Hybrid Trip-Based / Tour-Based Models

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Evansville Metropolitan Planning Organization

Agenda

- Background & Motivation
- Overview of Model Design
- Details of Two Innovations
  - Double Destination (Origin-Destination) Choice
  - Mode-Destination Choice Hierarchy
- Results
  - Comparison with Trip-based Model
  - New Policy Variables and Sensitivity
- What's Next?

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- ❖ What's Next?

KNOXVILLE REGIONAL TPO

EVANSVILLE MPO

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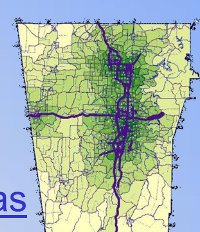
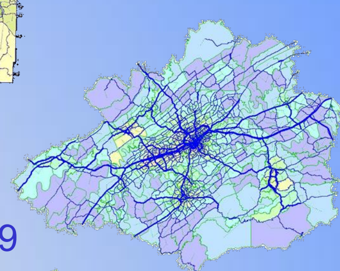
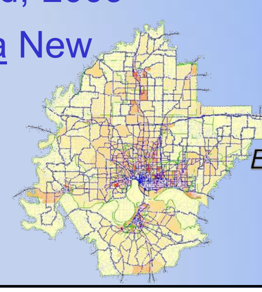
Background

- ❖ History
  - ➢ Northwest Arkansas Hybrid Aggregate/ Disaggregate, 2006
  - ➢ Knoxville Region 1st Hybrid Trip-based/Tour-based, 2009
  - ➢ Evansville Metro Area New Hybrid Model, 2011







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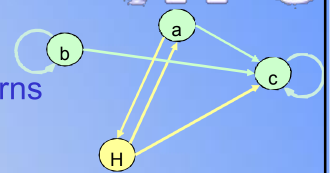
Limitations of Traditional Models



- ❖ Serious theoretical problems
  - Physically impossible travel patterns
  - Aggregation bias / inaccuracy
  - Reliance on fudge factors
- ❖ Lack of policy sensitivity
  - Insensitivity to gas prices, tolls, parking fees
  - Insensitivity to urban design / built environment
  - Insensitivity of timing of travel to congestion
  - Insensitivity of destinations to transit service

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Background

- ❖ Goal
  - Create an advanced model with **as much realism** and policy sensitivity as possible
  - With run times and development **costs low enough** for an average MPO to afford

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Cost-Effectiveness

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Activity-Based

- 2-3 years to develop
- $600-800k (+ data) consultant fees
- Runs in 1-2 days
- On computers with 10+ processors

Knoxville's Hybrid

- 9 months to develop
- under $300k (+ data) consultant fees
- Runs under 4 hours
- On standard dual core machines

- Importance of **data** and agency support for any advanced modeling

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Background: Knoxville

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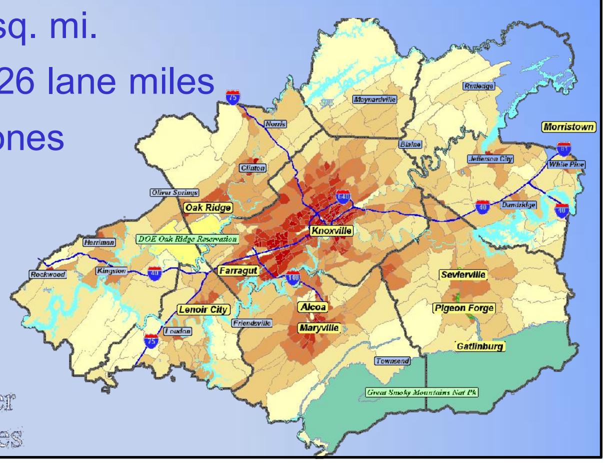
- Knoxville Area
  - Population: 863,000
  - Area: 3,425 sq. mi.
  - Network: 6,626 lane miles
  - TAZ: 1019 zones



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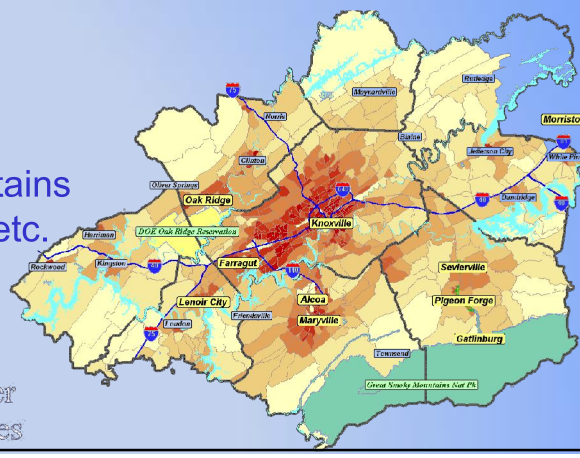
Background: Knoxville

KNOXVILLE REGIONAL TPO

- ❖ Knoxville Area
- ❖ Multinucleated
  - ➢ Knoxville
  - ➢ Maryville
  - ➢ Oak Ridge
  - ➢ Smoky Mountains / Gatlinburg, etc.



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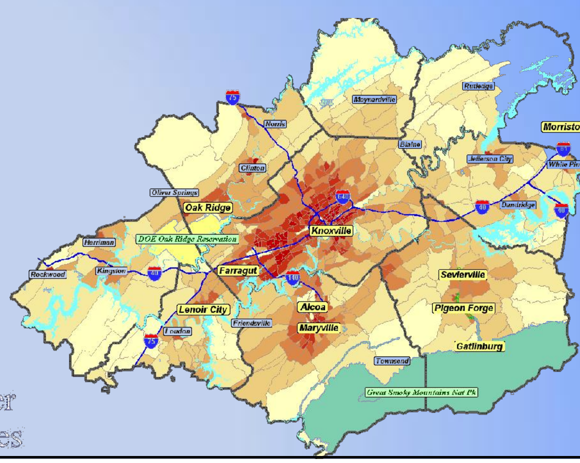
Background: Knoxville

KNOXVILLE REGIONAL TPO

- ❖ Knoxville Area
- ❖ Multinucleated
- ❖ Topography



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Background

2000	Household Travel Survey
2002	New Trip-based Model
2005	Model Peer-Review
2007	External Cordon Line Survey
2008	Land Use Model (ULAM)
2008	Household Travel Survey
2008	Transit On-board Survey
2009	New Hybrid Trip/Tour-based Model

Motivation

- Model Peer Review
  - Noted poor distribution and k-factors
- Policy and Planning Interests
  - Built environment / land use interactions
  - Importance of transit and walking
  - Future tolling / pricing scenarios?

New Model

- Hybrid Trip/Tour-based Model promised:
  - Improved fundamentals of travel behavior
  - Sensitivity to new planning / policy issues
  - Reasonable model run times
  - Reasonable development costs and timeframe

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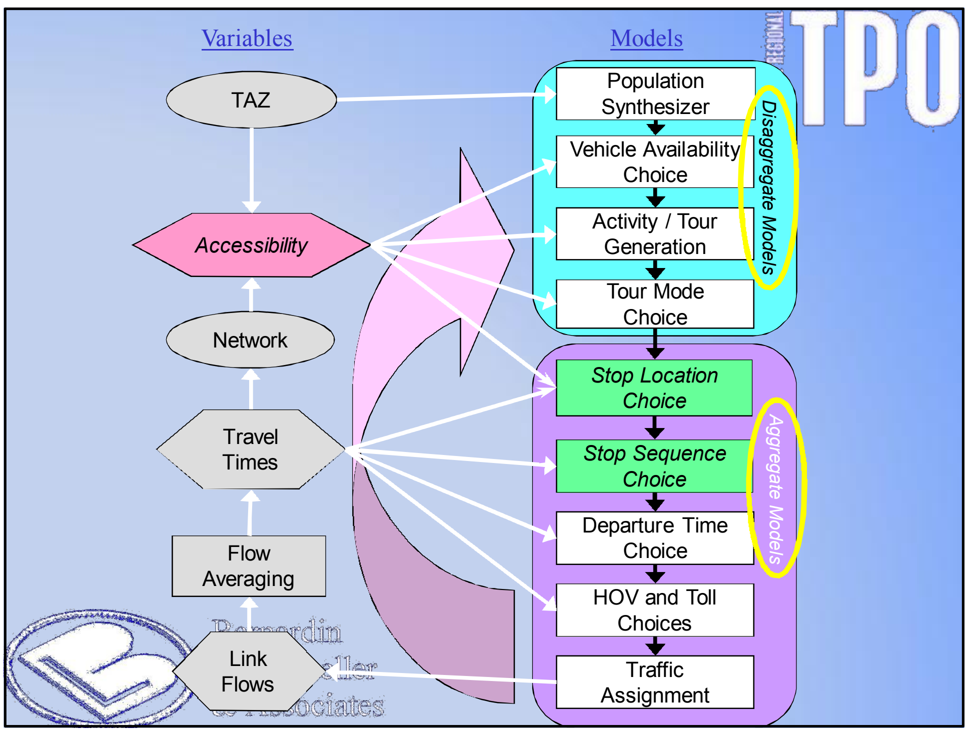
A New, Alternative Model Design

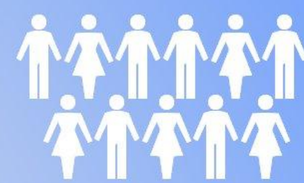
❖ Methodology

1. A hybrid disaggregate / aggregate system
   - To maximize model fidelity and minimize run time



Hybrid disaggregate / aggregate

- ❖ Disaggregate population
  - ➢ individual households choose activities and modes
- ❖ Deterministic outcomes
  - ➢ no simulation = no simulation error
  - ➢ average forecasts from a single model run
- ❖ Aggregate spatial and temporal models
  - ➢ some bias / insensitivity to demographics
  - ➢ reasonable run times



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Population Synthesis

- ❖ The synthetic population of households is generated from TAZ data and a seed / sample population using iterative proportional fitting (IPF)
- ❖ The marginal distributions for IPF are generated by ordered response / ordinal logit models
- ❖ Shadow prices are used in the logit models to ensure that the distribution exhibits the observed mean
- ❖ The process is deterministic, weighting households in the seed, rather than drawing them
  - ➢ This effectively limits the number of variables, but not too restrictively

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Population Synthesis

- Five dimensions
  - Persons, Workers, Students, Seniors and Income
- Zonal averages serve as primary input for each variable
- Secondary input variables included
  - population density
  - percent of zone within ½ mile of a bus route
  - an urban design factor (grid vs. cul-de-sac street design)
- Output
  - Number of Persons (1, 2, 3, 4, 5+)
  - Number of Workers (0, 1, 2, 3+)
  - Number of Students (0, 1, 2+)
  - Presence of Seniors (0, 1+)
  - Income Group (low, mid, high)

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A New, Alternative Model Design

- Methodology
  1. A hybrid disaggregate / aggregate system
     - To maximize model fidelity and minimize run time
  2. Disaggregate vehicle & tour mode choices
  3. Departure time choice

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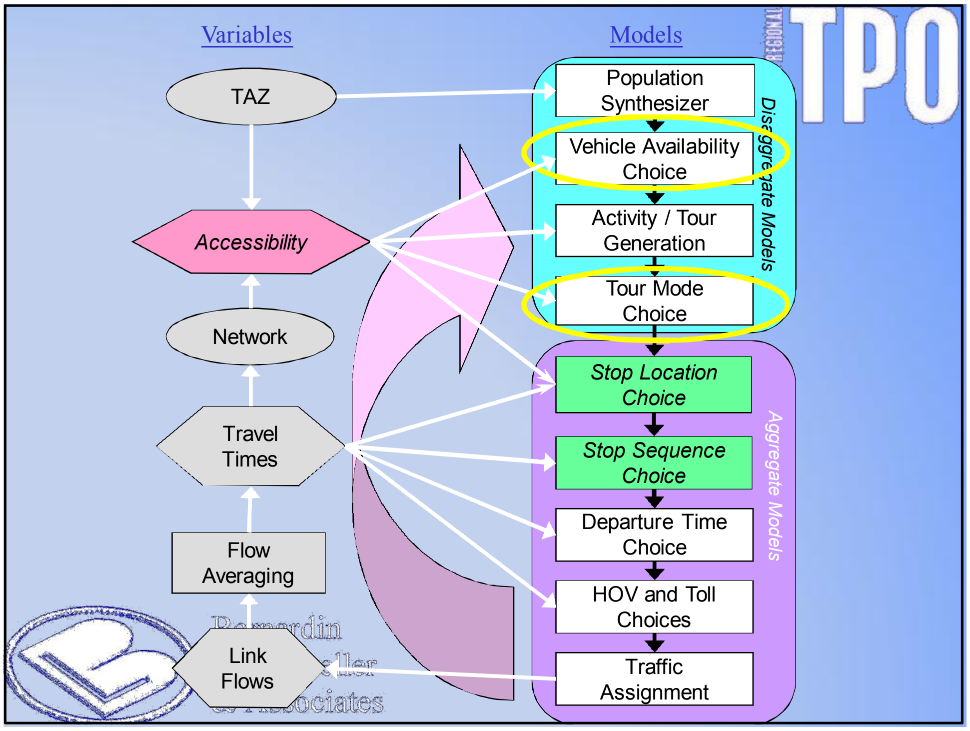
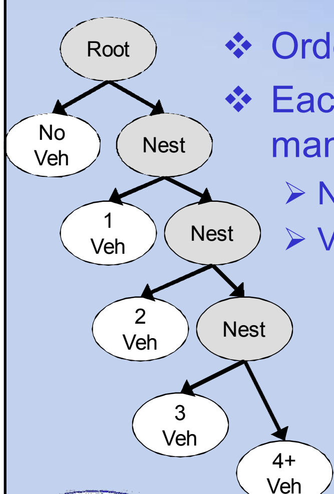


Vehicle Availability Choice



- Ordered response logit model
- Each individual household chooses how many vehicles to own / lease
  - No aggregation bias
  - Vehicle ownership levels respond to
    - Demographics (household size, income, number of workers, students, etc.)
    - Gas Prices
    - Transit Availability
    - Urban Design (pedestrian environment / grid vs. cul-de-sac design)

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Disaggregate Tour Mode Choice

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- ❖ Mode choices made by individual households
  - ➢ No aggregation bias
  - ➢ Consider the probability of transit use for:
    - 100 households with an average of 2.2 cars per household
    - 5 households with no cars, 15 hh with one car, 50 hh with two cars, 20 hh with three cars, 5 hh with four cars, 5 hh with five
- ❖ Mode choices consistent for whole tours

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Mode Shares by Tour Type

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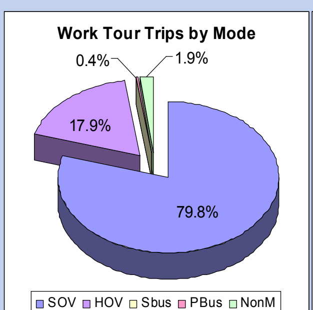
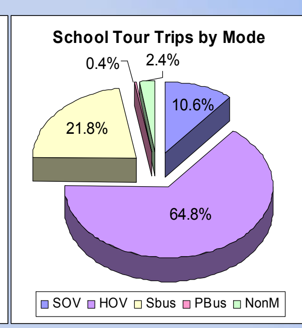
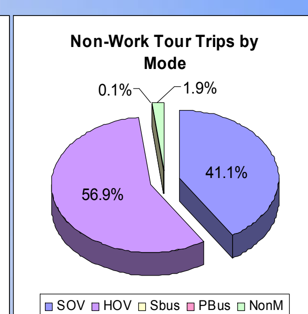
- ❖ Consistency with tours offers better mode shares (HBO / NHB on work tours, etc.)
- ❖ Each tour type has very distinct mode shares:







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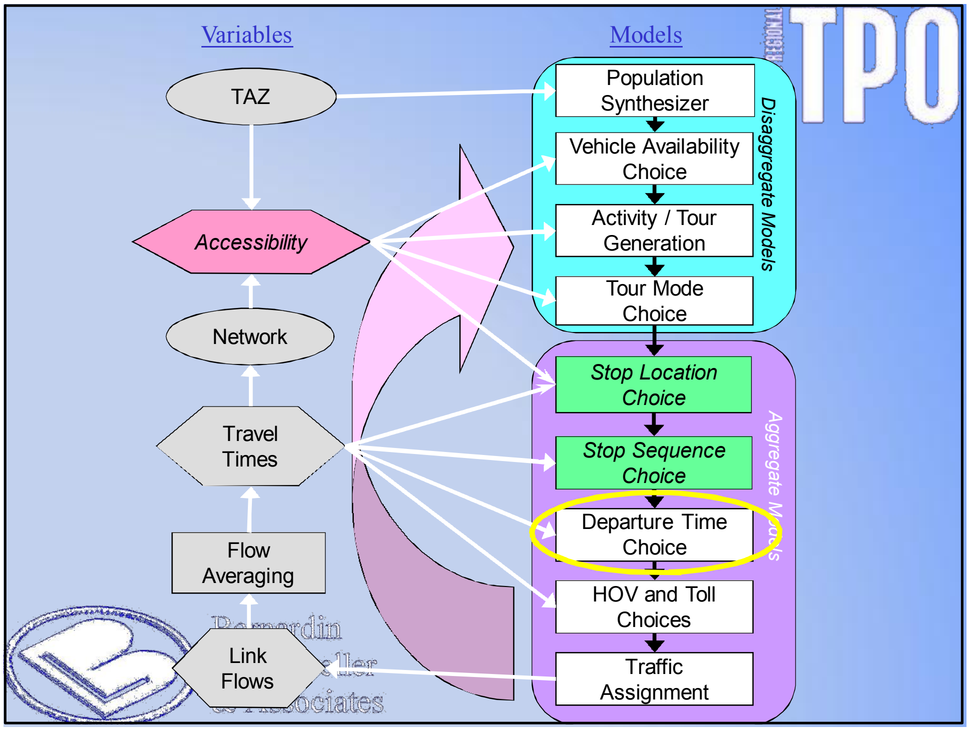
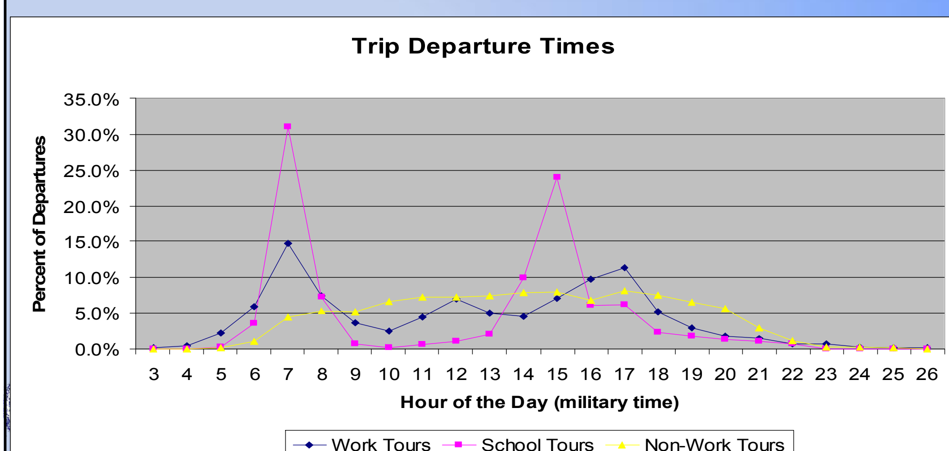


Departure Times by Tour Type

- Consistency with tours offers better time-of-day distributions (HBO / NHB on work tours, etc.)
- Each tour type has a very distinct temporal distribution:



Departure Time Choice

- ❖ Demand by 15-minute intervals based on:
  - ➢ Travel time during period (peak-spreading)
  - ➢ Bias variables interacted with *sinusoidal functions*:
    - ▪ Origin / Destination Accessibilities (urban vs. rural)
    - ▪ Return factor (ratio of employment to population at origin vs. destination)
    - ▪ SOV vs. HOV trip

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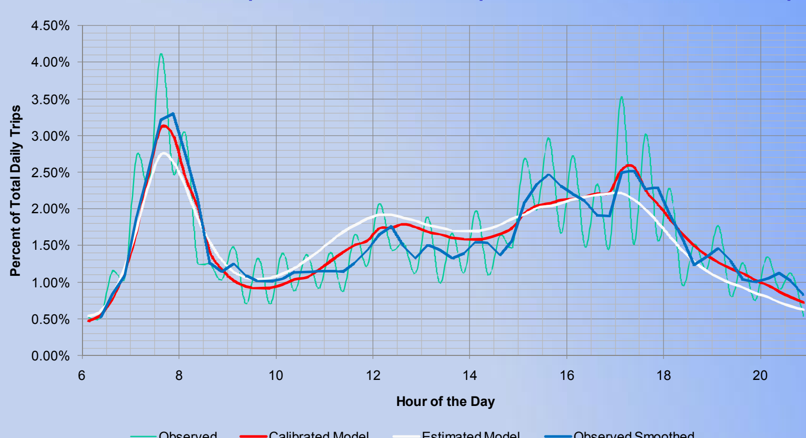
Departure Times by Time of Day

- ❖ The models reproduce the temporal distribution of trips



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A New, Alternative Model Design

❖ Methodology

1. A hybrid disaggregate / aggregate system
   - To maximize model fidelity and minimize run time
2. Disaggregate vehicle & tour mode choice
3. Departure time choice
4. Feedback of ACCESSIBILITY as well as travel time
   - To introduce sensitivity to ‘lower level’ choices in ‘upper level’ decisions

Knoxville Regional TPO

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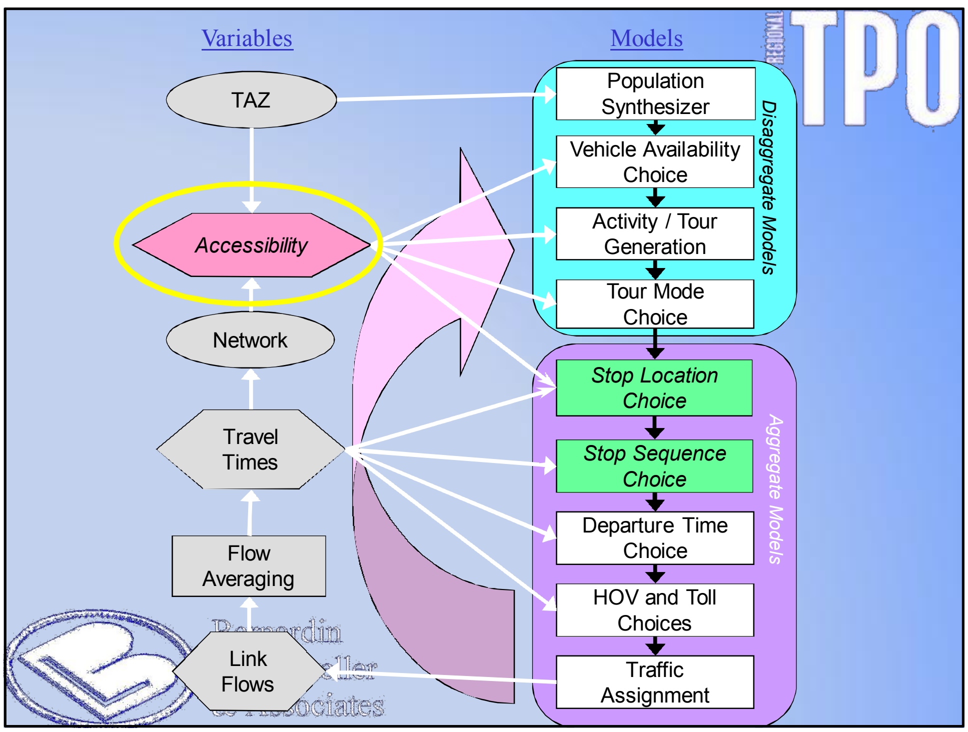

Accessibility

- What is Accessibility?
  - How easy is it to get somewhere else
- A simple example:

$$Accessibility_i = \ln\left[\sum_{zones(j)} Emp_j \times \exp\left(\beta \times time_{ij}\right)\right]$$

most accessibilities used were similar

- The average cost (expected disutility) of a trip from this zone [by a mode, etc]

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Accessibility

- Accessibility can be used to fix some of the important shortcomings of the four-step model
- How's this work?
  - The four-step model is limited because it is *sequential* (memory, but no foresight)
  - Accessibility introduces expectation or *foresight* into the models to produce a reasonable *simultaneity* of considerations

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Accessibility

- What does Accessibility (the expected cost of a trip) affect?
  - The likelihood of making a trip
    - land use / built environment effects; induced trip-making
  - The mode used for a trip
    - expected cost by transit vs. car
  - The destination of the trip
    - Trip chaining effects: convenience = the expected cost of a further trip (next trip in the chain) from a destination
    - Residential location effects on trip length

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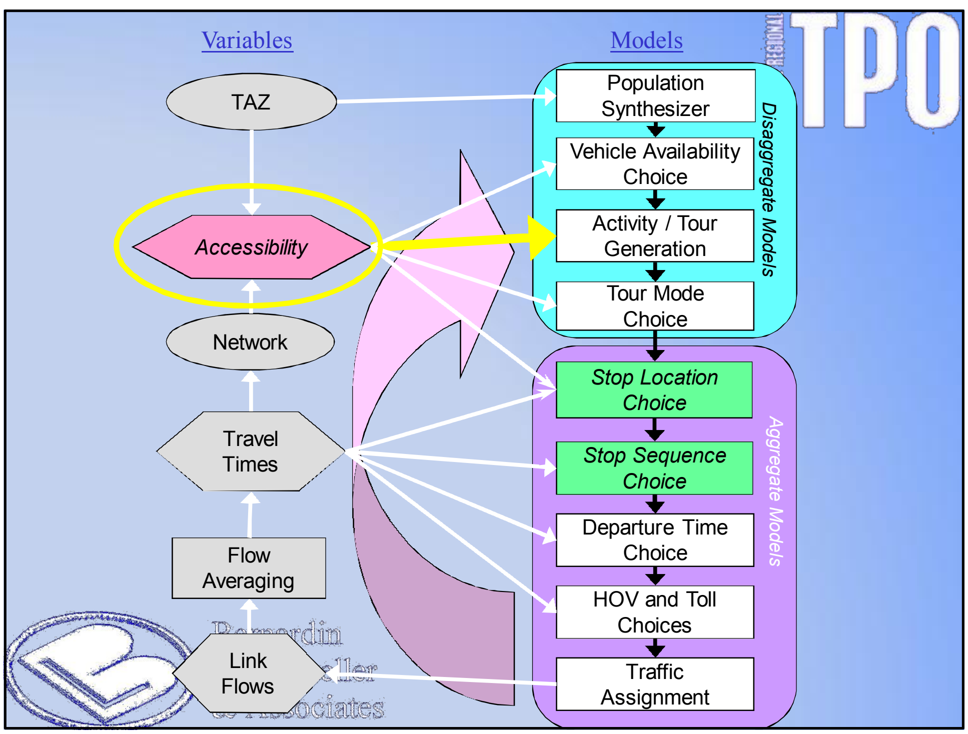

Travel Cost Elasticity

- Found elasticities of out-of-home activities with respect to accessibility of *0.13 - 0.16*
  - Lower tour-making by residents of rural (lower-accessibility) areas,
  - Decreased tour/stop-making in response to congestion (decreased accessibility),
  - Induced tour/stop-making in response to added network capacity (increased accessibility),
  - Induced tour/stop-making in response to new land use developments in other nearby zones (increased accessibility)

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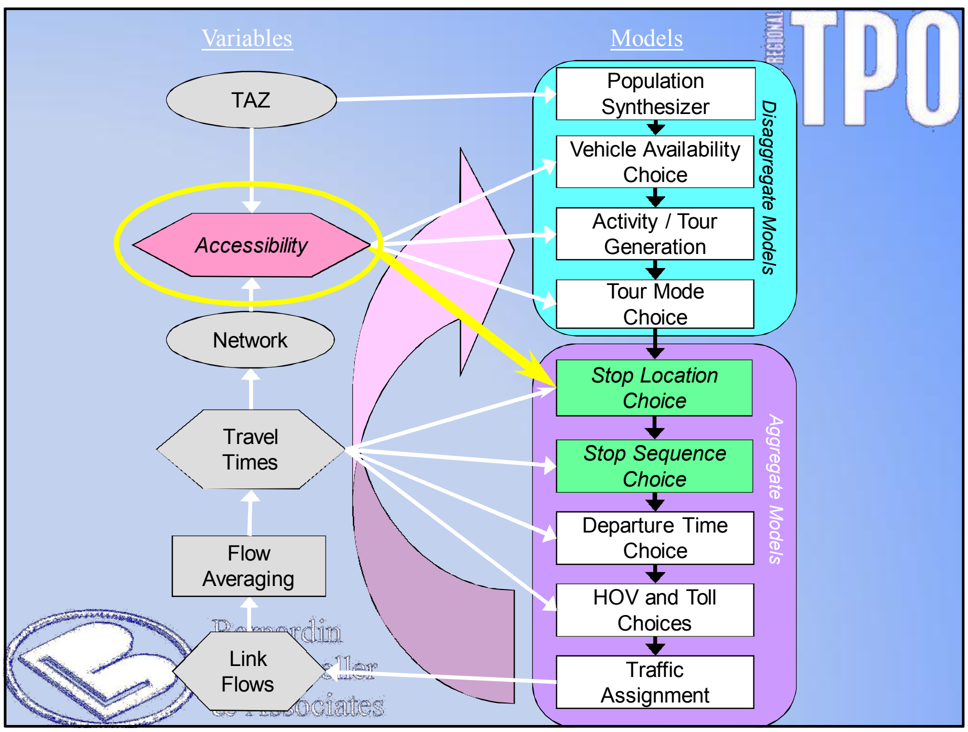
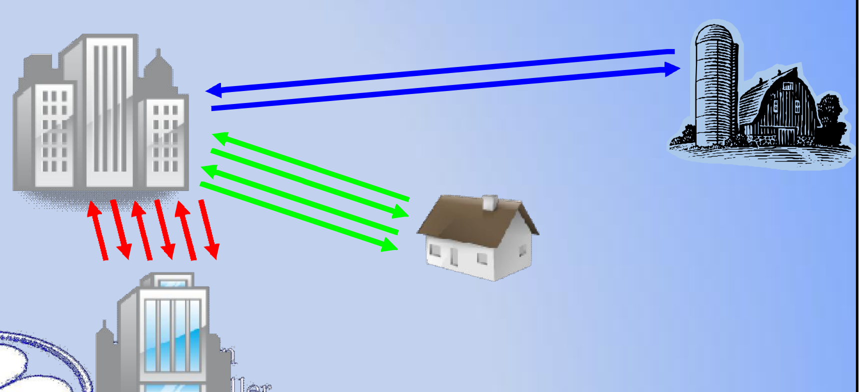


Residence Effects on Trip Length

- When people choose their residence location, they also choose how far they are willing to travel.
- We allowed travelers' willingness-to-travel, and hence, trip lengths to vary as a function of the accessibility of their residence location
  - The willingness-to-travel of residents of the most urban (most accessible) areas was about 10% lower than the regional average
  - The willingness-to-travel of residents of the most rural (least accessible) areas was about 200% higher or ***twice the regional average*** for most activity types

Cost Elasticity from Accessibility

- Including accessibility in both activity generation and stop location choice reflects *fewer*, but *longer rural* tours; *more shorter urban* tours



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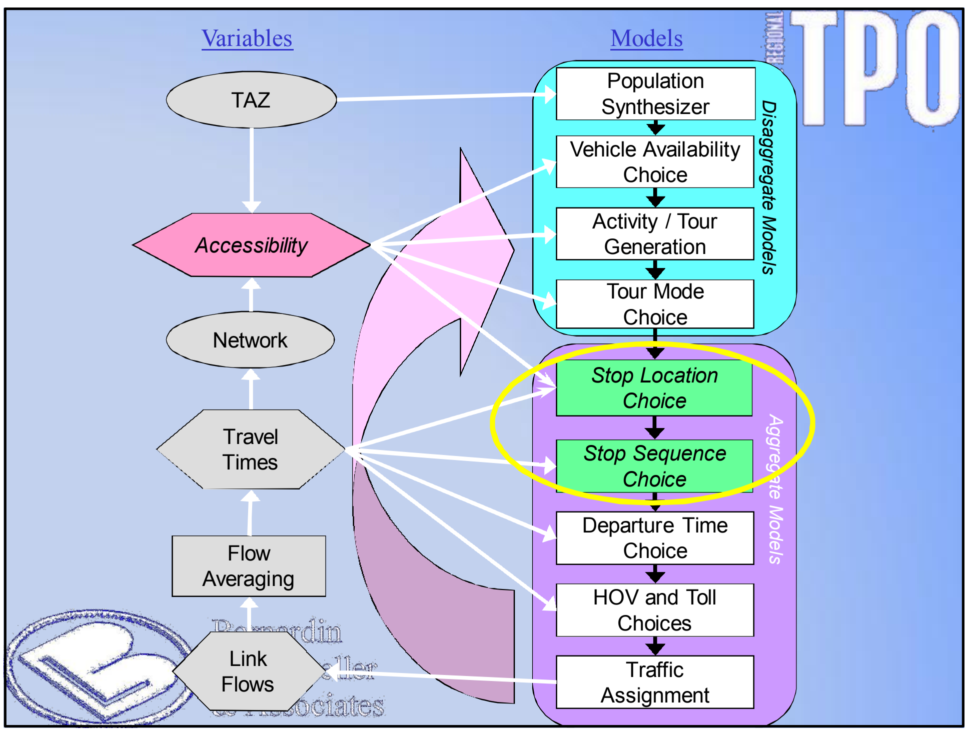
  4. Feedback of ACCESSIBILITY as well as travel time
     - To introduce sensitivity to ‘lower level’ choices in ‘upper level’ decisions
  5. A ‘*double destination choice*’ framework
     - Produce trips consistent w/ tours & trip-chaining behavior



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The Problem

- ❖ Trip distribution or destination choice is the largest source of error in traditional travel models (Zhao & Kockelman, 2002)
- ❖ Gravity models typically explain only about 10%-30% of the variation in destination choices

Why are the models so bad?

- Assumption all travelers behave the same
- Lack of data (prices, parking, etc.)
- Assumption that these unobserved variables are distributed randomly
- Assumption all destination choices are independent (no trip-chaining)

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Understanding the Problem

- Traditional trip-based models are commonly criticized for lack of consistency with tours, but what does this mean?
  - Open tours which are physically impossible
  - Inconsistency with tour cost minimization which is behaviorally implausible

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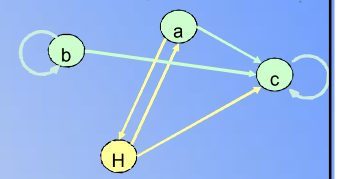
Open Tours

	H	a	b	c	
H	0	1	0	1	2
a	1	0	0	1	2
b	0	0	1	1	2
c	0	0	0	1	1
	1	1	1	4	7



- An example of a possible trip table from a gravity model with seven trips (H-a, H-c, a-H, a-c, b-b, b-c, c-c):
  - **There is no way that all seven of these trips can be arranged into one or more tours.**
  - Real travelers could **not** produce the travel pattern in this trip table, but a four-step model can!
  - For instance, one traveler doesn't return home!

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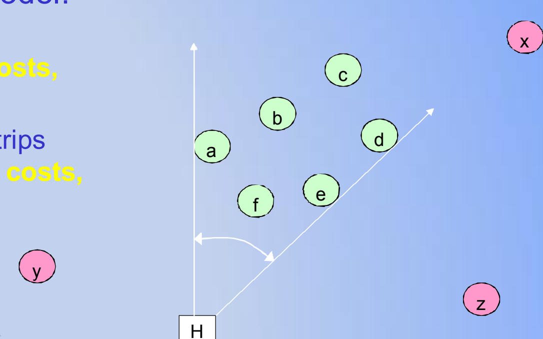
Tour Cost Minimization

- Stops Locations (trip ends) which Minimize Tour Costs:
  - Will be closer to home (radial dimension)
  - Will be closer to each other (angular dimension)
- In the Four-Step Model:
  - Home-based trips minimize radial costs, but ***NOT*** angular
  - Non-home-based trips minimize angular costs, but ***NOT*** radial



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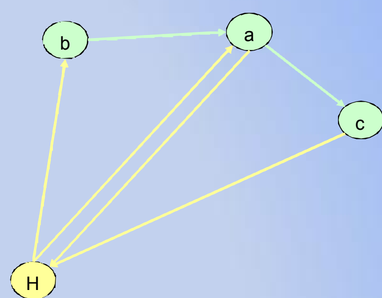
The Traditional (Sequential) Solution

❖ Proposed by Shiftan (1998), used in all tour / activity-based models in U.S.

ATT = Hb
+ba
-Ha



ATT = Hc
+ca
-Ha

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The New Problem

❖ Building tours sequentially
- Requires computationally intensive simulation
- Takes as many steps as stops
- Results in long model run times

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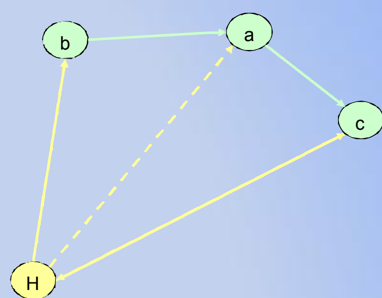
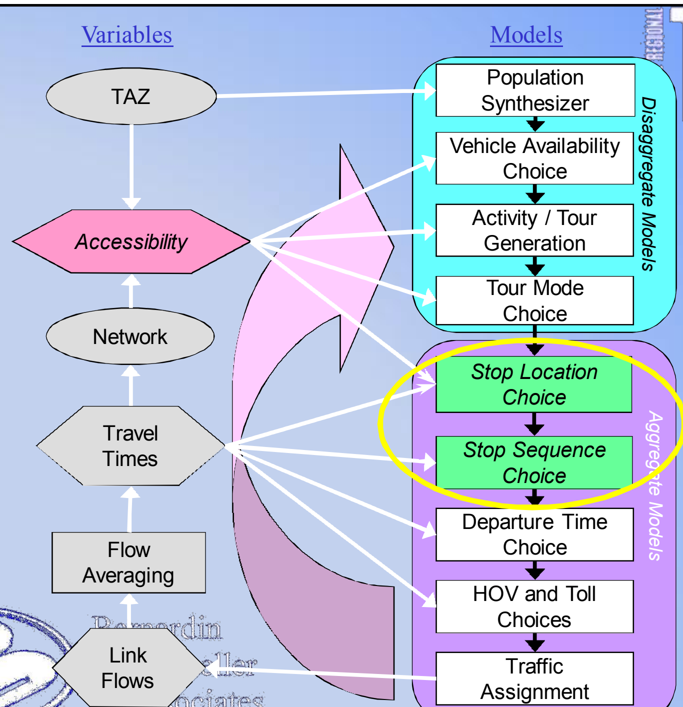
A New Simultaneous Solution

- First choose all stop locations (where to go)
- Then choose how to sequence them (where to go from)

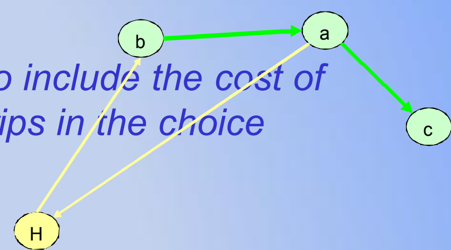




New Simultaneous Approach

KNOXVILLE REGIONAL TPO

- Advantage: *only two steps regardless of how many stops = fast run times*!
- Challenge 1: *how to insure that sequences form closed tours?*
- Challenge 2: *how to include the cost of non-home-based trips in the choice of stop locations?*



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Traveler Conservation Constraint

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- Requiring that whoever goes in, comes out results in consistency with tours

$$\sum_i T_{hij} = D_{hj} = T_{hj} = O_{hj} = \sum_k T_{hjk} \quad \forall h, j$$

	H	a	b	c	
f	0	5	0	3	8
g	1	1	0	3	5
H	2	3	1	1	7
a	1	4	0	2	7
	4	13	1	9	27

	H	a	b	c	
H	0	1	1	0	2
a	2	0	0	1	3
b	0	1	0	0	1
c	0	1	0	0	1
	2	3	1	1	7

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Under-determination of Tours

- In general, there are far more possible tours than (independent) trip probabilities, so the probabilities of tours cannot be determined from this model alone without further assumptions.

$$\sum_{s=1}^{S} Z^{s} \gg Z^{2} - 2Z + 1$$

- The approach is *fast* because it produces trips consistent with tours without determining the tours, themselves.

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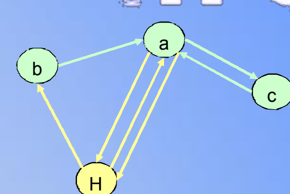
Closed Tours

	H	a	b	c	
H	0	1	1	0	2
a	2	0	0	1	3
b	0	1	0	0	1
c	0	1	0	0	1
	2	3	1	1	7



- An example of a possible trip table with a Traveler Conservation Constraint for seven trips (H-a, H-b, a-H, a-H, a-c, b-a, c-a):
  - These trips could be produced by either the tours
    - **H-a-H & H-b-a-c-a-H**
    - **H-b-a-H & H-a-c-a-H**
- It can be proved that ***any trip table with identical row and column sums is consistent with some set of tours.***

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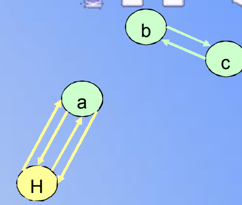
Pathological Tours

	h	a	b	c	
h	0	2	0	0	2
a	2	0	0	0	2
b	0	0	0	1	1
c	0	0	1	0	1
	2	2	1	1	6



- An example of a possible trip table from "forced symmetry" with a pathological tour
  - The traveler could not make the pathological tour **b-c-b** because they never visit b or c
- ***The double destination choice framework minimizes this.***
  - The probability of a pathological tour is an increasing function of the difference between the probability a traveler will visit a subset of stops and the probability they will visit that subset of stops from home

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New Simultaneous Approach

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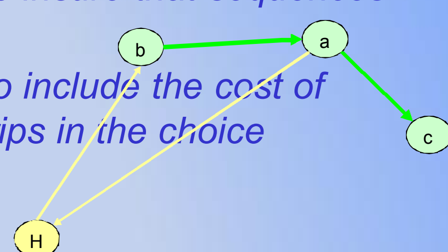
- Challenge 1: *how to insure that sequences form closed tours?*
- Challenge 2: *how to include the cost of non-home-based trips in the choice of stop locations?*



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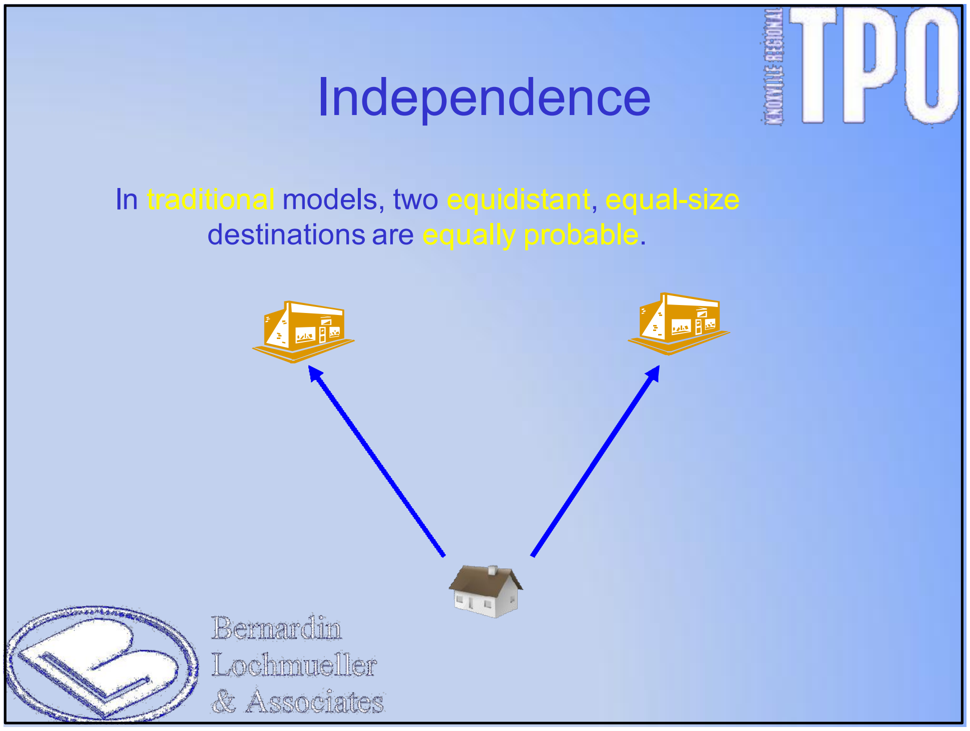
KNOXVILLE REGIONAL
TPO
Independence
In traditional models, two equidistant, equal-size destinations are equally probable.
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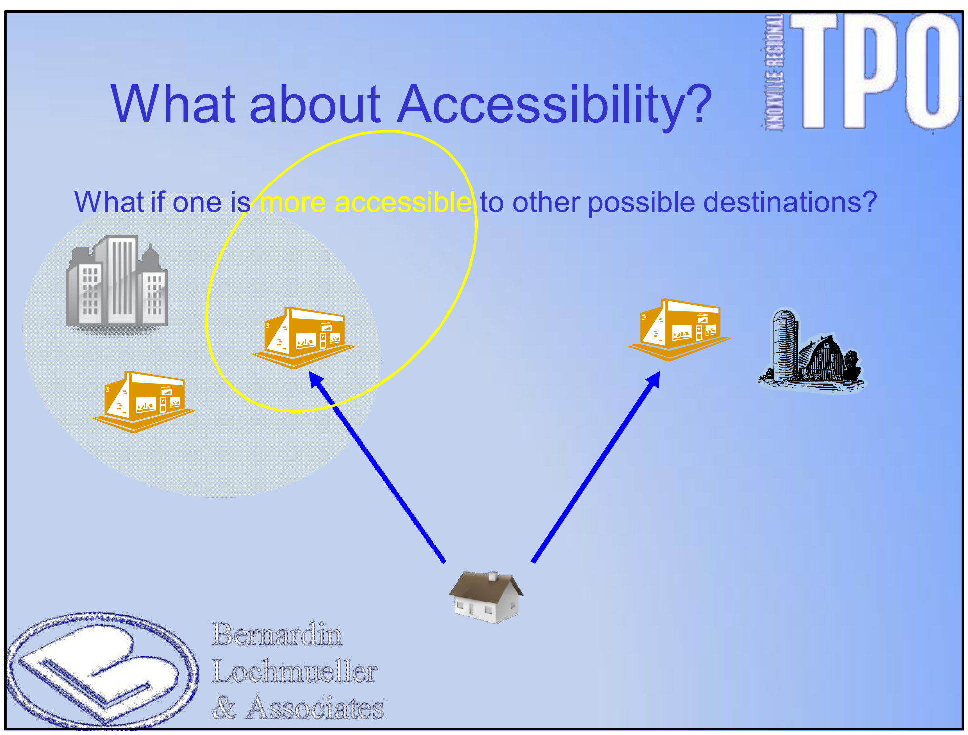
KNOXVILLE REGIONAL
TPO
What about Accessibility?
What if one is more accessible to other possible destinations?
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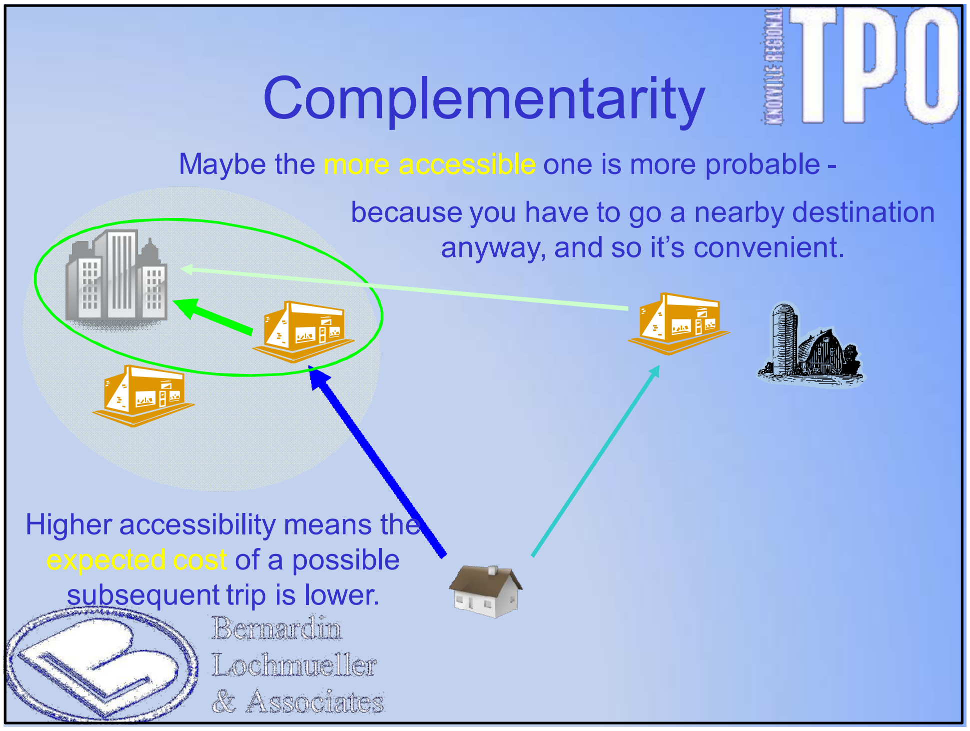
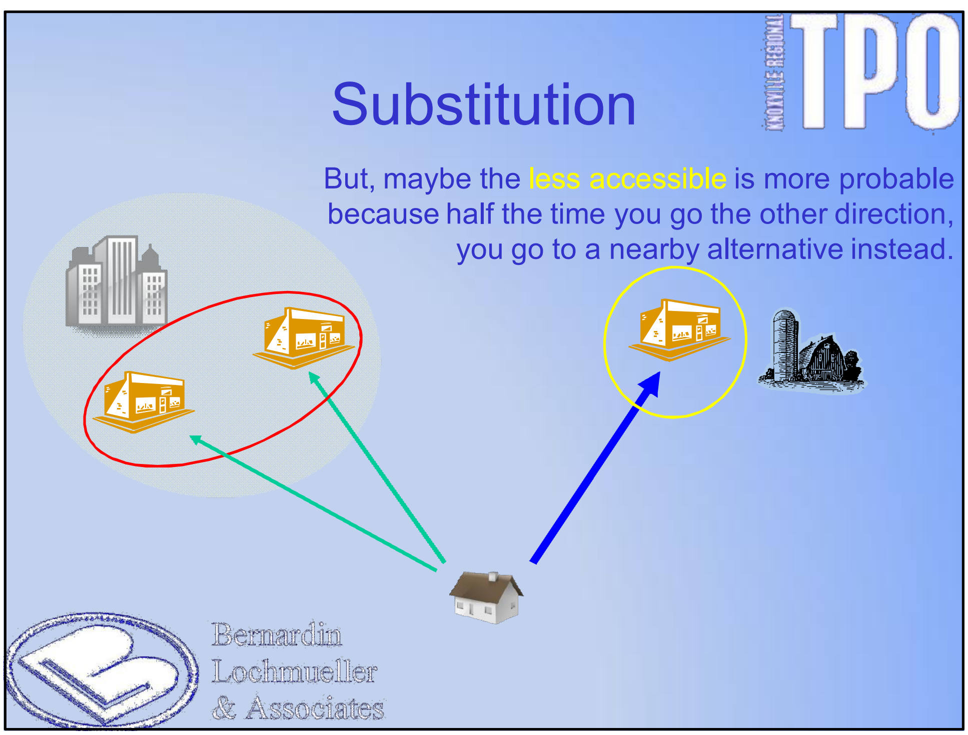

KNOXVILLE REGIONAL TPO
Complementarity
Maybe the more accessible one is more probable -
because you have to go a nearby destination anyway, and so it's convenient.
Higher accessibility means the expected cost of a possible subsequent trip is lower.
Bernardin Lochmueller & Associates


KNOXVILLE REGIONAL TPO
Substitution
But, maybe the less accessible is more probable because half the time you go the other direction, you go to a nearby alternative instead.
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Accessibility in Destination Choice

- In 1984, Kitamura used an accessibility variable to incorporate trip-chaining effects in destination choice
- The prior year, Fotheringham used an accessibility variable to incorporate differential spatial competition in destination choice
- More recently,Bhat & collaborators have found one or the other in different cases

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ACDC Models

(Bernardin, Koppelman & Boyce, 2009)

- Agglomerating and Competing Destination Choice (ACDC) Models
  - Use 2 *types* of accessibility:
    - Accessibility to **complements** (other places you need to go, regardless)
    - Accessibility to **substitutes** (other places you might go, instead)

$$P_{j|h} = \frac{e^{\ln \gamma S_j + \beta_c c_{hj} + \beta_{AS} A_j^S + \beta_{AC} A_j^C}}{\sum_{j'} e^{\ln \gamma S_{j'} + \beta_c c_{hj'} + \beta_{AS} A_{j'}^S + \beta_{AC} A_j^C}}$$

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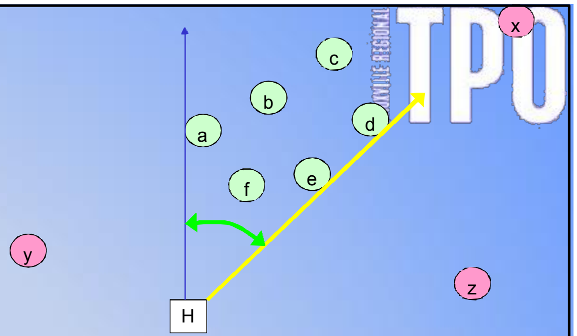
Tour Costs



- ACDC Models attempt to minimize both dimensions of tour costs:
  - Stops will be closer to home (radial dimension)
  - Stops will be closer to each other (angular dimension)

$$P_{j|h} = \frac{e^{\ln \gamma S_j + \beta_c c_{hj} + \beta_{AS} A_j^S + \beta_{AC} \ln \sum_k d_{jk} B_k e^{\beta_C c_{jk}}}}{\sum e^{\ln \gamma S_{j'} + \beta_c c_{hj'} + \beta_{AS} A_{j'}^S + \beta_{AC} \ln \sum_k d_{j'k} B_k e^{\beta_C c_{j'k}}}}$$

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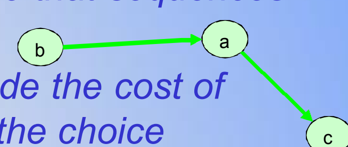
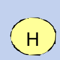
New Simultaneous Approach

- Advantage: *only two steps regardless of how many stops = fast run times*!
- Challenge 1: *how to insure that sequences form closed tours?*
- Challenge 2: *how to include the cost of non-home-based trips in the choice of stop locations?*





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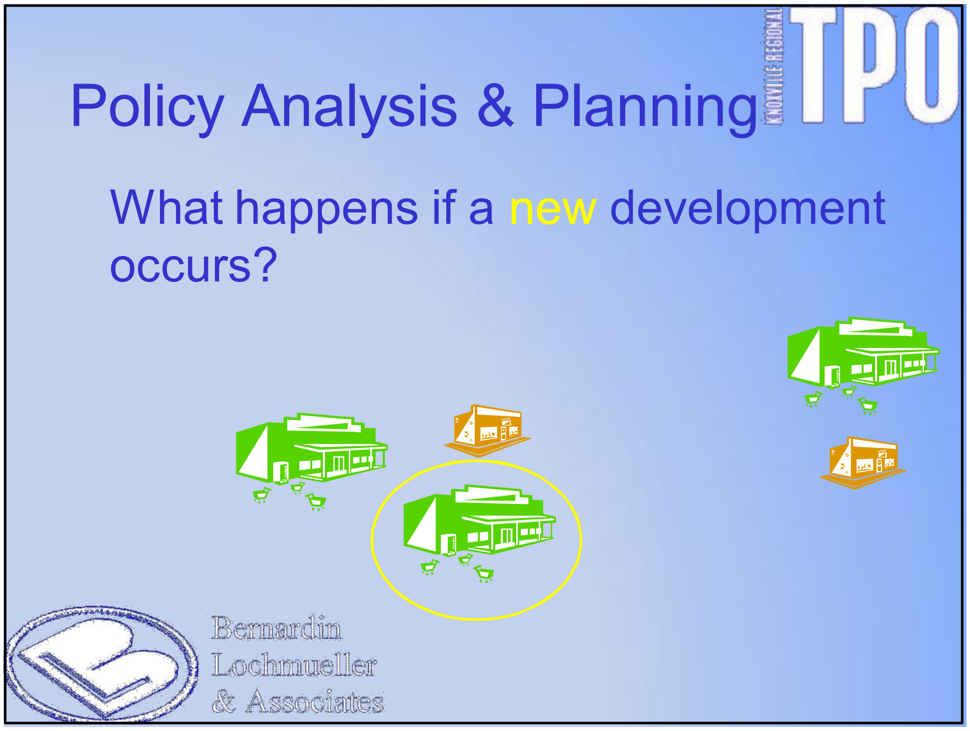

Policy Analysis & Planning
KNOXVILLE REGIONAL TPO
What happens if a new development occurs?
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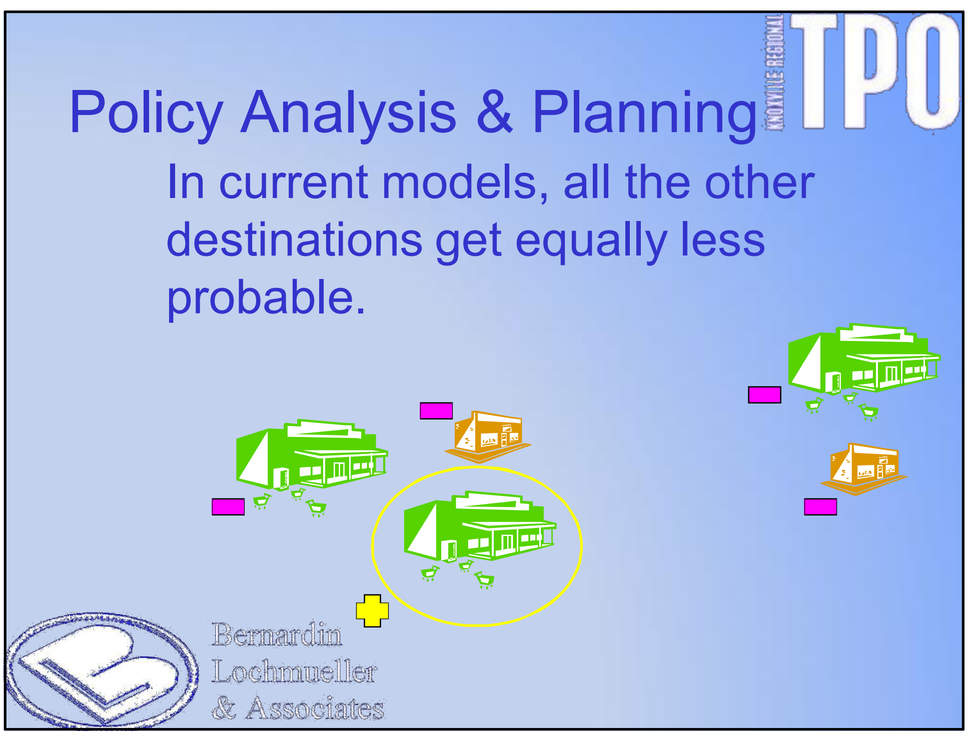

Policy Analysis & Planning
KNOXVILLE REGIONAL TPO
In current models, all the other destinations get equally less probable.
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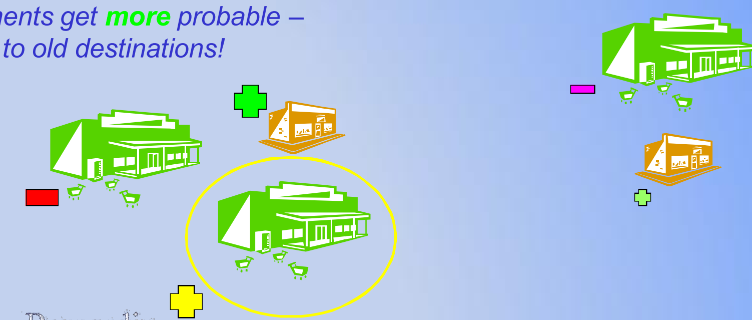
Policy Analysis & Planning

In ACDC models, **nearby** destinations are affected more than *distant* ones.

*Complements get **more** probable – new trips to old destinations!*

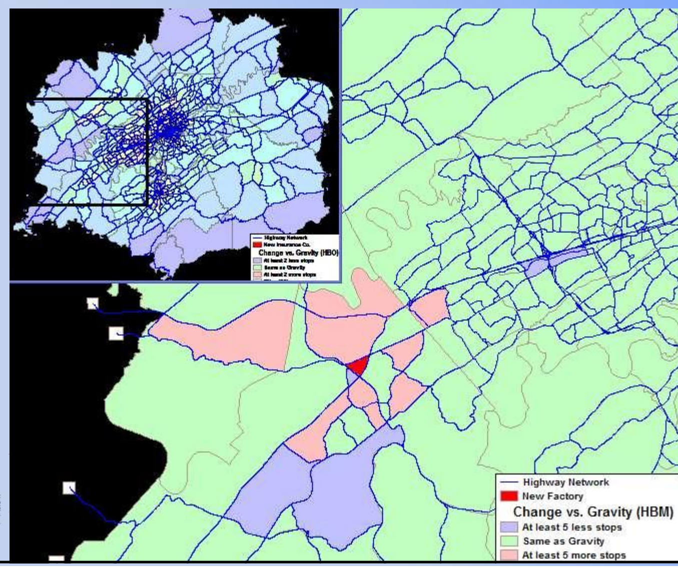


Sensitivity Analyses – Real World Examples

- Comparison of gravity and ACDC models for two new developments to illustrate spatial competition and trip-chaining effects.
  - A new factory employing 1,000 workers in Loudon county indirectly attracts 125 daily non-work stops to the county.

Sensitivity Analyses

- Loudon County factory's effect on shopping stops



Sensitivity Analyses – Real World Examples

- Comparison of gravity and ACDC models for two new developments to illustrate spatial competition and trip-chaining effects.
  - A new factory employing 1,000 workers in Loudon county indirectly attracts 125 daily non-work stops to the county.
  - A new Food City with 105 employees indirectly attracts a ***NET*** 27 (+55-28) daily trips to nearby zones (halo effect)

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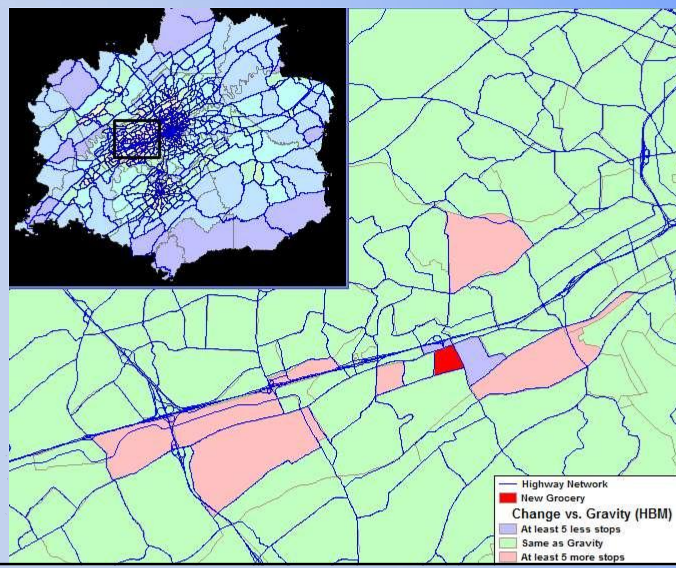
Sensitivity Analyses

- ❖ New Food City's effect on shopping stops



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- ❖ Details of Two Innovations
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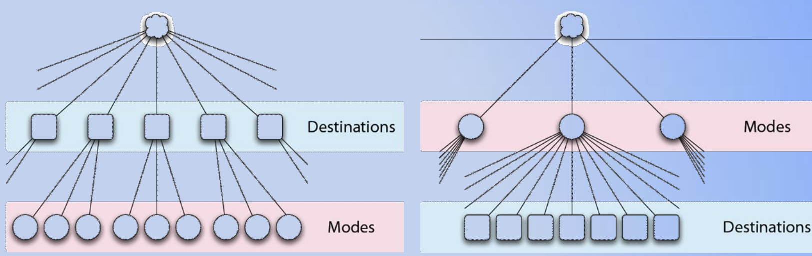
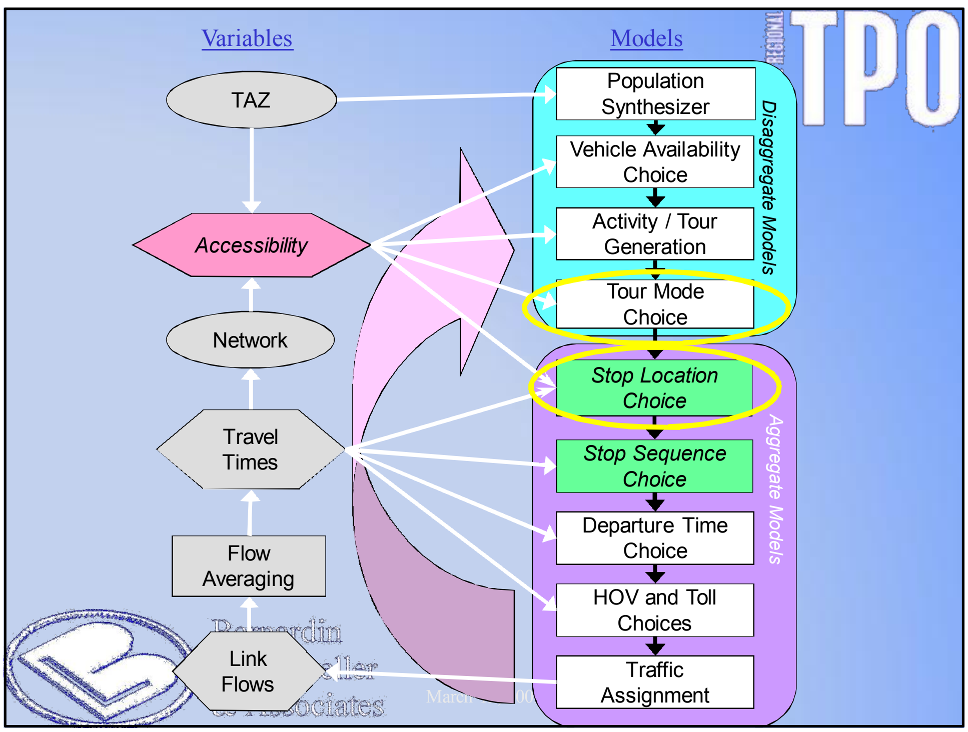
Choice Hierarchy

- In traditional four-step models, mode choice was modeled conditional on (after) destination choice (because the focus was on choice riders and commuting in larger MPOs).
- Instead, we modeled stop location or *destination choice conditional on (after) mode choice*





Choice Hierarchy

- In traditional four-step models, mode choice was modeled conditional on (after) destination choice (due to a preoccupation with choice riders and commuting).
- Instead, we modeled stop location or *destination choice conditional on (after) mode choice*
  - We sequentially estimated combined (nested logit) mode and stop location (and sequence) choice models
  - And all the logsum / nesting parameters were in the acceptable ranges without using constraints, which may suggest this is the correct choice hierarchy

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Choice Hierarchy

- This reverse choice hierarchy reflects the fact that *many travelers are more likely to change destinations than switch modes*
  - Even for work tours, the data suggests that in Knoxville, people are more likely to change jobs than change their travel mode to work
  - This may not be as unreasonable as it seems, considering captive riders, dependent on the bus to get to work
- Imposing the traditional hierarchy may be a source of "optimism bias" in transit forecasts

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Optional Levels of Detail

- According to TRB's SR288, no mode choice in
  - 75% of small MPOs
  - 10% of large MPOs
- Traditional hierarchy requires transit network
- Knoxville - reverse hierarchy with transit network
- Evansville - reverse hierarchy without network
  - Instead of transit accessibility variables based on transit network travel times (waits, transfers, etc.)
  - Evansville will use proxy variables such as % of TAZ within walk to bus and # of buses per hour

Optional Levels of Detail

- Reverse Hierarchy mode choice without network
  - Cannot produce route level ridership forecasts
  - Can produce system-level ridership forecasts sensitive to fares, fuel prices, headways, demographics, etc.
  - Can produce regional walk/bike trips sensitive to fuel prices, sidewalk coverage, activity density and diversity, network density and connectivity, etc.

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Improved Accuracy

- Care must be taken in making fair apples-to-apples comparisons between traditional and advanced models
- Knoxville's trip-based & hybrid models:
  - Different survey data, 2000 vs. combined 2000+2008
  - Essentially same
    - Network
    - TAZ
    - Counts
    - Through Trips

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Knoxville Hybrid Performance

- Better origin-destination patterns
  - Guaranteed physically possible
  - 33% increase over the ability of the previous model to explain observed trips in the household surveys
  - Able to reproduce commuting patterns from Census without the use of fudge factors

Commuting

Residence	Workplace	2000 CTPP	2009 KRTM	2008 KRTM	2004 KRTM
Blount	Knox	13,610	16,397	16,208	16,920
Knox	Anderson	11,015	11,677	13,834	2,752
Anderson	Knox	8,114	8,694	12,290	4,098
Sevier	Knox	6,520	5,792	7,951	6,998
Knox	Blount	5,329	6,569	4,895	2,796
Loudon	Knox	4,580	7,793	8,211	5,263
Jefferson	Knox	4,380	2,723	5,175	805
Union	Knox	3,558	3,795	4,648	3,953
Grainger	Knox	2,064	1,778	2,106	1,377
Jefferson	Sevier	1,755	2,182	2,373	3,139

Knoxville Hybrid Performance

KNOXVILLE REGIONAL TPO

- Better origin-destination patterns
  - Guaranteed physically possible
  - 33% increase over the ability of the previous model to explain observed trips in the household surveys
  - Able to reproduce commuting patterns from Census without the use of fudge factors
  - Better forecasting

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Forecasting

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- Opportunity to compare research versions of the destination choice models
  - which were estimated with the 2000 data
  - against the 2008 data to test forecasting validity
- Destination choice models with accessibility variables offered a modest improvement over gravity models compared to the 2000 base data
- But outperformed gravity models by twice as much at forecasting 2008

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Knoxville Hybrid Performance

- ❖ Better origin-destination patterns
  - ➢ Guaranteed physically possible
  - ➢ 33% increase over the ability of the previous model to explain observed trips in the household surveys
  - ➢ Able to reproduce commuting patterns from Census without the use of fudge factors
  - ➢ Better forecasting
- ❖ Better roadway volumes
  - ➢ 15% decrease in RMSE (32.95% to 28.13%)

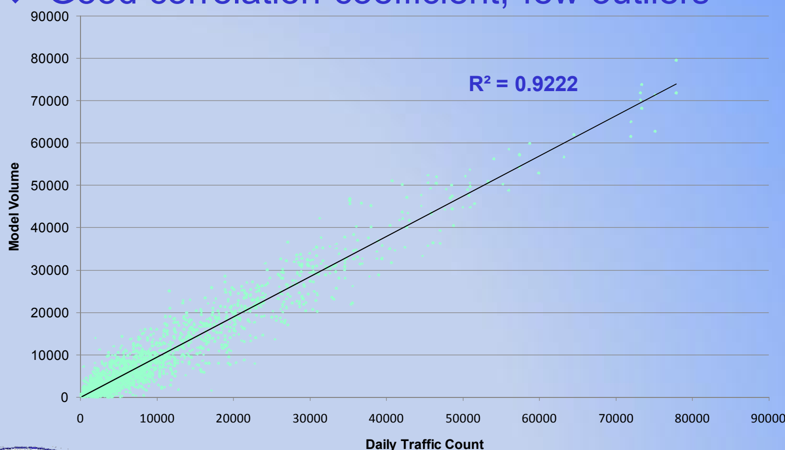
Network Assignment

- ❖ Improved accuracy versus base year counts

Volume Range	Acceptable Range	% Error		% RMSE	
		Trip-based	Hybrid	Trip-based	Hybrid
1,001 to 2,000	±200%	60.0	14.2	140.5	86.9
2,001 to 3,000	±200%	51.9	7.6	124.5	73.8
3,001 to 4,000	±100%	-1.0	-16.6	67.5	58.0
4,001 to 5,000	±100%	6.8	-2.3	65.1	55.4
5,001 to 6,000	±50%	1.2	-4.4	61.9	45.0
6,001 to 8,000	±50%	5.2	-4.1	44.9	37.3
8,001 to 10,000	±50%	-10.9	-13.0	41.0	35.5
10,001 to 15,000	±20%	-1.8	-3.3	33.9	33.7
15,001 to 20,000	±20%	-4.2	-9.7	31.1	27.7
20,001 to 25,000	±20%	2.8	-5.0	21.4	17.1
25,001 to 30,000	±15%	7.3	-4.9	20.5	16.6
30,001 to 40,000	±15%	3.1	-4.4	17.3	16.9
40,001 to 50,000	±15%	8.6	-2.5	17.0	12.9
50,001 to 60,000	±10%	3.7	-4.0	11.7	7.2
> 60,000	±10%	-3.5	-6.0	5.3	8.0
All	**±10%**	**2.9**	**-5.2**	**33.0**	**28.1**

Network Assignment

- Good correlation coefficient, few outliers



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Knoxville Hybrid Performance

- Better origin-destination patterns
  - Guaranteed physically possible
  - 33% increase over the ability of the previous model to explain observed trips in the household surveys
  - Able to reproduce commuting patterns from Census without the use of fudge factors
  - Better forecasting
- Better roadway volumes
  - 10% decrease in %RMSE (32.95 vs. 29.85)
- Better response properties & policy sensitivity

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Realism & Policy Sensitivity

- ❖ The hybrid model design offers:
  - ➢ **Guarantee** of **physically possible** travel patterns
  - ➢ Sensitivity to **gas prices**, parking costs and tolls
  - ➢ **Transit**, **bicycle** and **pedestrian** travel
  - ➢ Sensitivity to **urban design** / built environment
  - ➢ More realistic representation of **seniors**, the poor…
  - ➢ More accurate **commuting patterns**, **traffic impacts** and **travel times**
  - ➢ Ability to predict shifts in the **timing of travel**
  - ➢ Improved **truck** and **external** models

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Tour & Stop Generation

	Workers	Non-Workers	Students	Seniors	Vehicles	Income	Gas Price	Access-ibility
Work Tours	+			-				+
Work Stops	+			-		+	-	+
Non-UT Univ Stops	+	+		-		-		+
Other Stops	+	-	+	-		+	-	+
School Tours			+			+		
School Stops			+			+		
Other Stops	+		+			+		
Other Tours		+			+	+		+
Short Maintenance Stops		+			+	+		+
Long Maintenance Stops		+	-	+	+	+		+
Discretionary Stops		+			+	+	-	+

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Factors Affecting Mode Choice

	Level of Service			Costs		Demographics					Built Environment		
	Accessibility by mode	Distance to UT	% of TAZ Near Bus	Gas Price	Bus Fare	Workers	Students	Senior HH	Income	Vehicles per Person	Percent Sidewalks	Activity Diversity	Intersectio Density
Work Tours													
Auto	+			-	+		+	+	+	+	-	-	
Bus	+			+	-		-	-	+	-	-	-	
Walk	+			+	+		+	-	-	-	+	+	
UT Tours													
Auto		+	-	-						+	-		
Bus		-	+	+						-	-		
Walk		-	-	-						-	+		
School Tours													
Auto	+			-					+	+			
Bus	+			+					-	+			
Walk	+			+					-	-			
School Bus	+			+					-	-			
Other Tours													
Auto	+			-	+	+	+	+		+		-	-
Bus	+			+	-	+	-	-		-		-	-
Walk	+			+	+	-	+	-		-		+	+

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Stop Location Choice

		Impedance				Destination qualities						Destination size (Attractions)						
		Time by Access	River Xing	County Line Xing	Intrazonal	General Accessibility	Access to Complements	Access to Substitutes	Access to Bus	Activity Diversity	Pay Parking	Basic Employment	Industrial Employment	Retail Employment	Service Employment	University Enrollment	K-12 Enrollment	HH / HH Population
Work Tours	Low Inc Work	-	-	-	+				+			+	+	+	+			
	Mid-Hi Inc Work	-	-	-	+	+						+	+	+	+			
	Non-UT College	-		-												+		
	Other	-	-	-	+		+	-						+	+		+	
School Tours	School	-	-	-	+	+											+	
	Other	-	-		+		+			+				+	+		+	+
Other Tours	Short Maint.	-	-		+		+	-		+	-			+	+			
	Long Maint.	-	-		+	+								+	+			
	Discretion	-	-	-	+	+				+				+	+			+

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Knoxville Applications

- Possible tolling / pricing scenarios?
- Scenario planning with multiple land use scenarios from ULAM land use model
  - To support East Tennessee Quality Growth (ETQG) initiative
  - To investigate livability and sustainable mode usage

EVANSVILLE MPO

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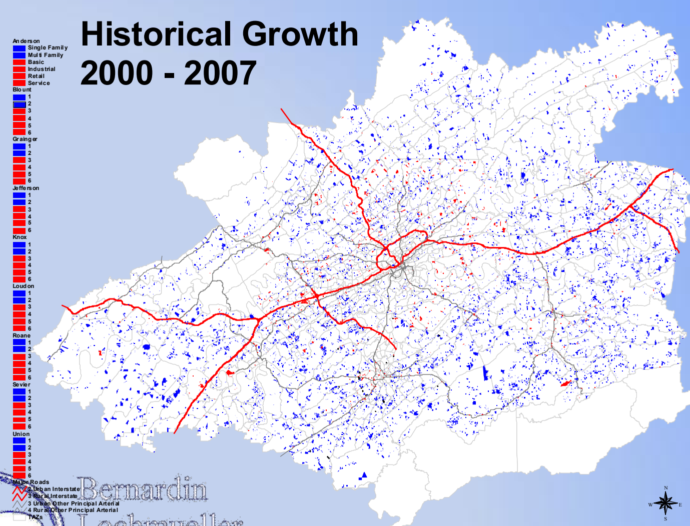
Knoxville Land Use Modeling Historic Trend/Status Quo Scenario



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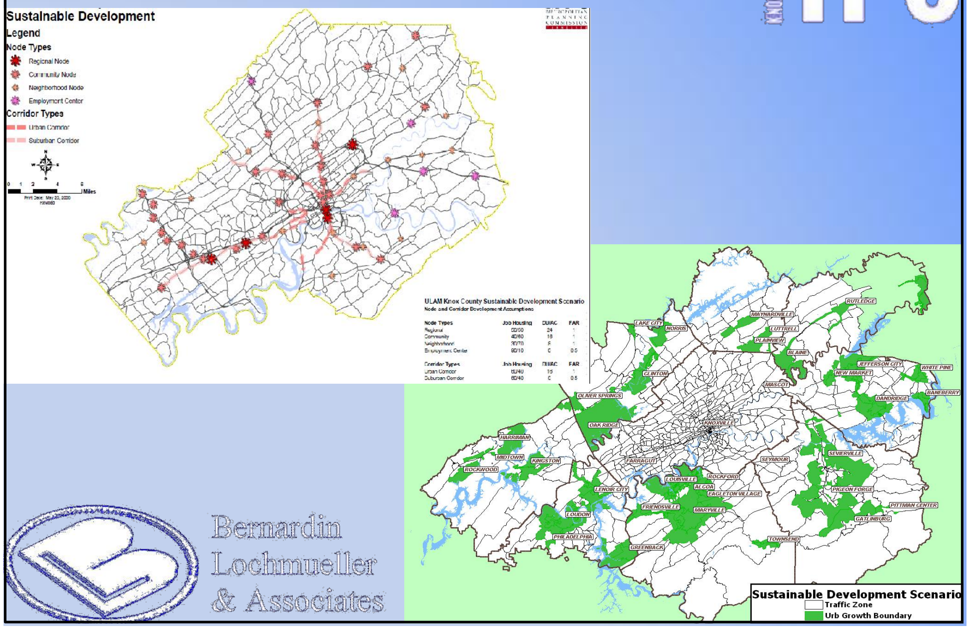
Sustainable Growth Scenario



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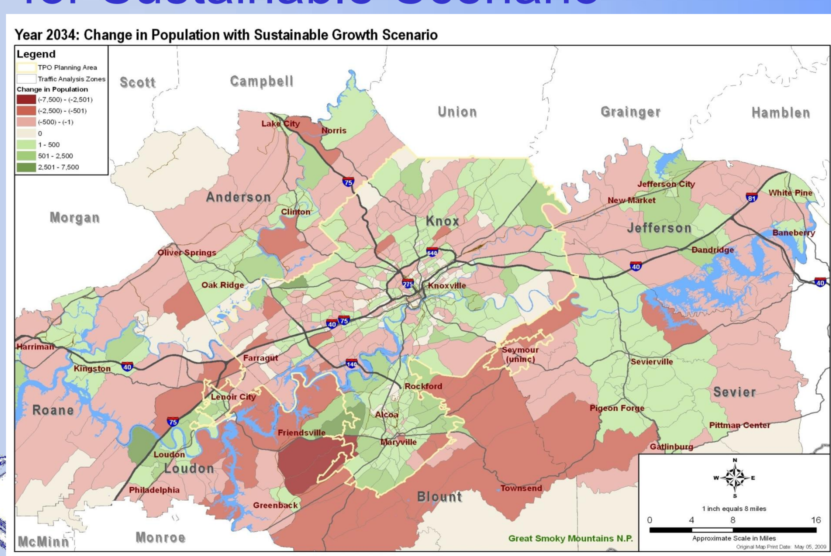
Land Use Allocation Results for Sustainable Scenario



Potential Travel Demand Model Scenario Performance Measures

- Vehicle Miles of Travel (VMT)
  - Current Model Projects -1.5% less VMT for Sustainable Growth Scenario
- Vehicle Hours of Travel (VHT)
- Total Daily Vehicle Hours of Delay
- % of Lane Miles Congested
- Mode Share
  - Shift to Transit for Transit Oriented Design
  - Shift to Pedestrian/Bike for Mixed Use Development Patterns

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Evansville's Motivations

- Desire to move forward toward more accurate advanced modeling methods
  - Cost-efficiency of the hybrid design
- Desire for sensitivity to fuel prices / economy and land use / urban design
- Desire for better inputs to micro-simulation and move toward dynamic assignment

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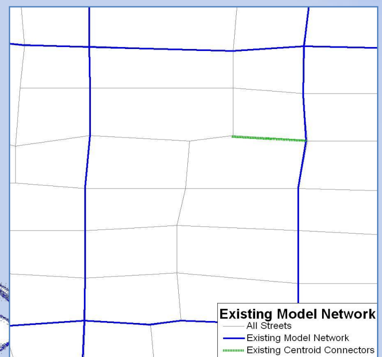
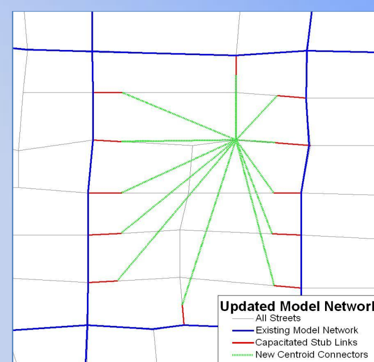
Evansville Model

- ❖ Differences from Knoxville
  - ➢ Reverse hierarchy mode choice ***without*** network
  - ➢ Allocation of stops to tours
  - ➢ Diffused network loading experiment





Evansville's Future Apps

- ❖ Future intended applications include scenario planning examining
  - ➢ Fuel price & economic growth scenarios
  - ➢ Land use development pattern scenarios (mixed uses / density, etc.)
- ❖ Dynamic traffic assignment?

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Related Publications

- Bernardin, V., F. Koppelman and D. Boyce. Enhanced Destination Choice Models Incorporating Agglomeration Related to Trip Chaining While Controlling for Spatial Competition. *Transportation Research Record*, No. 2132, 2009, pp. 143-151
- Newman, J. and V. Bernardin. Hierarchical Ordering of Nests in a Joint Mode and Destination Choice Model. Forthcoming in *Transportation*, 2010.
- Bernardin, V. and M. Conger. From Academia to Application: Results from the Calibration and Validation of the First Hybrid Accessibility-based Model. Forthcoming in *Transportation Research Record*, 2010.

Pros & Cons of the Hybrid

- Cons:
  - Limited disaggregate results for data-mining
  - Limited ability to model intra-household interactions
  - Limited ability to deal with complex scheduling issues
- Pros:
  - Consistency with tours and trip-chaining behavior
  - Improved accuracy vs. trip-based
  - Improved policy sensitivity vs. trip-based
  - Reasonable run times and development costs

Final thoughts

- There's no one "right" way of modeling travel behavior for every region.
- There are a variety of different advanced model designs each with different pros and cons.
  - This approach has some advantages, in terms of computational efficiency / run time and development costs,
  - And it allows incremental improvements from existing models
  - But it does not offer all the advantages of activity-based models
- The 'double destination choice' framework allows for a new set of options for model designs.

Thank You!

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KNOXVILLE REGIONAL TPO

EVANSVILLE MPO