

# Agent-based demand models

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# Why use models?

Forecasting

Scenario testing (alternative land uses, networks, policies)

Project planning/corridor studies

Growth management/  
development regulation/  
public facility adequacy

Manage complexity, when eyeballs are insufficient, different people have different intuitions

Understanding travel behavior

Influence decisions

Estimation in the absence of data

# History

1950 - 60s

- Interstate construction era
- Extremely simple models

Very few TAZs

Only major highways

- Focus on trips to downtown
- Models to identify capacity requirements on highways

## 1970 - 80s

- Refinement of model
- More detailed structure

Increased zonal structure

Different type of roadways included

- Expanded focus on suburban movement

## 1990s

- Transit networks incorporated into the models
- Models used to analyze policy scenarios
- Focus on suburban movement
- Shifting trips from car to other modes

## 2000s

- Disaggregation (individuals, households)
- Increased complexity in models (trips, tours, time of day)
- Greater focus on integration with other aspects such as land use

# Modeling Approaches

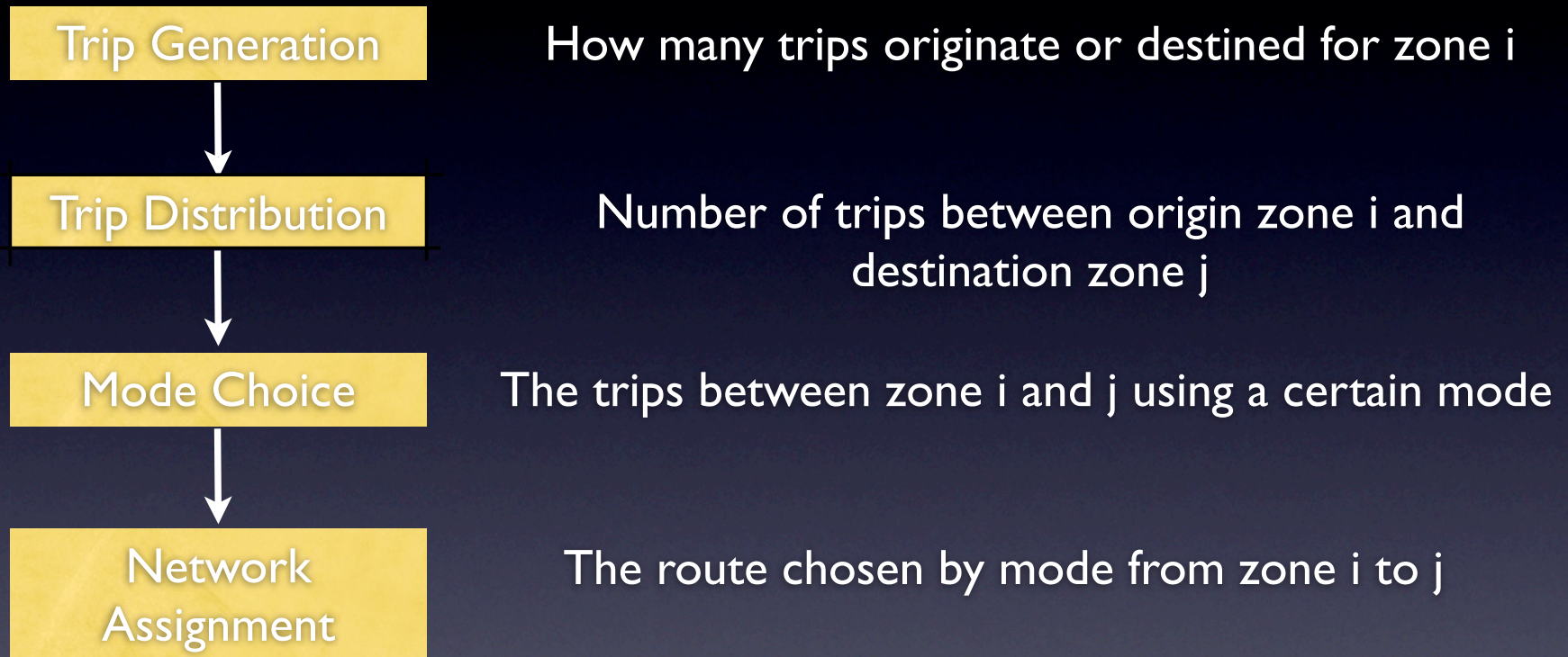
- Traditional four-step modeling
- New Approaches

Activity-based modeling

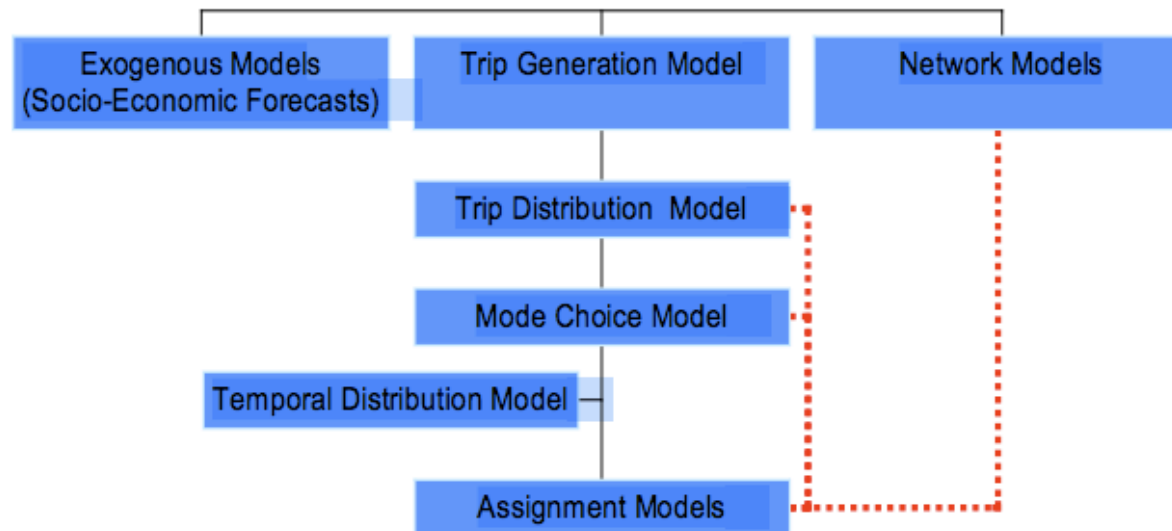
Agent-based modeling

The new approaches typically use micro-simulation

# Four-step modeling



# Current Twin Cities Travel Demand Forecast Model



Source: <http://www.dot.state.mn.us/trafficeng/modeling/workshop/C06-Forecasting.pdf>

# Criticisms

- Trip is the basis of analysis

Trips analyzed as a function of zonal attributes, ie, reason for traveling not included

Each trip is analyzed independent of the other trips

Trip scheduling not considered

Activity participation of individuals/  
household constraints not considered

- Aggregate (zonal) level of analysis

Heterogeneity of travelers not considered

- Sequential approach
- Theoretical mis-specifications

- Traditional focus on

Home to work trips

Higher volume roadways

- Endogenous/Exogenous inputs
- Incorporation of feedback routine

- Static and deterministic nature of supply and demand in the model

Can not handle the dynamic nature of traffic

- Limited policy analysis

Congestion Pricing

Toll Lanes

Evacuation Scenarios

# Micro-simulation

Refers to a broad range of tools used in modeling systems

Micro refers to the simulation done at the micro or disaggregate level - ex. individuals, households

- System characteristics for microsimulation

Dynamic nature

Complex behavior

Path dependent processes

Open system

Existence of significant uncertainties

Transportation definitely fits these conditions!

- Typically used to generate inputs in disaggregate modeling

Usually difficult to obtain data for disaggregate modeling

- Creates micro-level outputs that can be aggregated to any level

Better understanding of policy scenarios

- Considered to be computationally more efficient than conventional models
- Many applications in transportation

# Activity based models

- Considers travel to be a derived demand

This is the fundamental difference between these models and conventional four-step models!

- Travel decisions are components of a broader process

Model the demand for activities rather than modeling trips

- What does 'derived demand' mean?

Travel is not undertaken for its own sake

Travel is a demand that arises from people's desire to participate in activities

Trips connect the spatially separate activities that individuals participate

- People undertake activities based on their desires to participate in activities subject to constraints

Capability constraints

Coupling constraints

Authority constraints

Time Constraints

- It is **NOT** easy to model the demand for activities
- But we know that

Households moderate activity demand and influence activity decisions

The influence varies by household structure  
- size, age, gender etc.

Households with children have significantly more constraints and demands

- Activity based models provide a holistic framework that understands and incorporates the relationships between activity and travel behavior
- Individual decision making typically accomplished using micro-simulation and then aggregated for travel forecasting

# Methodologies

- Computational Process Models

Explicitly models the process used by individuals to make decisions

Examples:

CARLA, SCHEDULER, STARCHILD - Treat activity generation as given and focuses on scheduling

ALBATROSS, AMOS - Focus on both activity generation and scheduling

PCATS, CATGW - Focus on both activity generation and scheduling within continuous time domain

- Hazard based duration models

Models the conditional probability of an activity terminating (referred to as failure) at time  $t$ , provided that it hasn't been terminated prior to  $t$ .

- Approach generally used to model duration of activities and time spent at home between two trips

- Discrete and Discrete-Continuous Choice Models/Econometric Choice Models

Has already been applied in conventional 4-step models in mode choice routine (nested logit formulation)

Applied to interrelated activities (tours) and travel

- Subdivided into three classes

## Trip-based models

- ex. San Francisco MTC model

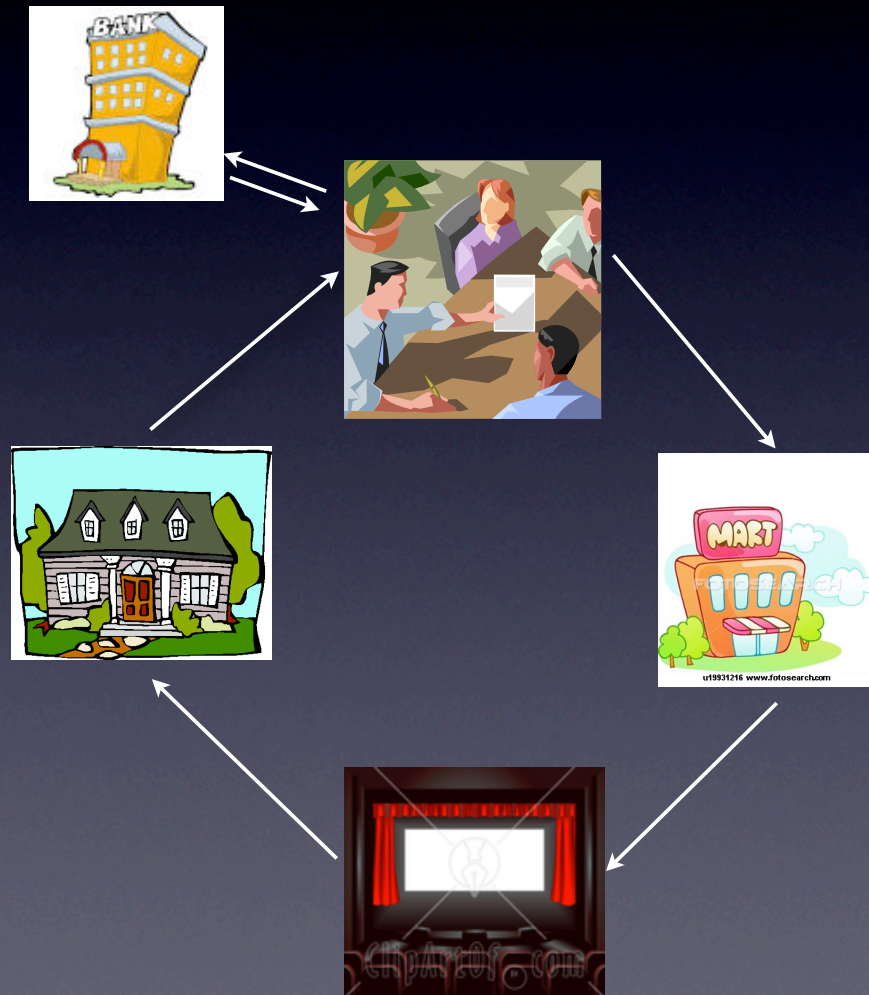
## Tour-based models

- ex. Netherlands National LMS model

## Daily schedule models

- ex. Portland daily activity schedule models

# Concept of tours and daily schedule

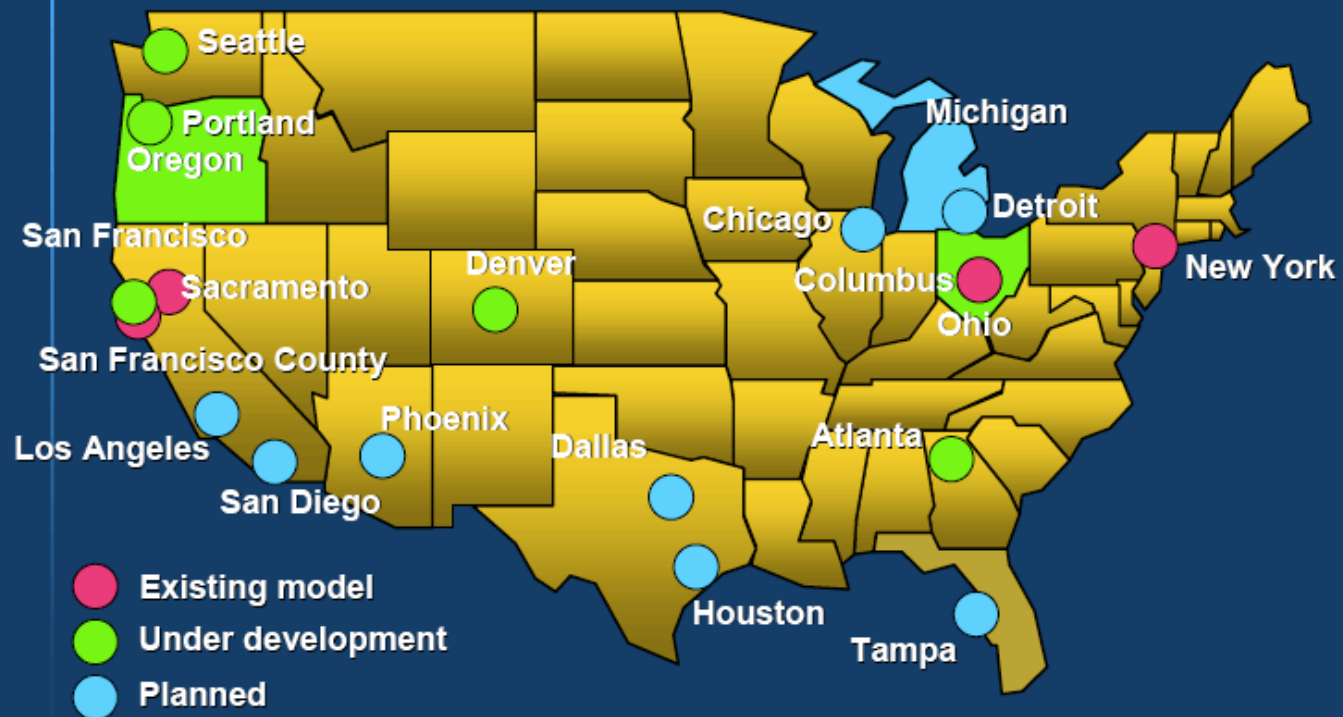


Trip based models:  
Six separate one-way trips

Tour based models:  
Two separate tours;  
one primary home tour  
one secondary work tour

Daily schedule models:  
Combines the tours

## U.S. Activity Based Models



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CAMBRIDGE  
SYSTEMATICS

# Agent-based models

- Another approach to travel demand forecasting
- Typical agent-based models come from different fields such as genetics, artificial intelligence, cognitive science, social science

- Activity-based demand models use sophisticated methods

Much better than traditional models

- However there is a degree of aggregation involved especially in traffic assignment level

Aggregate OD matrices feeding into dynamic traffic assignment models

# Typical elements

- Agents

Like “people” who have characteristics, goals and behavioral rules

- Environment

Space where agents live

- Interaction rules

Describe how agents and environment interact

- The agent-based model evolves once the micro-level elements are specified

Once initial conditions are specified, agents behave according to their characteristics, learning and behavioral rules

- Macro-level properties emerge from the evolutionary process

# TRANSIMS

- **T**Ransportation **A**Nalysis **S**IMulation **S**ystem
- Integrated travel demand model
- Developed by Los Alamos National Laboratory
- Long term effort to redesign the modeling process from the ground up
- Can be considered as a framework handling different modules
- Modules utilize micro-simulation techniques and activity-based approach

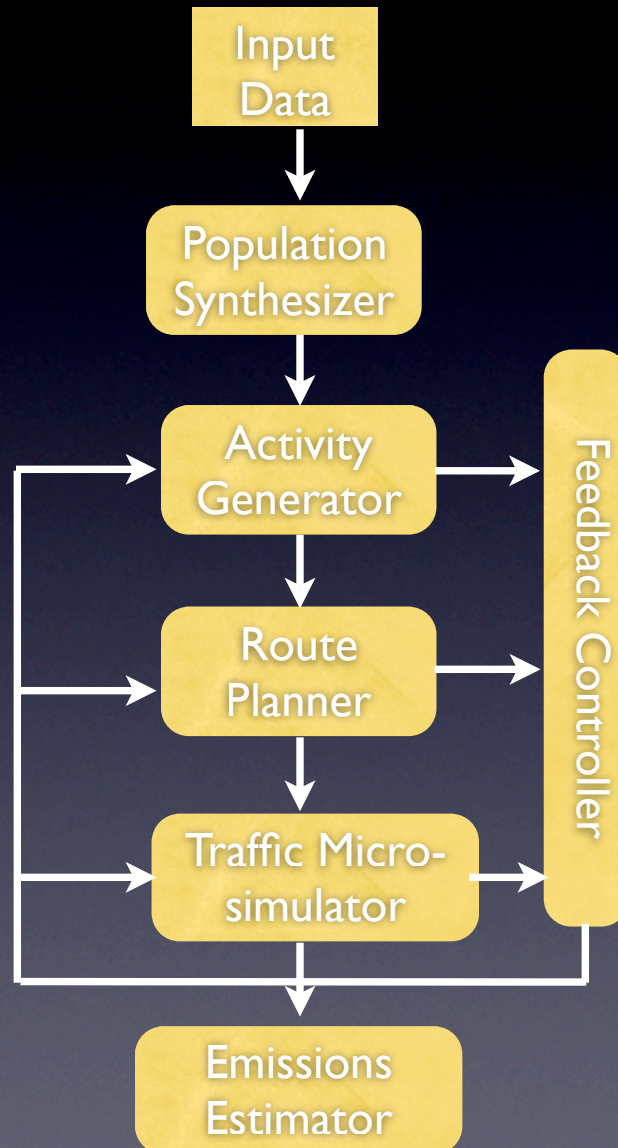
- Goal is to provide planning agencies with a tool to

Handle increased policy sensitivity

Detailed vehicle-emissions estimates

Improved analysis and visualization capabilities

# TRANSIMS Framework



Module	Inputs	Outputs
Population Synthesizer	Census data files, TIGER line files	Synthetic Persons Synthetic Household Vehicles
Activity Generator	Synthetic Population, Household Activity Survey, Network Data	Activities
Route Planner	Activities, Link travel time, Vehicles, Transit Data, Network Data	Traveler Plans
Traffic Micro-simulator	Network data, Vehicles, Transit data, Traveler plans	Traveler Events, Snapshot data, Summary data
Emissions Estimator	Vehicles, Micro-simulation Outputs, External data sets, Network data	Emissions Inventory

# MATSIM

- **M**ulti-**A**gent **T**ransportation **S**IMulation
- Developed by two groups based in Europe

*Transportation Planning* at the Institute for  
Transport Planning and Systems (IVT),  
Swiss Federal Institute of Technology  
Zurich, led by Prof. Dr. Kay W. Axhausen

*Transport Systems Planning and Transport  
Telematics* at the Institute for Land and  
Sea Transport Systems, Technische  
Universität Berlin, led by Prof. Dr. Kai  
Nagel

- Agent- based approach similar to the approach used in TRANSIMS

Was developed since TRANSIMS was difficult to obtain outside the US

- Differences between MATSIM & TRANSIMS

File formats

Handling of agents & activity chains

Faster traffic flow simulation

Traffic assignment routines

# Summarizing

- Activity-based and agent-based models provide a new approach to travel demand modeling
- Both models superior in performance to conventional four-step models
- Much more applicable to evaluating current demand management scenarios such as congestion pricing, parking cost etc.

- However many agencies still use the conventional models for forecasting and scenario evaluation

Data requirements for inputs and calibration

Existing modeling softwares haven't been able to accommodate the model requirements

Many more models to estimate and higher run times compared to traditional model

Staff skills and comfort level

The list goes on....

# U of M research on Agent-based models

- MATSIM & TRANSIM utilize the theory behind agent-based demand models

Similar to activity-based demand models, activities are the unit of analysis

Analysis is conducted at the individual/agent level all the way through assignment

But they still use some aspects of traditional models - for example, TRANSIMS uses the shortest path algorithm

# Agent-based route choice models

Zhang & Levinson (2004); Zhu & Levinson (2007)

Goal was to develop a route choice model utilizing the behavioral framework of individuals

Agents defined in the model

- Traveler
- Node
- Arc or link

- Traveler Characteristics

Value of time: influence route choice decision

Travel budget: decide job location choice

Knowledge: learn both through experience and from node, spread along travel route

- Node Characteristics

Number of jobs: available position for traveler to compete

Knowledge: pooled knowledge from visiting travelers

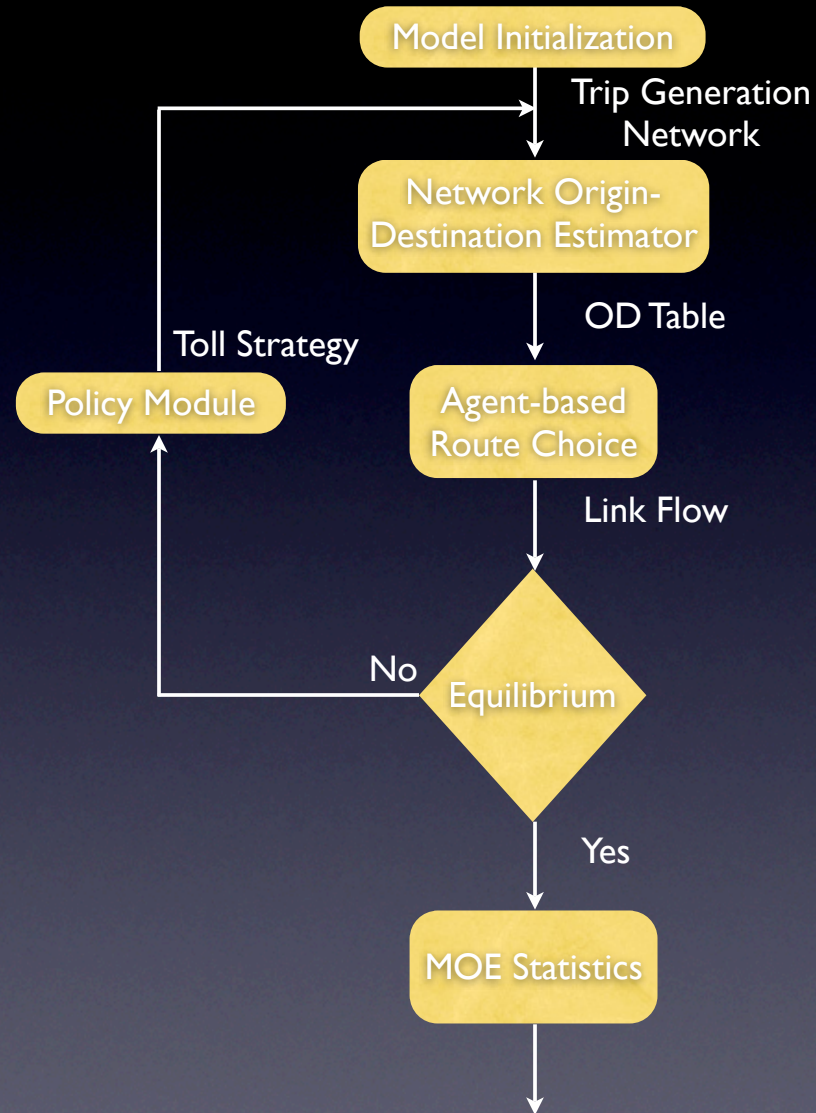
- Rules

Travelers form knowledge and exchange this knowledge through nodes

Travelers choose route with bounded rationale

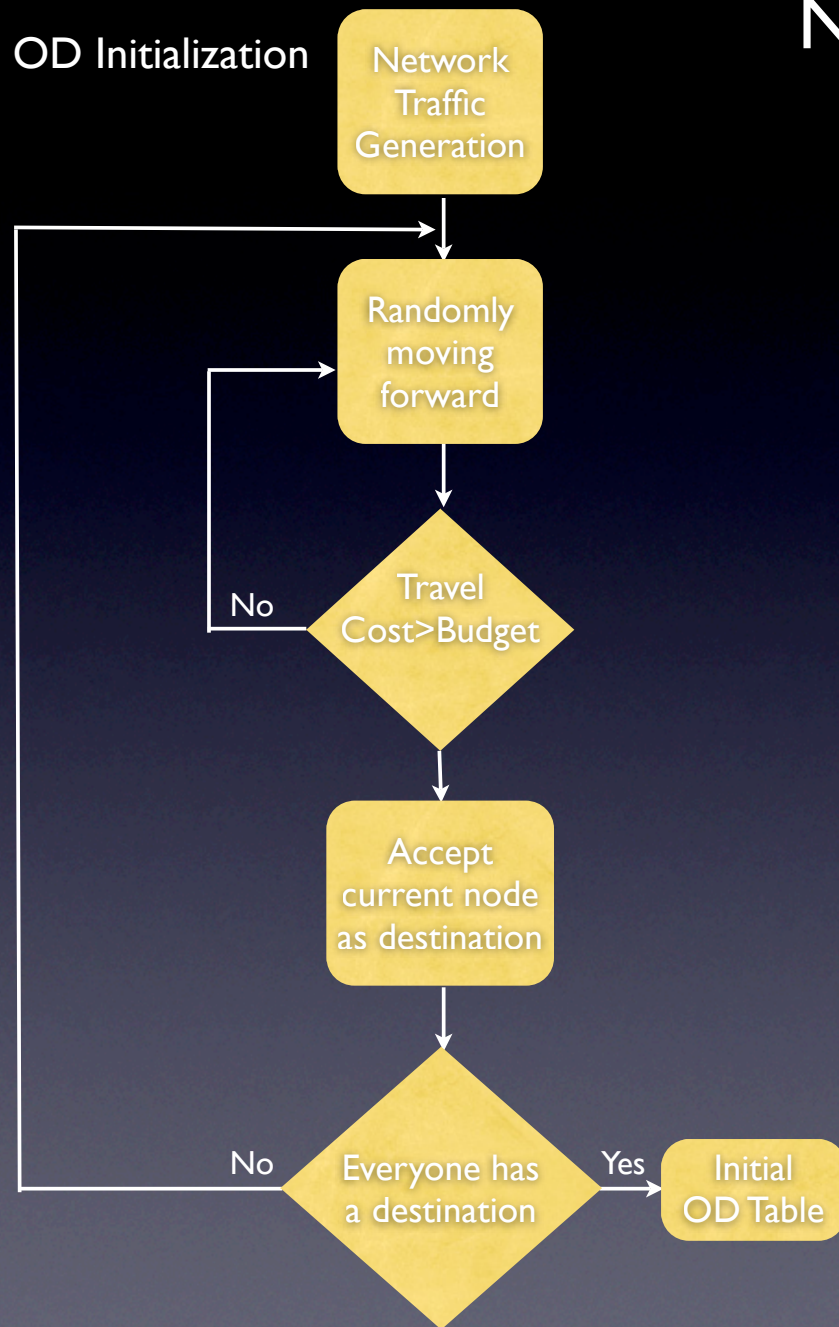
Travelers change job location once they suffer losses and their ability to move is limited

# Model Framework

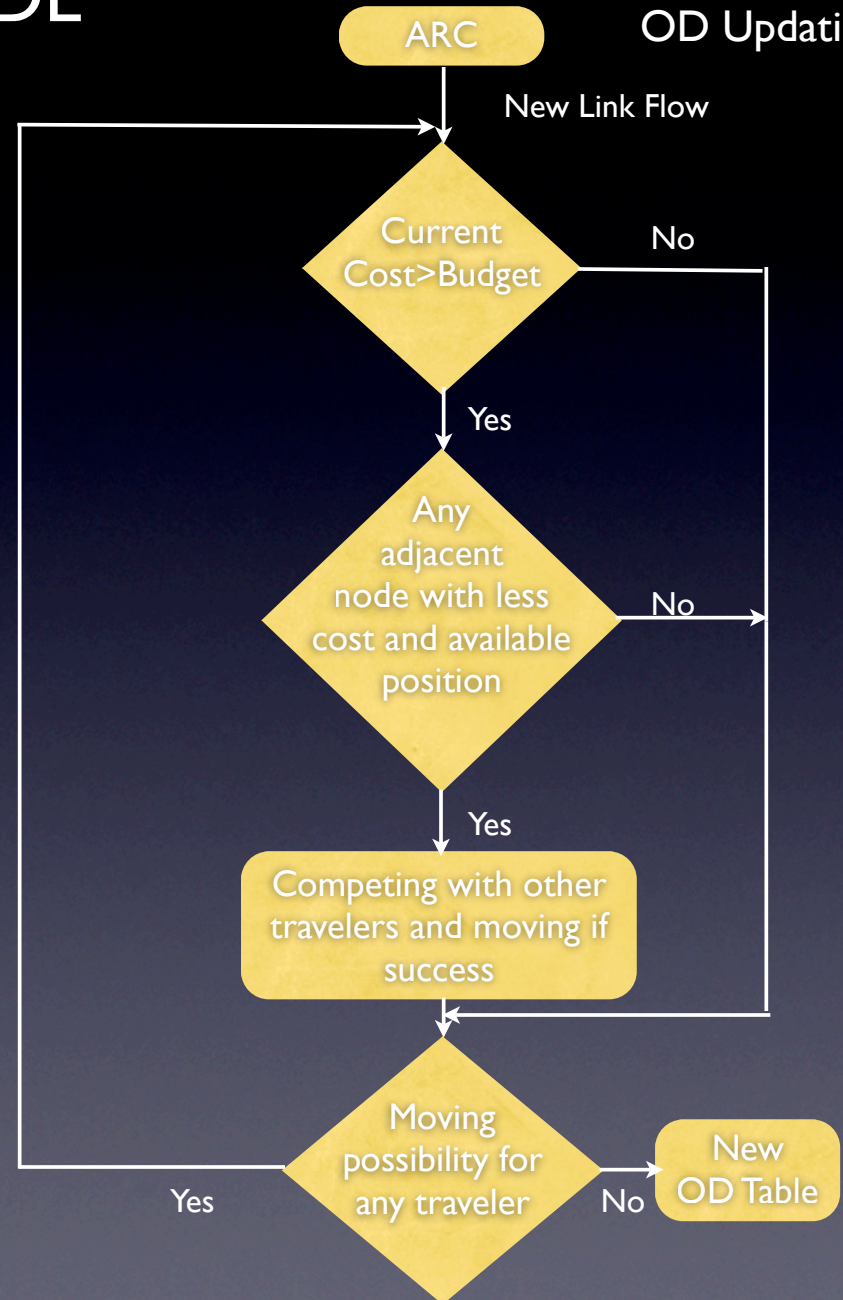


# NODE

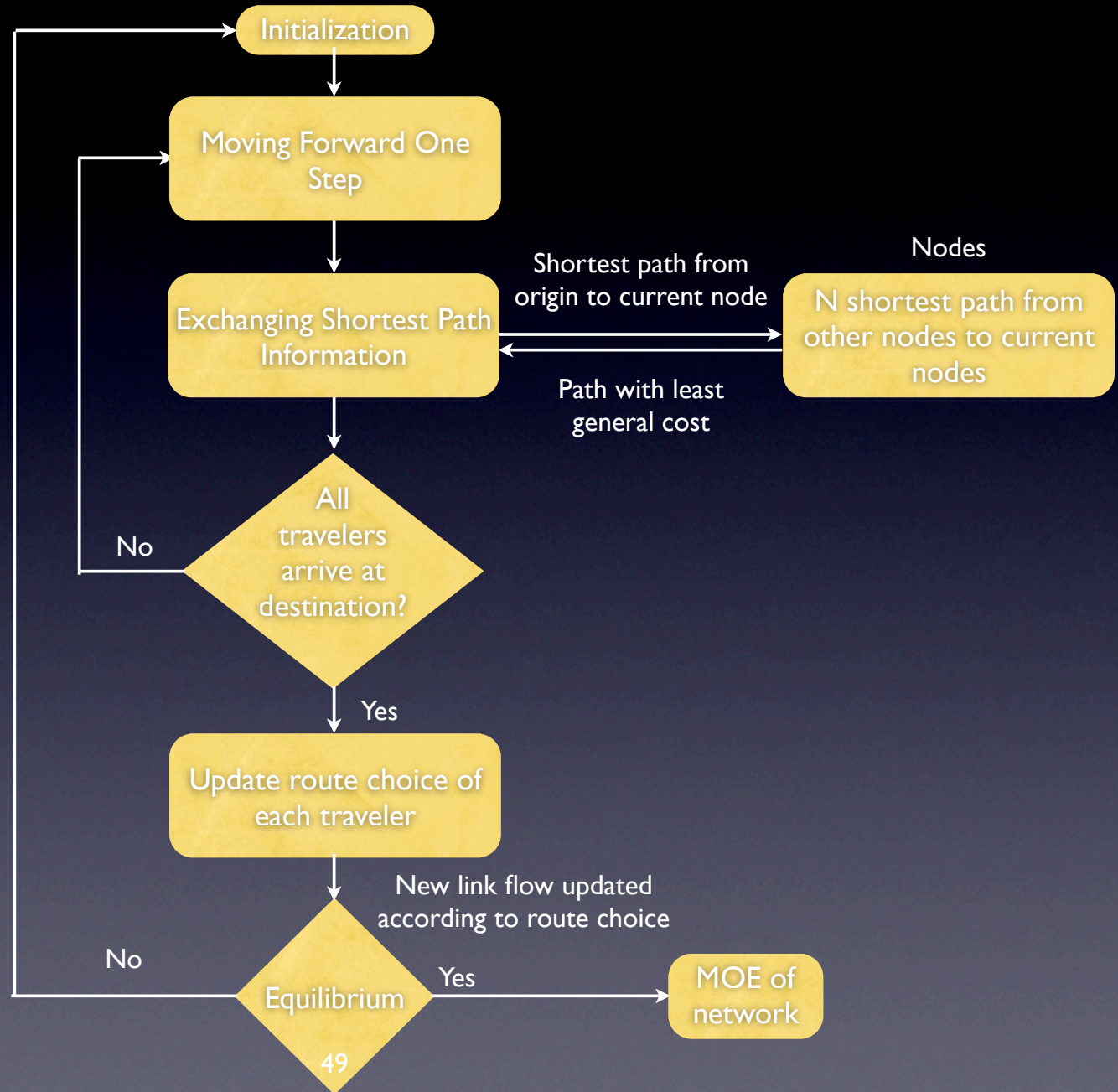
## OD Initialization



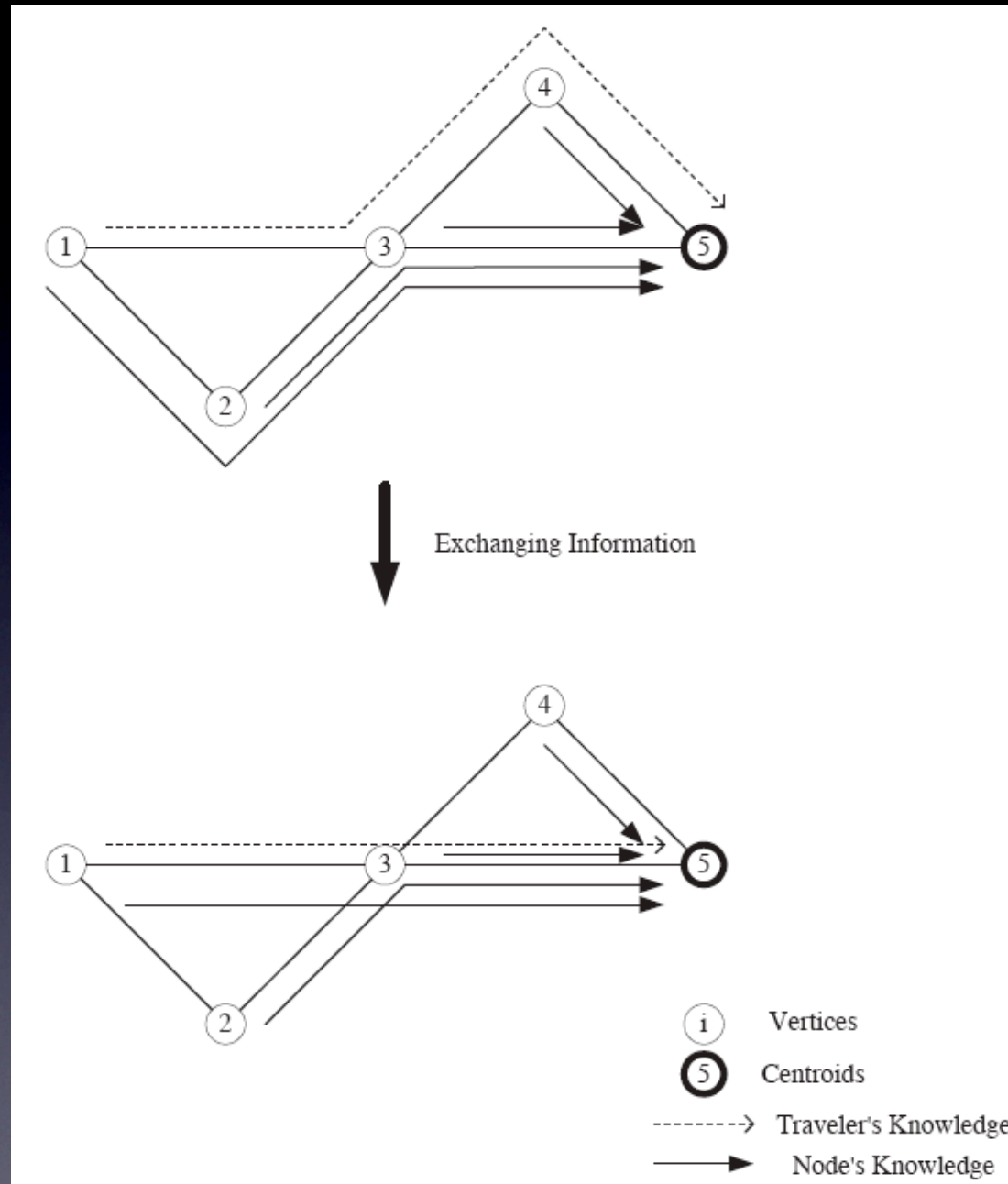
## OD Updating



# ARC



# Information Exchange



# Model Application

- Chicago Sketch Network

387 centroids

933 nodes

2950 links

1.13 million traveler agents

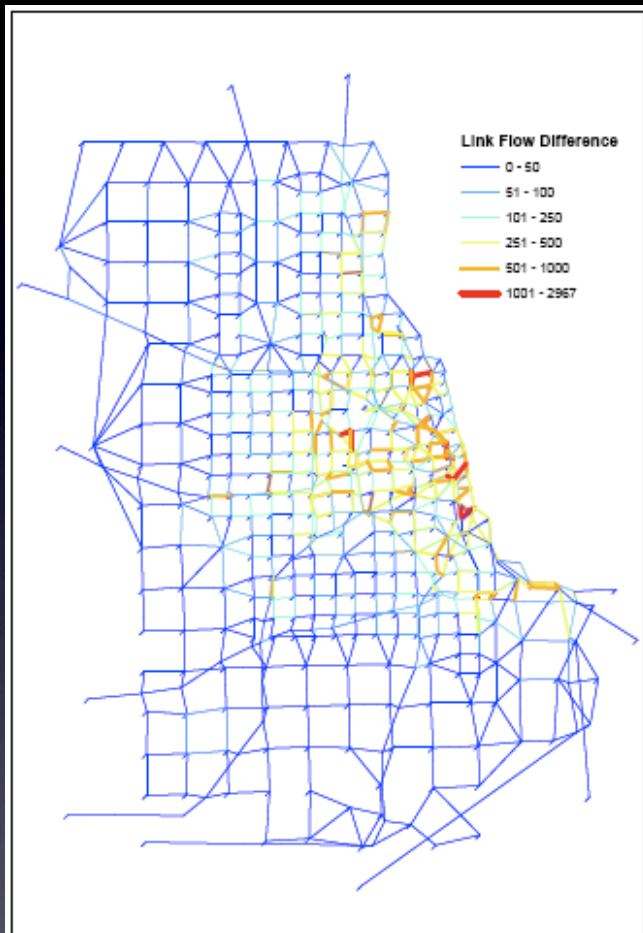


Figure 4: Error in Link Flow between ARC and OBA assignment on CHS

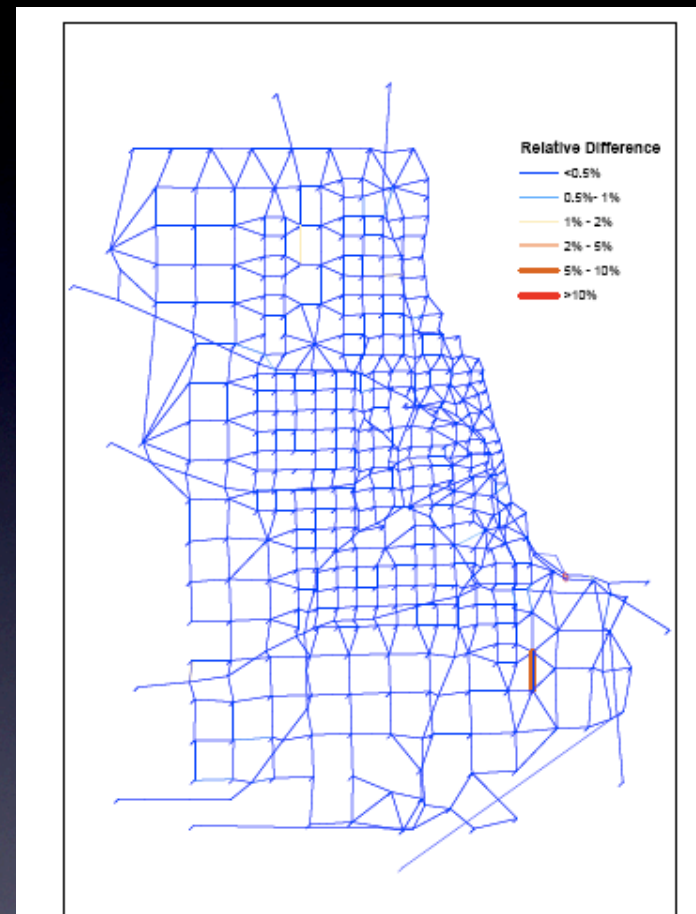


Figure 5: Relative Error in Link Flow between ARC and OBA assignment on CHS

# Conclusions

- The agent-based route choice model simulates how individuals make route choice decisions
- Incorporates the behavioral framework of individuals considering the acquisition and processing of spatial information
- Model seems realistic even when applied to large networks

- Biggest advantage over traditional model
  - Ability to track the evolutionary decisions of travelers
- Accounts for heterogeneity in travelers
  - Allows for evaluation of policy measures such as congestion pricing (tolls)

# Extra Slides

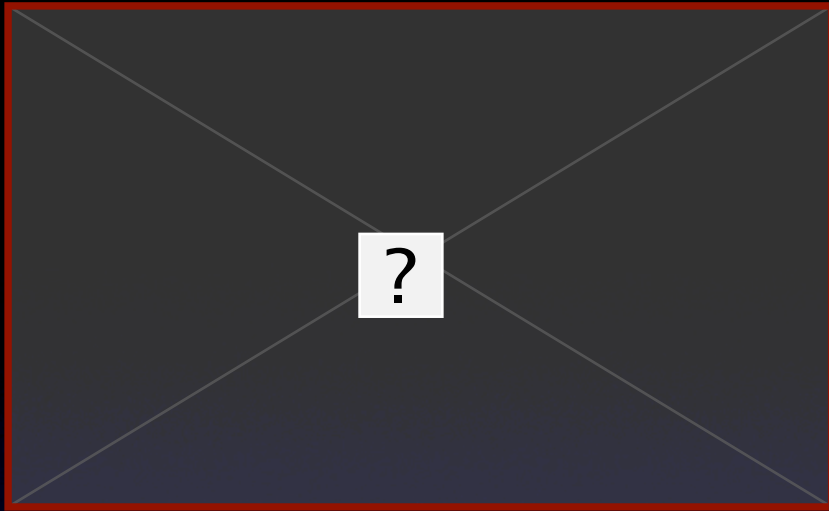


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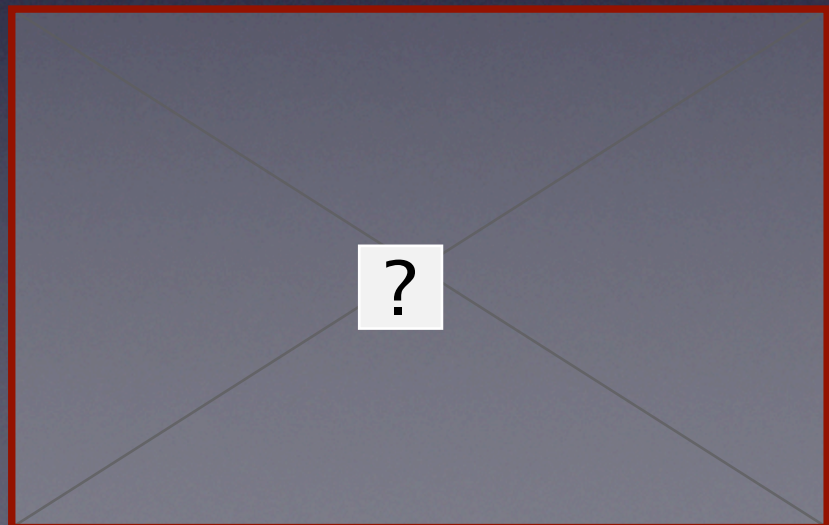
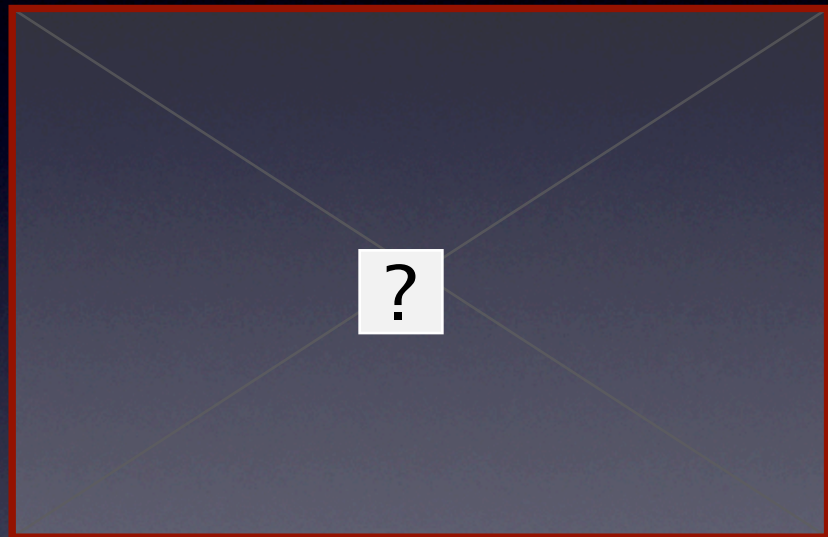
Assignment from  
a conventional 4-  
step model



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Assignment outputs  
from TRANSIMS



# Activity-based Modeling Approach

- Disaggregate analysis usually at individual level

Generation of representative population

- Output - simulated daily travel itinerary

Individual's activities

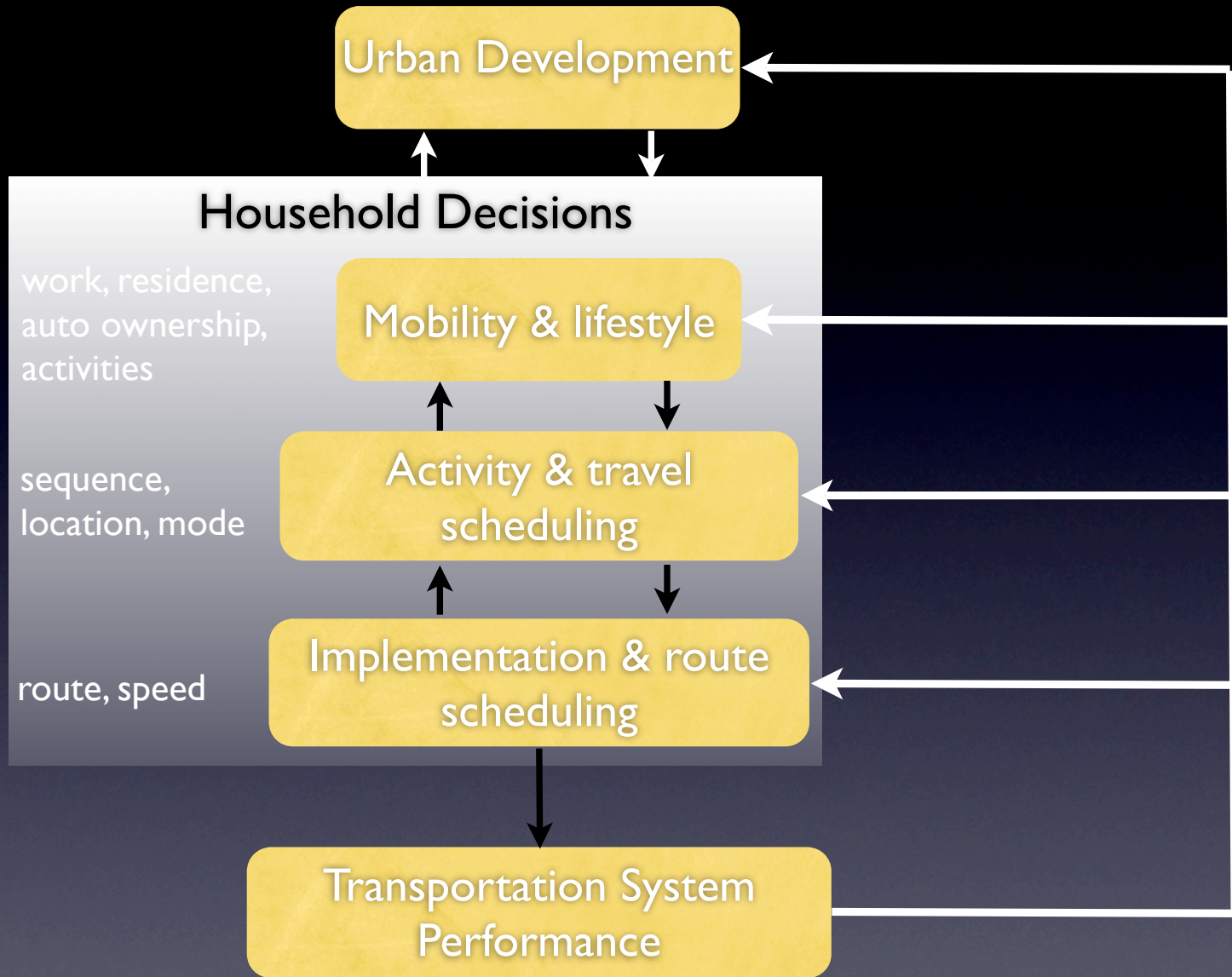
Location

Sequence

Travel between activities

- Trips then aggregated typically to zonal level (Monte-Carlo procedure)
- Zonal level trips then assigned to the network

# ACTIVITY & TRAVEL DECISION FRAMEWORK



Source: Ben-Akiva

