A New Alternative
to Four-Step and Activity-Based Models:

Touring in a Trip-Based Model

Vince Bernardin, Jr.

Accessibility-Based Models

- The all-or-nothing choice between a simple trip-based or a complex activity-based model design is a FALSE dilemma.

- Accessibility-based models offer a new alternative which combine many attractive features of the two.

Accessibility-Based Models

- Developed for real world applications with academic rigor
  - Northwest Arkansas, FQ 2007, early prototype for the new design, partially experimental
  - Knoxville, TN, currently under development, 2008
  - My Ph.D. dissertation at Northwestern

Accessibility-Based Models

- Behaviorally more realistic than four-step models, incorporating trip-chaining, induced demand, peak-spreading, etc.
- Statistically superior, avoiding both
  - aggregation bias, as in four-step models, and
  - simulation errors, as in activity-based models
- Development and application costs slightly more than four-step, but far less than activity-based

Overview

- Background: The Problem & the Goal
- Accessibility: The Foundation of a Solution
- The Anatomy of a New Model
- The Evolution of the New Model
  - The eight component mutations
- Conclusion: Debunking the Myth

Background: A Problem

- Traditional four-step models suffer from:
  - Aggregation bias which can skew results
  - Broad insensitivity to
    - spatial interdependence of trips related to trip-chaining as observed in poor trip distribution models
    - induced travel, including trip-making, related to
      - new land use developments in zones other than the origin/production zone,
      - reduced congestion, etc.
    - temporal shifts in traffic due to
      - congestion (e.g., peak-spreading),
      - demographic change such as the aging of the population, etc.

A Non-Solution

- After ten years, only 4 activity-based models in use
  - 99% (381 of 385) MPO's use more-or-less traditional models (their coverage is >95% of the population)
  - By 2015 there may be 12 or so ABM's in the US, leaving 97% of planning agencies with trip-based models
- There are 2 MPO's with activity-based models they *don't use*!

A Non-Solution

- Activity-based models generally cost about an order of magnitude more than traditional models to develop (~$2 mill vs. $200k, not including data)
- Their application costs in computer hardware, computing time and staff costs are often even more disproportional (computing time for an alternatives analysis may be two orders of magnitude greater)

The Goal

- To better support planning and policy analysis (*not just fulfill regulatory requirements!*)
  - To actually support planning, the application costs for these techniques must be realistic in relation to planning agency budgets.
  - This requires greater architectural simplicity than the activity-based approach.

Accessibility:
The Foundation of a Solution

- What is Accessibility?

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

- How easy is it to get somewhere else?
- The expected (average) cost of a trip from this zone during this time period
  - (we can measure accessibility in minutes)

Accessibility:
The Foundation of a Solution

- What does Accessibility (the expected cost of a trip) affect?

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Accessibility:
The Foundation of a Solution

- What does Accessibility (the expected cost of a trip) affect?
  - The likelihood of making the trip (induced demand)
  - The timing of the trip (peak-spreading)
  - The destination of the trip (trip-chaining)
    - Consider the expected cost of a further trip (next trip in a chain) from a destination

Accessibility:
The Foundation of a Solution

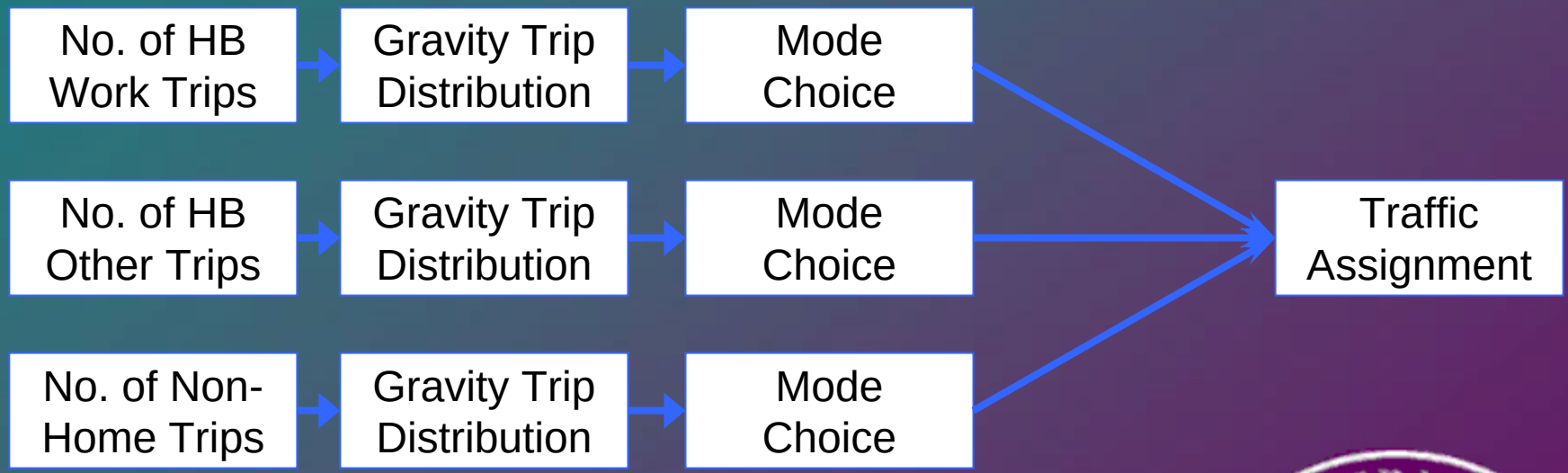
- We can use Accessibility to fix some of the most important shortcomings of the four-step model!
- What's going on?
  - Four-step model is limited because it is *sequential* (memory, but no foresight)
  - Accessibility introduces expectation or *foresight* into the model, or *simultaneity* of considerations

Accessibility:
The Foundation of a Solution

- What does the new model look like?
  - A hybrid
    - Four-step model and activity-based models as parents
    - Inherits features from both, but different from either
    - A few new mutations completely of its own

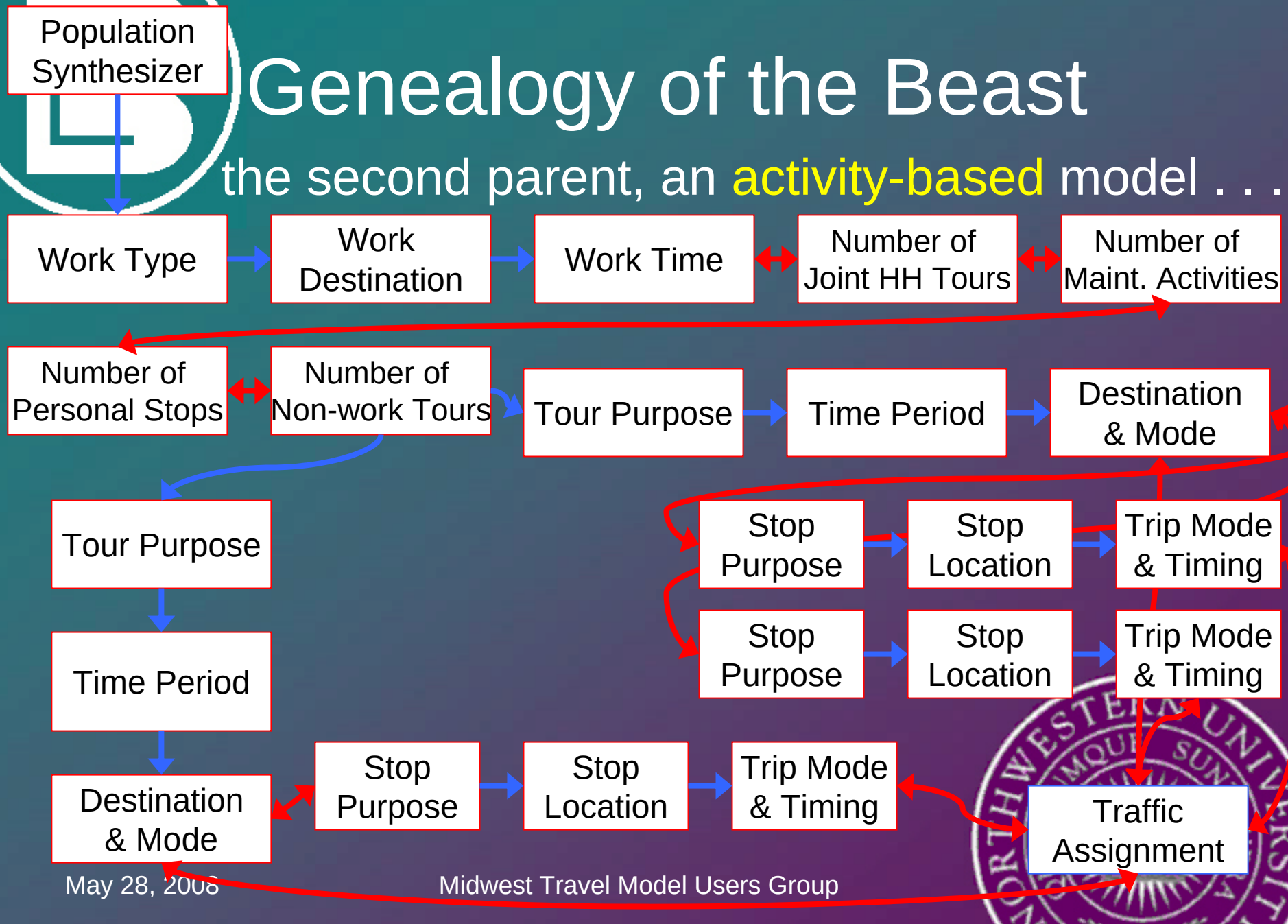
Genealogy of the Beast

- The first parent, the four-step model . . .

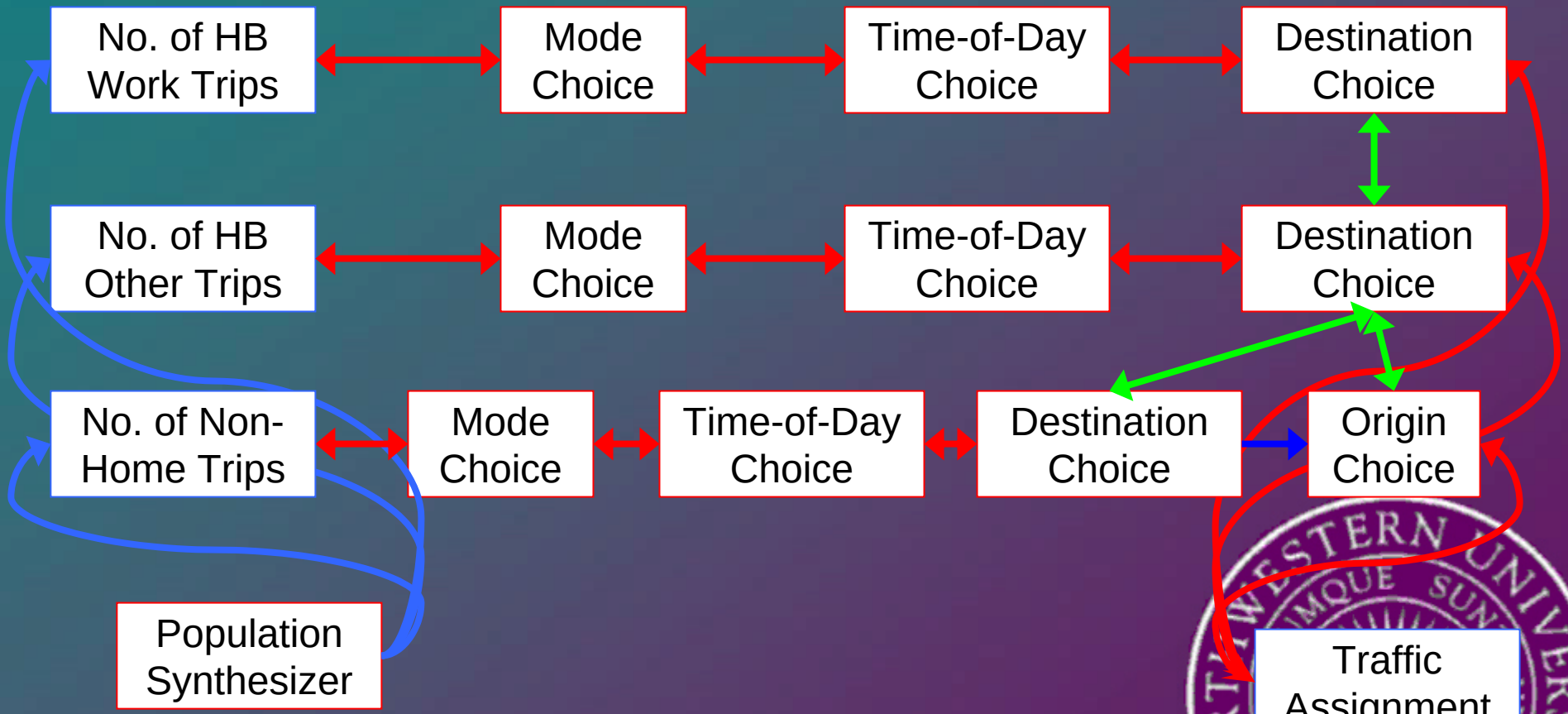


Genealogy of the Beast

the second parent, an activity-based model . . .



The New Beast



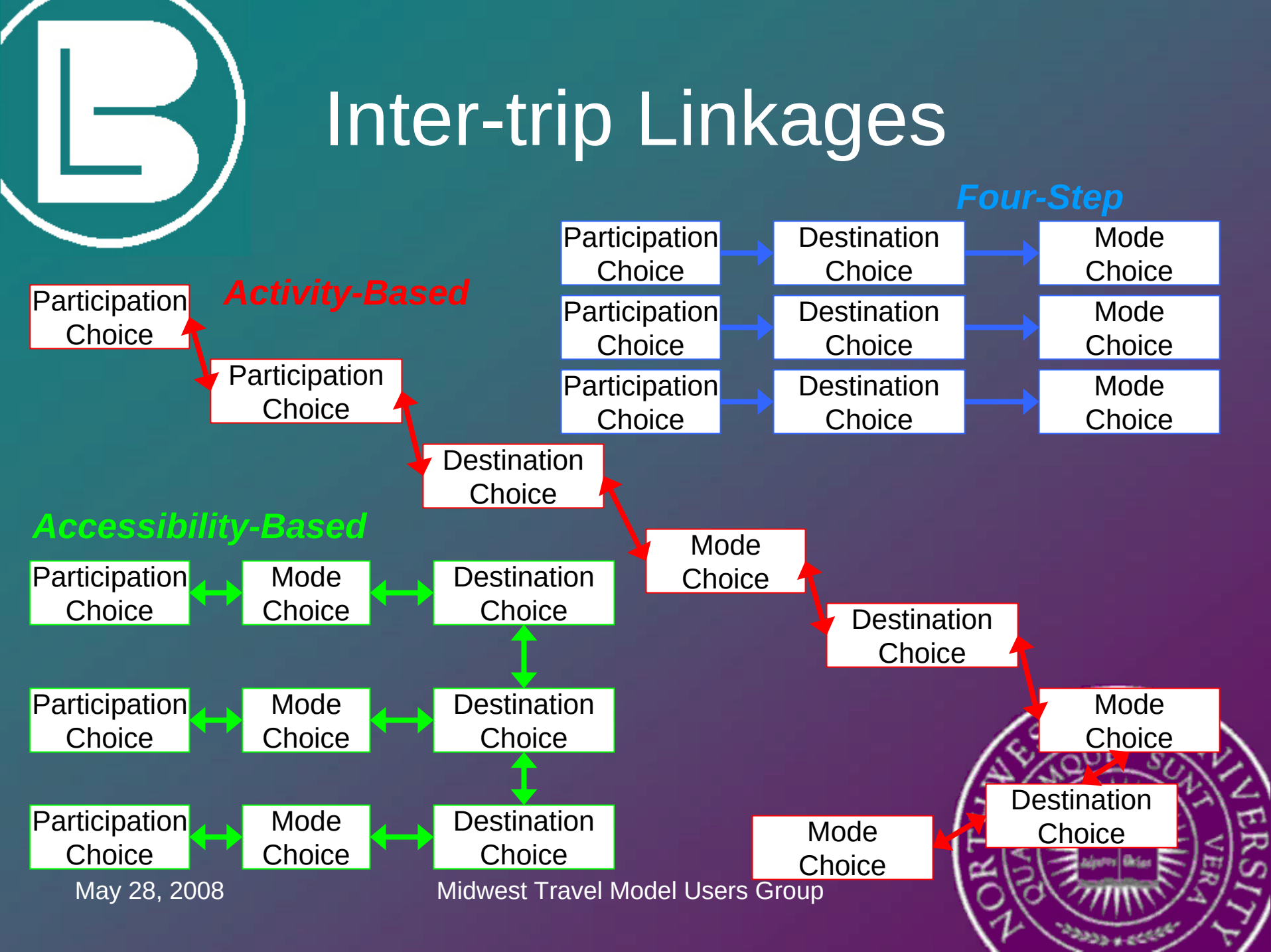
Accessibility-Based Models

- There are 8 structural differences between the four-step model and "the" accessibility-based model presented here
- But "accessibility-based models" really refer to a whole family of models between the four-step and activity-based model
  - Those which use perhaps 2-8 of the structural improvements proposed here

Marks of the (New) Beast

- Accessibilities and other expected utility variables (= simultaneity in considerations) WOVEN rather than LACED throughout the model

Inter-trip Linkages



Marks of the (New) Beast

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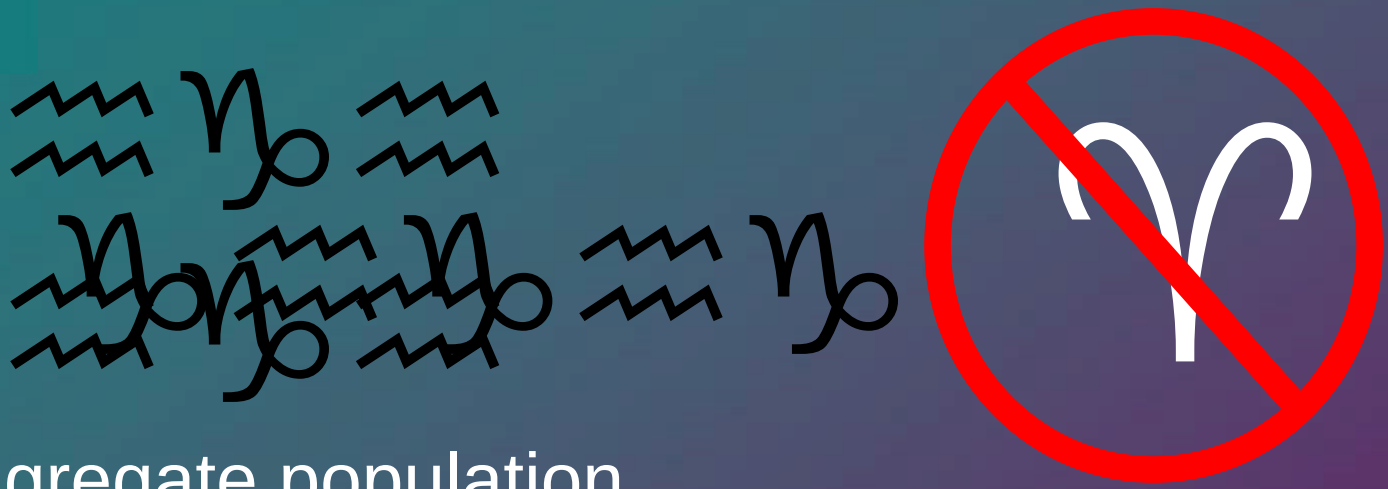
- Disaggregate population, but deterministic outcomes (= no simulation = expected values from a single application!)

Disaggregate Deterministic



- Disaggregate population
  - travelers choose, not zones
  - no aggregation bias
- Deterministic outcomes
  - no simulation
  - expected values from a single application!

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- Origin AND Destination modeling for NHB trips
- Pseudo-continuous treatment of time in a real time-of-day choice

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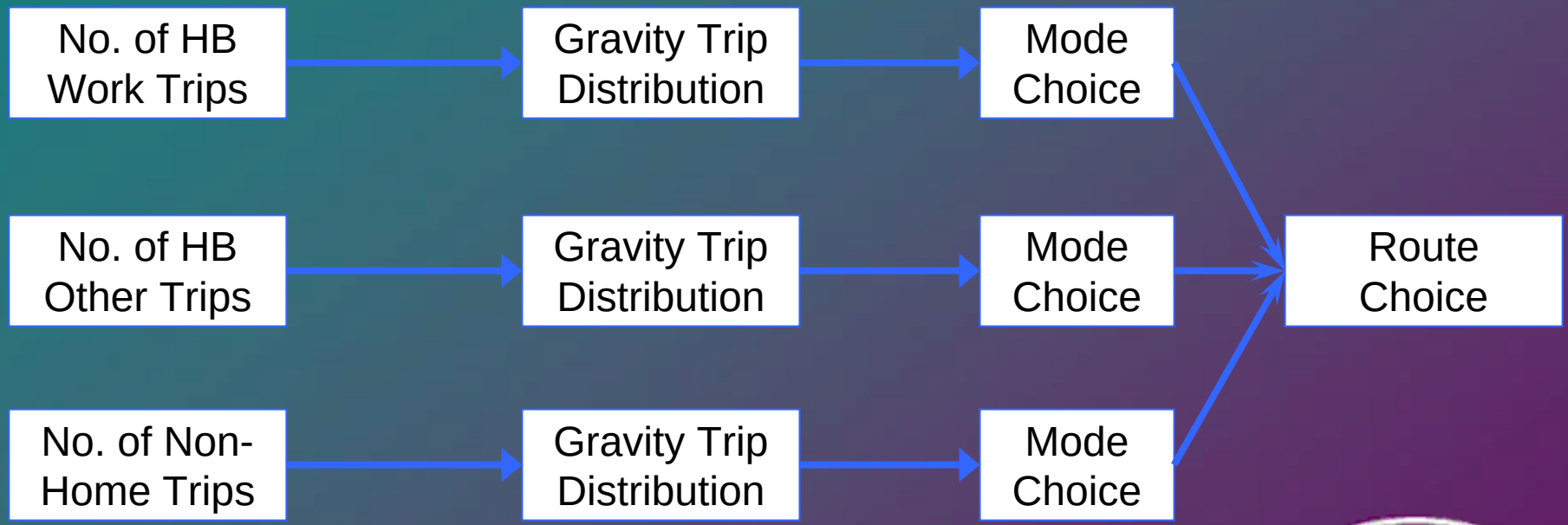
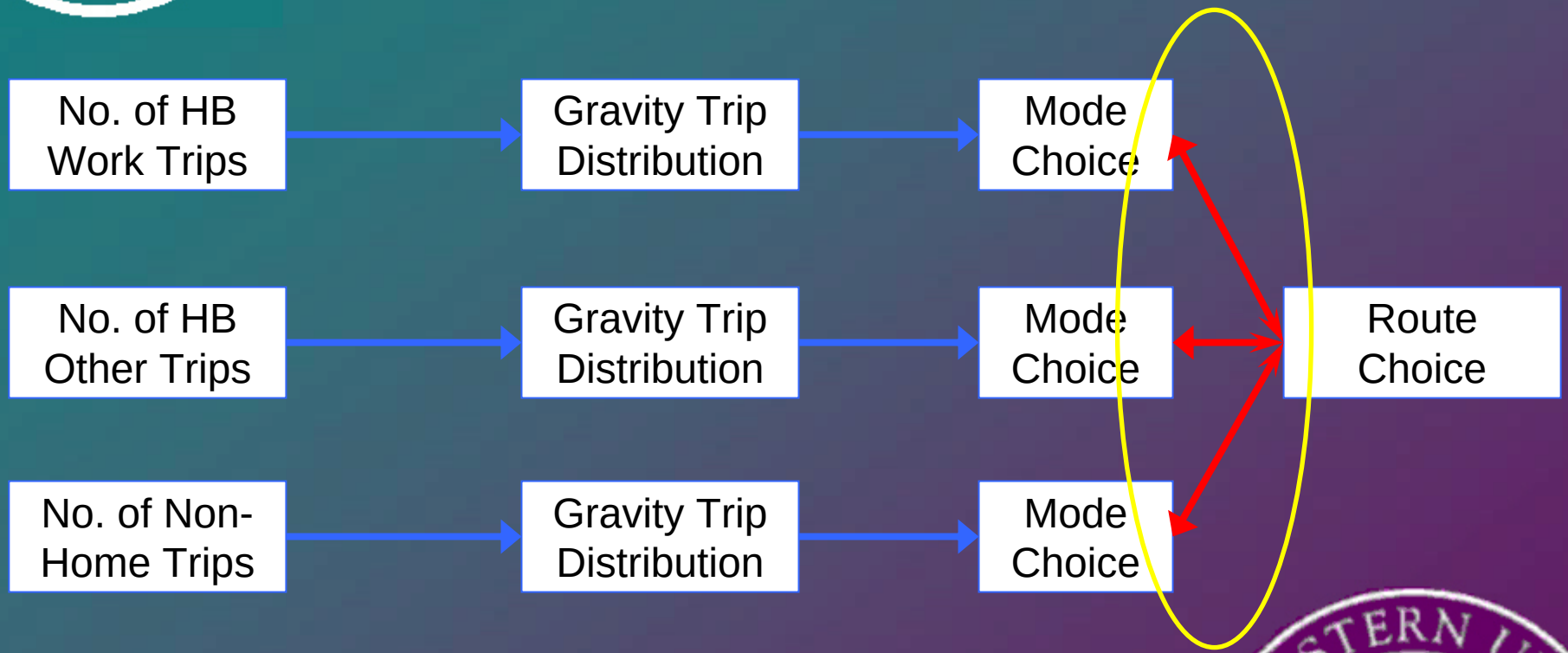
Evolution (0)
Four Step Model



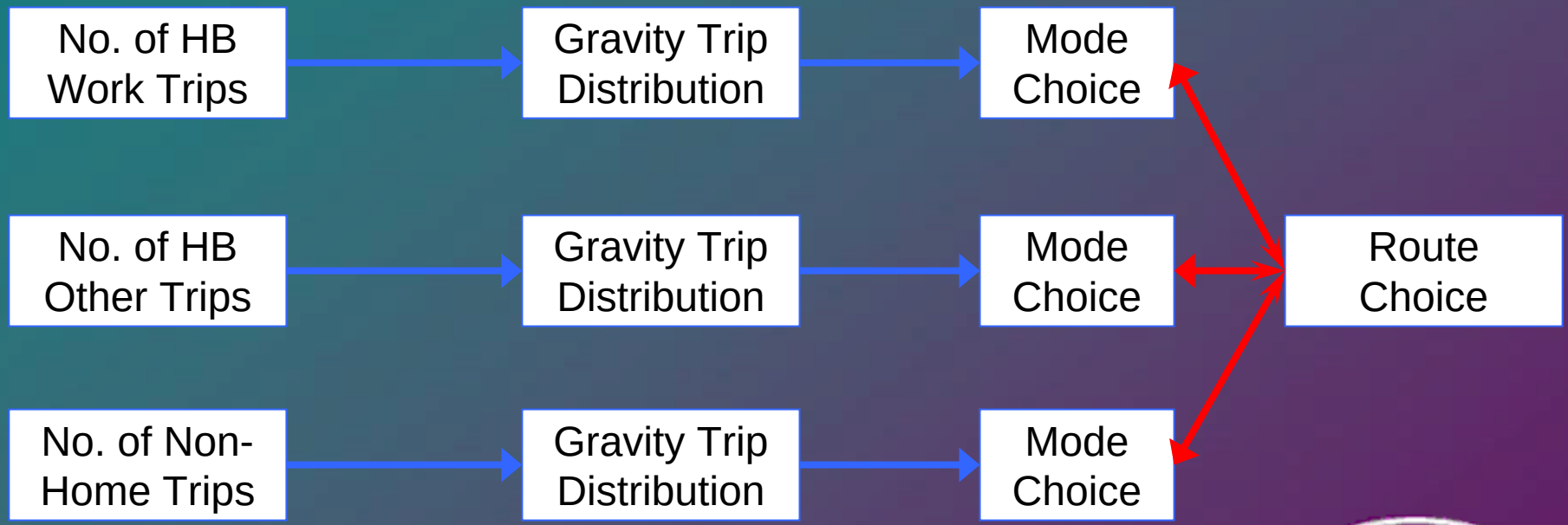
Evolution (1)
Feedback from Assignment



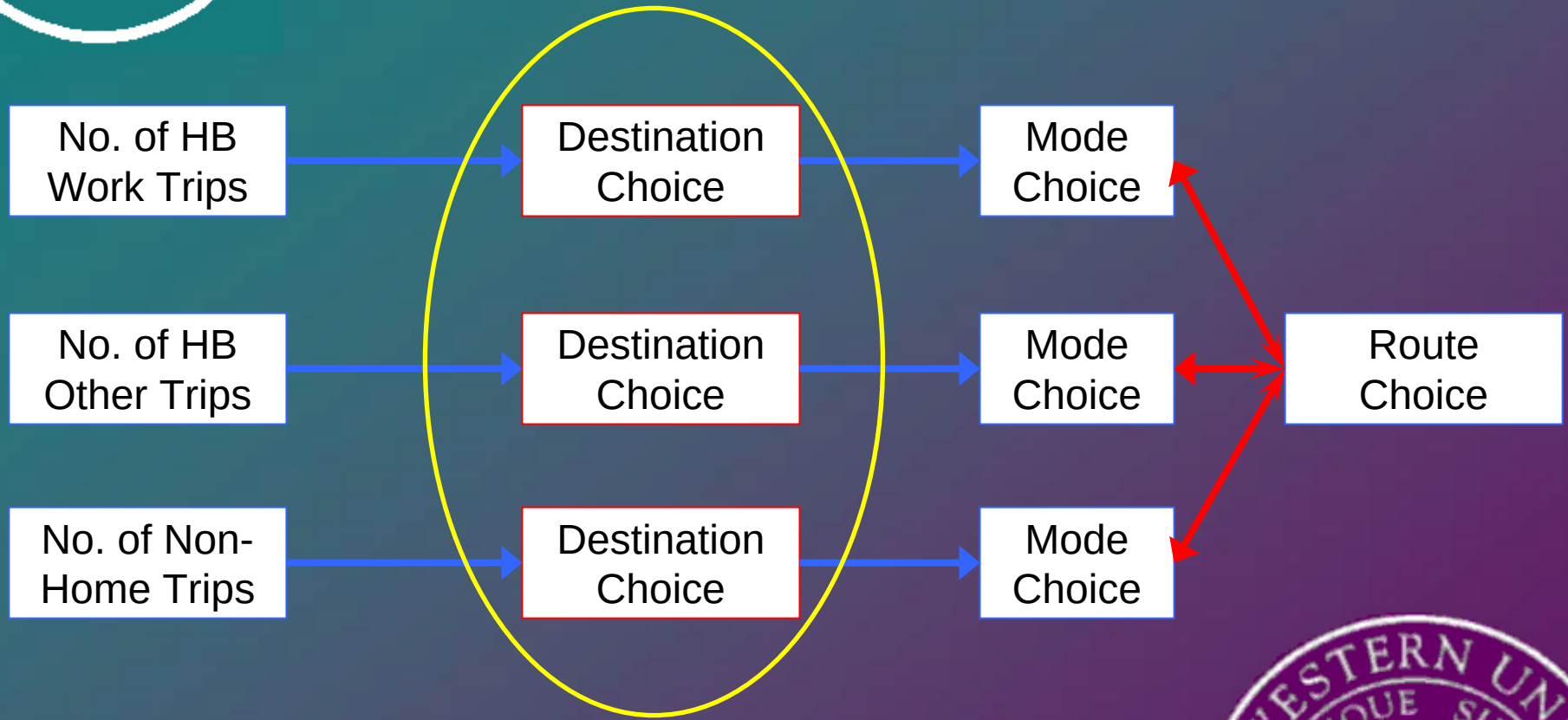
Feedback from Assignment

- The expected cost of a route choice is the route's travel time.
- Feedback of equilibrated travel times from assignment to distribution [*IF DONE CORRECTLY*] is equivalent to a combined distribution-assignment model of simultaneous destination and route choice (= foresight in destination choice)

Evolution (1)
Feedback from Assignment



Evolution (2)
Destination Choice



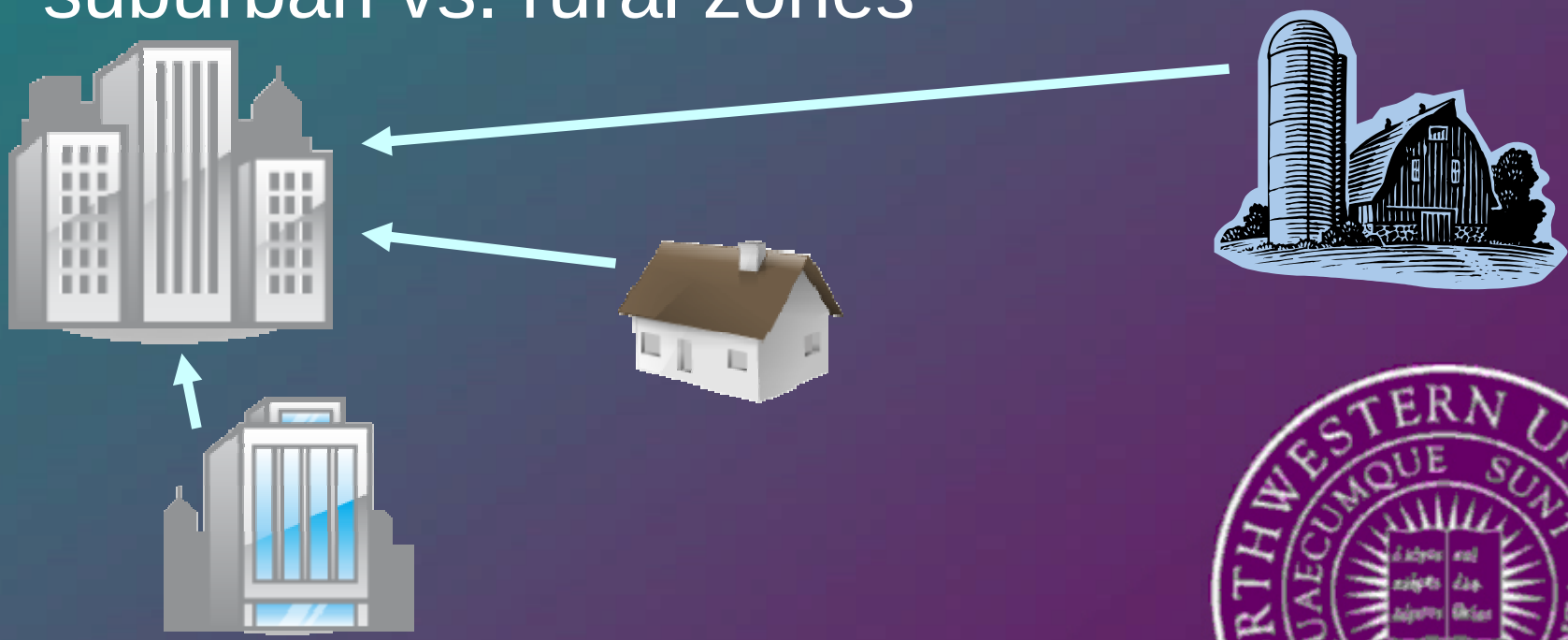
Destination Choice

more general form of gravity models which allows the incorporation of new variables such as income & accessibilities

Gravity	Destination Choice
Employment	Employment
Enrollment	Enrollment
Households	Households
Travel Time	Travel Time
K factors	Travel Time Squared
	Distance
	Income of Traveler
	Accessibility of Origin Zone
	Accessibility of Destination Zone
	Estimable Bias factors

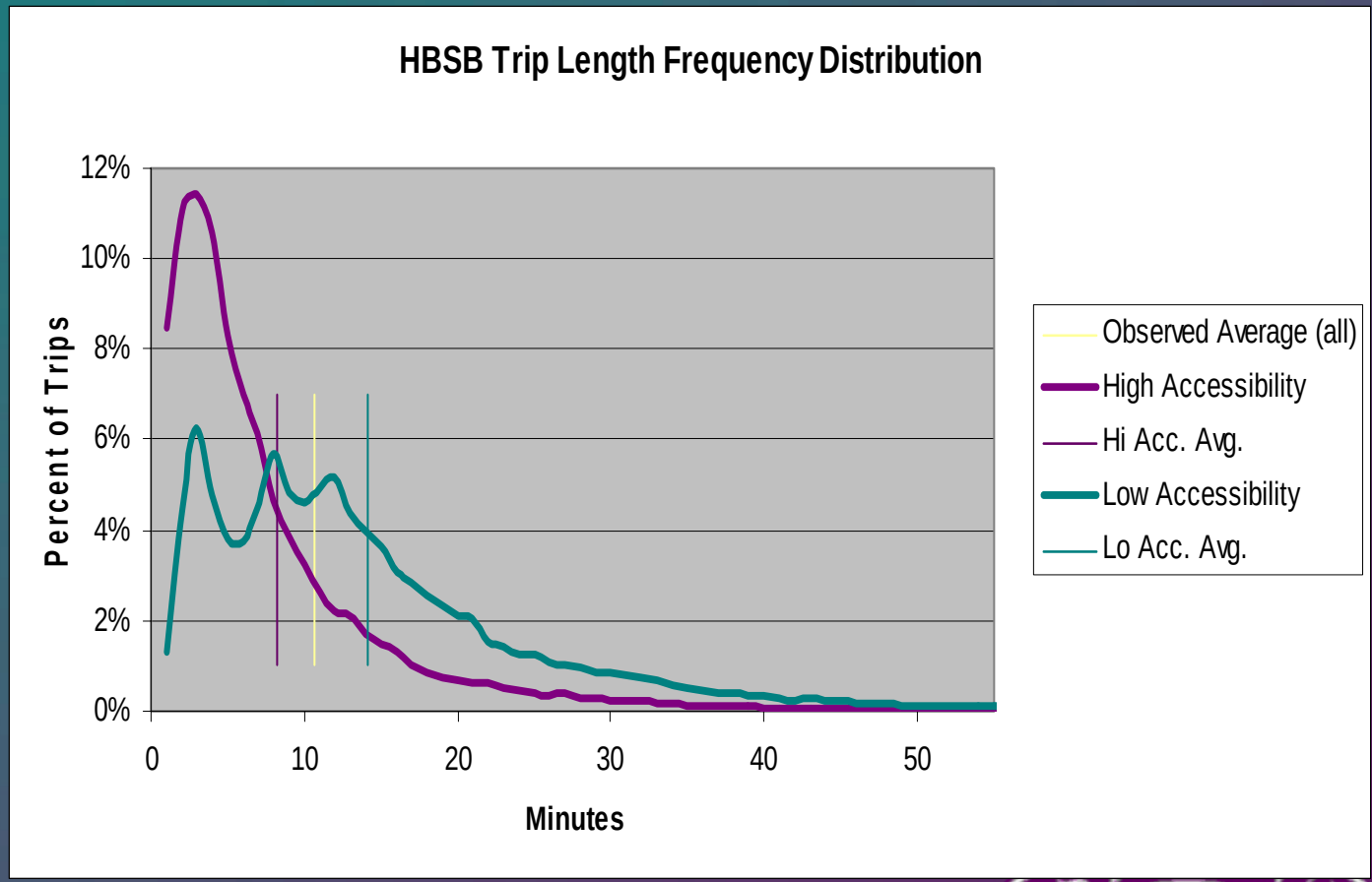
Destination Choice

- Use of origin zone accessibilities allows different trip lengths for urban vs. suburban vs. rural zones



Destination Choice

- Home-based shopping trip lengths from NW Arkansas



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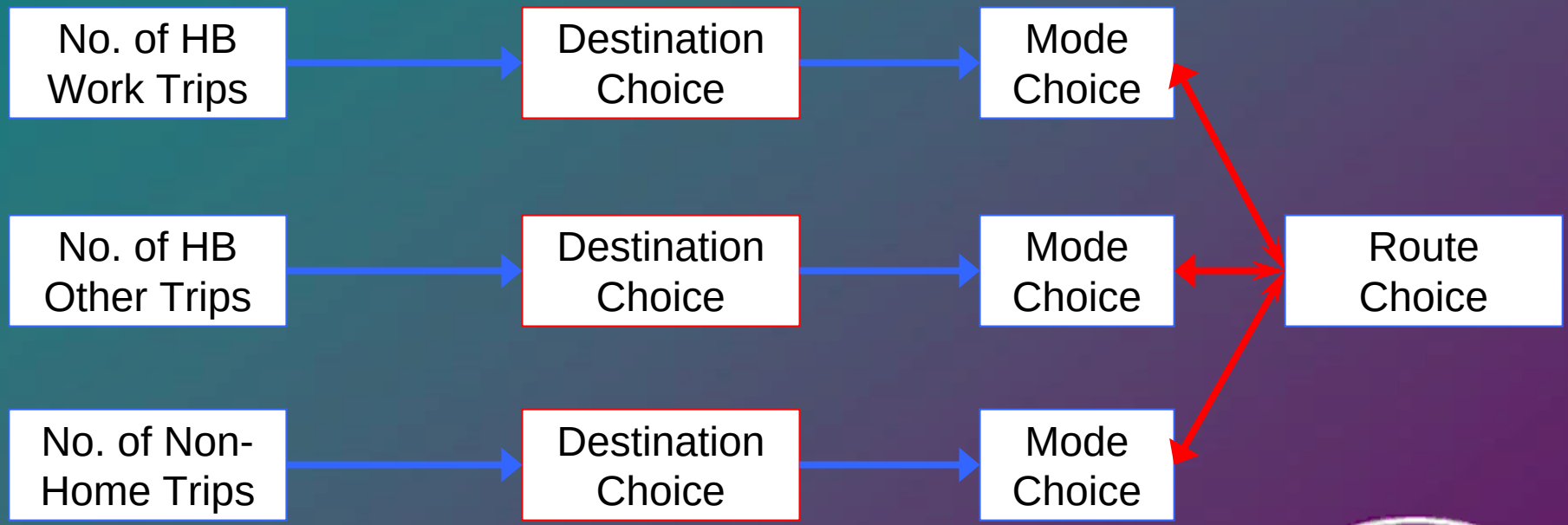
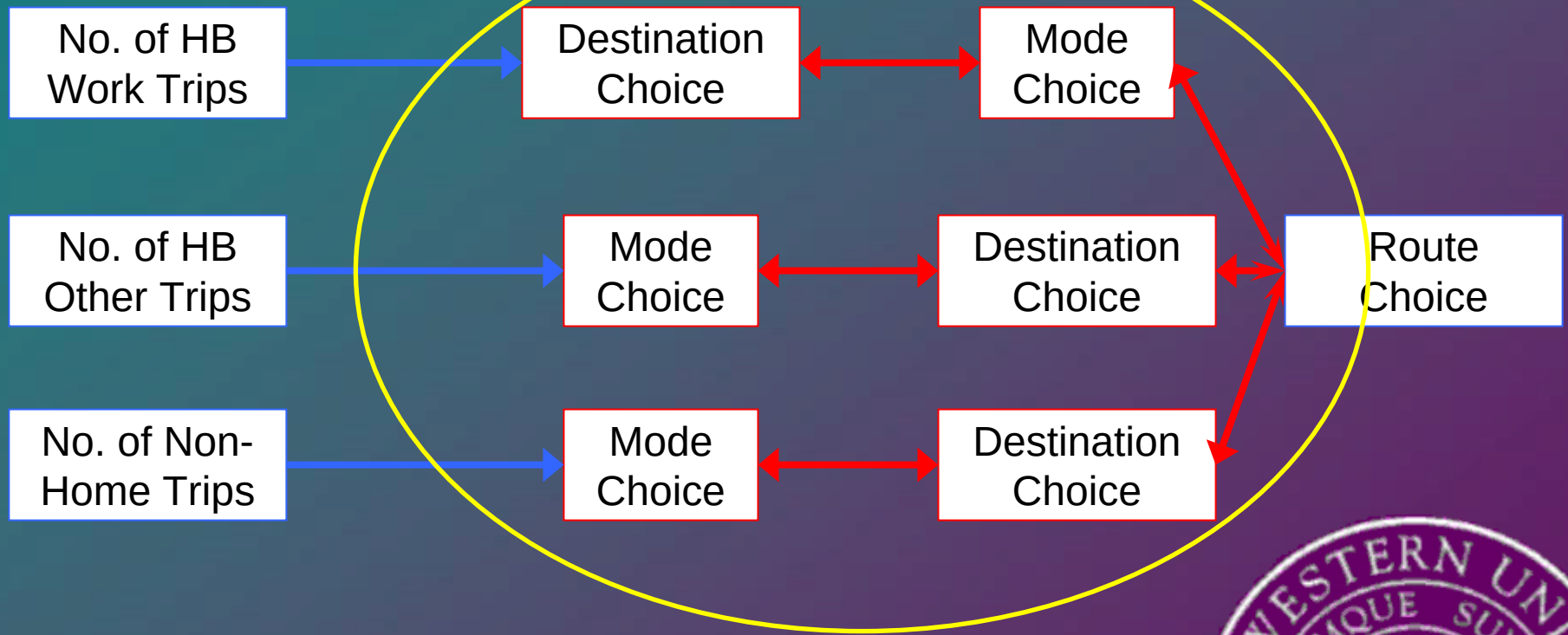


Evolution (3) Nested Mode & Destination Choice



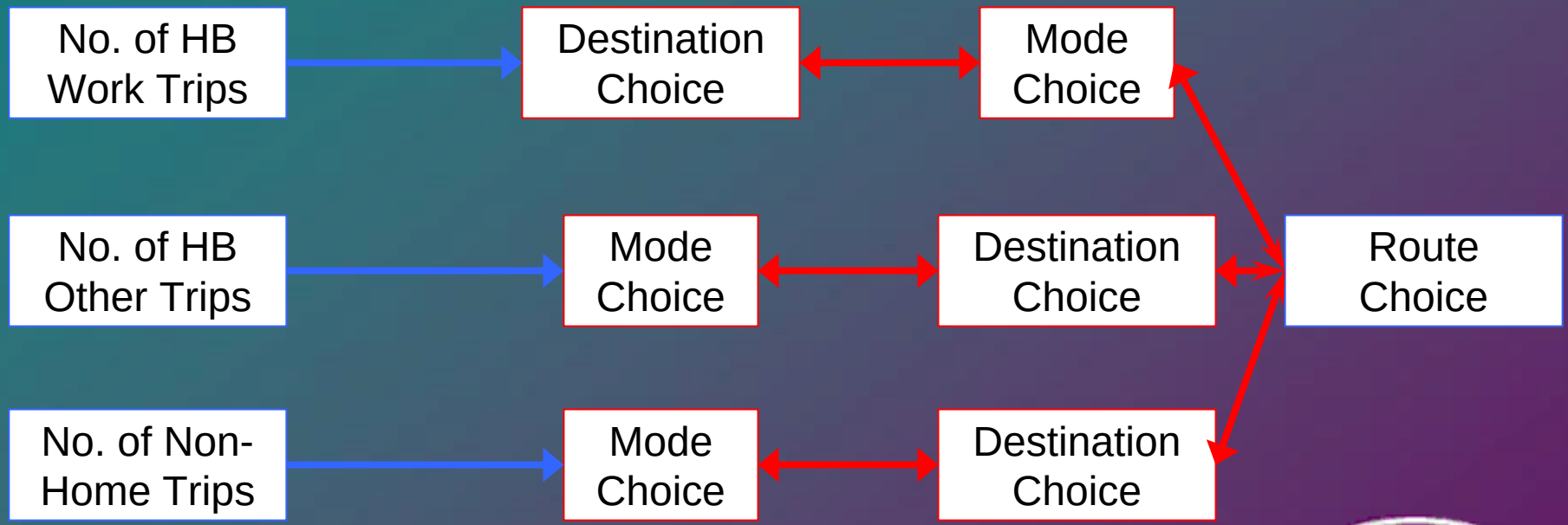
Nested Mode & Destination Choice

- In the traditional four-step model, mode choice was modeled as conditional on (after) destination choice
- This is due to a preoccupation with choice riders and commuting.
- However, for the vast majority of trips, there is strong evidence that destination choice should be modeled conditional on (after) mode choice (how it is done in activity-based models).

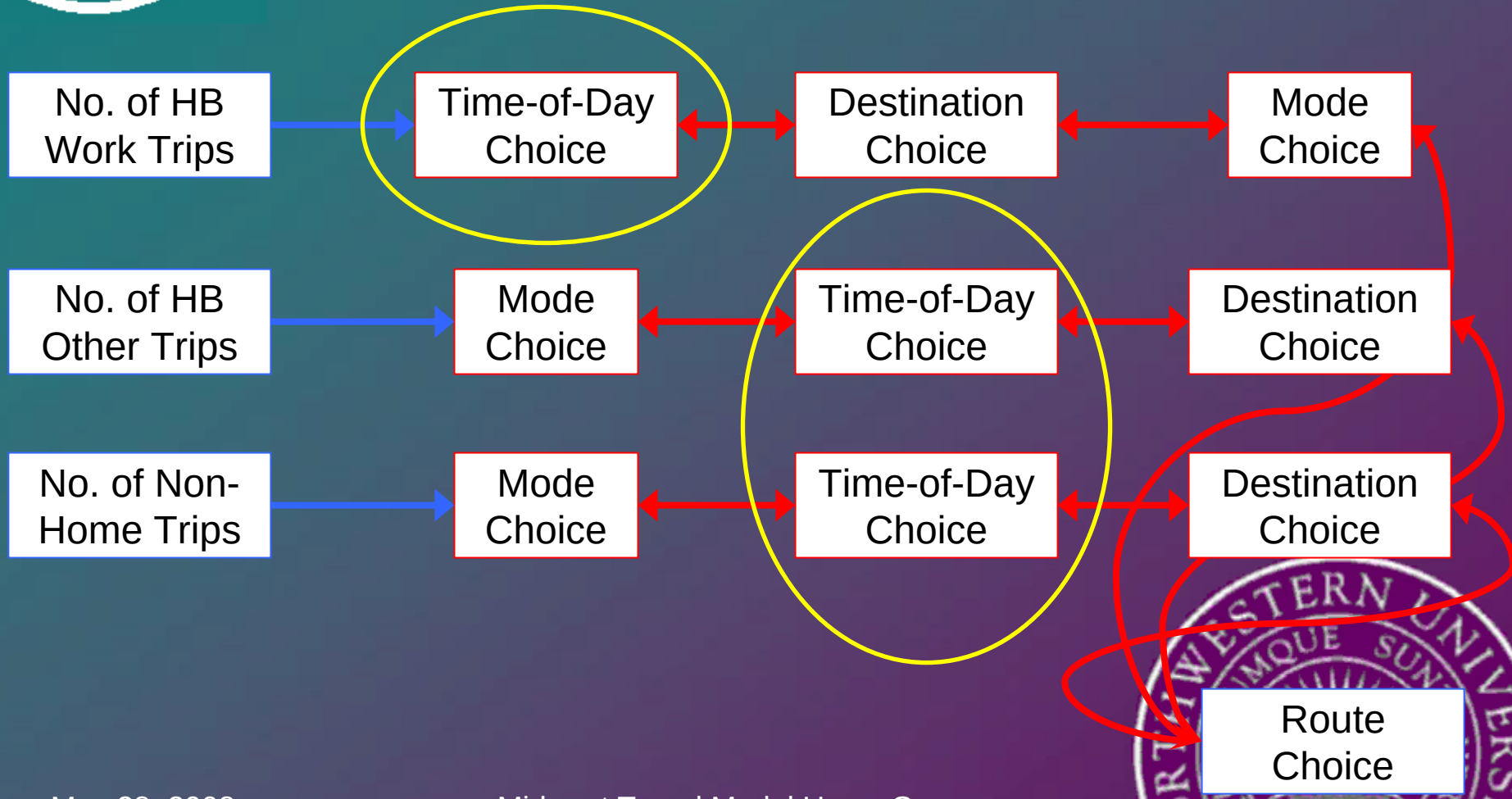
Allows Simplified Mode Choice

- Simplified zonal rather than route level-of-service variables but disaggregate demographic variables (frequency of service to zone rather than travel times between zones)
  - Shifts focus from choice to captive rider markets
  - Obviates need for skim-able transit network model
    - GREATLY reduces cost of model!!!

Evolution (3) Nested Mode & Destination Choice



Evolution (4)
Nested Time-of-day Choice



Nested Time-of-day Choice

- Accessibility variables allow peak-spreading due to congestion
- Demographic variables capture temporal shifts from aging population, etc.
  - U.S. Census projects US pop 65+ to more than double from 2000 to 2030 from 12.4% in 2000 to over 19.7% in 2030
- Pseudo-continuous treatment of time allows creation of trip tables for any time period
  - useful for micro-simulation!

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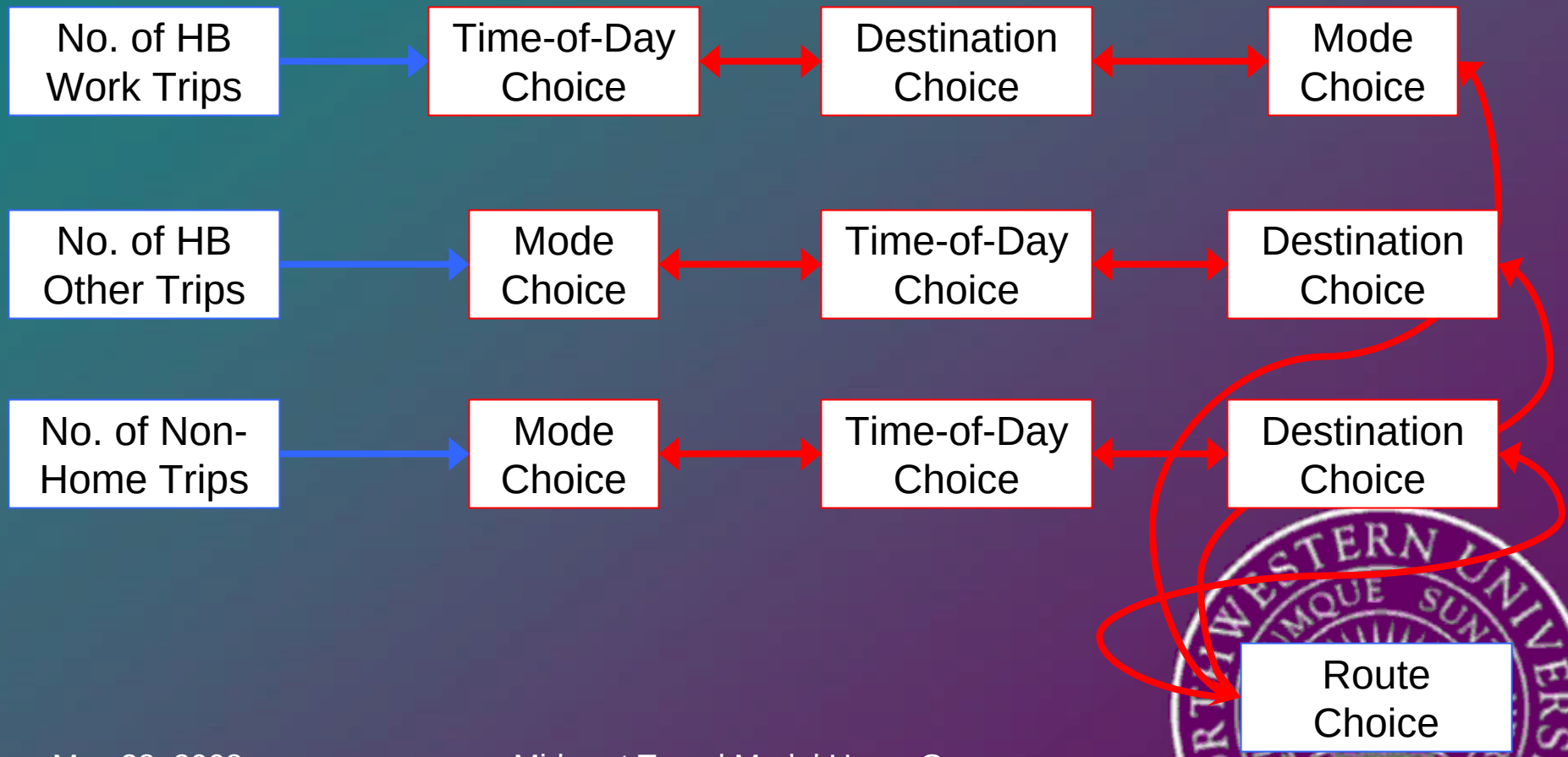
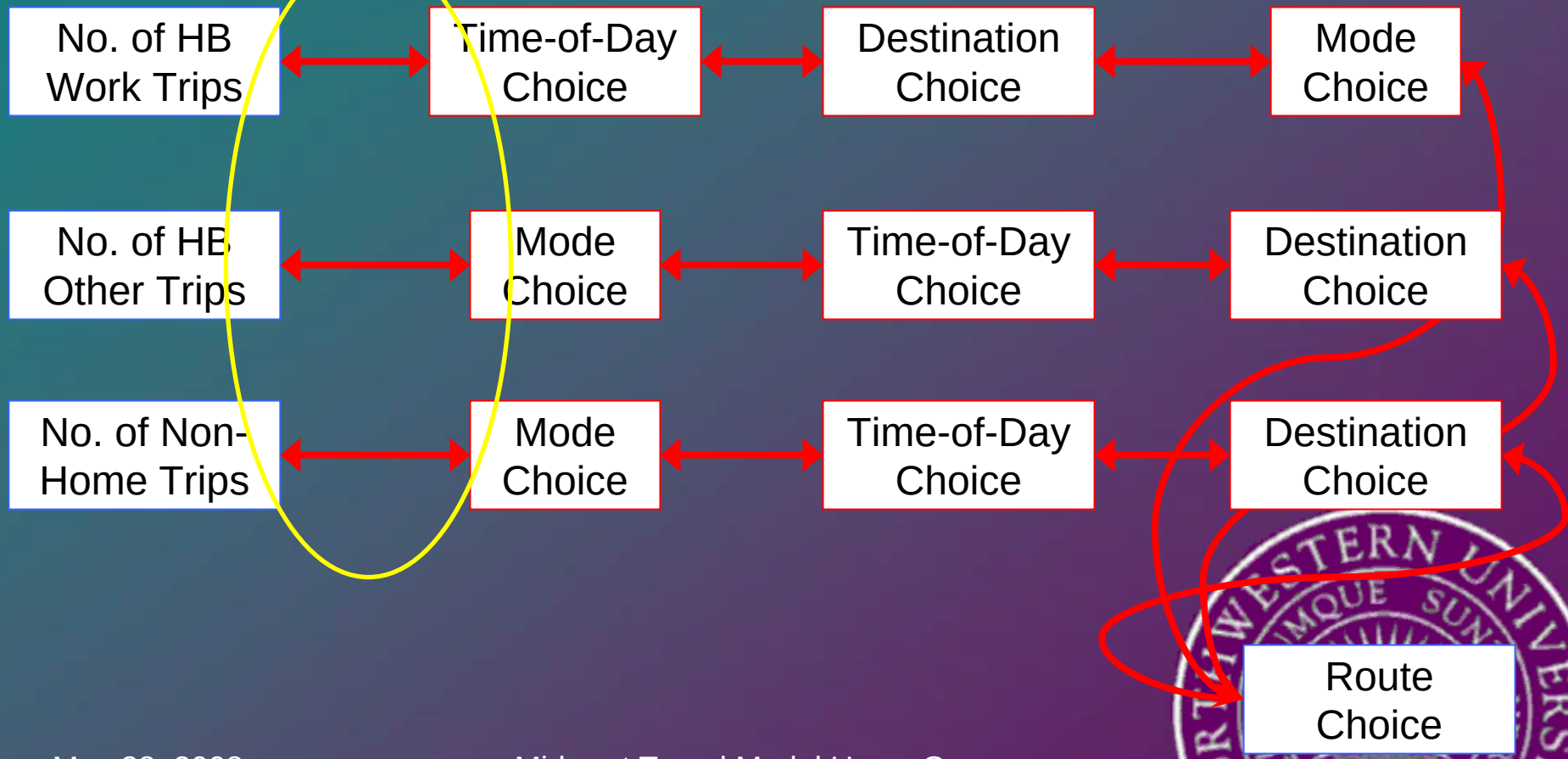
Nested Time-of-day Choice



Evolution (5)
Elastic Trip Demand



Elastic Trip Demand

- Incorporation of accessibility (the expected cost of a trip) in trip generation makes trip-making cost elastic and sensitive to both network and the land use environment
- NW Arkansas HBW and NHB trips were cost inelastic, but the number of HB Shopping and HBO trips were sensitive to the expected cost of these trips

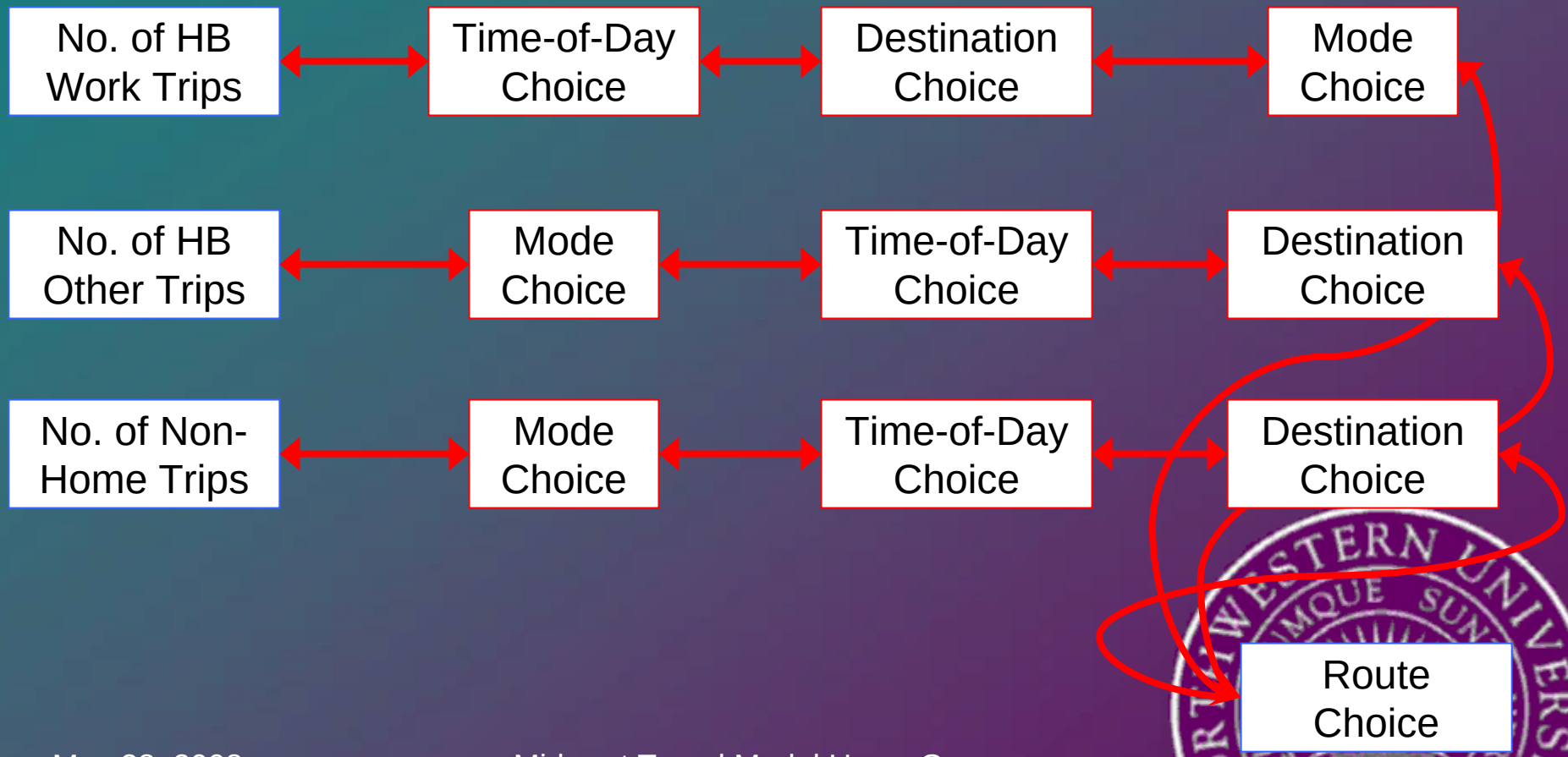
Rural Trips

- Including accessibility in both trip generation and distribution reflects fewer, but longer rural home-based trips; more shorter urban trips

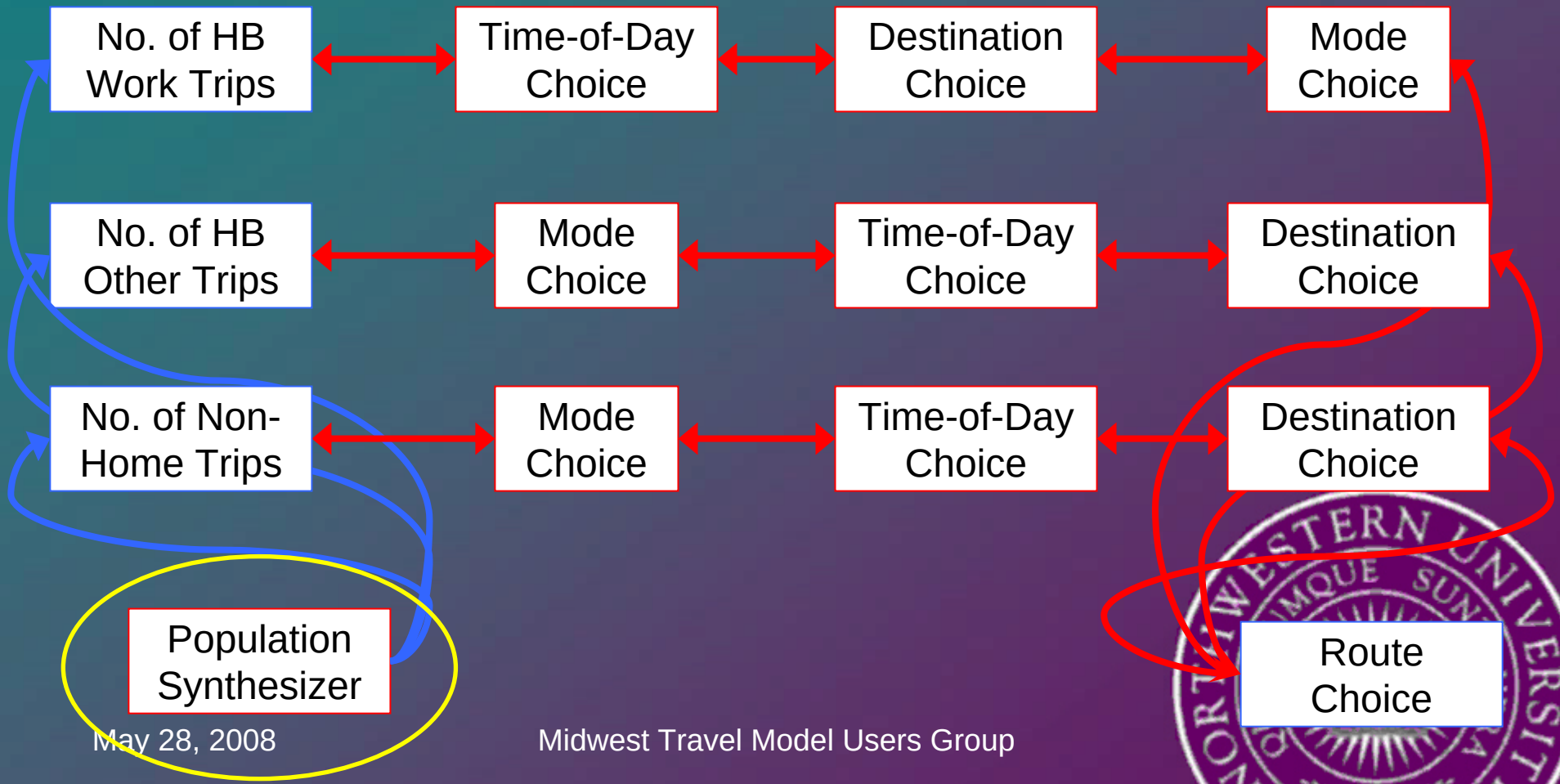
Elastic Trip-making

- Lower home-based trip making by residents of rural (lower-accessibility) areas,
- Decreased trip-making in response to congestion (decreased accessibility),
- Induced trip-making in response to added network capacity (increased accessibility),
- Induced trip-making in response to new land use developments in other nearby zones (increased accessibility)

Evolution (5)
Elastic Trip Demand



Evolution (6)
Disaggregate Population



Aggregation Bias

- Use of zones rather than travelers in traditional models limits the number of demographic variables which can be used and can skew the model results
  - For example, the number of trips (or the percent trips by transit) calculated using the zonal average income is NOT equal to the average zonal number of trips (or percent trips by transit) based on individual travelers' incomes!

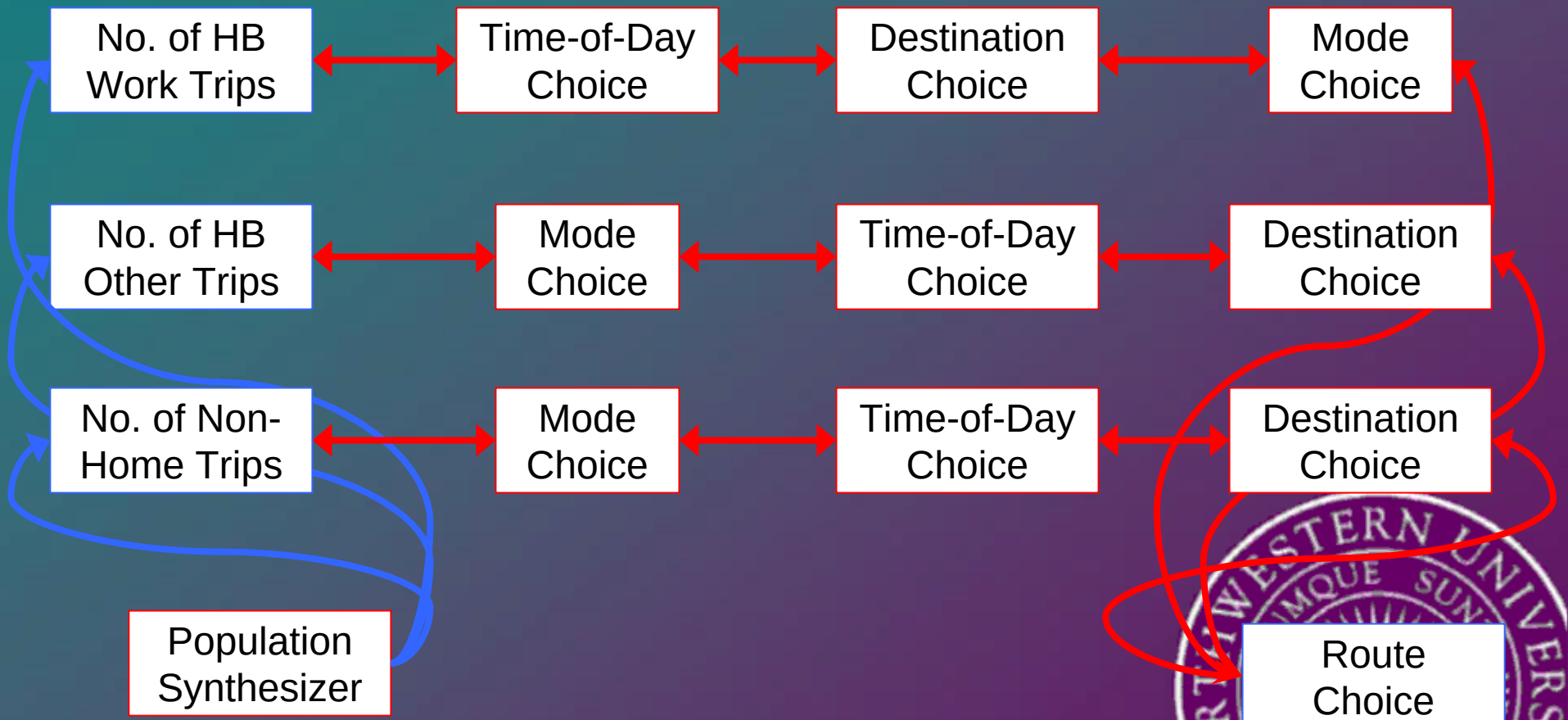
Simulation Error

- Activity-based models represent each traveler, but use random number draws to realize probabilities (Monte Carlo simulation)
- Any Monte Carlo simulation, including an activity-based model, must be run multiple times to generate an average, expected outcome

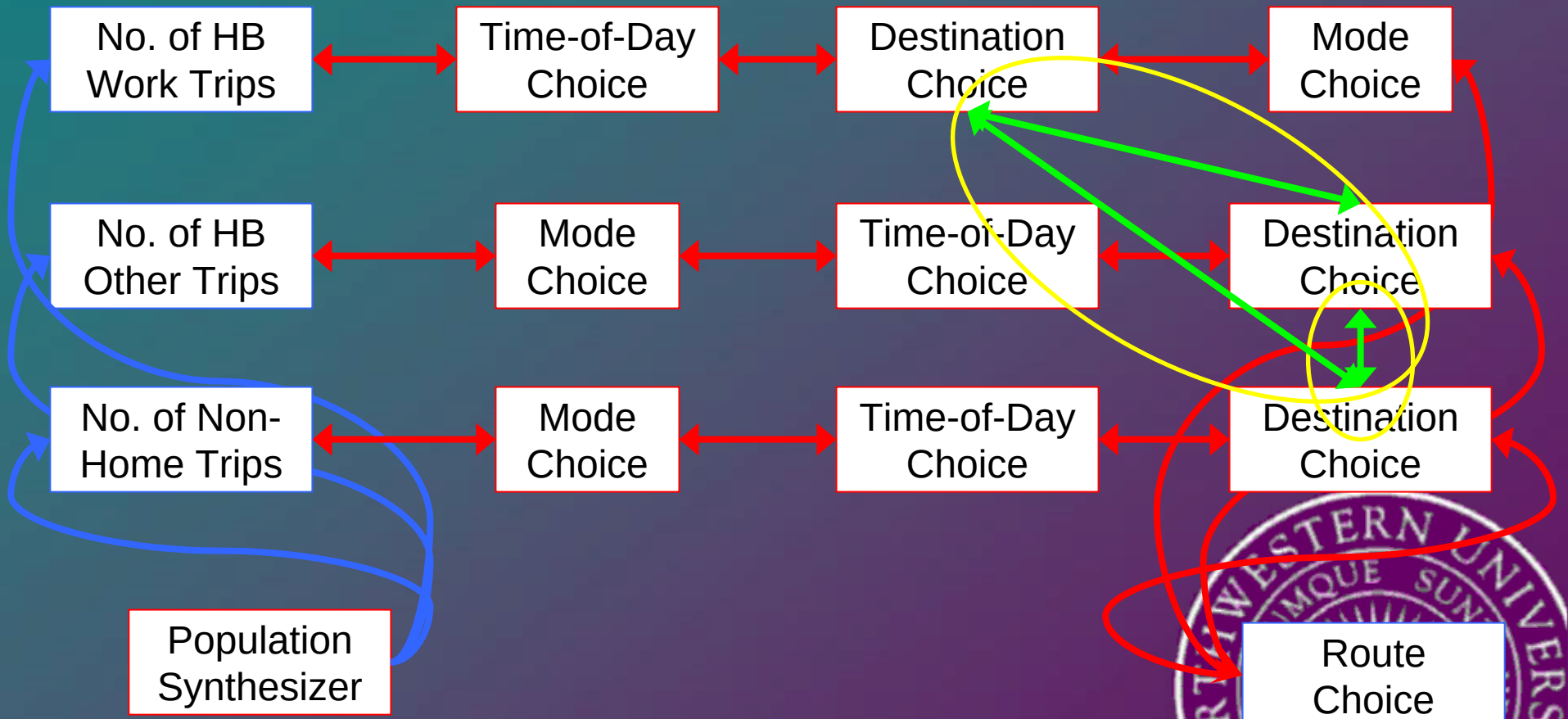
Disaggregate Population, Deterministic Outcomes

- Accessibility-based models represent individual travelers, but do NOT use random draws.
- This is only possible because of their simpler design as compared to activity-based models.
- Thus, they AVOID both
  - Aggregation bias, and
  - Simulation error!

Evolution (6)
Disaggregate Population



Evolution (7) Accessibility-Based Destination Choice

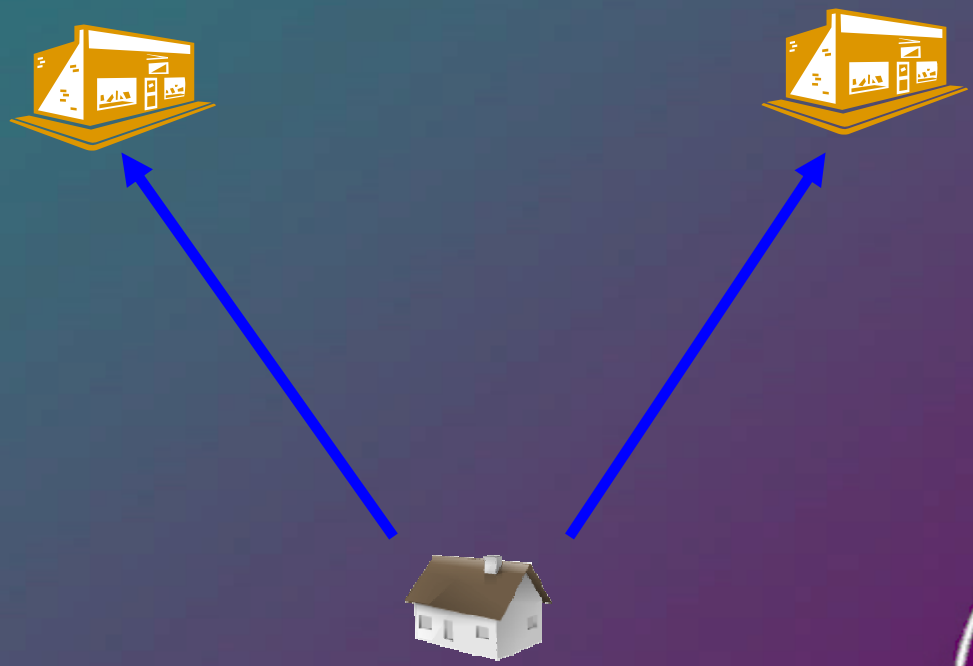


Accessibility-Based Inter-trip Linkages

- The ***proper*** use of destination zone accessibilities in destination choice can link destination choices for different trips.
- This introduces the simultaneity of considerations of different trips
- The result is the agglomeration of trip ends from people grouping their destinations together into convenient tours.
- However, spatial competition effects must be controlled for

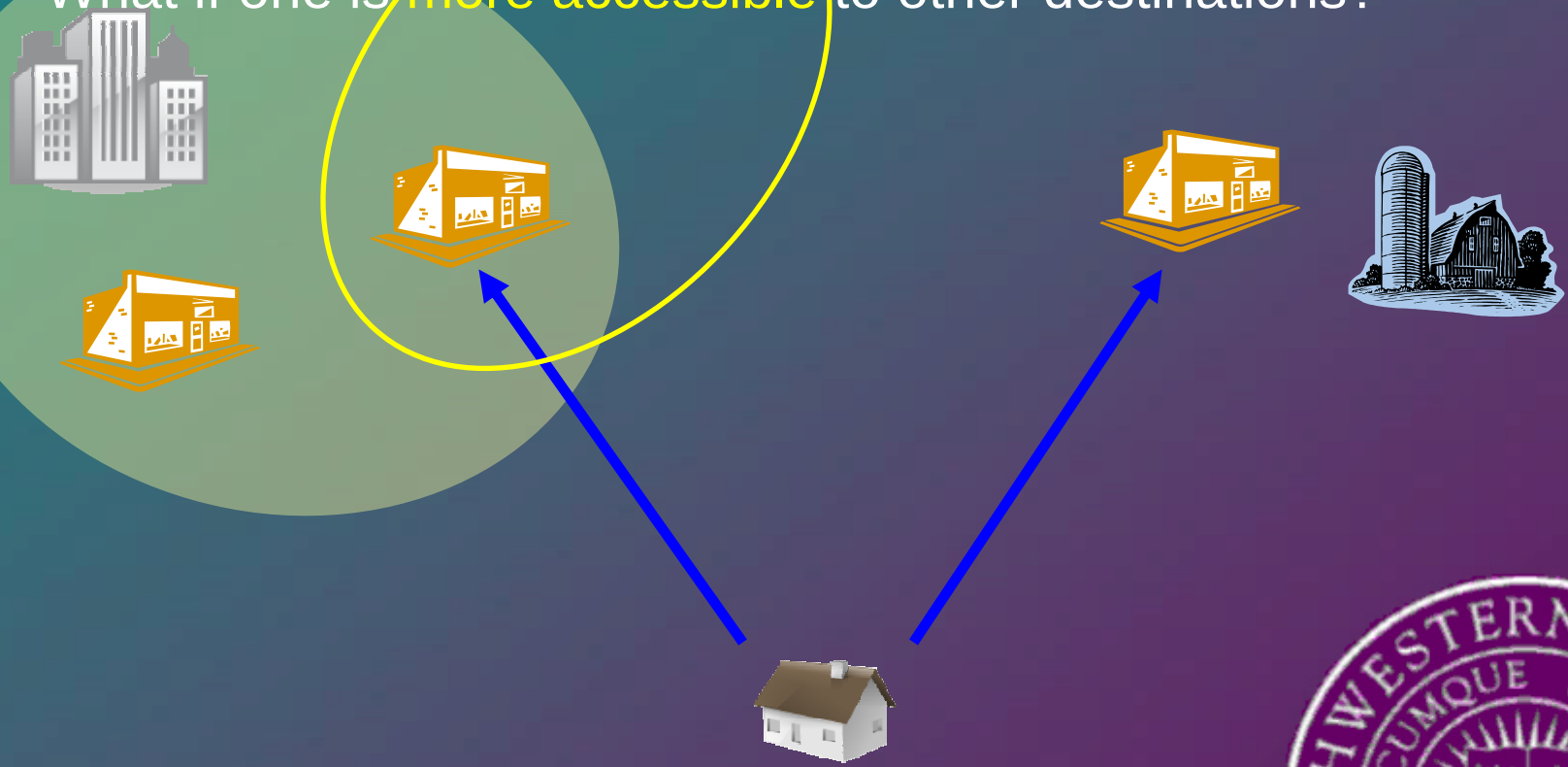
What about Destination Accessibility?

In traditional models, two equidistant, equal-size destinations are equally probable.



What about Destination Accessibility?

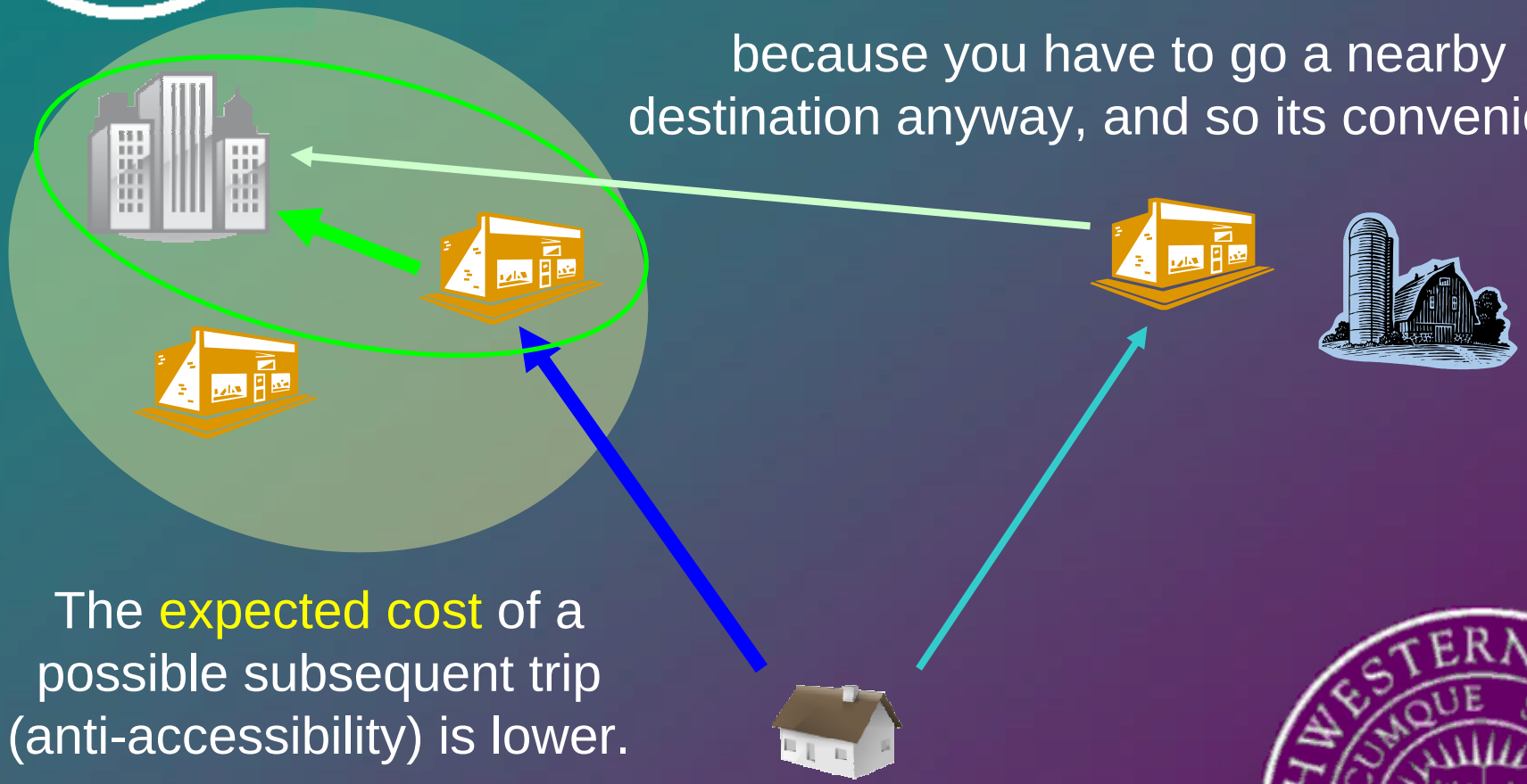
What if one is more accessible to other destinations?



Destination Accessibility

Maybe the more accessible one is more probable -

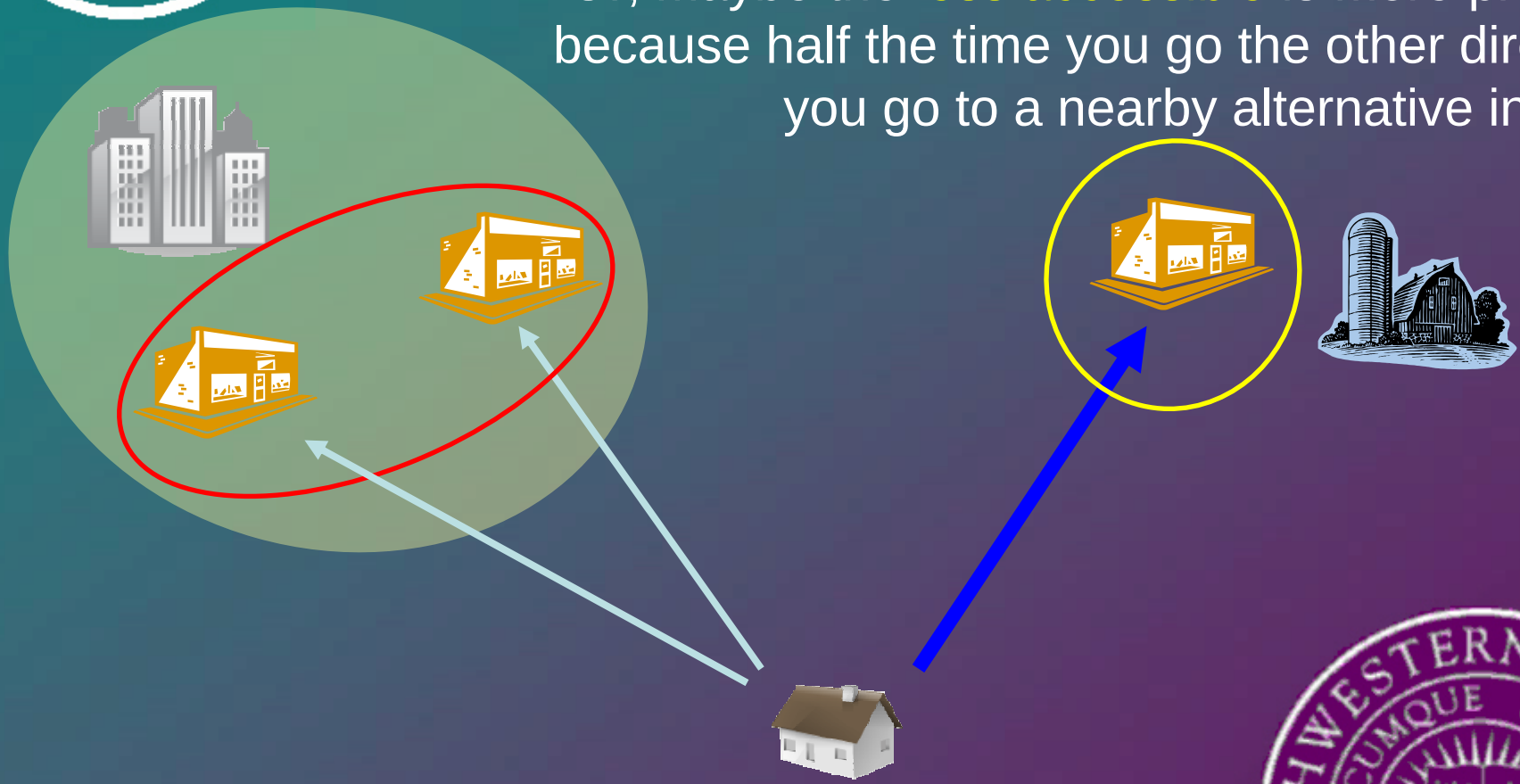
because you have to go a nearby destination anyway, and so its convenient.



The expected cost of a possible subsequent trip (anti-accessibility) is lower.

Destination Accessibility

Or, maybe the less accessible is more probable because half the time you go the other direction, you go to a nearby alternative instead.

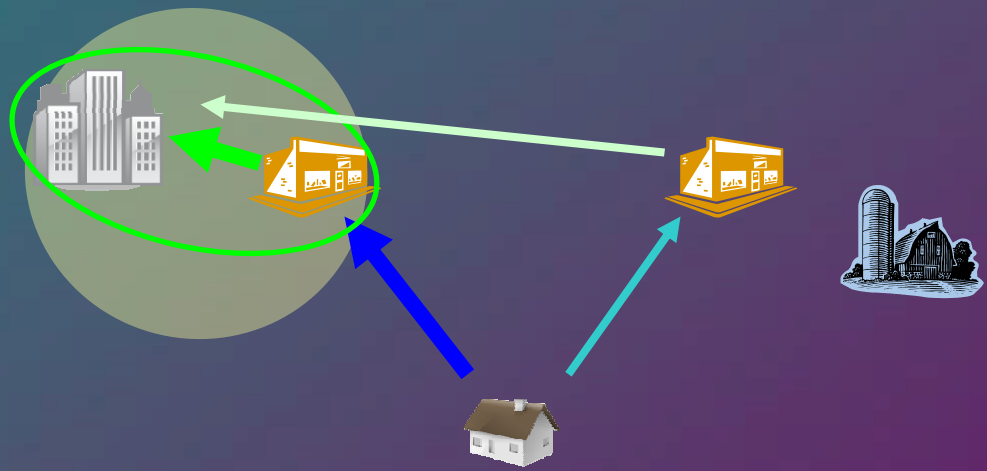


What's going on?

- Accessibility plays *2* different roles!
  - Or, alternately, there are *2 types* of accessibility:
    - Accessibility to **complements** (other places you need to go, regardless)
    - Accessibility to **substitutes** (other places you might go, instead)

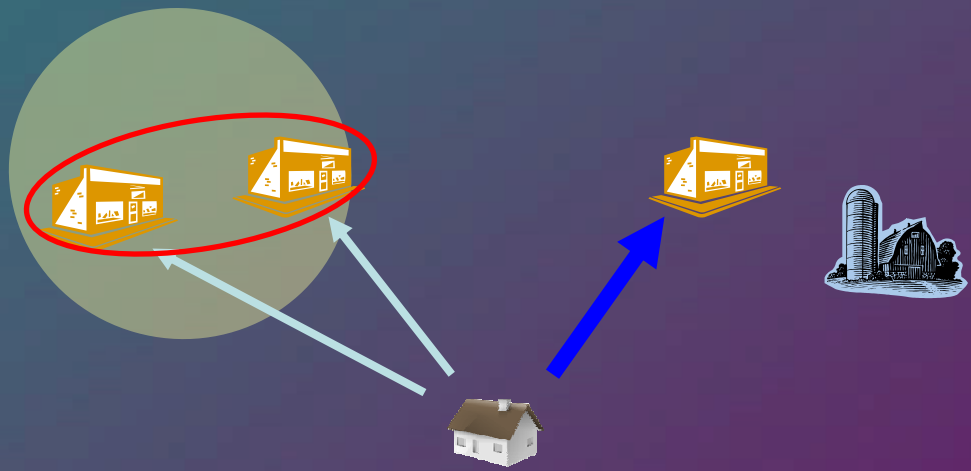
Accessibility to Complements

- Accessibility to complements increases the probability of a destination
  - because it decreases the total cost of a tour!



Accessibility to Substitutes

- Accessibility to substitutes decreases the probability of a destination
  - because it increases the likelihood of substitution.

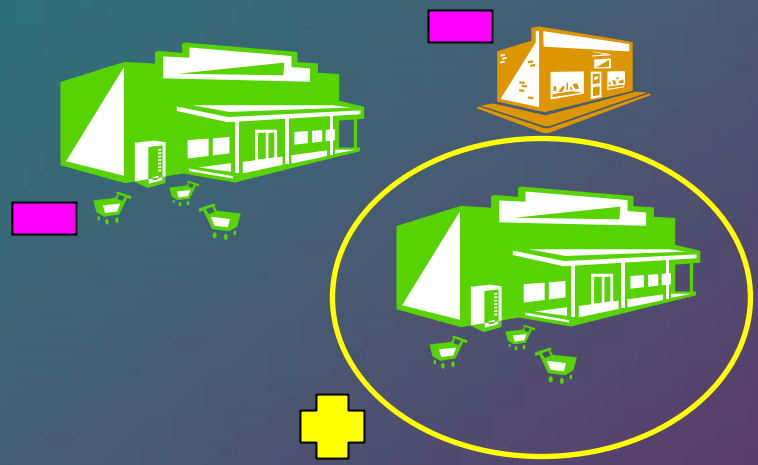


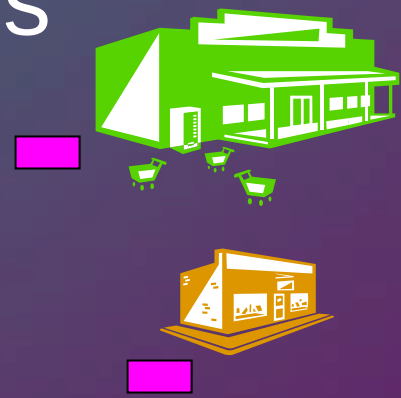
Policy Analysis & Planning

What happens if a new development occurs?

Policy Analysis & Planning

In current models, all the other destinations get equally less probable.



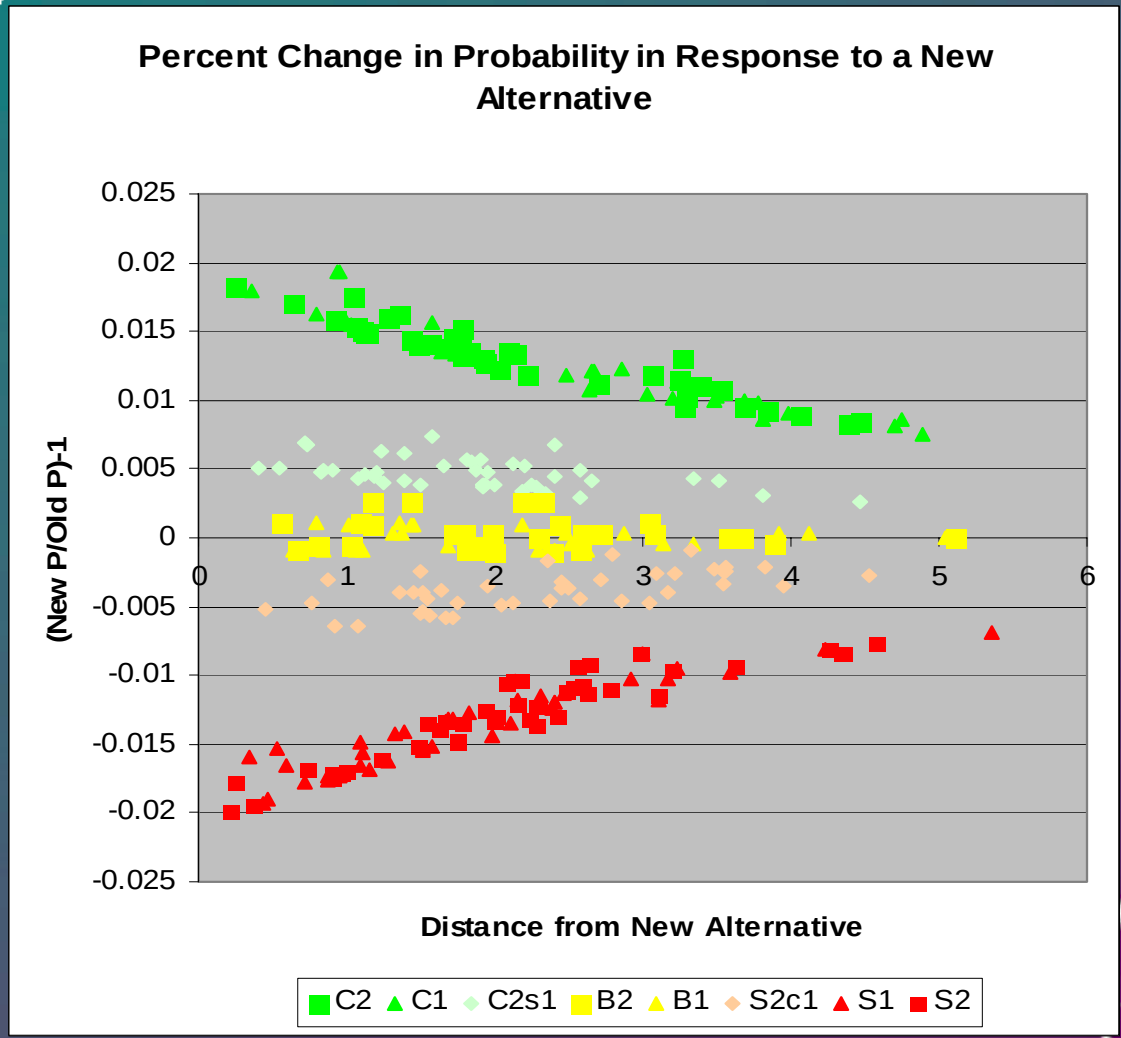


Policy Analysis & Planning

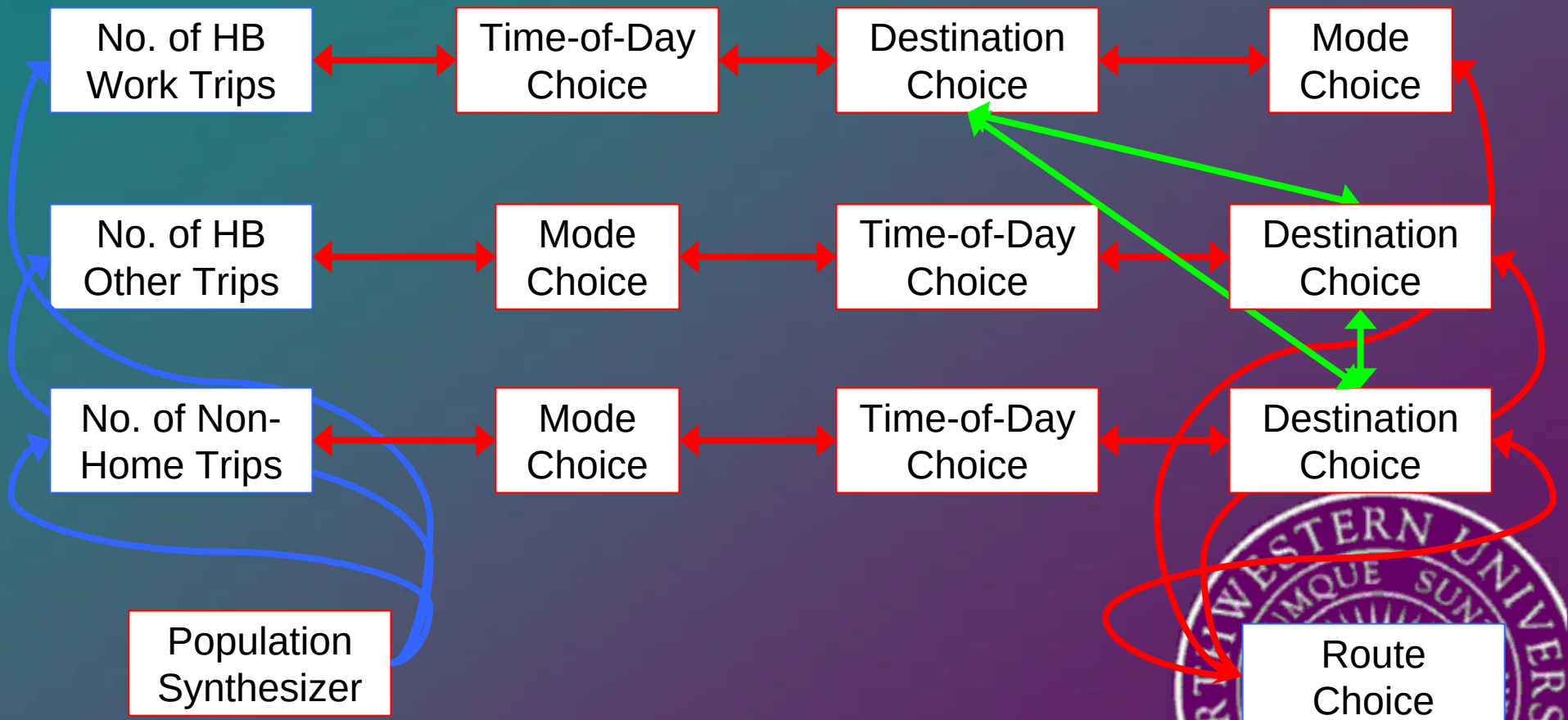
In my models, **nearby** destinations are affected more than *distant* ones.

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

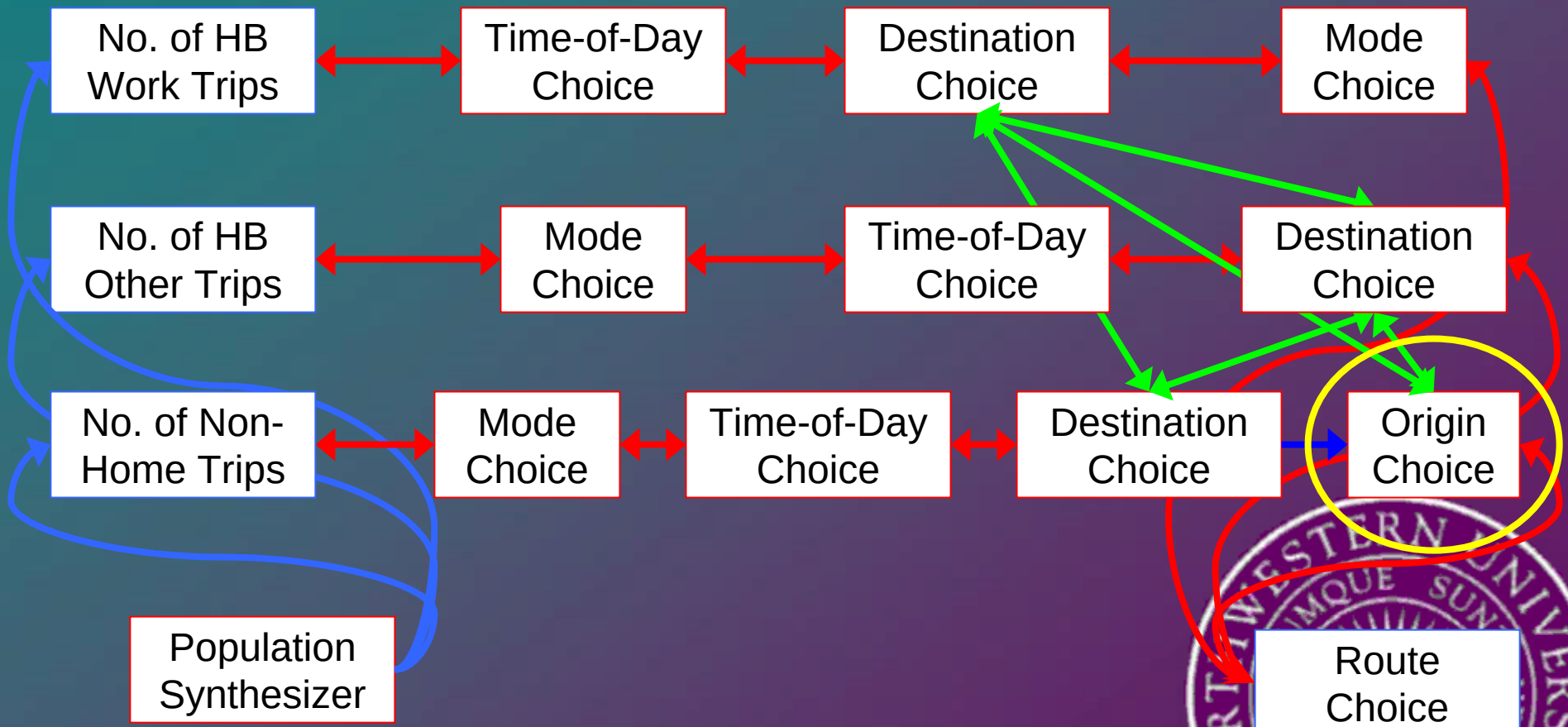
Numerical Experiment



Evolution (7) Accessibility-Based Destination Choice



Evolution (8)
NHB Origin Choice



NHB Origin Choice

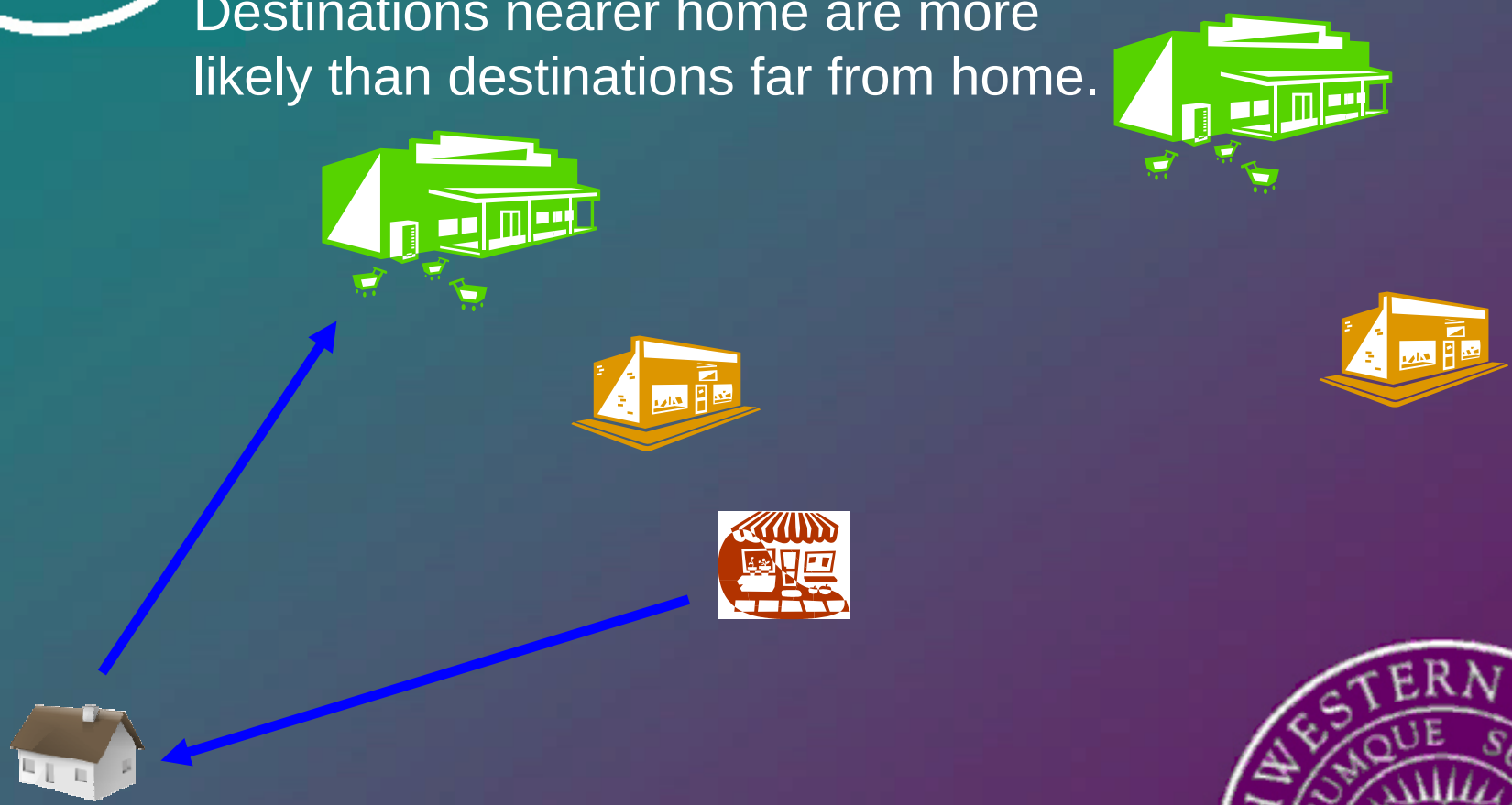
- In traditional four-step models, the location (origin & destination) of non-home-based trips bear no relation to the home location.
- One alternative is to use a "double destination choice" for NHB trips
  - Destination (or stop location) choice using the home location
  - Origin (or stop sequence) choice using the destination locations

NHB Origin Choice

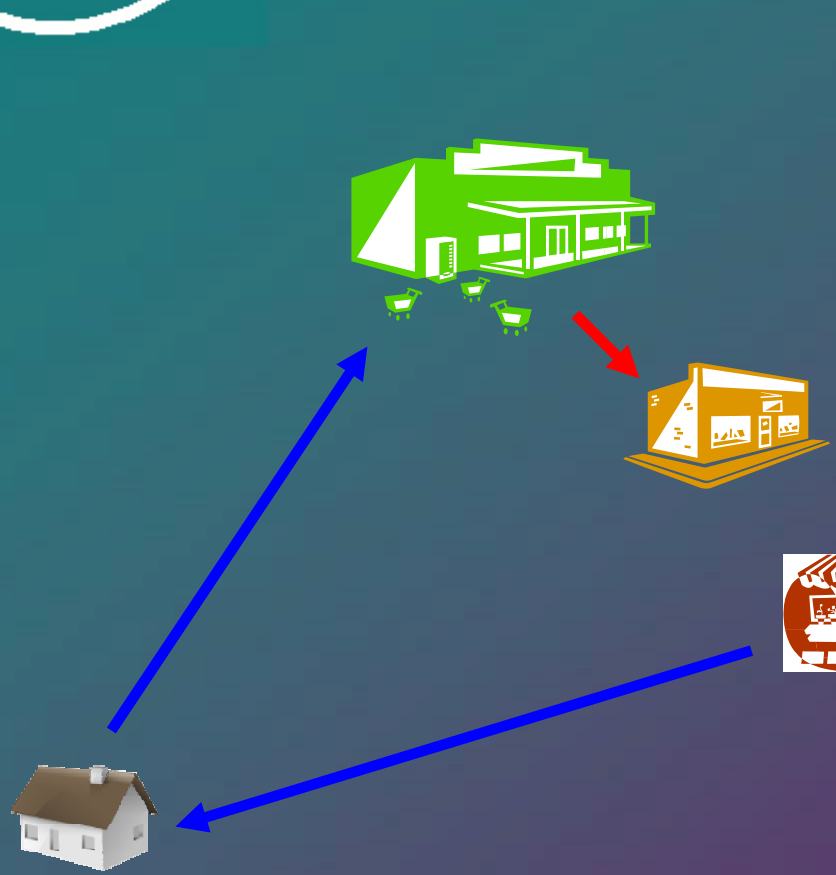
- Traditional four-step models are NOT consistent with touring behavior because they *ignore* one of these TWO choices.
- Advanced trip-based models can GUARANTEE that *all travel is conducted in closed tours* using this double destination choice structure and imposing a double constraint on the second (origin) choice.

Home-Based Trips

Destinations nearer home are more likely than destinations far from home.



Four-step Model
Non-home-based Trips



Trips far from home are *just* as likely as trips nearer home.

This implies open tours!

Non-home-based Trips With Origin Choice Model

Trips far from home are NOT as likely as trips nearer home.

Trips are GUARANTEED to form closed tours!

Trip-Chaining without Trip Chains

- The combination of accessibility-based destination choice models and NHB origin choice models, allows accessibility-based models to represent the effects of realistic trip-chaining behavior on trip distribution WITHOUT explicitly modeling trip chains!
- Explicitly modeling tours still does allow for some increased realism / control
  - particularly over the ratio of stops served on a main tour (rooted at the home) versus being served on a sub-tour (rooted at another location, like work)

Conclusion

- Compared to four-step models, accessibility-based models offer
  - Greater accuracy (no aggregation bias / simulation error)
  - Better sensitivity to demographic changes (aging population, employment rates, student populations, new developments)
  - Induced demand & built environment (urban vs. rural, densification, mixed use developments) effects,
  - Peak-spreading due to congestion,
  - Effects of trip-chaining on trip distribution.

Conclusion

- Compared to activity-based models, accessibility-based models
  - are much simpler and easier to understand,
  - and have significantly lower costs both in terms of development and application,
  - although they lack some behavioral realism (e.g., inter-trip linkages between time-of-day or mode choices, etc.).

Conclusion
Debunking the Myth

- You've been told you have to choose between
  - a 1960's model with no features
  - and the largest luxury model every made

Conclusion
Debunking the Myth

I’m telling you – there are other models!

Questions?!