Introduction to Travel Forecasting Webcast

July 14th, 2010

Agenda

- Need for Travel Forecasting Methods
- Introduction to Travel Forecasting
  - Trip Generation
  - Trip Distribution
  - Mode Choice
  - Trip Assignment
  - Time of Day
  - External and Commercial Markets
  - Travel Surveys and Model Validation
- Case Study: Travel Forecasting in the Atlanta Region
  - Trip Based Model
  - Activity Based Model
- Questions and Answers

1

What New Issues Are We Trying To Address?

Then:

- Highway design (1950's and 1960's)
- Transit design (1970's)

Now:

- Congestion management
- Air quality
- Title VI/Environmental justice

2

What New Issues Are We Trying To Address?

- Pricing policies
- New rail starts and other transit projects
- Changing population and household characteristics
- Impacts of transportation accessibility on land-use and economy
- Commercial vehicles

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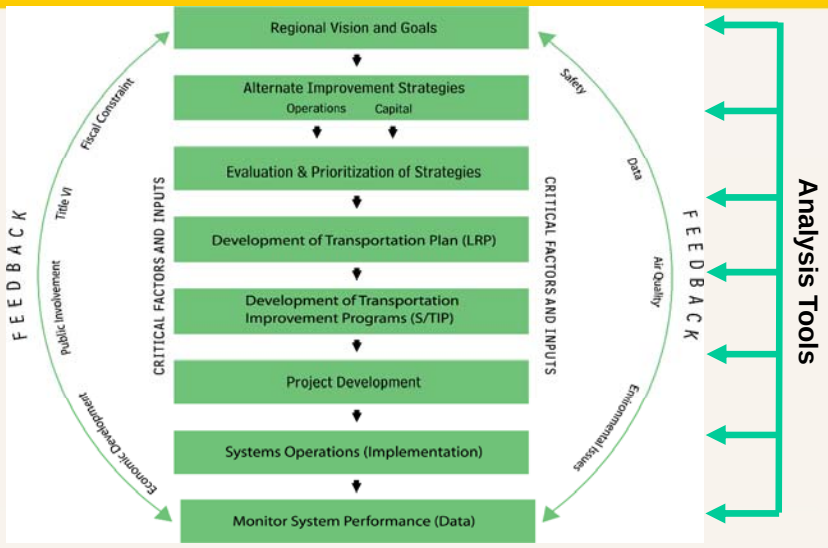
How Analysis Tools Support the Planning Process



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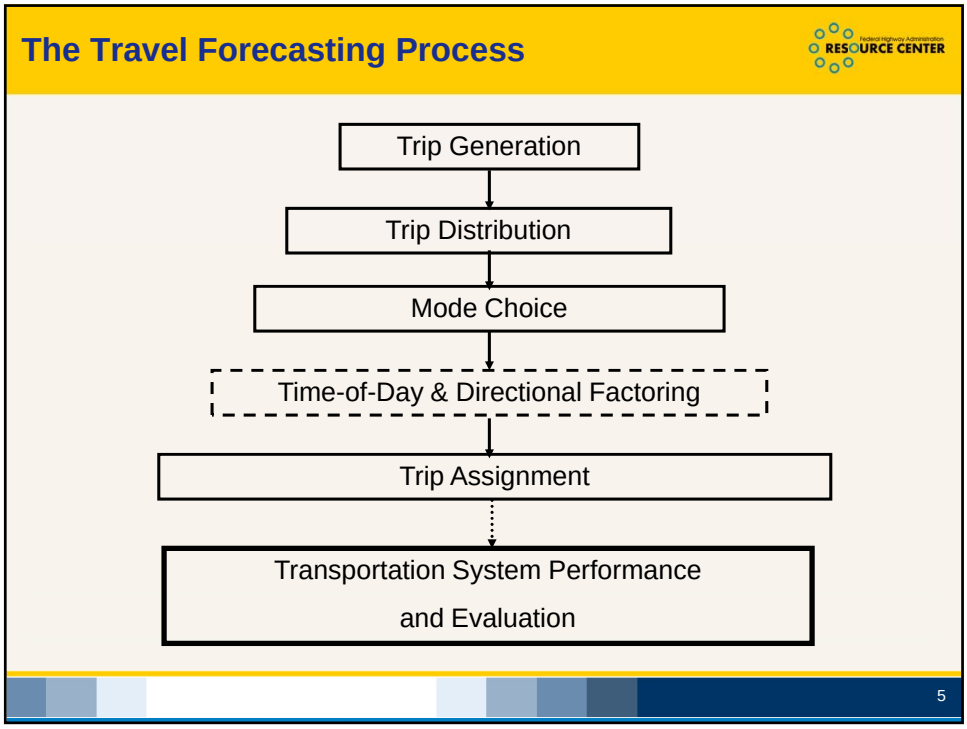
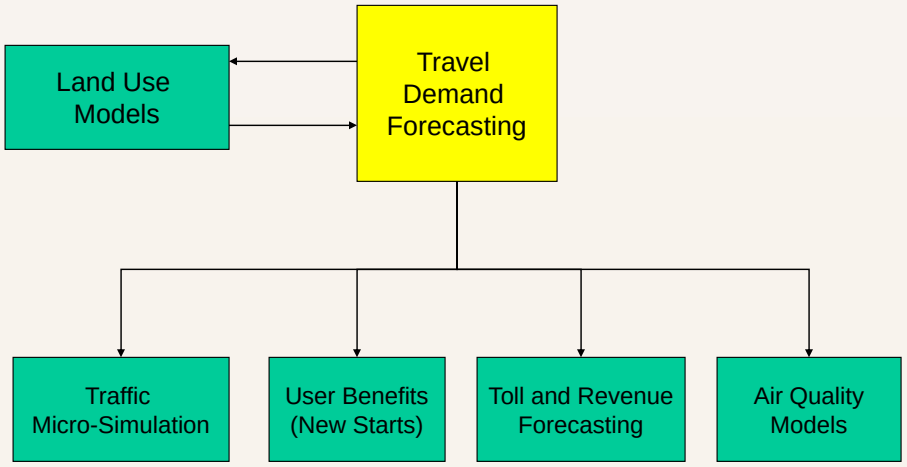


Fact Sheet Title/Page Number	Operations Objective
System Efficiency	
Extent of Congestion	• Reduce the percentage of facility miles (highway, arterial, rail, etc.) experiencing recurring congestion during the peak period by X percent by year Y. • Maintain the rate of growth in facility miles experiencing recurring congestion as less than the population growth rate (or employment growth rate). • Reduce the share of major intersections operating at LOS F by X percent by year Y.
Duration of Congestion	• Reduce the daily hours of recurring congestion on major freeways from X to Y by year Z. • Reduce the number of hours per day that the top 20 most congested roadways experience recurring congestion by X percent by year Y.
Intensity of Congestion (Travel Time Index)	• Reduce the regional average travel time index by X percent per year.
Travel Time	• Annual rate of change in regional average commute travel time will not exceed regional rate of population growth through the year Y. • Improve average travel time during peak periods by X percent by year Y.
Delay	• Reduce hours of delay per capita by X percent by year Y. • Reduce hours of delay per driver by X percent by year Y.
Energy Consumption	• Reduce total energy consumption per capita for transportation by X percent by year Y. • Reduce total fuel consumption per capita for transportation by X percent by year Y. • Reduce excess fuel consumed due to congestion by X percent by 2020.

Other Planning Methods



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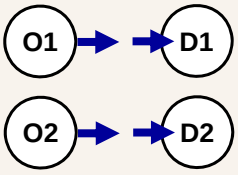
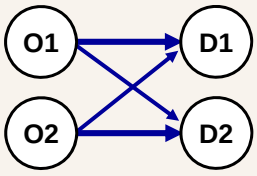
Trip Generation and Distribution

Trip Generation defines the size of the flows into or out of a zone



Trip Distribution defines the size of the freight flows between zones, constrained by the totals from Trip Generation



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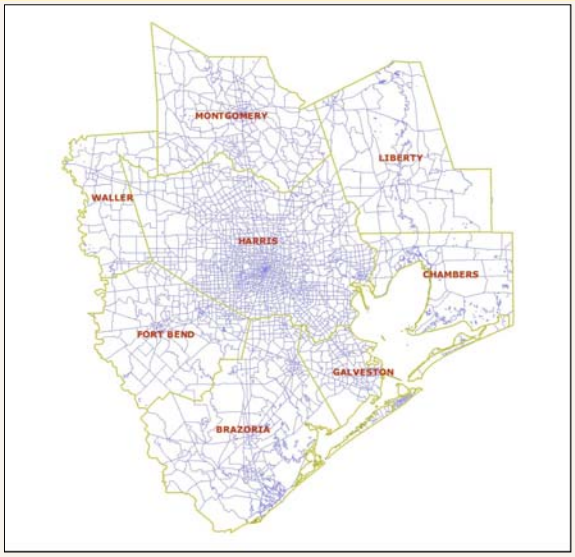
Traffic Analysis Zones



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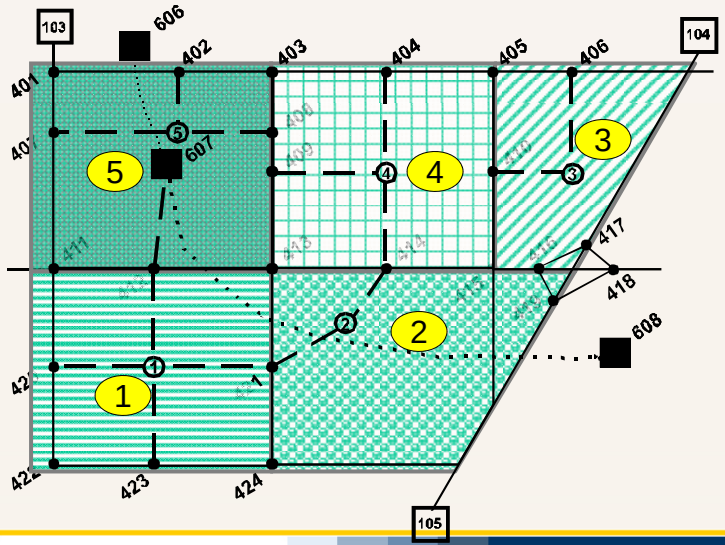
Defining Traffic Analysis Zones



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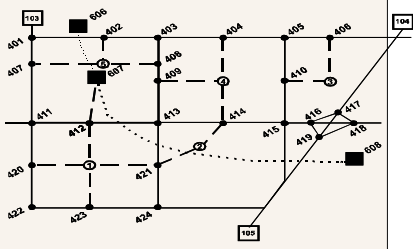
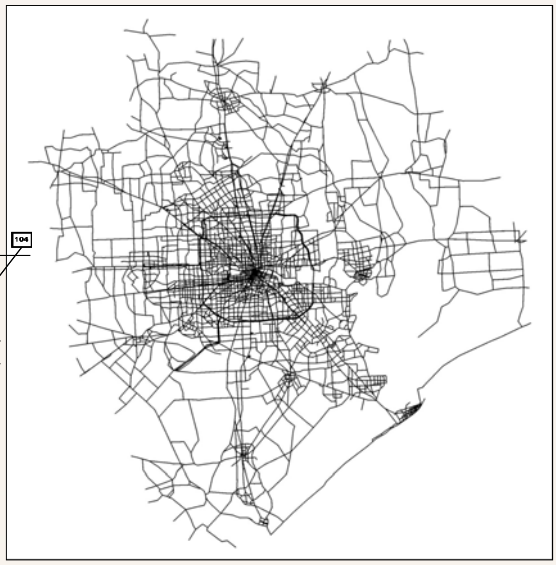
Transportation Network File





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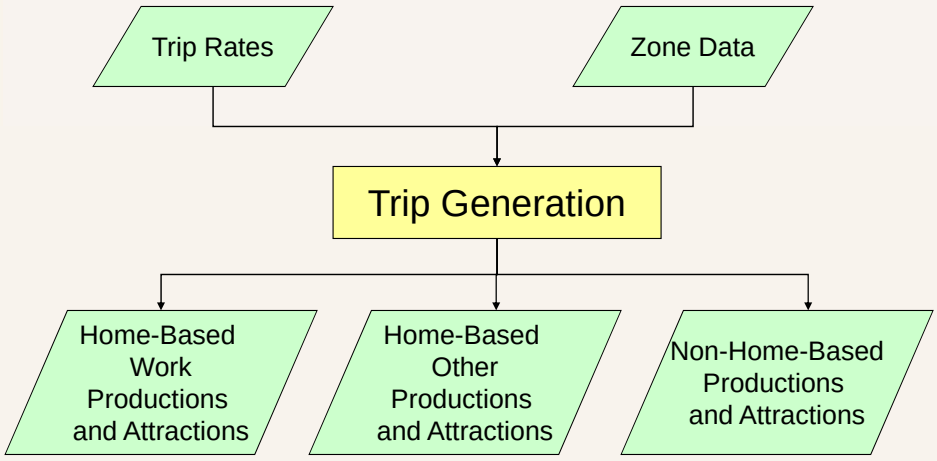
Trip Generation Models



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Zone-Based Model Inputs

HOUSEHOLD CHARACTERISTICS

1	18	2	3	6	27	8	21	17	14	44	6	20	13
2	13	1	1	3	14	6	7	12	10	24	3	15	4
3	0	0	0	0	2	2	3	4	5	9	0	1	2
4	1	0	0	0	3	3	3	2	4	12	1	2	3
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.	.	.	.	.	.	.	.	.	.	.	.	.	.

EMPLOYMENT CHARACTERISTICS

1	20	25	126	265	1134	33	173	0	0	4	0	1	13
2	13	17	51	141	599	0	0	0	0	7	0	1	13
3	3	7	15	62	238	390	309	0	0	2	0	1	13
4	2	9	42	94	328	32	394	0	0	2	0	1	13
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PARKING COST/ACCESS AND TRANSIT ACCESS

1	0	0	0	1	2	50	90	0	0
2	0	0	0	1	2	20	90	0	0
3	0	0	0	1	2	50	90	0	0
4	0	0	0	1	2	10	80	0	0
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.

Characteristics of "zones":

- Number of households
- Number of persons
- Income, auto ownership
- Number of jobs by industry
- Density/area-type
- Parking costs
- Percent of zone within transit walk distance

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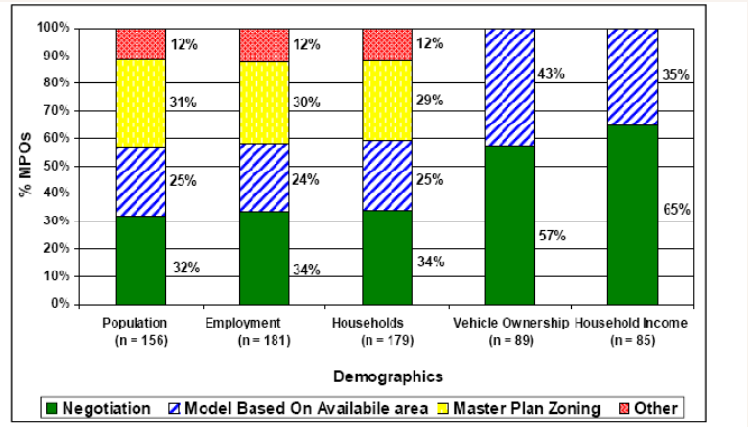
Techniques for Developing Demographic Forecasts



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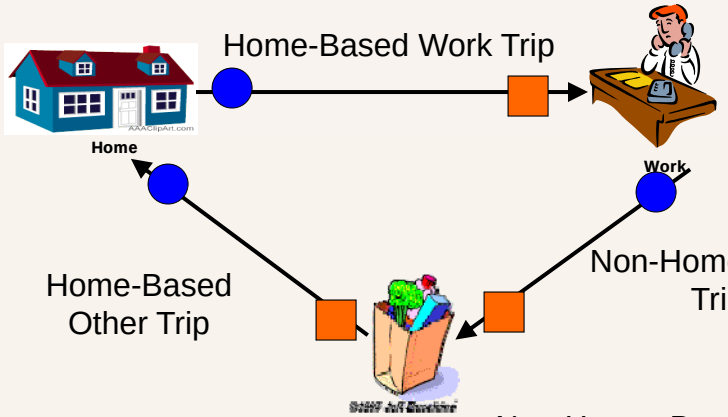
Productions and Attractions



Home-Based Trips

- Households *produce* trips
- Employment *attracts* trips

Non-Home- Based Trips

Origin is *production* end

Destination is *attraction* end

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Production Model

Cross-Classification Model

Daily Home-Based Work Trip Rates

Purpose	HH Size	Auto Ownership			
		0	1	2	3+
Low Income (<$20,000)	1	0.583	0.583	0.583	0.583
	2	0.583	0.583	0.583	0.583
	3+	1.393	1.393	1.975	1.975
Medium Income ($20,000-$45,000)	1	1.062	1.062	1.062	1.062
	2	1.488	1.488	1.488	1.488
	3+	1.723	1.723	1.723	2.665
High Income (<$45,000)	1	1.109	1.109	1.109	1.109
	2	1.832	1.832	1.832	1.832
	3+	1.946	1.946	1.946	2.962

Source: Triad Region Travel Demand Models

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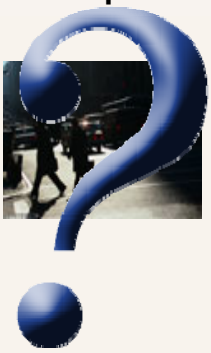
How many trips per job?
Trip Attractions

Will 10,000 jobs

attract

10,000 worker trips?



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Trip Attraction Equations

Example Equation for Work Trips:
Source: Amarillo MPO

Total work attractions = 1.6* basic employment + 1.3 * retail employment + 1.4 * service employment + .08 * households

Where –

Total work attractions = Total work-based trip ends in a zone

Note: Work attractions are generally lower than total employment

- Impact of telecommuting

- Irregular work patterns

- Absence of traditional “round trip”

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Special Generators

The Trip Generation equations will not apply for

- Airports
- Regional hospitals
- Any use with unusual demand patterns

Treated as “special generators” or “special events”

- Local data on the number of trips

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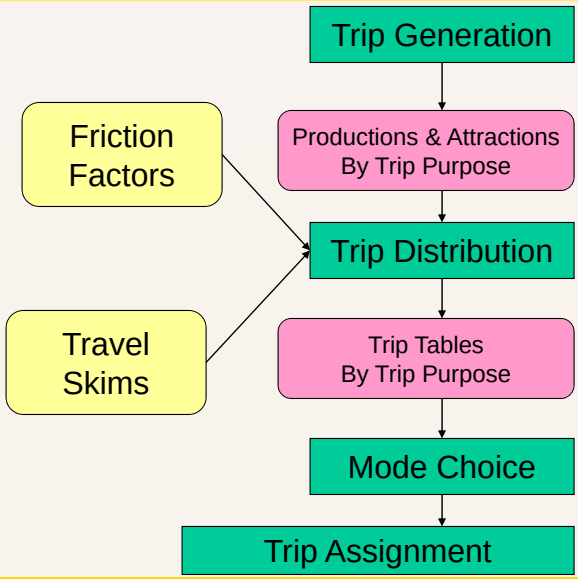
Trip Distribution

- Distribute trips produced in one TAZ to all other TAZs
- Calibrate to reflect current travel patterns
- Apply to forecast future travel patterns



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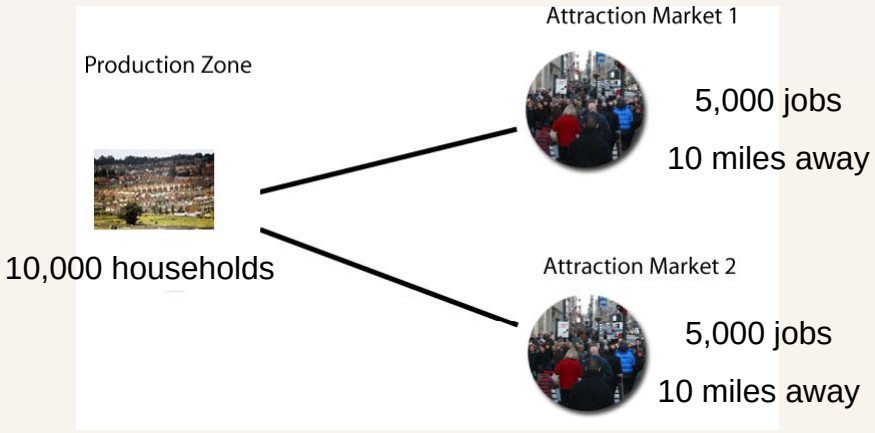
Home-Based Work Trip Distribution



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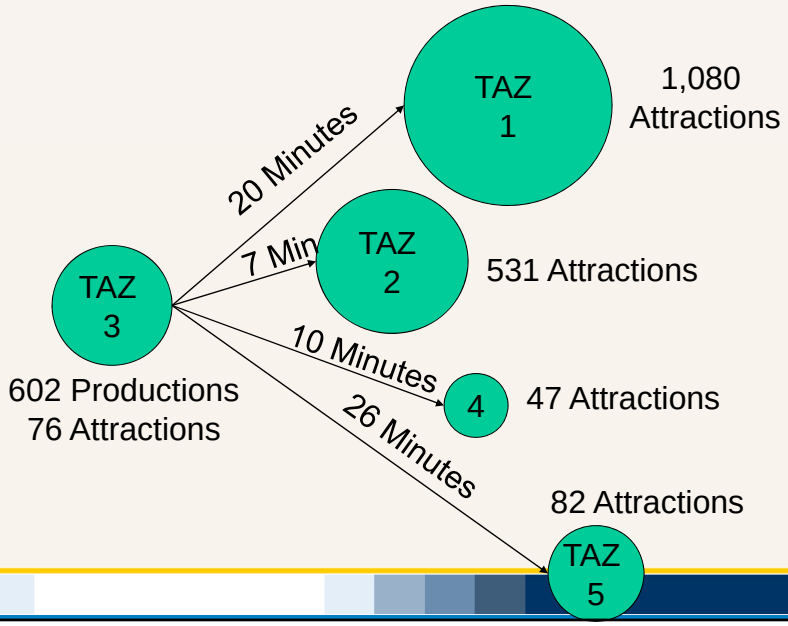
Productions and Attractions Allocated to TAZs



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Trip Distribution: The Gravity Model

The gravity model distributes person trips based on:

Flow in total passenger travel between two zones is a function of

*the **trips produced** in the first zone times*

*the **trips attracted** in the second zone times*

*the **difficulty of travel between** those zones times*

adjustment factors to make the outcomes balance

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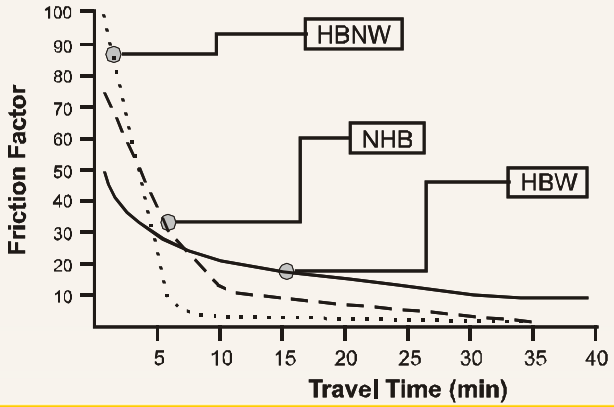
Friction Factors

What are F-factors ??

- F-factors relate the cost of travel to the propensity to travel
- F-factors are higher for zones that are closer together, and lower for zones that are further apart



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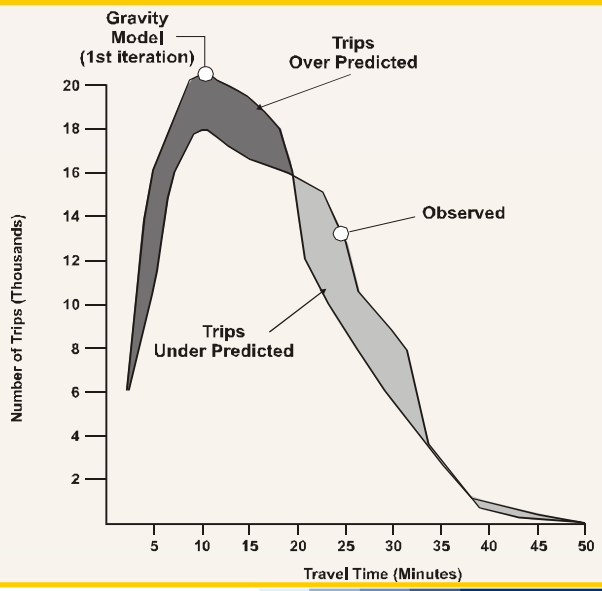
Calibrating a Gravity Model



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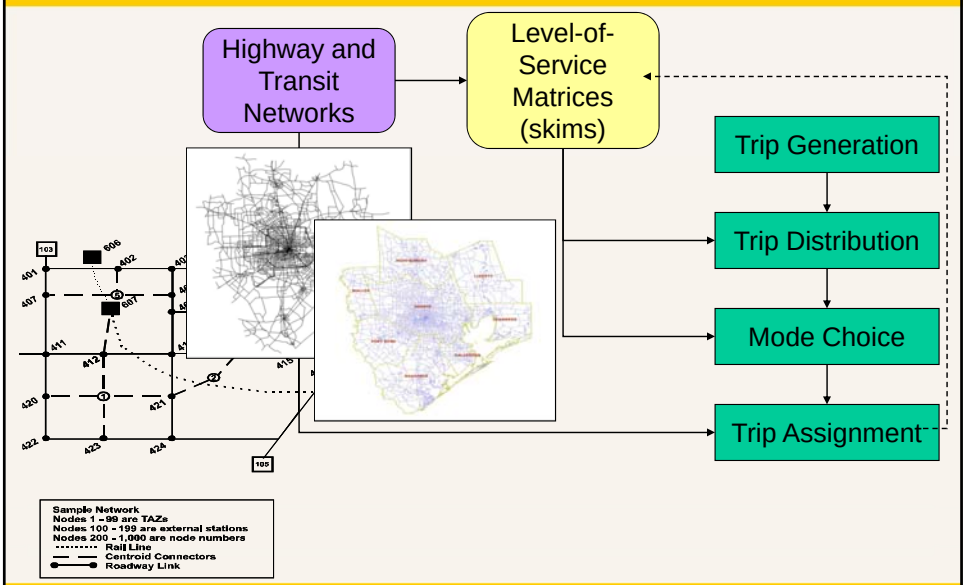
Travel Times and Costs in Travel Models



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Inputs and Outputs

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Trip Generation

Trip Productions (P_i)

Zone	P_i
1	34
2	66

Trip Attractions (A_j)

Zone	A_j
1	82
2	18

Path Skimming:
Level of Service Matrix

From Zone	To Zone 1	To Zone 2
1	20	12
2	47	18

Trip Distribution

Trip Table

From Zone	To Zone 1	To Zone 2	Total P_i
1	27	7	34
2	55	11	66
Total A_j	82	18	100

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Travel Forecasts

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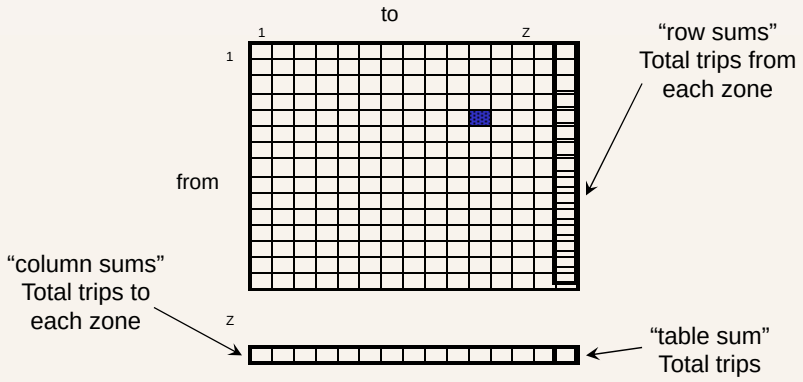
Travel between zones: “trip tables”



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Trip Distribution Calibration: Average Travel Time and Distance Comparisons

Estimated Versus Observed Average Travel Time and Distance

	Average Time				Average Dist			
Purpose	Obs.	Est.	Diff.	% Diff	Obs.	Est.	Diff.	% Diff
HBWORK	15.24	15.93	0.69	4.5%	8.7	9.31	0.61	7.0%
HSCHOOL	8.82	9.84	1.02	11.6%	4.48	4.74	0.26	5.8%
HBSHOP	9.35	9.32	-0.03	-0.3%	4.96	5.08	0.12	2.4%
HBOTHER	9.86	10.22	0.36	3.7%	5.21	5.33	0.12	2.3%
NHB	9.88	11.53	1.65	16.7%	5.18	6.22	1.04	20.1%

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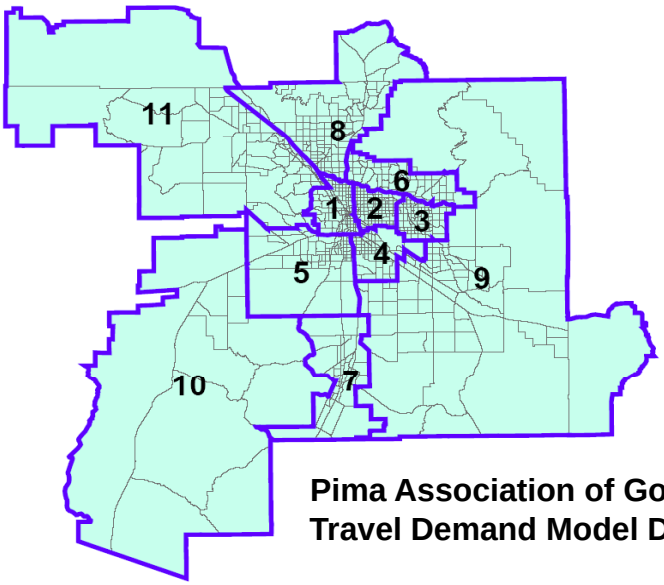
District Geography



Pima Association of Governments Travel Demand Model District Map

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District Level Trip Table Comparison

Estimated – Observed Home-Based Work Trips

Production District	Attraction District													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1 CityW	3,558	-1,898	-683	-1,354	-39	505	329	-573	-	-56	299	-100	13	0
2 CityE	4,688	-6,529	64	2,164	501	314	4	-853	-	33	-135	-144	-105	0
3 SubE	294	619	3,545	-4,559	-36	1,054	-26	-360	-8	-22	-117	-329	-55	0
4 AfbTia	-1,093	926	105	-333	-105	36	234	59	-	-7	-33	28	184	0
5 SW	-2,277	61	-305	1,750	-391	53	886	-27	-	89	112	-126	175	0
6 NE	2,345	-807	1,709	-3,882	-111	795	5	500	-	31	246	-138	-693	0
7 GV	-29	-65	12	212	106	10	-448	-55	-	215	-15	47	9	0
8 FarN	3,953	-3,103	-565	-4,624	38	2,506	-139	2,447	-	-10	606	-481	-627	0
9 FarNE	-13	-1	30	-2	2	9	1	-5	-28	-	1	1	4	-
10 FarSW	-12	-228	-12	-110	192	-14	-154	-54	-3	384	42	-27	-6	0
11 FarNW	1,013	-287	-5	-759	78	197	1	-316	-8	-39	410	-88	-196	0
12 FarSE	-44	-146	-13	376	58	-8	-242	-59	-	9	-13	-68	152	0

Trip Distribution Challenges

Distribution is a complex social behavior with longer-term impacts

- Availability & location of desirable housing
- Employment location based on supply, availability, cost & general preferences
- Destination choice also a function of household-level interactions
- Non-work travel often difficult to represent with gravity-based methods

Travel Patterns for Special Markets

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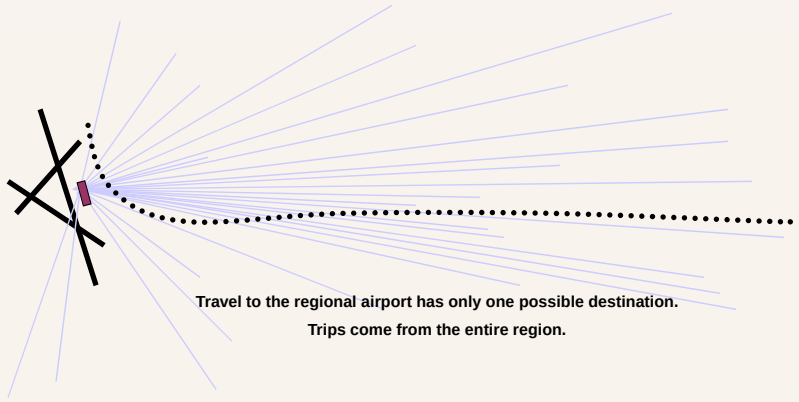
Example: Travel to an Airport



Travel to the regional airport has only one possible destination.

Trips come from the entire region.

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Mode Choice

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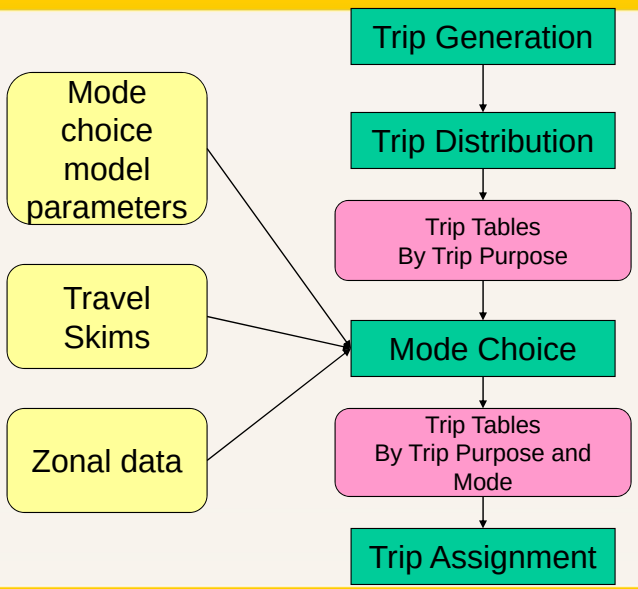

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The choice of mode is affected by:

- Travel time (in-vehicle, wait, access, etc)

- Cost (parking, tolls, fare, auto operating, etc)

- Other modal characteristics (reliability, safety, comfort, etc)

- Person/Household characteristics (income, autos owned, age, etc)

- Trip purpose characteristics (shopping, number of stops, etc)

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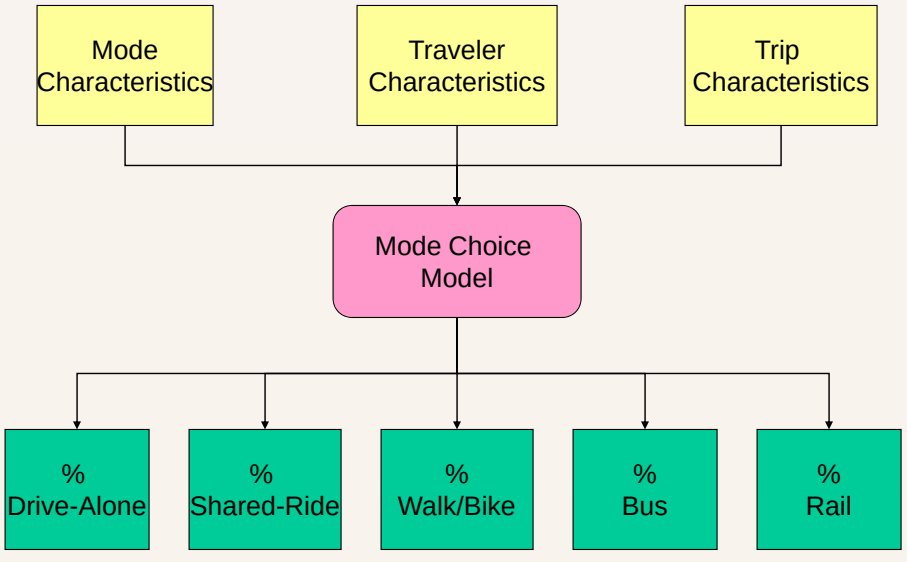
Mode Choice Overview



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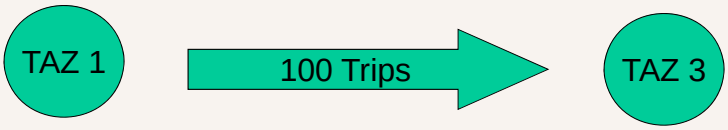
Mode Share Calculations



How many choose auto?
How many choose transit?

$$\text{Share}_{transit} = \frac{\text{Attractiveness}_{transit}}{\text{Attractiveness}_{auto} + \text{Attractiveness}_{transit}}$$

The Logit Model

P_i = Probability of mode i
U_i = Utility for mode i

$$P_i = \frac{e^{U_i}}{\sum_{i \in I} e^{U_i}}$$

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Describing Mode Attractiveness: The Utility Expression

$$\text{Utility}_{transit} = a * \text{in-vehicle time} + b * \text{fare} + c * \text{access time + egress time} + d * \text{wait time} + \text{mode-specific constant}$$

$$\text{Utility}_{auto} = a * \text{in-vehicle time} + b * \text{parking cost and operating cost} + c * \text{access time and egress time} + \text{mode-specific constant}$$

- *Utility is the weighted sum of the attributes*
- *a, b, c, d are the weights, or parameters, in the model*
- *Parameters are estimated from survey data or borrowed/asserted*
- *They convert the times and costs to utiles*
- *They are negative if multiplied by time/cost (disutility)*
- *The mode-specific constant is the value of the "non-included" attributes*

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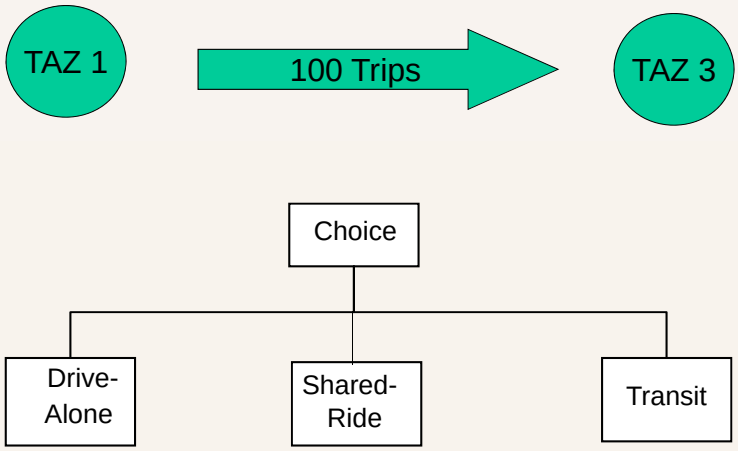
Simplified Mode Choice Model



Example Multinomial Logit Model

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Mode Choice: Computing Mode Shares

Mode Choice Equation for Transit

$$\text{Share(tran)} = \frac{\text{Mobility(transit)}}{\text{Mobility(drive)} + \text{Mobility(carpool)} + \text{Mobility(tran)}}$$

Mobility(m) = g [a x (in-vehicle time)
+ b x (walk and wait time)
+ c x (tolls/parking costs)
+ d x (number of transfers)
+ ……..
+ non-quantifiable factors

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Mode Choice Mathematics

Example No Build Condition:

$$\text{Share(Transit)} = \frac{2}{7 + 1 + 2} = 0.20 = 20 \text{ percent}$$

sum = 10.0

Example Build Condition:

$$\text{Share(Transit)} = \frac{2.2}{7 + 1 + 2.2} = 0.216 = 21.6 \text{ percent}$$

sum = 10.2

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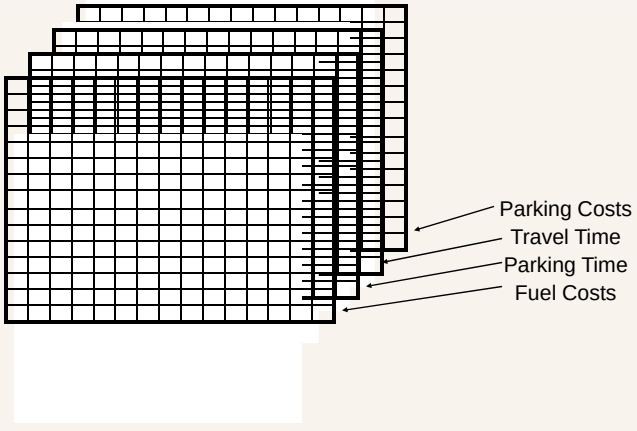
Mode Choice Inputs: Impedance Tables

Times and costs between zones: “impedance tables”



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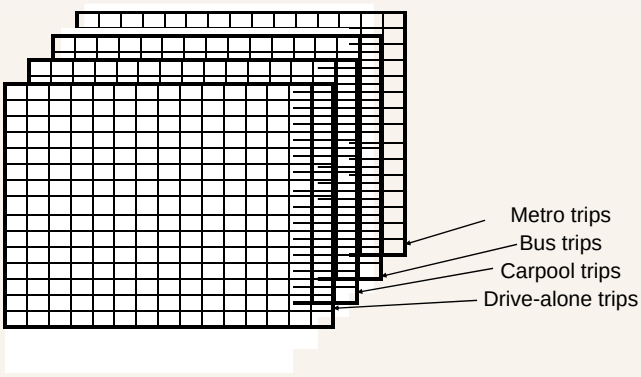
Mode Choice Outputs: Mode Specific Trip Tables

Trip Tables by Mode:



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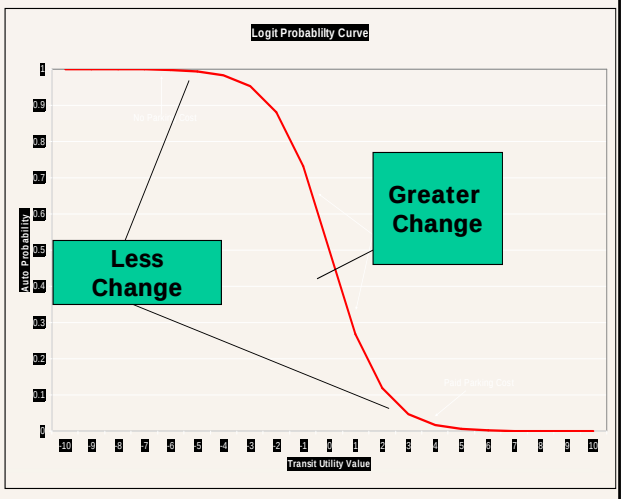
Market Segmentation and Aggregation Error

- The model applied for each zone pair (P to A)
- Market Segments
  - Trip purpose
  - Transit access
  - HH characteristics
    - Income, Autos
  - Time Periods
- Segmentation and aggregation bias
  - Small change in utility can yield unrealistic response



Transit utility – auto utility

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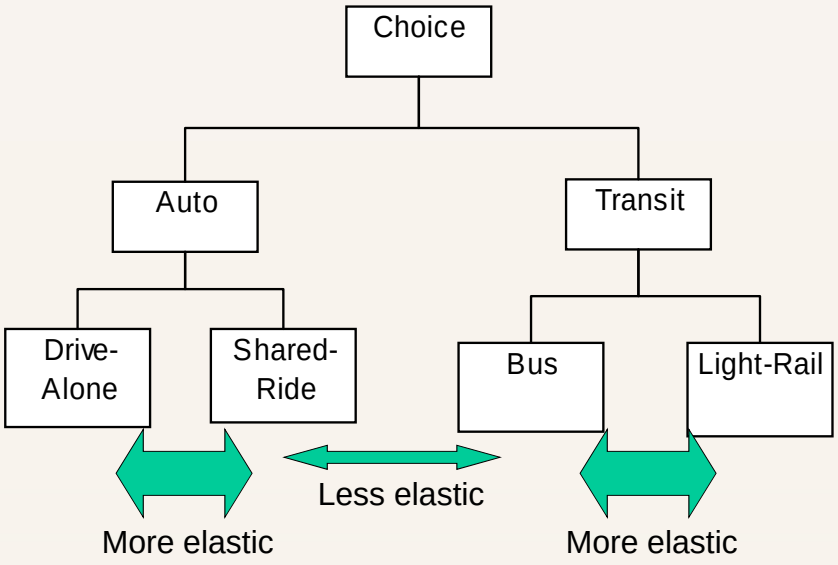
Nested Logit Model



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Mode Choice: Calibration and Validation

Calibration

- Aggregate mode shares match reasonably well?
- Transit shares in specific markets (e.g. downtown)
- Estimated versus observed number of transfers?

Validation

- Does the model make logical predictions in forecasting?

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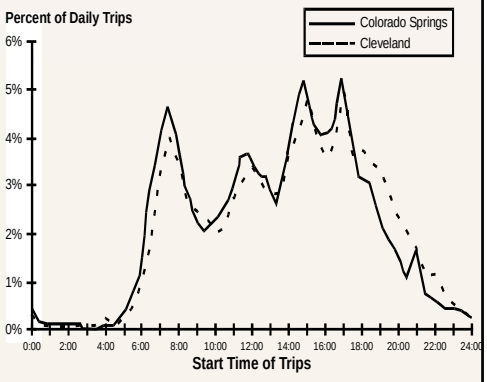
Accounting for Time of Travel

First generation models:

- Provided traffic projections for geometric and pavement design

Now:

- Evaluating policy and project design alternatives
- Understanding future congestion and its affects on travel
- Evaluation of pricing and 'managed lane' policies
- Alternatives to single-occupant vehicles (HOV lanes, transit)
- Air quality analysis



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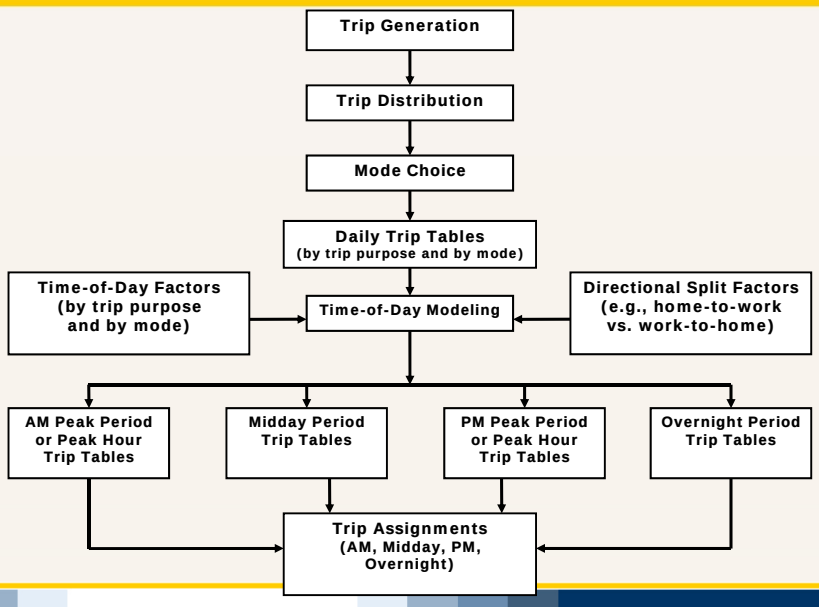
Time-of-Day Modeling



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Trip Assignment

Assignment Approaches

- All-or-nothing Assignment
- Equilibrium Assignment
- Stochastic Assignment

Inputs and Outputs

Inputs
O&D trip table
Coded network

Outputs
Link flows as per coded network
Link travel times/speeds
Vehicle-miles of travel (VMT)
Vehicle hours of travel (VHT)
Delay
Turning Movements
Boardings and Alightings (Transit)

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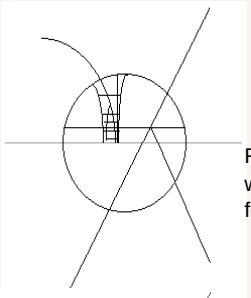
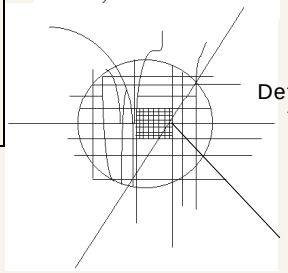
Highway Network Files

Speed Table

	Area Type			
Facility Type	CBD	Urban	Suburb	Rural
Freeway	--	26	38	28
Rural Arterial	--	--	32	34
Collector	20	11	18	19
Ramp	--	--	34	32
Major Arterial	12	13	19	21
Local	10	16	27	20
Minor Arterial	10	12	22	12



Regional network with localized detail for corridor study.



Detailed network for regional analysis.

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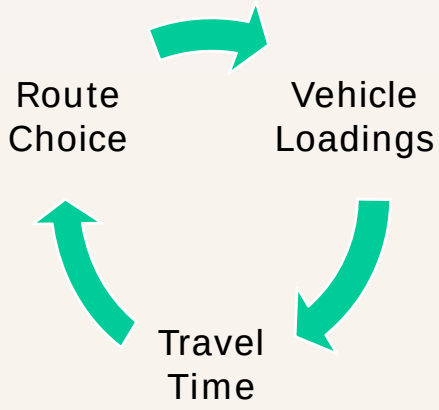
Frank-Wolfe Assignment Algorithm

1. Compute time on all links using flows from current solution
2. Find shortest paths between zone pairs.
3. Assign all demand between zone pairs to the shortest paths.
4. Make a weighted average of current and previous solutions (lambda search).
5. Stop if converged; otherwise back to 1.

- ***Equilibrium is achieved when no individual trip maker can reduce path costs by switching routes.***



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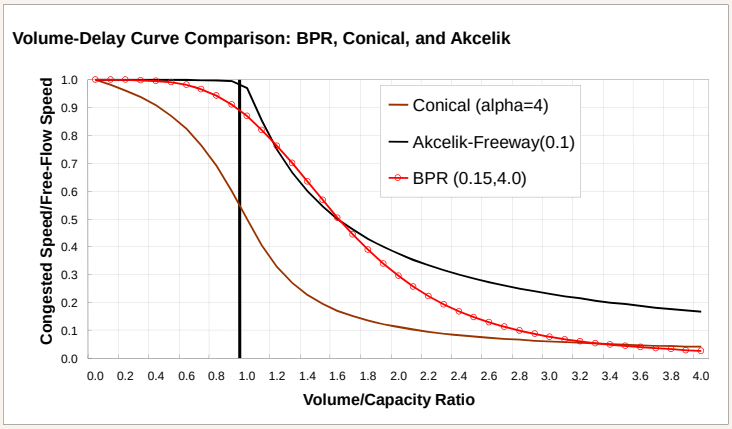
Volume Delay Functions



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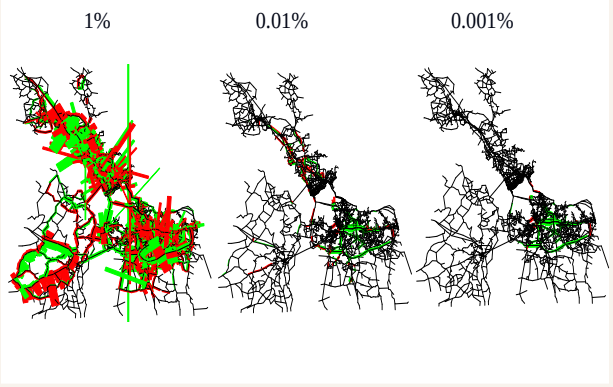
Assignment Stability

Tighter equilibrium closure criteria does improve link assignment stability… eventually



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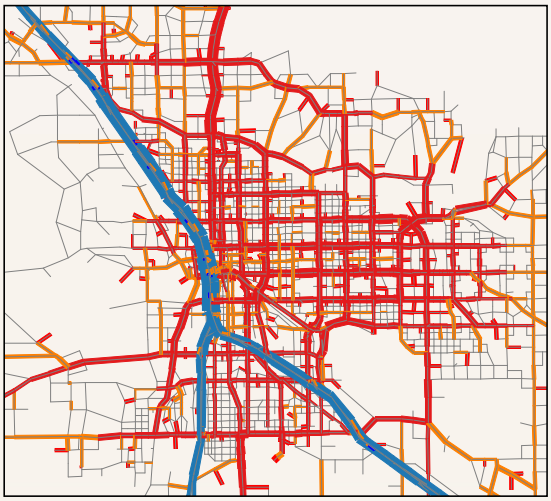
"Loaded" Highway Network



Highway Assignment Bandwidth Plot

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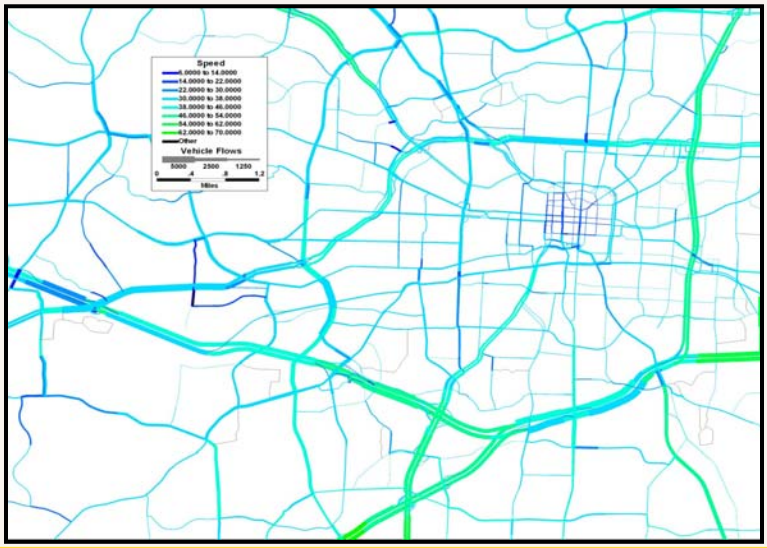
Speed Bandwidth Plots



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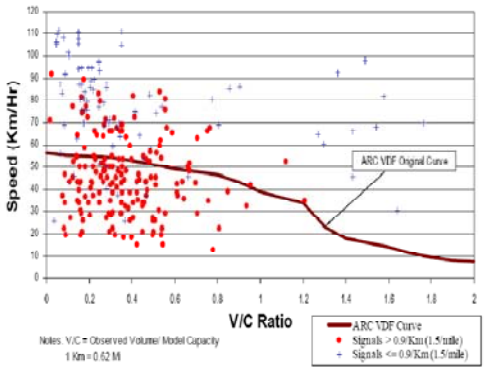
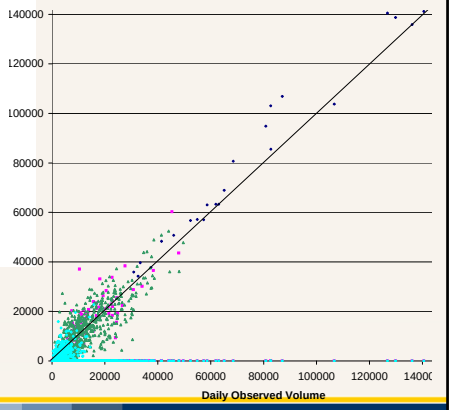
Trip Assignment Calibration



Source: Atlanta Regional Commission

Traffic Volumes
Estimated vs. Observed



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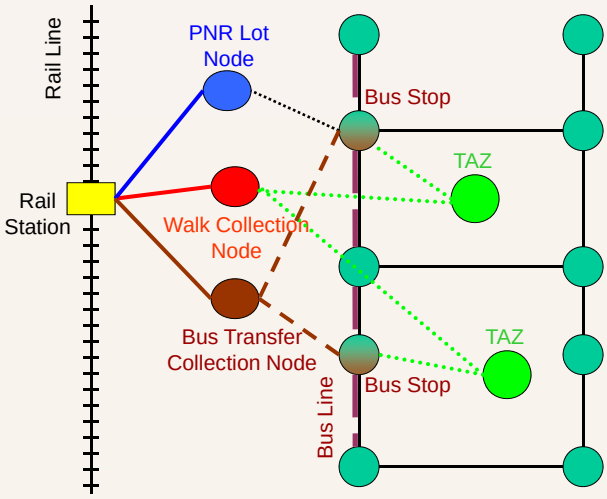
Transit Assignments

Complex interchange patterns associated with passenger movements

- Some paths offer more than one parallel service with complex associated choices
- Network coding can reflect several access modes
- Allocation of trips to paths for route level boardings



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External and Commercial Vehicle Trips

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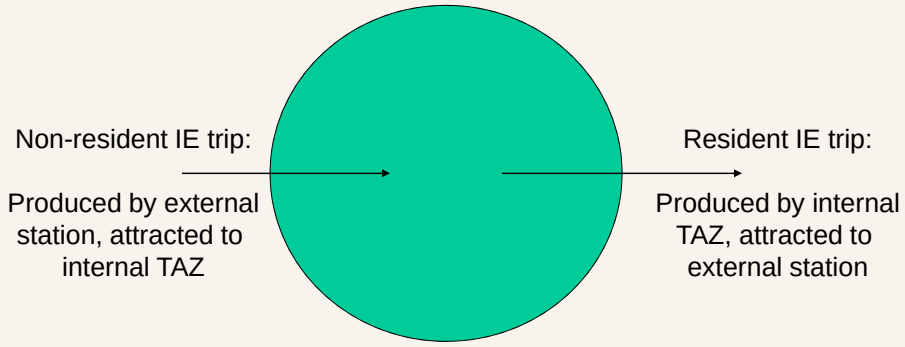
Internal to External Travel

External stations produce non-resident trips and attract resident trips

Internal TAZs produce resident IE trips and attract non-resident IE trips



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Data and Methods for Internal -External Travel

Data on external trips can be collected with origin destination (roadside) surveys at external stations

Internal-external trips modeled using production-attraction format

- Gravity model

External-external trips left in origin-destination format

- Matrix fitting (Fratar)

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Commercial Vehicles

Trip tables can be developed by:

- Factor an existing trip table
- Apply a simple 'quick response truck model'
- 'Synthesize' matrices via truck counts, using truck matrices as a 'seed'
- Develop and apply a more sophisticated commodity flow model

Data Sources

- Vehicle Classification Counts
- National data products (FAF/3)
- Establishment Surveys
- Intercept Surveys

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Model Validation and Reasonableness Checking

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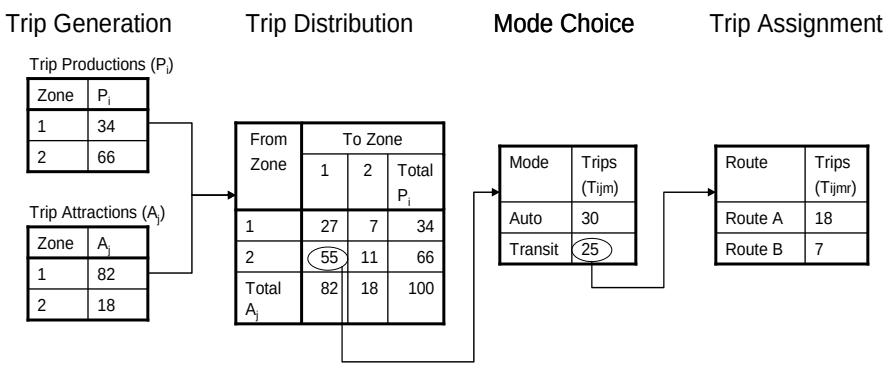
Error Propagation



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Model Application Steps

1. Forecast household and employment data for each TAZ
2. Apply trip generation model
3. Forecast and code future year networks
4. Apply trip distribution model
5. Apply mode choice model
6. Apply time-of-day and directional factoring
7. Apply trip assignment model

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Evaluating Forecasts: Do they look reasonable?

Test: Back-casting

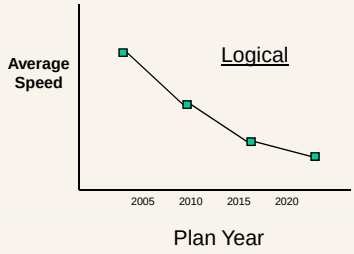
- After base-year calibration, run model for a past year and validate

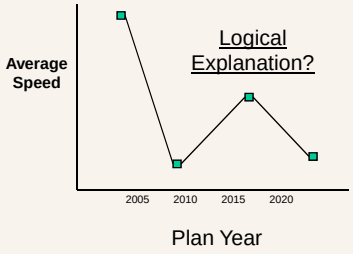
Step-wise build-up of travel forecasts

- Run model holding various steps constant between baseline and build to determine effect of each on forecast

Risk and uncertainty analysis

- Run model multiple times, varying the assumption and inputs, to determine effect on results – produce range of forecasts





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Home Interview Surveys

- Activity and travel information for 24-hour weekday period
  - Provide up-to-date travel information
  - Provide information about household and travel characteristics
  - Provide a basis for future projections
- Considerations for survey design and implementation
  - Coverage Bias
  - Response Bias
- TRB Data Collection Manual
  - http://tmip.fhwa.dot.gov/resources/clearinghouse/browse/list/25/1378

TABLE M-2: HOUSEHOLD TRAVEL SURVEY DATA ITEMS

Household Data File	Person Data File	Vehicle Data File	Travel/Activity Data File
For each household	For each person in HH	For each HH vehicle	For each person trip
Home Address	Relationship	Year	Destination Address
Geographic Location	Gender	Make	Departure time
Household Size	Age	Model	Arrival Time
# Vehicles Owned	Licensed Driver	Body Type	Activity
Dwelling Type	Employment Status	Fuel Type	Activity Duration
Own/Rent Status	# Jobs Held		Travel Mode
Telephone Ownership Details	Travel Mode to Work		Trip Duration
Household Income	Work Address		Travel Party Details
Household Ethnicity	Educational Attainment		HH vehicle used
Travel Day and Date	Student Status		Parking Details
Summary Statistics	School Address		Transit Access and Egress Details
Special Population Identifiers	Travel Mode to School		Transfer Details
	Travel Summary Statistics		HOV and Hot Lane Usage
			Vehicle Availability for Transit

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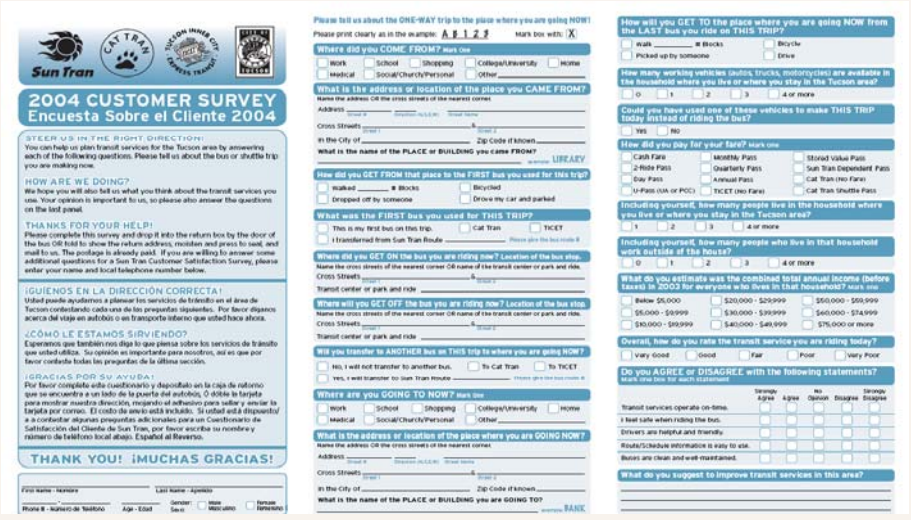
Trip Tables from Home Interviews

TABLE T-17: ORIGINS AND DESTINATIONS OF TRAVEL FOR HOME-BASED WORK TRIPS

Origin	Destination									
	Central	North City	South Suburban	East Suburban	North County West	North County East	East County	Out of Area	Unknown	Total
Central	43.3%	26.1%	11.8%	12.0%	1.9%	1.7%	.0%	0%	3.3%	100.0%
North City	14.8%	63.3%	3.8%	6.5%	5.0%	3.7%	.1%	0%	2.8%	100.0%
South Suburban	21.4%	13.4%	53.8%	6.5%	.5%	.9%	.0%	0%	3.5%	100.0%
East Suburban	18.5%	21.3%	5.4%	50.4%	1.3%	1.4%	.3%	0%	1.5%	100.0%
North County West	3.3%	15.3%	.4%	1.3%	53.5%	19.0%	.0%	0%	7.0%	100.0%
North County East	2.5%	11.1%	.9%	1.8%	18.3%	59.0%	.0%	0%	6.3%	100.0%
East County	3.8%	7.3%	.0%	11.8%	.0%	.0%	71.2%	0%	5.4%	100.0%
Out of Area	0%	.0%	.0%	.0%	.0%	.0%	.0%	0%	.0%	.0%
Unknown	18.8%	28.3%	13.2%	4.9%	15.5%	18.6%	.4%	0%	.0%	100.0%
Total	18.6%	34.0%	10.0%	11.7%	10.9%	10.9%	.4%	0%	3.6%	100.0%

Source: San Diego HH Survey, NuStats, 2006

On Board Survey Questionnaire



Model ready for prime time?

Base year model results compared to observed travel

Judgment as to model suitability

- Reasonably match base year conditions?
- Logical response to changes in inputs?

Once validated, model available for forecasting

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Questions?

Thank You!

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