-transit tours tend to have as many, if not more, stops as auto tours)
- Explicit ride-sharing for escorting kids to school

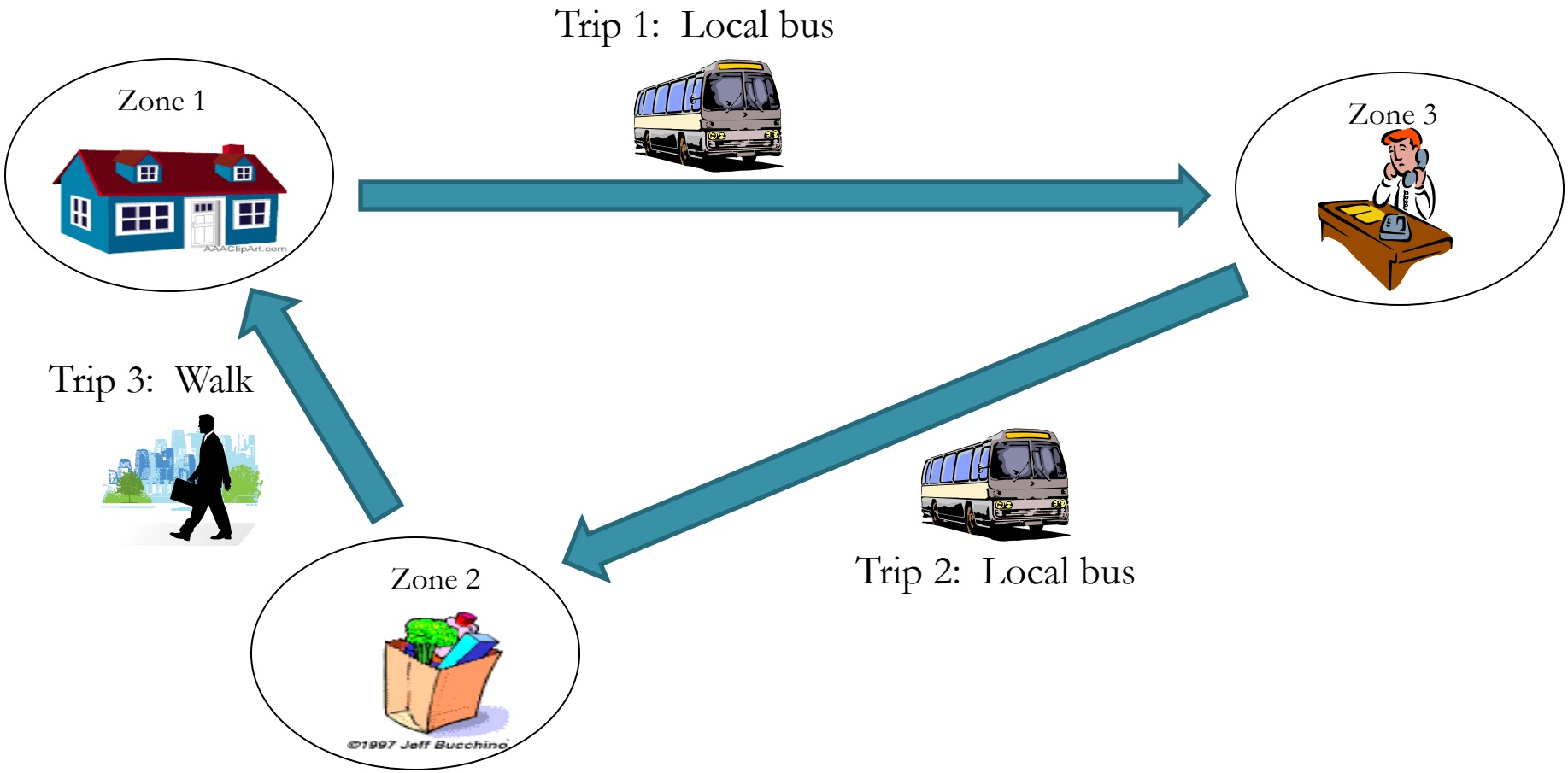
Defining Tour Mode – Shared-Ride Tours



Typically highest occupancy used in the case of switching

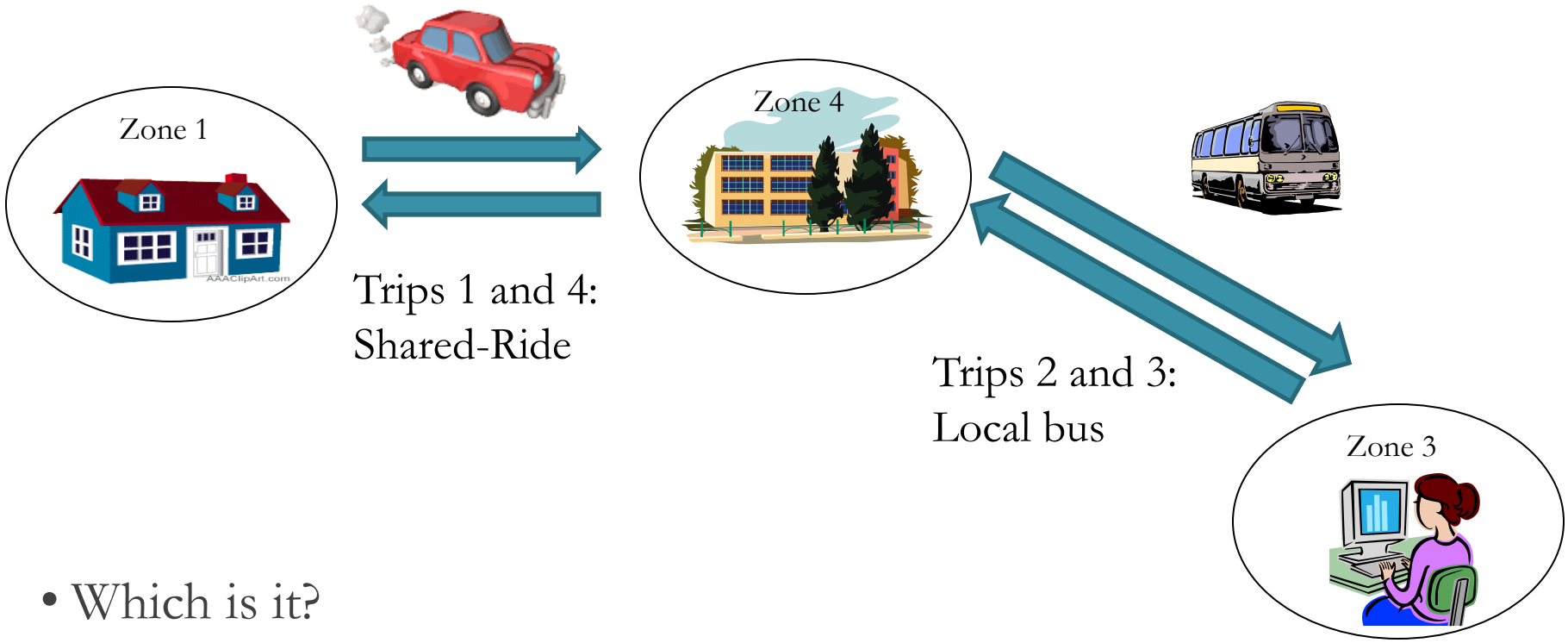
- Child: Shared-Ride 2 Tour (no switching)
- Parent: Shared Ride 2 Tour (with drive-alone trip legs)

Determining Tour Mode – Walk-Transit Pattern



- Transit tour with stop (walk): Tour mode = walk-transit

Determining Tour Mode – Drive-Transit Pattern



- Which is it?
  - Transit tour with stop (auto): Tour mode = Drive-transit (P&R)
  - Transit tour with stop (auto): Tour mode = Drive-transit (K&R) for one person; drive (auto) for the other.

Tour Mode—Trip Mode Consistency

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

Highest occupancy trip mode identifies auto tour mode

Presence of walk-transit identifies walk-transit tour

Types of Modes Considered

HOV\Managed Lanes

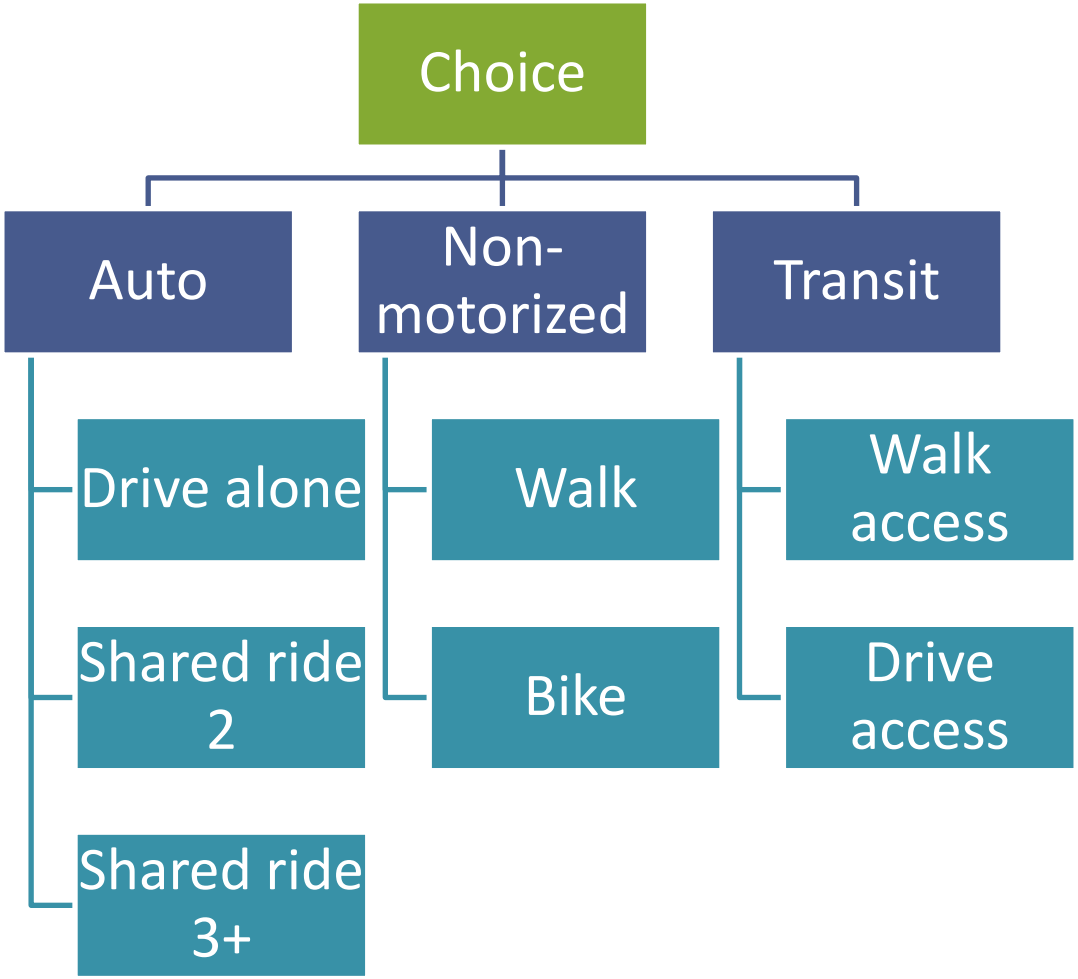
Bus Rapid Transit

Light-Rail

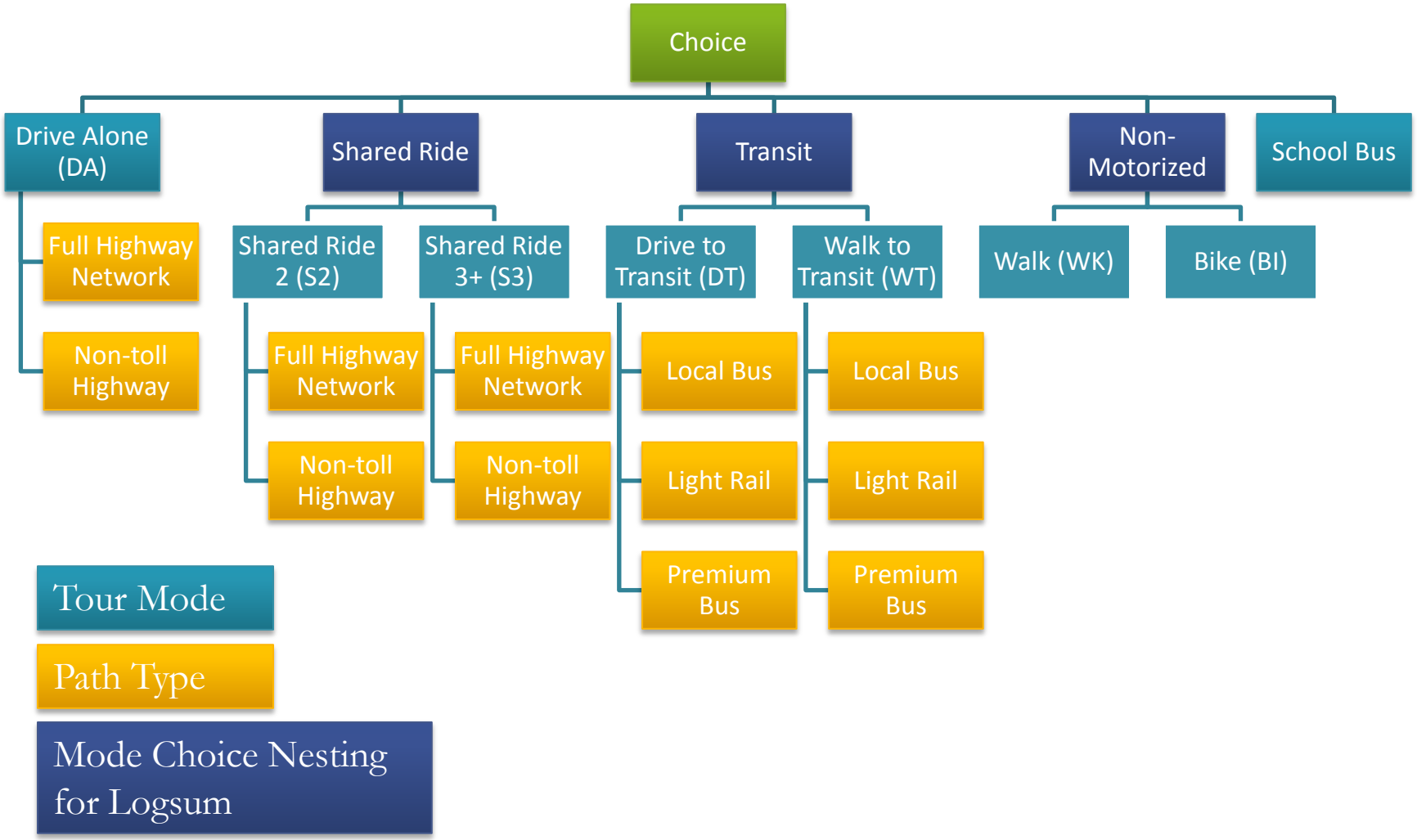
Heavy Rail

Commuter Rail

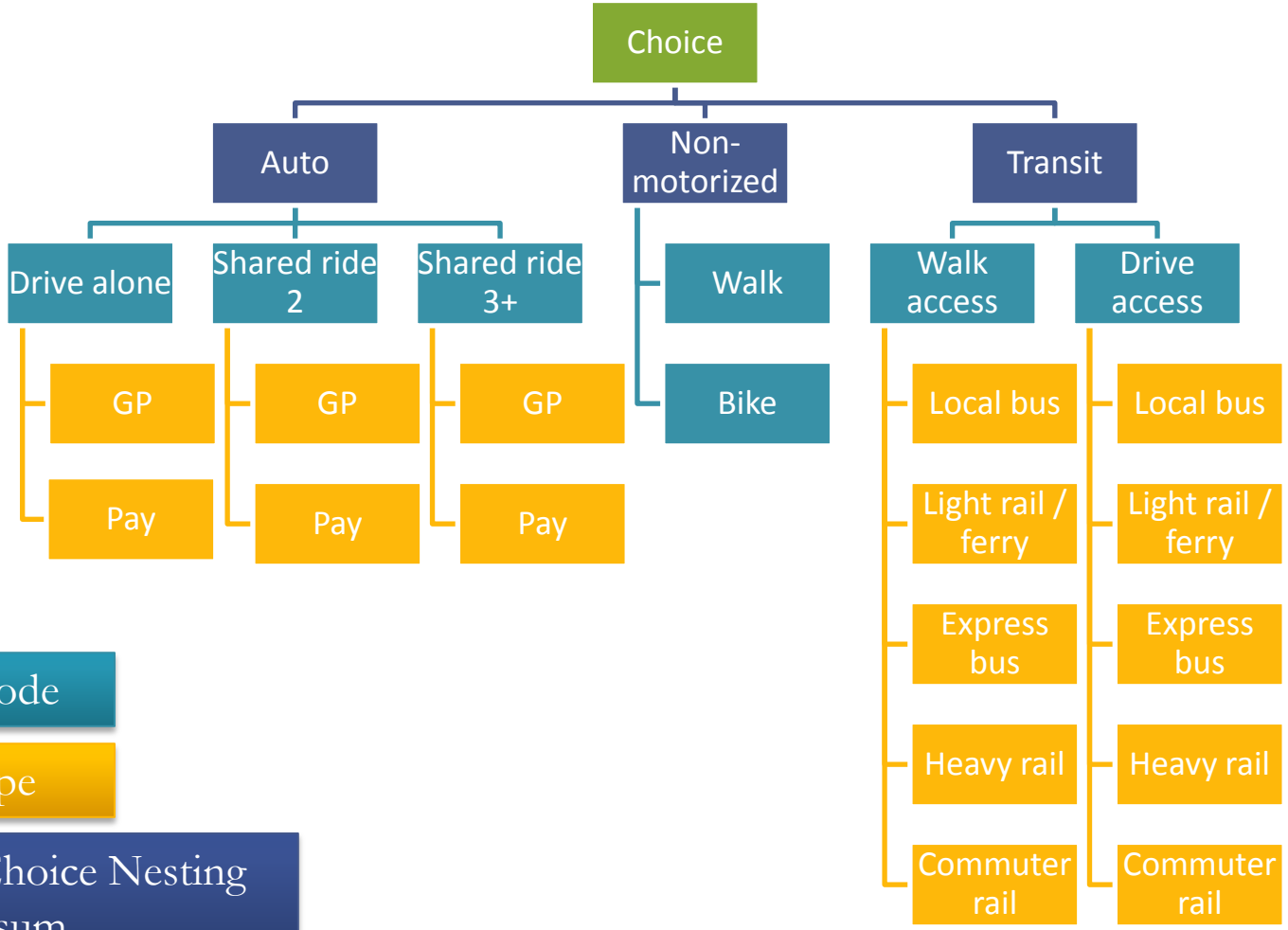
Tour Mode Choice Structure I: SFCTA (1st Generation)



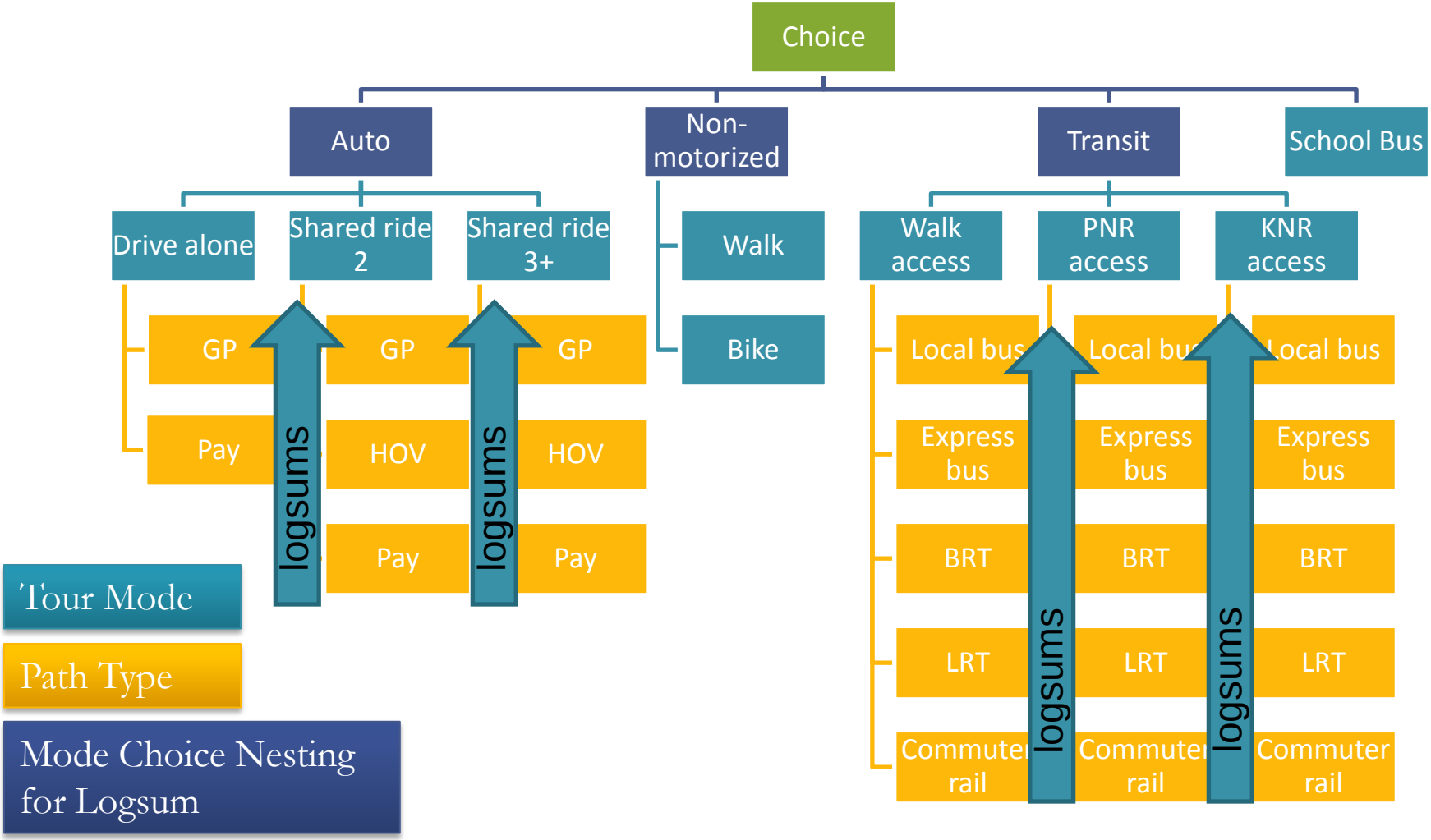
Tour Mode Choice Structure II: SACOG



Tour Mode Choice Structure III: MTC



Tour Mode Choice Structure IV: SANDAG



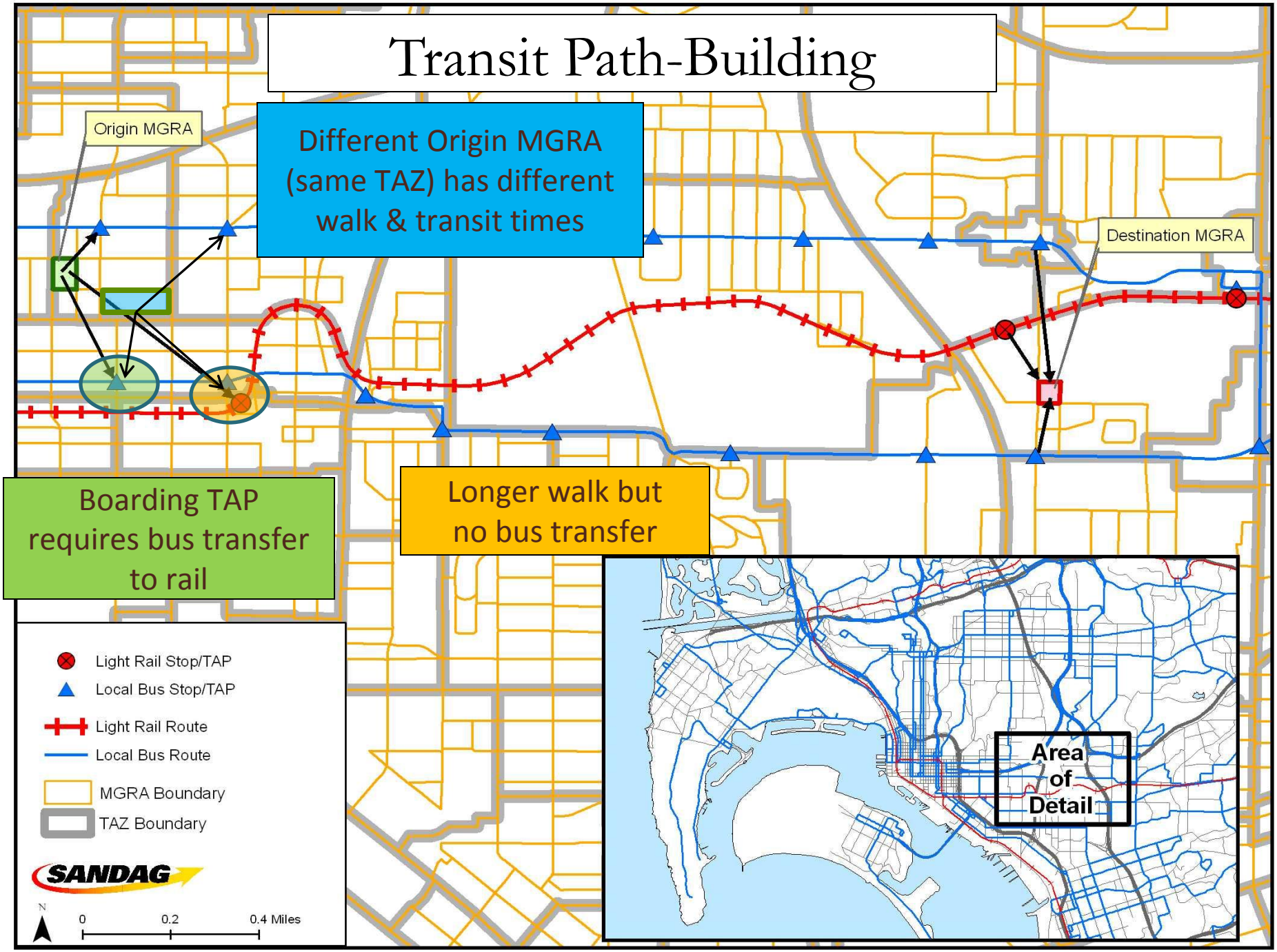
Tour Mode Choice Model Inputs

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

Travel Time and Cost Skims

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

Transit Path-Building



Tour Mode Choice Specification

Explanatory variables

Level of Service	• Cost (operating cost, fare, toll) • In-vehicle time • Out-of-vehicle time (wait, transfer, walk access, terminal time) • Non-motorized travel times.
Land Use	• Mixed land use density • Intersection density
Pattern-specific	• Escort stop dummy (shared ride chance increase) • Number of stop purposes other than escort (auto chance increase)
Demographics	• Auto sufficiency (no cars, cars fewer than driver, cars fewer than workers) • Income (low, medium, high) • Household type/size (one person HH, # of children under 5, # of children 5-15) • Age (adult 18+, child under 5, child 16-17, etc.) • Gender
Interaction	• Mode to work (only used in work-based tour) –mode used in work-based tour tends to be the same as home-based work tour mode • Some purposes tend to use some particular modes, e.g., shopping more likely to use shared ride

Tour Mode Choice: Non-Traditional Variables

- Traditional:
  - Purpose & time of day
  - Travel time & cost
  - Car ownership
  - Car sufficiency
  - Household income
  - Household size
  - Urban density
  - Pedestrian friendliness
  - School bus availability
  - Driver license/driving age
- Made possible by disaggregate modeling:
  - Tour complexity
  - Mode reliability
  - Travel party
  - Escorting arrangement
  - Transit pass
  - Free parking eligibility
  - Toll transponder
  - Person type
  - Age
  - Gender
  - Daily schedule, time pressure
  - Planned, casual carpool

Working With Data

- Household survey data is used for model estimation and calibration
- On-board survey data is often required to compensate for low levels of transit trips in household surveys
- But, on-board data is typically origin-destination based…how do we convert data for use in models?
  - Need to determine tour purpose
  - Need to determine tour origin & destination
  - Need to determine tour mode
- Additional questions are helpful

On-Board Survey Tour-Level Questions

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

Four Step Purpose versus Tour Purpose

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

Source, Atlanta Regional Commission 2010 On-Board Survey

Tour and Trip Mode Choice Parameters

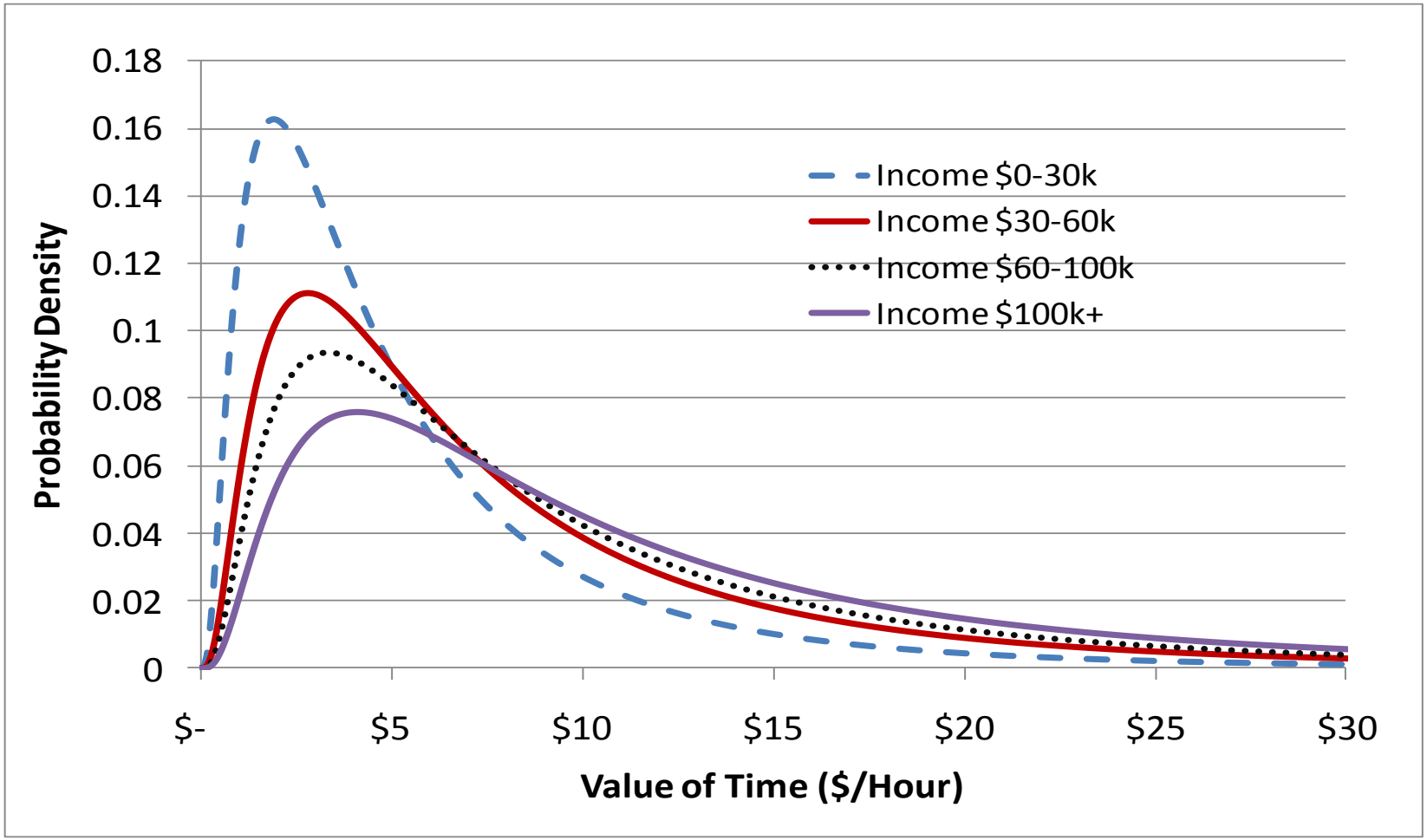
- Typically tour mode choice time and cost variables are smaller than trip mode choice parameters
  - Why? Time and cost represented for both outbound and return directions at tour level – at least twice as high for tour mode choice than for trip mode choice
- Typically tour mode choice alternative-specific constants are twice as high as constants for trip mode choice
  - Why? Reflects non-included attributes of modes for two legs of tour
- Ensures consistent elasticities between tour and trip mode choice

$$Elasticity_{trip} = Parameter_{i*} * Variable_{i*} * (1 - Probability_{i*})$$

$$Elasticity_{tour} = Parameter_{i*}/2* (Variable_{i*} * 2) * (1 - Probability_{i*})$$

$$Elasticity_{trip} = Elasticity_{tour}$$

Individual Parameter Variation Applied to Value of Time

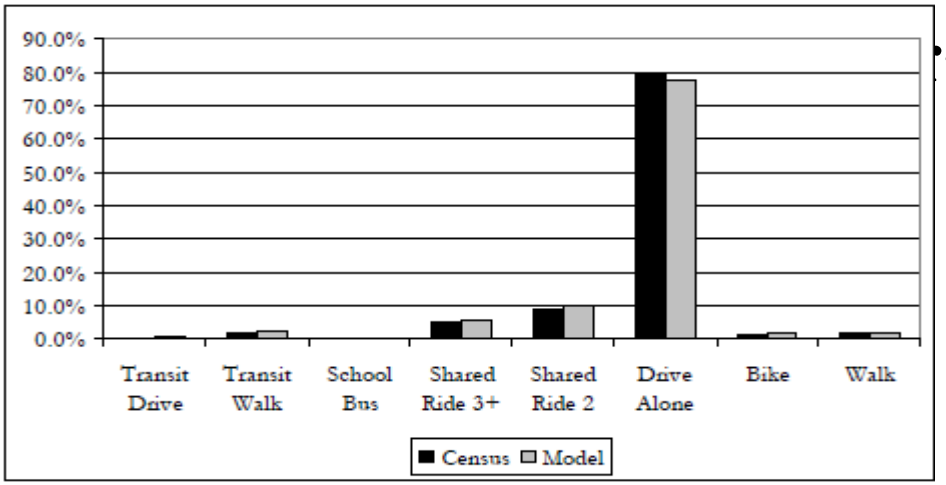


Calibration of Tour Mode Choice Models

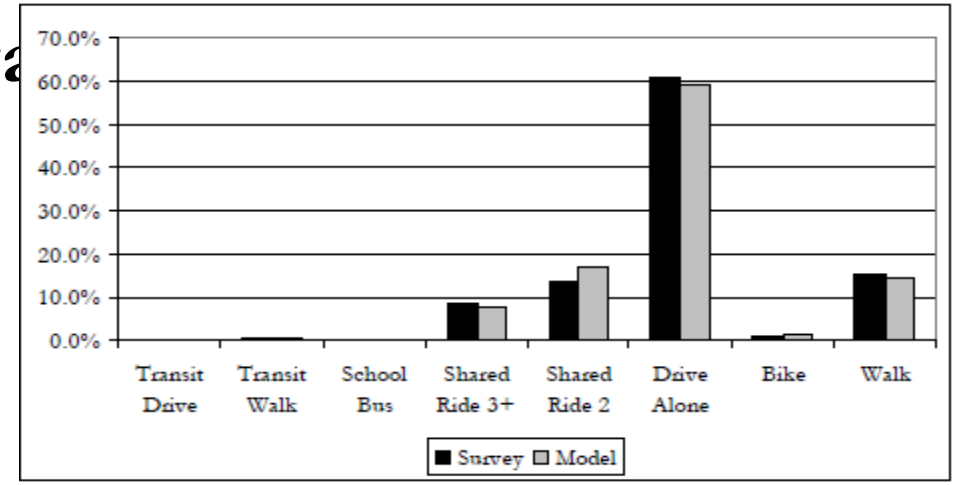
- Calibration methodology
- Things to check:
  - Tours by mode and district
  - Tours by mode and socio-economic market segment
  - Tours by mode and time-of-day

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

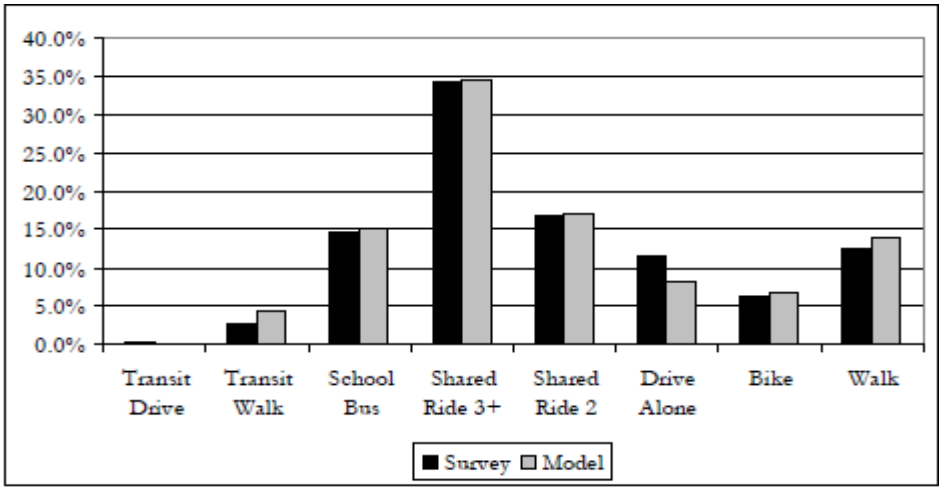
DaySim (SACOG) Tour Mode Choice



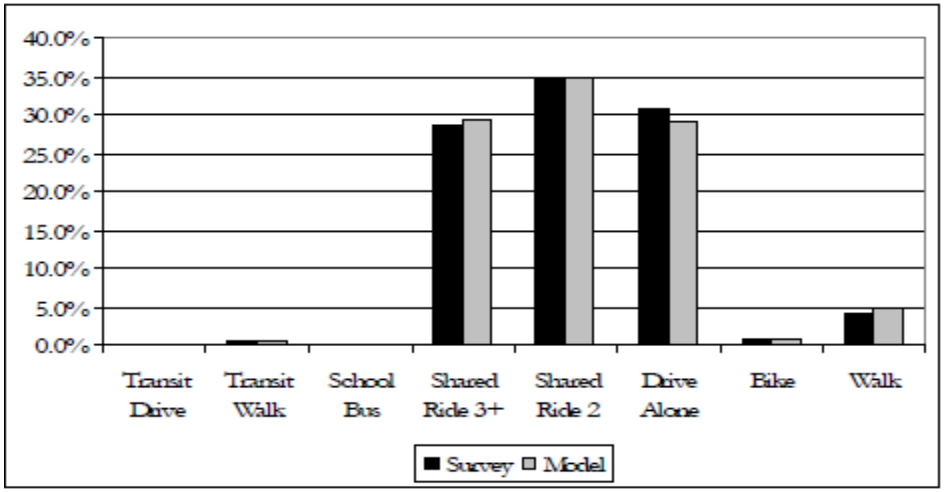
Home-Based Work Tour



Work-Based Sub-tour

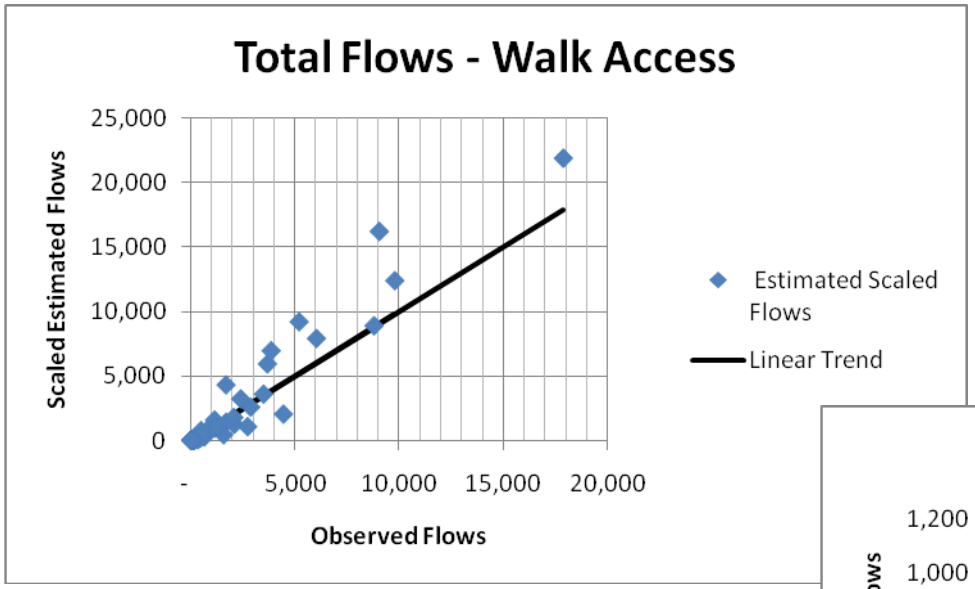


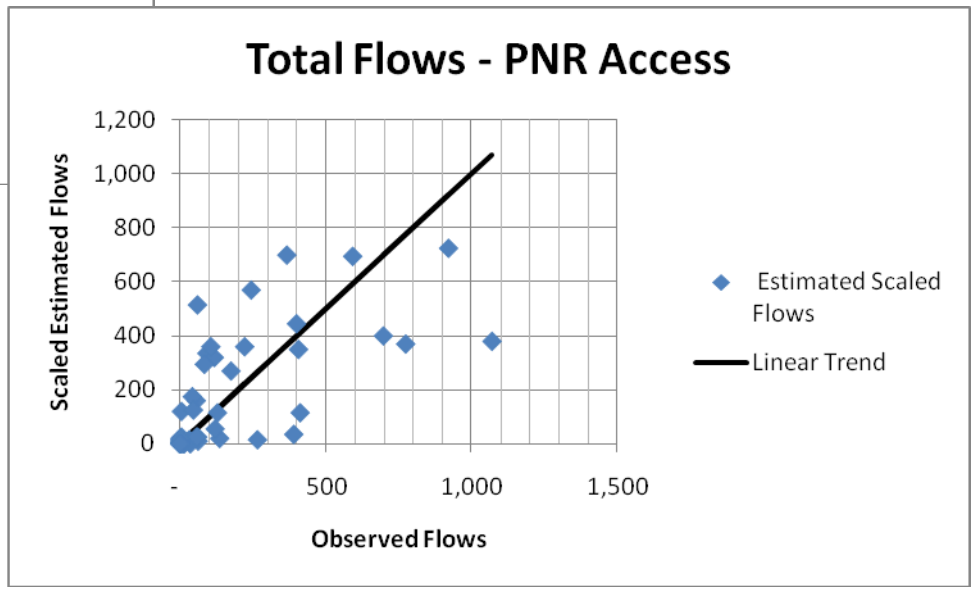
Home-Based School Tour



Home-Based non-Mandatory Tour

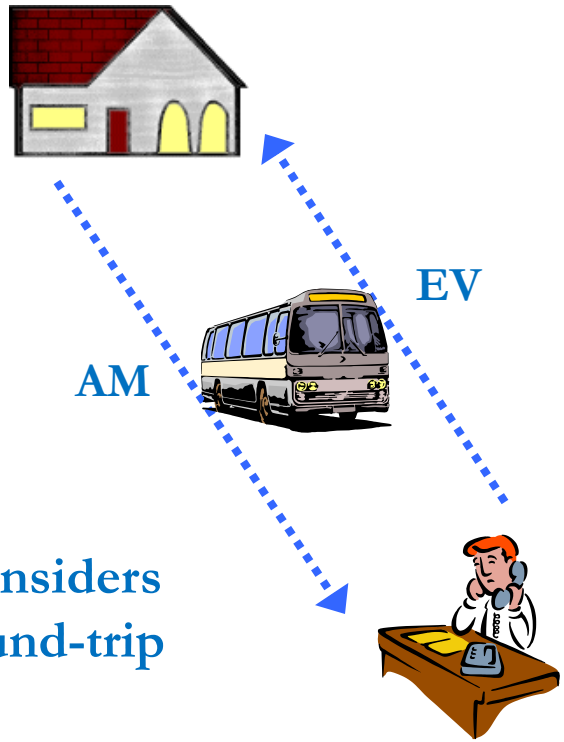
CT-RAMP (SANDAG) District-level Summaries





Tour Mode Choice Sensitivities

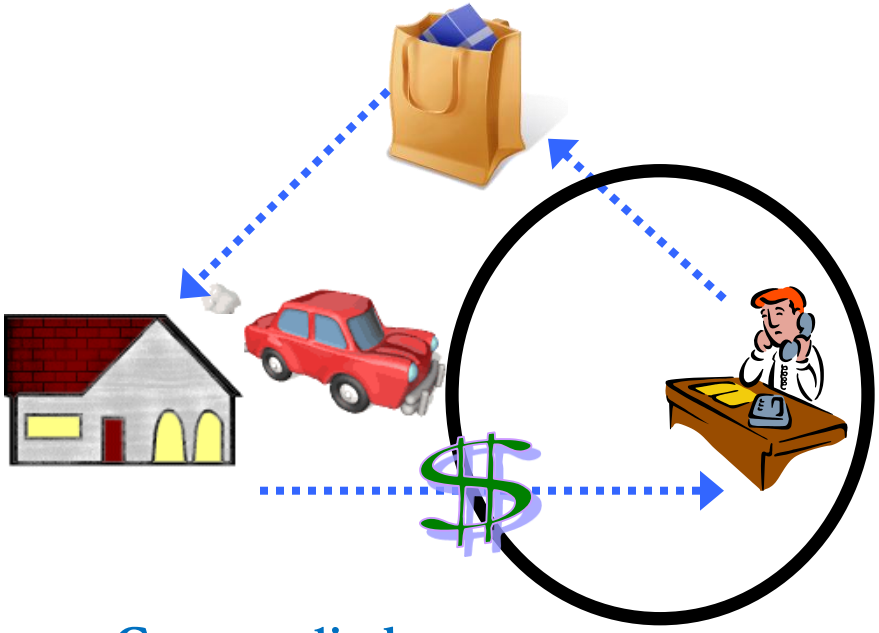
Improved Evening Transit Service



Considers round-trip

Working late. Can I take the bus to work?

Directional Pricing



Cost applied to Tour Decisions

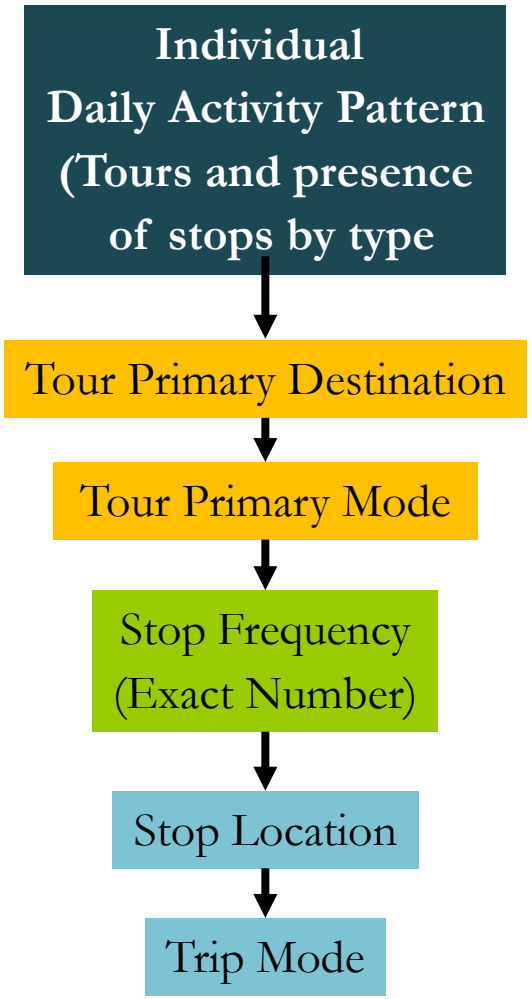
Work tour with shopping stop

Questions and Answers

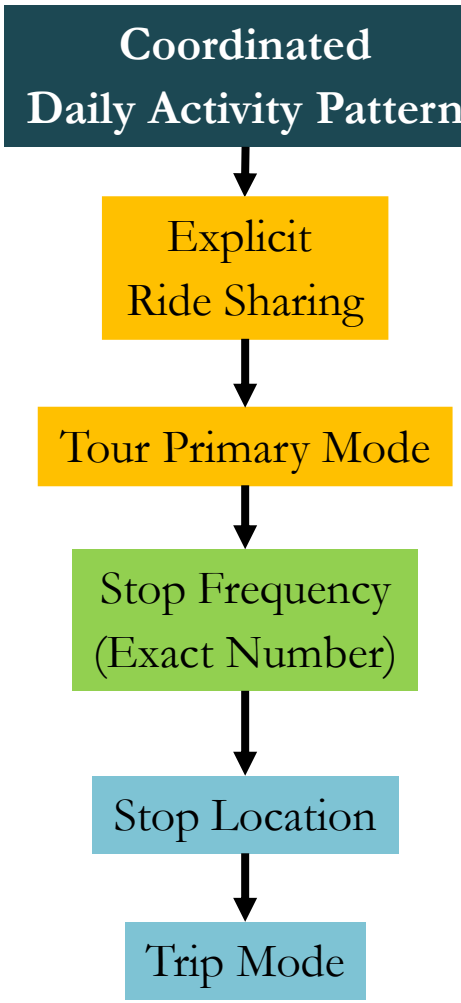
The Travel Model Improvement Program

Intermediate Stop Location Choice

DaySim Structure



CT-RAMP Structure



Destination Choice Model Review

- TAZs represent aggregations of (or *quantities* of) opportunities…therefore a special treatment is required
- Variables that describe quantity are known as size terms and their natural log is taken
- The size term is combined with an impedance, in this case the out-of-direction travel cost

Sample Utility Equation:

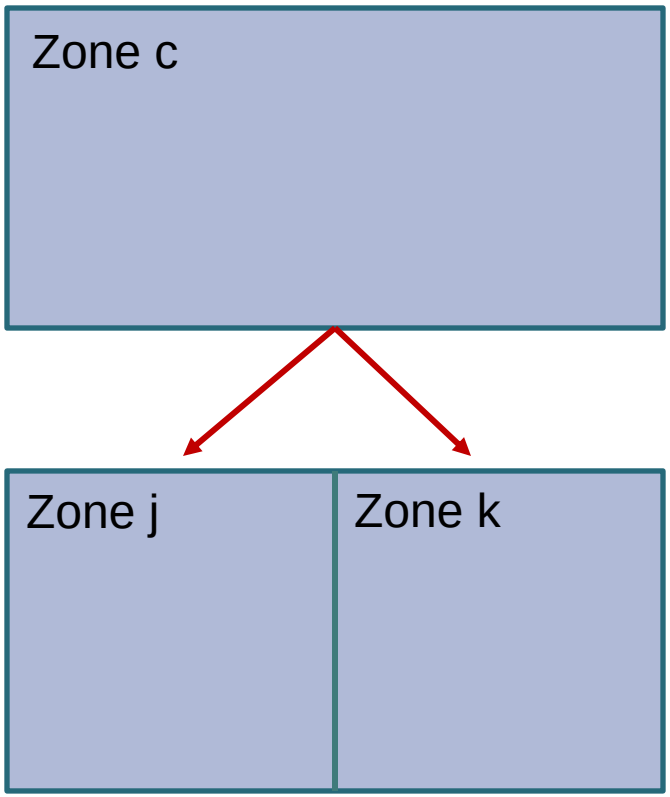
"Quality" variables

$$U_j = \beta_{time} * time_{ij} + \beta_{dist} * dist_{ij} + \ln(retail\_emp + \theta_{service\_emp} * service\_emp)$$

"Quantity" variables (size term)

Review: Why a 'size term'?

- Avoids potential bias of modifiable areal unit problem



- If we split a zone into two (or more) smaller zones, we expect the summed probability of choosing the two split zones to be equal to that of the original single zone (all else being equal)

$$P_{nc} = P_{nj} + P_{nk}$$

- For a logit model, this holds when

$$e^{V_{nc}} = e^{V_{nj}} + e^{V_{nk}}$$

Derivation of Size Term

- If representative utility is specified as $V_{nl} = \ln(\beta' X_l)$ for all zones,

  $e^{\ln(\beta' X_j)} + e^{\ln(\beta' X_k)} = \beta' X_j + \beta' X_k = e^{\ln(\beta' X_c)} = \beta' X_c$

- Therefore, we specify representative utility inside a log function:

  Let $V_j = \ln\left[A_j f(d_{ij})\right]$ be the utility of zone j

  Let $f(d_{ij}) = \exp(-\alpha C_{ij})$ be an impedance function based on travel cost (time, or generalized cost).

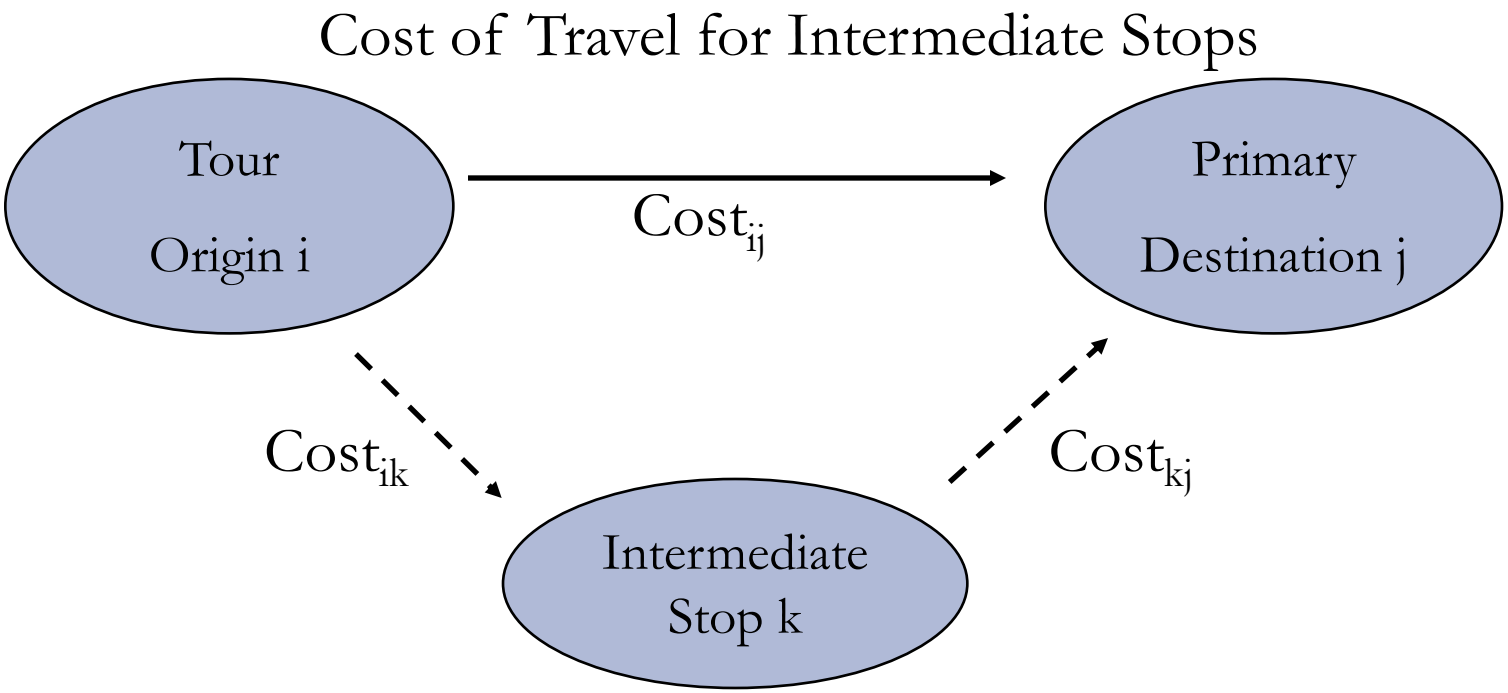
  Then $V_j = \ln A_j - \alpha C_{ij}$

- Total attractions, A_j is also referred to as the "size" of the zone, S_j, as it represents a positive quantity.
- "Size" can also include multiple attraction variables, (e.g., shopping and dining). We can identify a size function as:

  $S_j = \theta_1 S_{1j} + \theta_1 S_{1j} + \ldots$

- Thus, we have $V_j = \beta \ln(\theta_1 S_{1j} + \theta_2 S_{2j} + ..) - \alpha C_{ij}$

Intermediate Stop Location Choice: out-of-direction travel cost ("rubber banding")

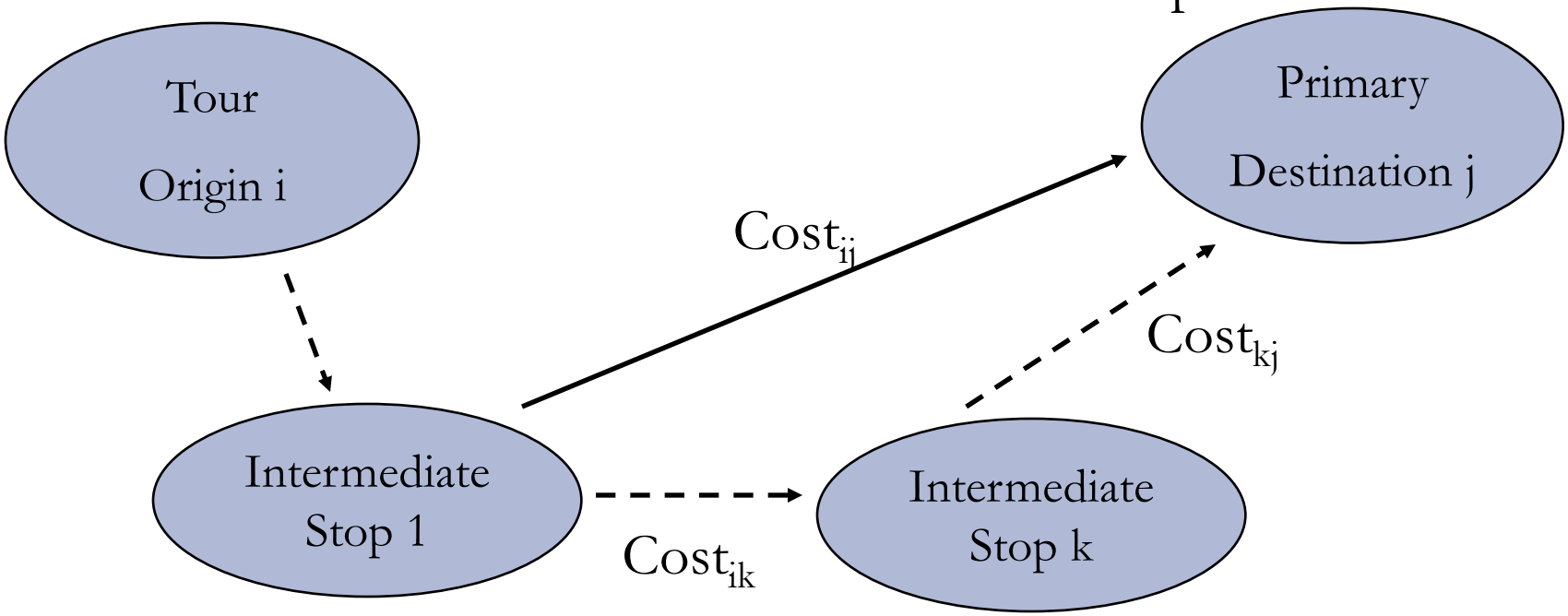


Out-of-Direction travel cost:

$$Cost_{ijk} = [Cost_{ik} + Cost_{kj}] - Cost_{ij}$$

Intermediate Stop Location Choice: out-of-direction travel cost

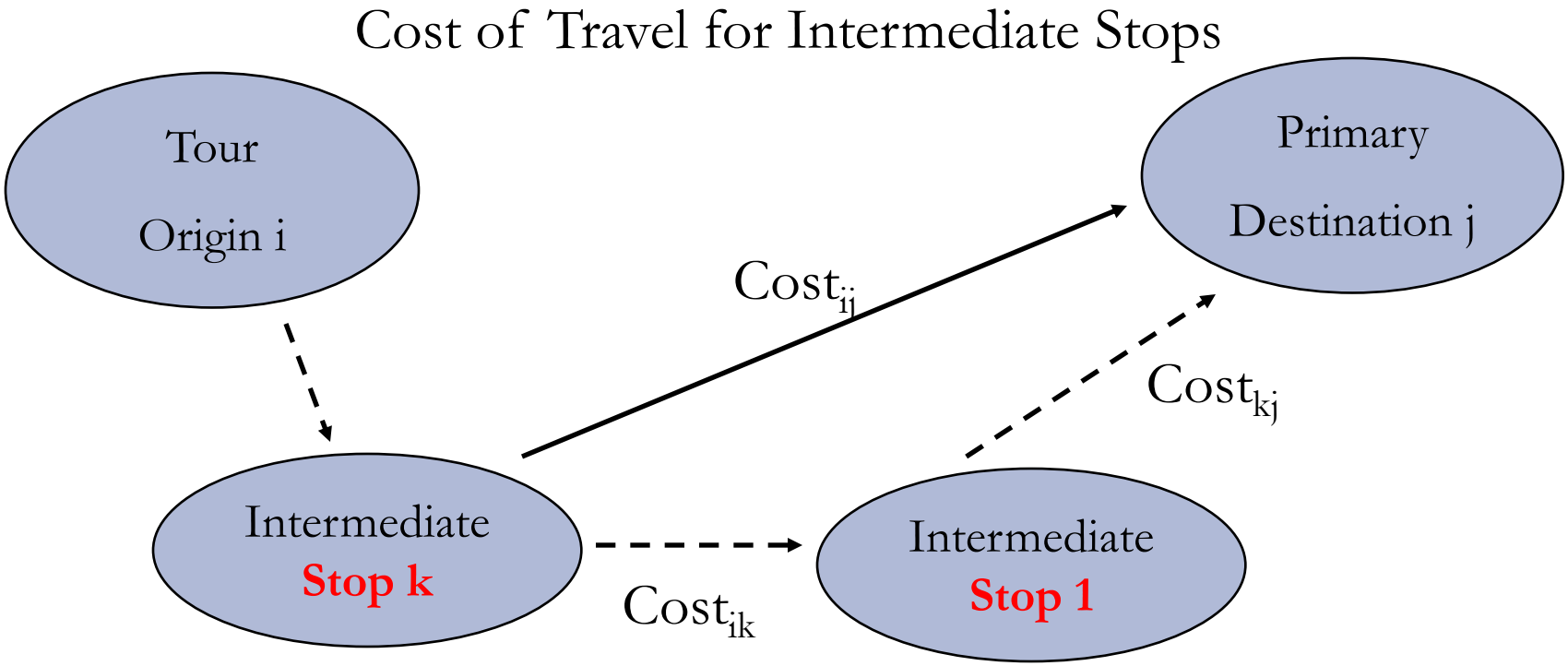
Cost of Travel for Intermediate Stops



Out-of-Direction travel cost (2nd stop):

$$Cost_{ijk} = [Cost_{ik} + Cost_{kj}] - Cost_{ij}$$

Intermediate Stop Location Choice: out-of-direction travel cost… a variation



Out-of-Direction travel cost (2nd stop):

$$Cost_{ijk} = [Cost_{ik} + Cost_{kj}] - Cost_{ij}$$

Intermediate stop location choice: "quality" utility terms

- Out-of-direction travel cost
- Distance from tour anchor and primary destination
  - Often stops are near the tour endpoints
- Trip mode choice logsums
  - Specific to the chosen tour mode, to reflect a higher weighting for relevant trip modes
- Other
  - Household and person demographics
  - Land-use/urban form
  - Purpose of tour (impedance term segmentation)
  - River crossings (use with caution)

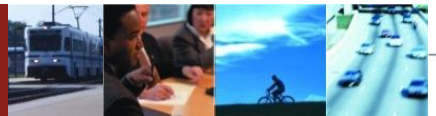
Intermediate Stop Location Choice Size Terms

- Stop purpose used for size term

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

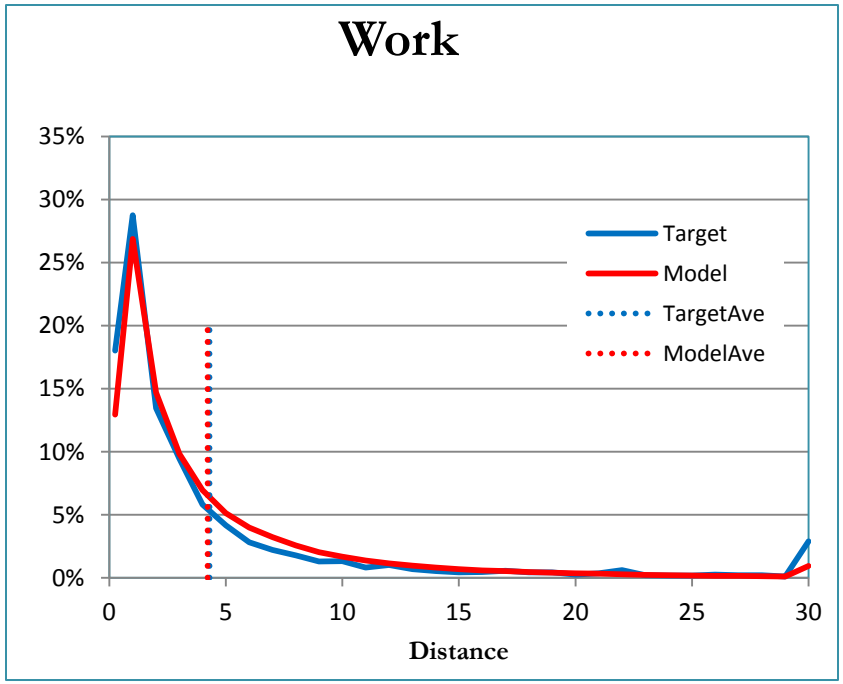
Intermediate Stop Location Choice Sampling

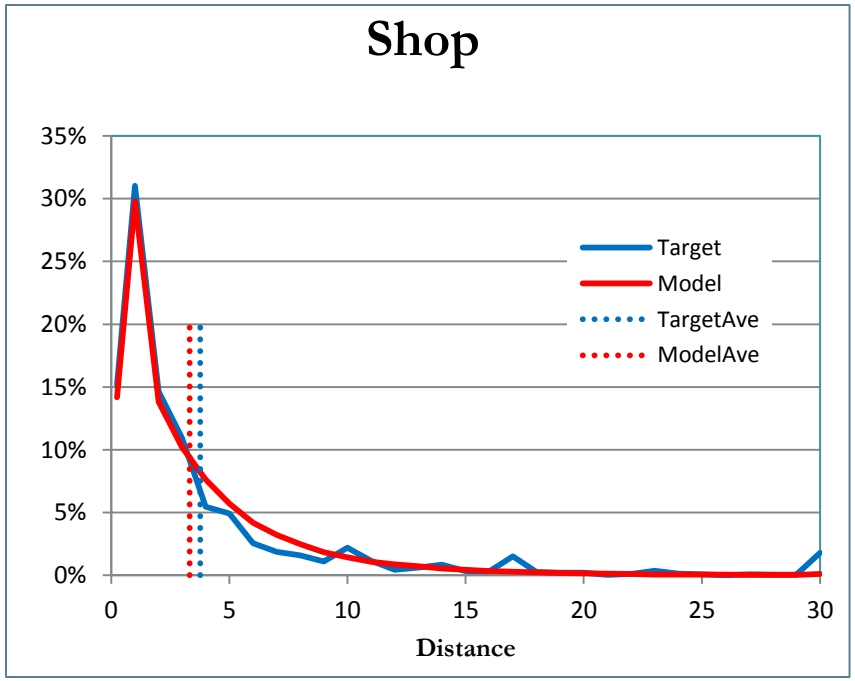
- Required due to number of alternatives
  - Both in estimation and application
- Sampling approaches
  - Naïve – choose n alternatives at random
    Intelligent - based on simplified model
- Availability constraints
  - Size term > 0
  - Available according to tour mode
    - For walk-transit tours, must be able to get there via transit or walking
    - For walking tours, stop must be within walking distance of both tour origin and destination
  - Guarantees that intermediate stops can be accessed by modes allowed and are reasonable



Calibration of Intermediate Stop Location Models

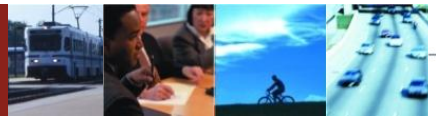
- Stop out-of-direction trip length frequency distribution
- Distance from tour anchor trip length frequency distribution
- Distance from tour primary destination trip length distribution
- Average distances





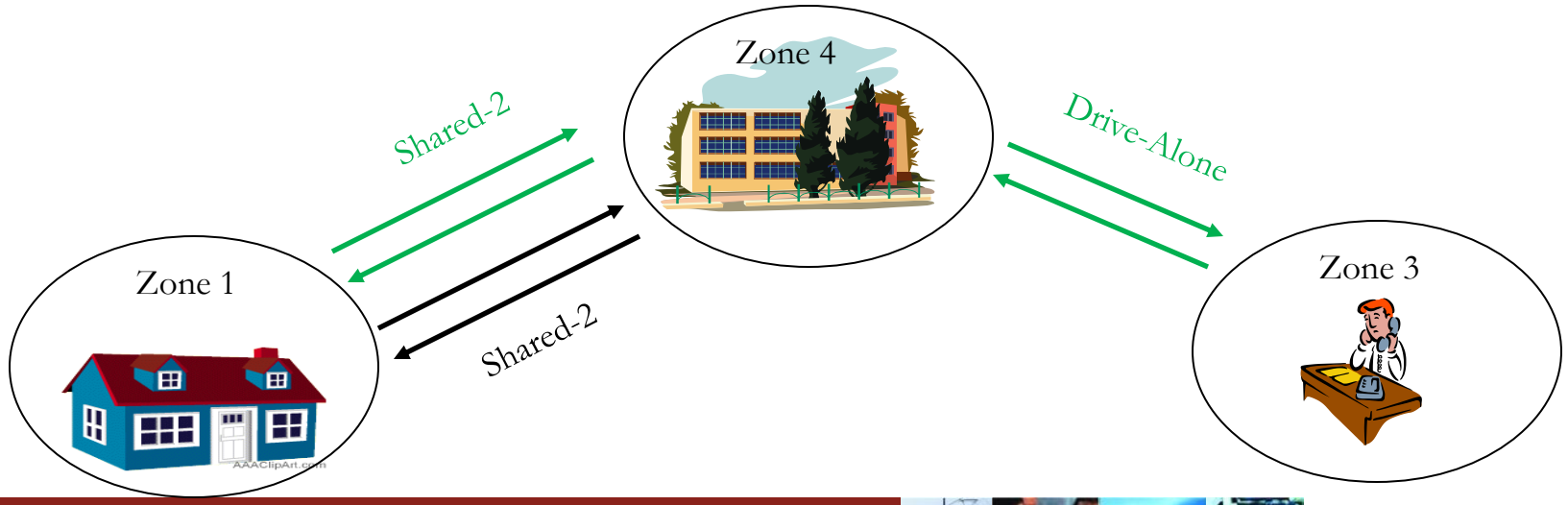
Trip Mode Choice

- Determines mode for each trip on each tour
- Also known as mode "switching" model
  - Can switch from drive-alone to shared ride, or from bus to rail
- Constrained by tour mode
  - It is hard to drive home, if you don't have a car at work
- Variables include
  - Traditional mode time and cost variables for origin-destination
  - Land-use\urban form
  - Tour mode
  - Traveler characteristics
  - Trip sequence (next slide)

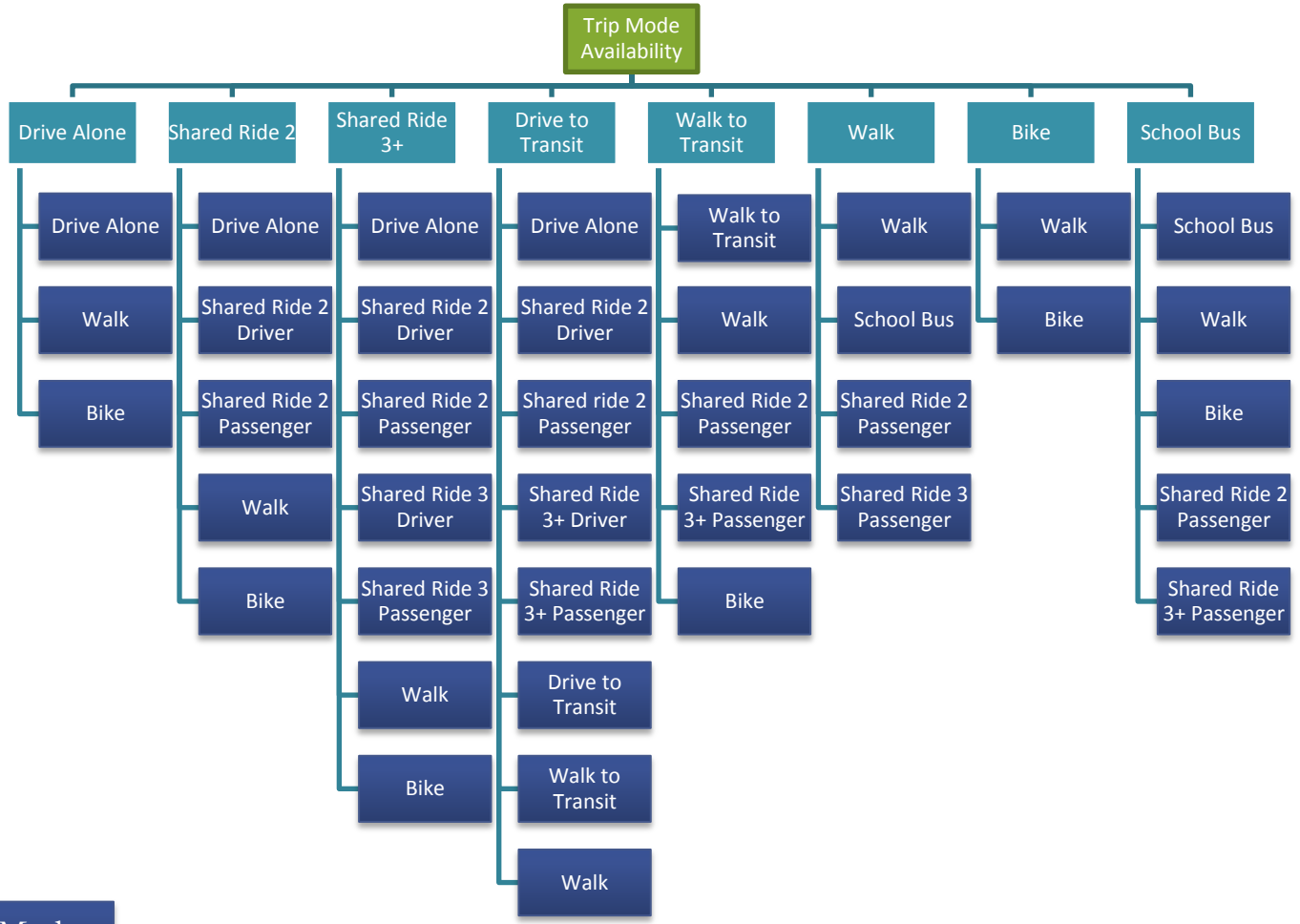


Trip Mode Choice: Mode Sequence

- Shared ride tours with stops
  - First, last trip on tour tends to be shared-ride; intermediate trips tend to be drive-alone
- Park-and-ride tours with stops
  - First, last trip on tour tends to be drive-alone
- Kiss-and-ride tours with stops
  - First, last trip on tour tends to be shared-ride



Trip mode choice structure

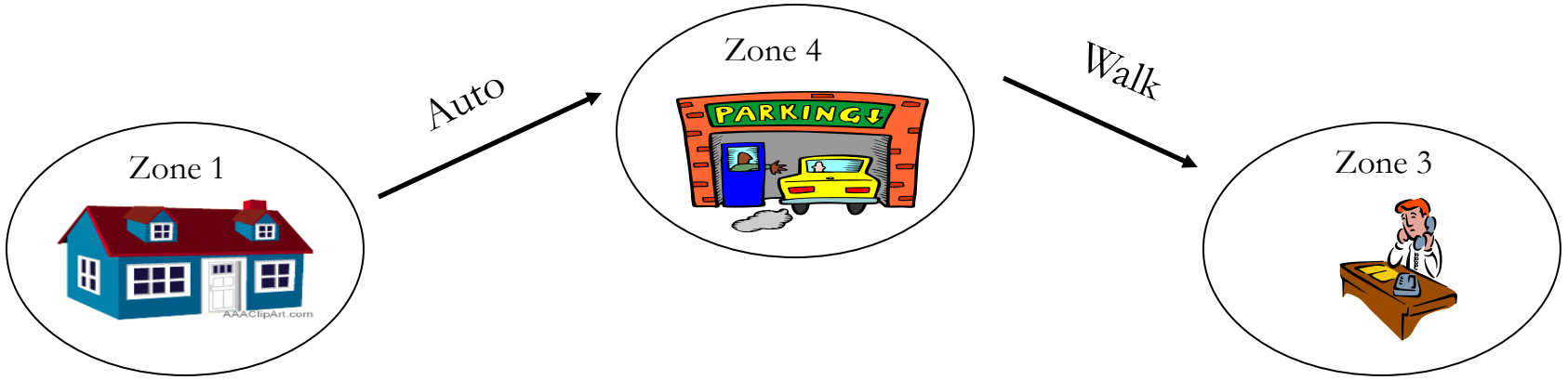


Tour Mode

Available Trip Mode

Trip Mode Choice: Parking Location Choice & Capacity Restraint

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



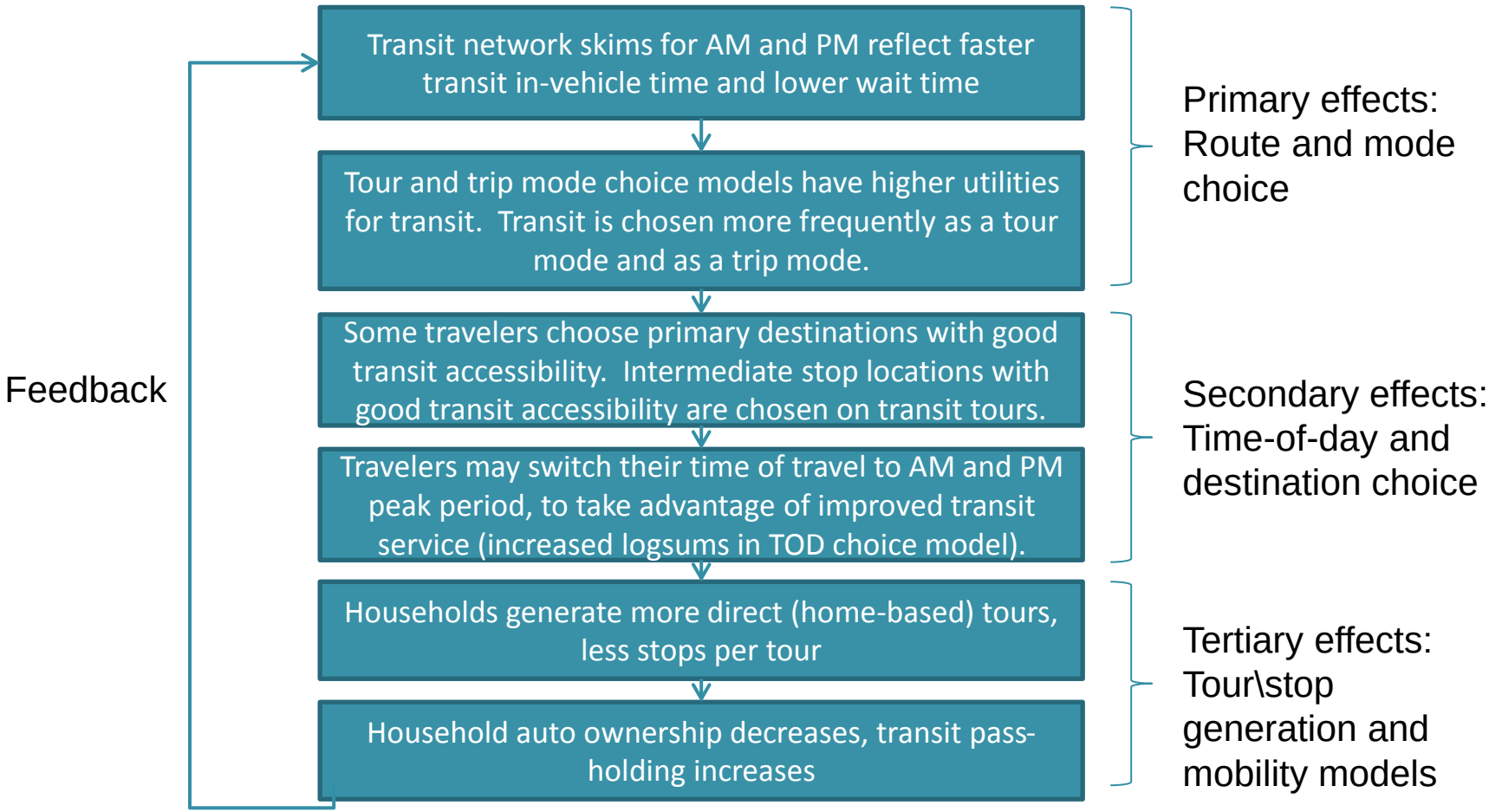
Calibration of Trip Mode Choice Models

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

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

Putting It All Together: Transit Scenario

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



Putting It All Together: Land Use Scenario

- Land-uses are more dense in a corridor study

Travelers are more likely to choose primary destinations in corridor due to increased opportunities. Work location choice models typically match employment. Non-work models reflect increased opportunities for shopping.

↓

Likelihood of intermediate stops increase due to increase opportunities; particularly if corridor is en-route between household and employment locations.

↓

Increased non-motorized travel if trip lengths decrease, more transit trips if corridor is well-served by transit, toll trips if toll corridor.

↓

Travelers may switch their time of travel depending on network differences in corridor; if more congested due to increased density, travelers may switch out of peak.

↓

Closer households likely to generate more direct tours, less stops per tour. Distant households may generate more intermediate stops per tour as a result of increased opportunities.

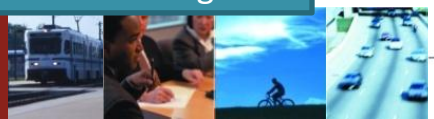
↓

Household auto ownership may increase or decrease, depending on whether corridor is conducive to non-motorized or transit usage.

Primary effects: Destination choice

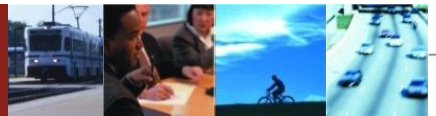
Secondary effect: Mode choice

Tertiary effects: Time-of-day, Tour\stop generation and mobility models



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

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



Ongoing research and advancements

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

Review: Learning Outcomes

- Tour mode
  - Primary or preferred mode for tour
  - Takes into account round-trip level of service, among other attributes
- Trip mode
  - Actual mode used for each trip on tour
  - Constrained by tour mode
- Importance of consistency between:
  - Tour mode and trip mode
  - Tour anchor location, primary destination and stop location
  - Tour mode and intermediate stop location
- Rubber-banding
  - Out-of-direction travel cost for intermediate stops

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 Mobility Choice Models	June 7
Activity Pattern Generation	June 28
Scheduling and Time of Day Choice	July 19
Tour and Trip Mode, Intermediate Stop Location	August 9
Network Integration	August 30
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