



# Dynamic Microsimulation: UrbanSim

Webinar 5 of an 8-part TMIP  
Webinar series on land use  
forecasting methods.

# Land Use Forecasting Webinar Series

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1. The Evolving State of the Practice
2. Land Use Theory and Data
3. Scenario Planning and Visioning (I-PLACE3S)
4. Spatial Input-Output Frameworks (PECAS)
- 5. Dynamic Microsimulation (UrbanSim)**
6. Modeling Real Estate Demand
7. Modeling Real Estate Supply
8. Scenario Planning and Visualization

# **1. UrbanSim Overview**

- a. Background**
- b. Theoretical Basis**
- c. Software Implementation**
- d. Data Inputs and Outputs**
- 2. Anatomy of the Model**
- 3. Application in Practice**
- 4. Assessment**

# UrbanSim Background

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- UrbanSim is a model system to support land use, transportation and environmental planning
- Licensed as an Open Source software system, and is freely downloadable from the project website ([www.urbansim.org](http://www.urbansim.org))
- Designed by Dr. Paul Waddell, University of California Berkeley
- Developed with numerous collaborators
- It is a full microsimulation model system: simulates choices of millions of agents: households, businesses, developers
- Funded mainly by NSF, with additional grants from EPA, FHWA, state and local governments, and the European Research Council
- Recent surveys show that UrbanSim has become the most widely used land use model system by planning agencies in US

# Selected UrbanSim Applications

(Completed or In Progress)

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## United States:

- Detroit, MI
- Durham, NC
- Eugene-Springfield, OR
- Honolulu, HI
- Houston, TX
- Phoenix, AZ
- Salt Lake City, UT
- San Antonio, TX
- San Francisco, CA
- Seattle, WA
- Tucson, AZ
- Decision Theater at ASU

## International:

- Accra
- Amsterdam
- Beijing
- Brussels
- Durban
- Paris
- Rome
- Seoul
- Taipei
- Tel Aviv
- Turin
- Zurich

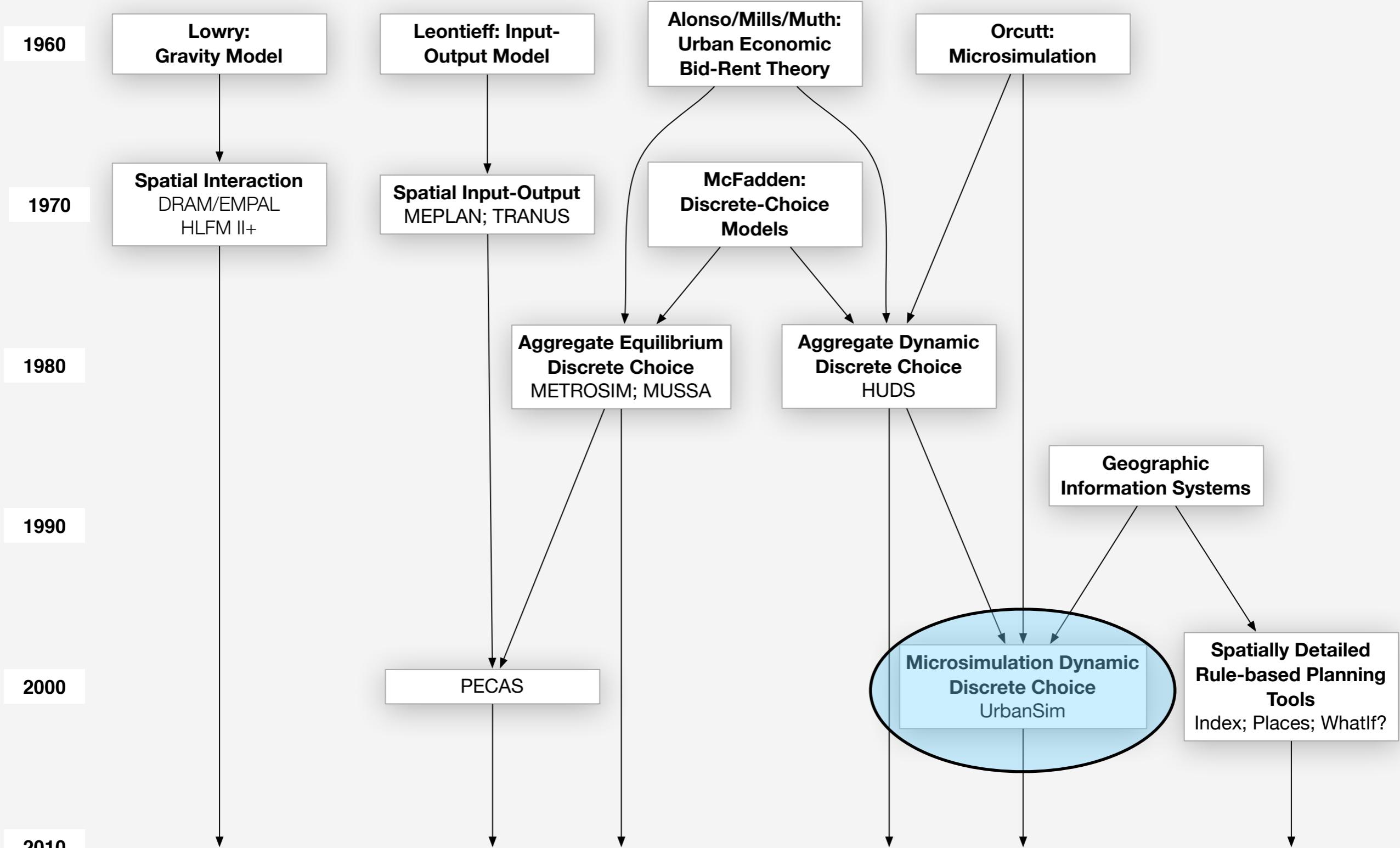
# The State of the Practice: Survey of MPOs in 2010

## Currently Using

	Used in last projection series	Used in last RTP update
<b>PECAS</b>	1	0
<b>OPUS/UrbanSim</b>	3	4
<b>CUBE Land</b>	0	0
<b>Places3</b>	0	0
<b>CommunityViz</b>	0	0
<b>DRAM/EMPAL</b>	5	3
<b>Home Grown</b>	6	5
<b>Other</b>	0	1

MARICOPA ASSOCIATION OF GOVERNMENTS

# Evolution of Land Use Model Frameworks



# Theoretical Basis of UrbanSim

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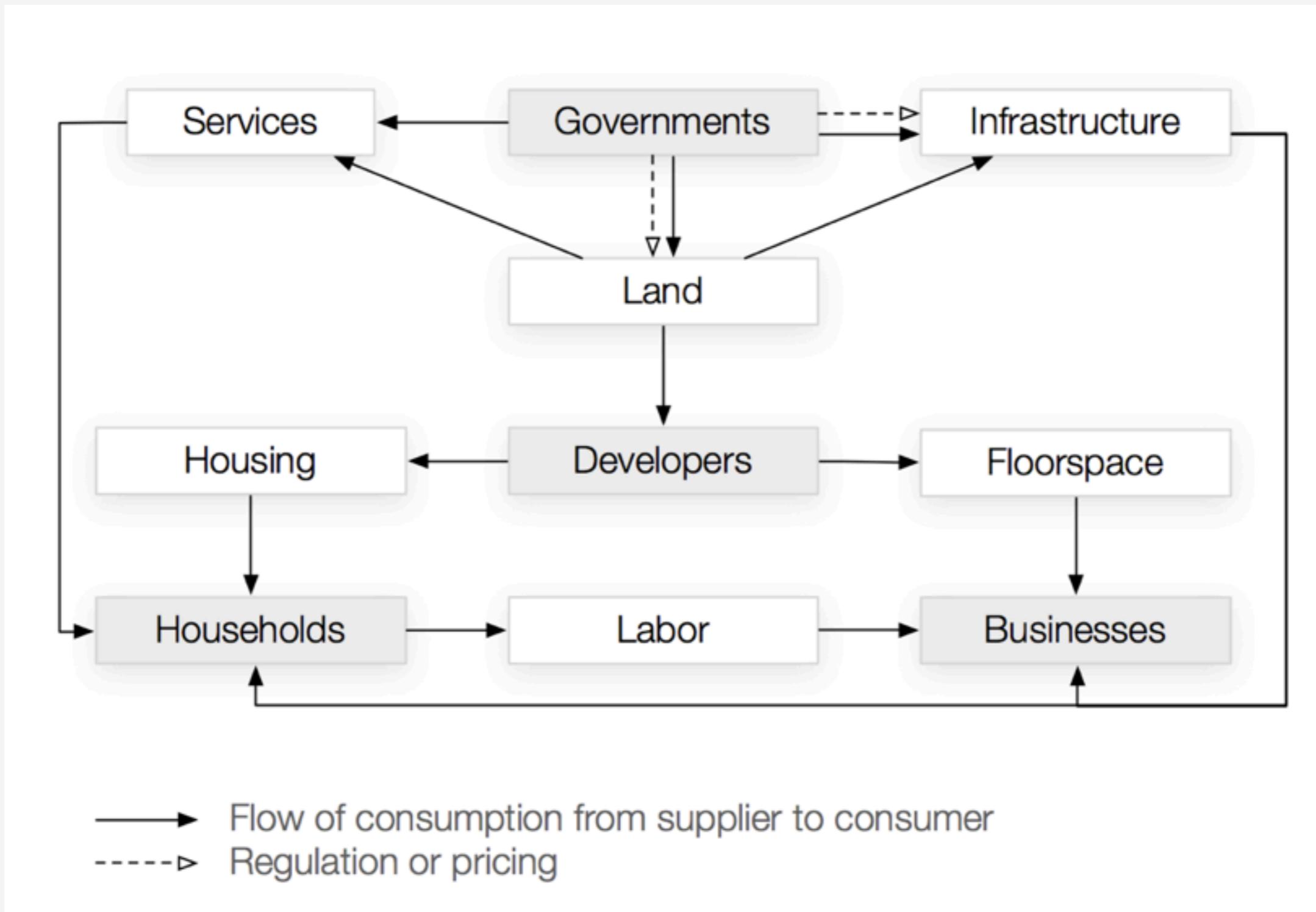
- Random Utility Theory (McFadden)
  - Theoretical basis for discrete choice models (such as mode choice): agents choose among alternatives based on the relative utility of the available options
  - Multinomial and nested logit models, more general forms relaxing the IIA property
- Urban Economics/Bid Rent Theory (Alonso, Mills, Muth)
  - Explains land use outcomes: density, rents, as outcome of bidding process based on willingness to pay for locational amenities: trade-off travel time vs housing cost
- Hedonic Price Theory (Rosen)
  - Observed prices of composite goods like housing can be ‘decomposed’ to the implicit prices of their attributes; widely used to measure the market valuation of locational amenities or disamenities

# Theoretical Basis of UrbanSim

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- Dynamic Market Equilibrium, Price Adjustment, Disequilibrium
  - Markets are rarely in equilibrium; especially real estate due to supply lags and high transactions costs; information is imperfect; speculation can lead to bubbles
  - Current housing market crisis is an excellent example of market disequilibrium
- Microsimulation (Orcutt)
  - Initially a computational framework to explore individual level impacts of policies; later found more computationally efficient than complex aggregate models
  - Strong empirical support for microsimulation to avoid aggregation bias and ecological fallacy (attributing to individuals behavior from aggregate patterns)
- Geographic Information Systems and Spatial Analysis (Tobler, Anselin)
  - Radical advance in spatial analysis capabilities;
  - Representation of walking scale accessibility

# UrbanSim Models Agents Interacting in Urban Markets



# Outcomes and Indicators

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- Land and Development
  - Housing units by type, density, price (affordability)
  - Non-residential buildings by type, density, price
  - Acreage in agricultural land, forest, open space
- Demographics: households by income, size, life cycle
- Economics: employment by sector and building type
- Transportation
  - Accessibility, Mode Shares, Vehicle Miles Traveled, Congestion Delay
- Environment
  - Greenhouse Gas Emissions
  - Pollution
  - Energy Use
  - Water Use

# Policies to Evaluate

(over 1-30 years)

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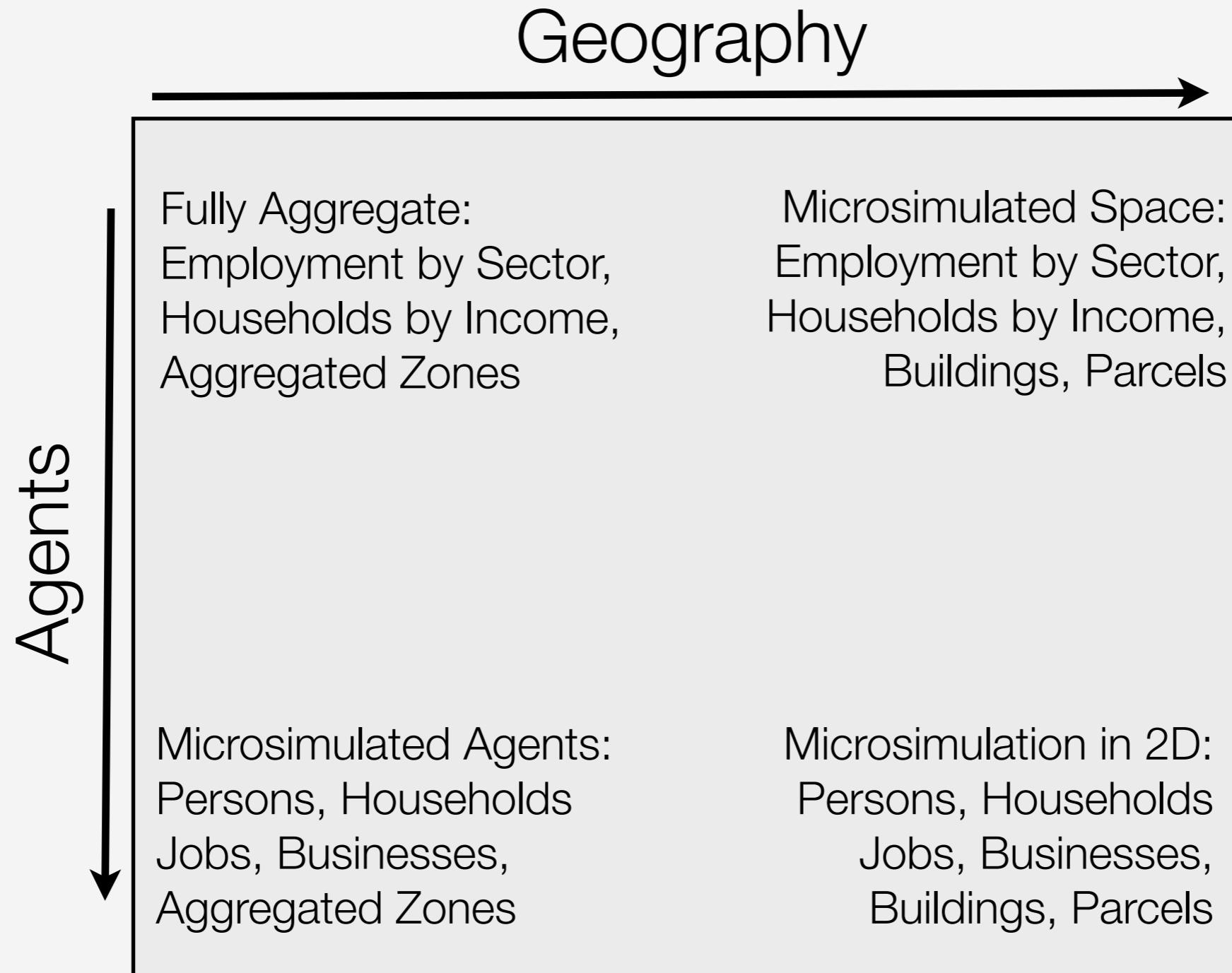
- Transportation
  - Transit investments (Rail, Bus)
  - Roadway investments (GP, HOV, HOT, Bike, Pedestrian)
  - Pricing (Tolls, Congestion)
- Land Use Regulations
  - Comprehensive Plans
  - Transit Oriented Development, Urban Villages & Centers
  - Subsidies, Impact Fees
  - Urban Growth Boundaries
  - Protection of Environmentally-sensitive Areas

# How Much Detail do we need in Integrated Modeling?

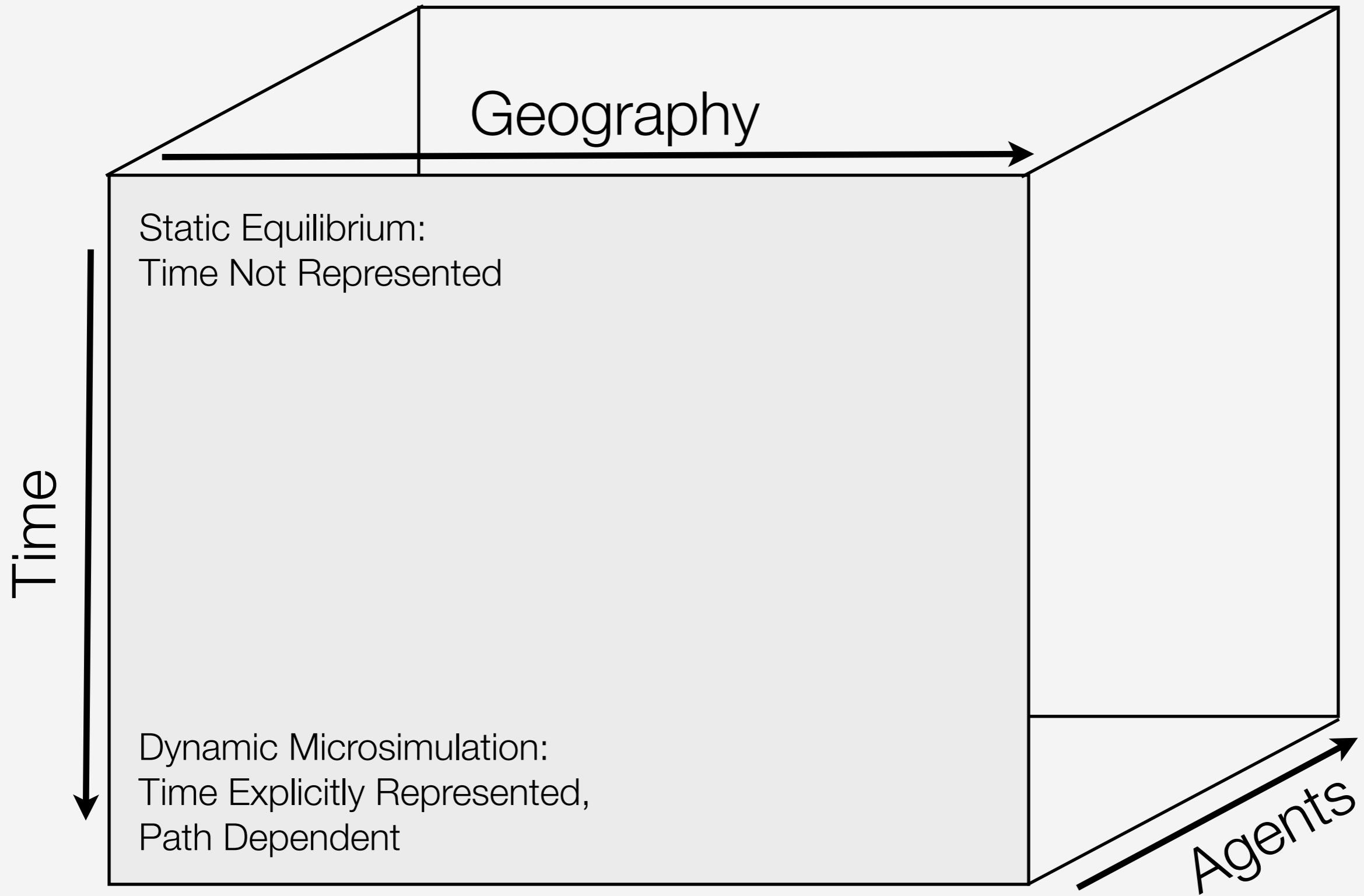
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- How much detail do we need in land use and transportation models in order to achieve models that are unbiased and allow us to assess relevant transportation and land use policies?
  - How small should zones be?
  - Should we use zones at all? What about using parcels, or small gridcells?
  - How much detail do we need in terms of population and employment?
  - Should we use aggregations of households and jobs, or microsimulate?
- Which details are important?
- What biases might our models have if we leave out details?
- What errors might we introduce if we use too much detail?

# Detail in 2 Dimensions



# Detail in 3 Dimensions



# To Microsimulate, or Not to Microsimulate. That is the Question

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- **Traditional urban models have ALL been aggregate**
  - Spatial Interaction Models (e.g. DRAM/EMPAL)
  - Spatial Input-Output Models (TRANUS, MEPLAN, PECAS)
  - Econometric Models (METROSIM, MUSSA)
- **Economic models use a representative agent to motivate model**
- **Urban economics is based on the Monocentric model**
  - Disaggregated at most by industry, households by high vs low income
  - Analytically based models are not tractable with much detail
- **Later, more applied models began disaggregating:**
  - DRAM/EMPAL: households by income quartile, employment by sector
  - TRANUS/MEPLAN/PECAS: use more sectors and household categories
- **Microsimulation models are fundamentally different:**
  - Originated with work of Guy Orcutt, initially for policy analyses like tax incidence
  - Represent individual agents (households, persons, jobs, businesses)
  - Maintain these as lists, and update them as the model progresses

# To Microsimulate, or Not to Microsimulate. That is the Question

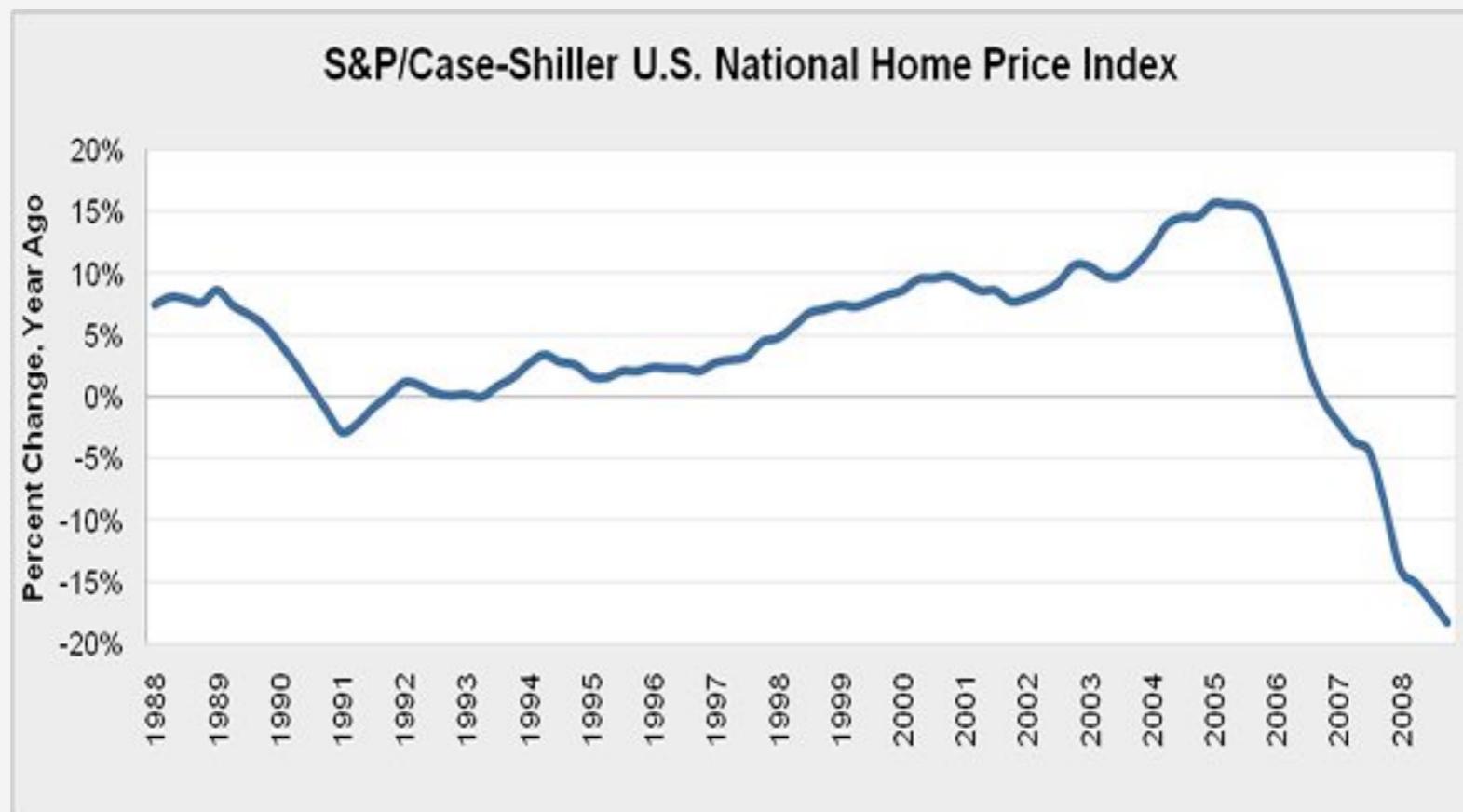
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- **Arguments used in favor of aggregating individual agents:**
  - Data is more compact and easy to use (when small numbers of types used)
  - Leads to simpler models (depends on model logic: can be very complex / black box)
  - Models run faster (this is debatable and depends on complexity and implementation)
  - Less prediction error due to aggregation (this is an empirical question)
- **Arguments used in favor of microsimulating individual agents:**
  - Data are more natural to understand and work with since they represent real agents
  - Models can be more transparent in their logic: agents make choices
  - Models can be designed to run at least as fast as aggregate models (especially aggregate models with many categories of agents and outcomes)
  - Avoids Ecological Fallacy: a common error in social science research, where individual behavior is inferred from aggregate data
  - Model parameters are less likely to be biased
- **Applied land use modeling is moving towards microsimulation of agents**

# Interaction of Real Estate Demand and Supply

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- Demand is elastic in the short run
- Supply is inelastic in the short run
- Change in demand signals supply response, but time lags and constraints may create sustained disequilibrium
- Can you find the evidence for equilibrium in this graph?



# Time is of the Essence

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- **Urban models have generally ignored time**
  - Time-abstract models use a notion of static equilibrium from economics
  - We assume that a city-region is in equilibrium, perturb the equilibrium, and observe a new static equilibrium
  - Attractive for theoretical analysis since it follows from initial assumptions and provides consistent answers every time (at least this is a goal)
- **Recent models have begun to represent time explicitly**
  - Empirical observation suggests that markets may often be in sustained disequilibrium: subprime mortgage crisis and subsequent global recession
  - Increasingly common to represent annual time steps reflecting differing response times in real estate supply, intra-year changes in household location, business location, prices
  - Path dependence is a feature of this kind of modeling: changes today have implications for later choices (developers go bankrupt because of imperfect foresight)
- **Applied land use modeling is moving towards explicitly representing time, with path dependence and dynamic adjustment rather than static equilibrium**

# Location, Location, Location

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- **Most common arguments in favor of using zones vs parcels are:**
  - Less data requirements
  - Easier to develop
  - Easier to diagnose
- **Most common arguments against using zones:**
  - Modifiable Aerial Unit Problem (MAUP): model results depend heavily on configuration of zones; parameters sensitive to zone configuration
  - Ecological Fallacy: easy to fall into a classic mistake in social science research: inferring individual behavior from aggregate data
  - Walking scale is below the radar: may bias models with respect to intra-zonal trips, non-motorized trips, transit trips (with walk access); this is compounded by using travel networks that exclude local streets

# Location, Location, Location

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- **Most common arguments in favor of using parcels vs zones are:**
  - Data is becoming more readily available from tax assessors and commercial sources
  - Parcels are real: they are the unit of land that is owned, subdivided, and developed
  - Easier to interface local jurisdictions plans and zoning with regional plans
- **Most common arguments against using parcels:**
  - Messy data
  - Large data storage and processing
  - Messy data
  - Difficult to standardize across jurisdictions
  - Messy data
  - Can take 2+ years to make parcel-level data useful for modeling using generally available data techniques
- **Applied land use modeling is moving towards using parcels, but with increasing interest in spatial hierarchies: e.g. neighborhood then parcel**

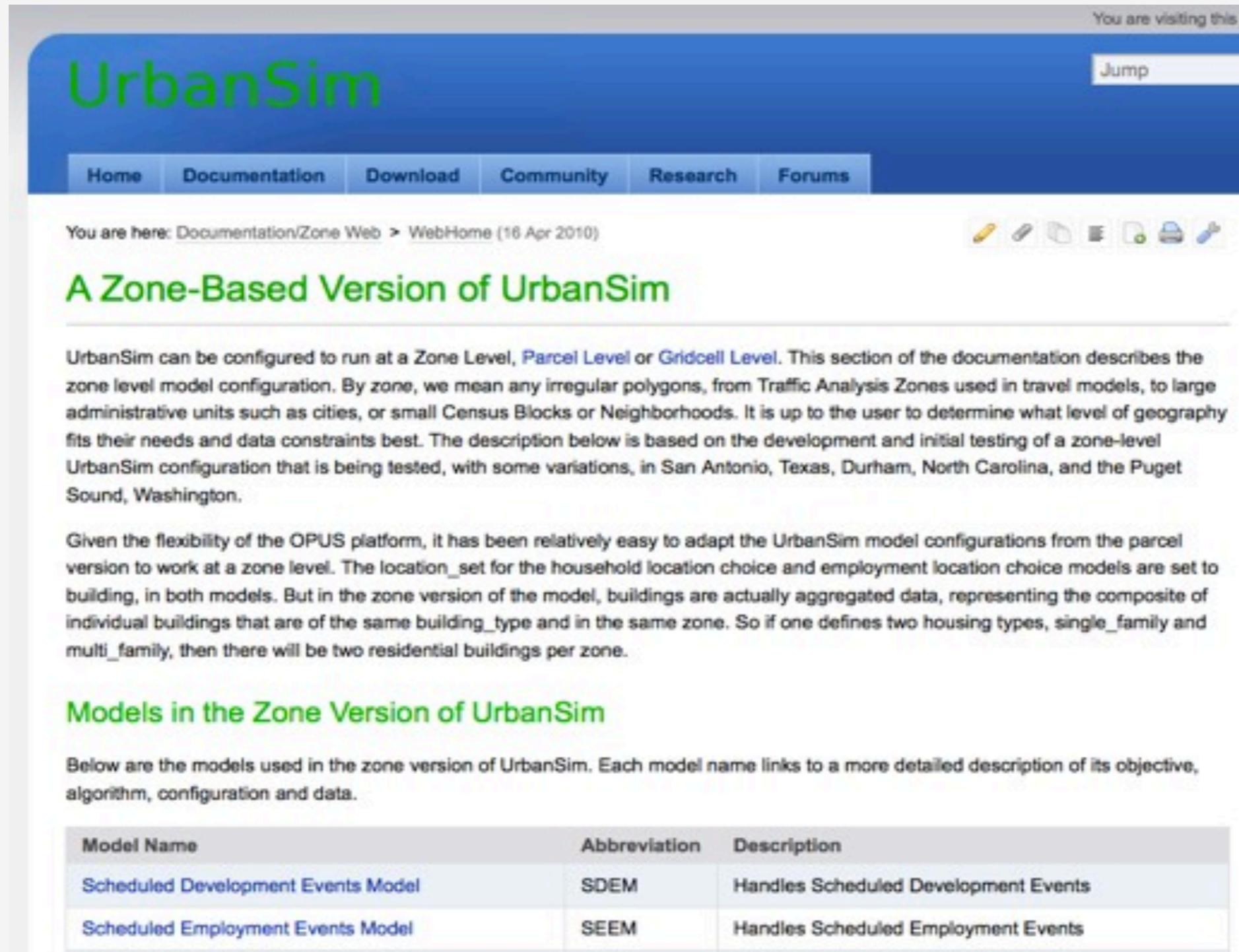
# UrbanSim Software Implementation

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- **Open Source**, freely available for download from [www.urbansim.org](http://www.urbansim.org)
- **Programming Language**:
  - Initial version was coded in Java; later migrated to Python for speed and productivity
  - Python, an easy to learn high level language; de facto scripting language for ArcGIS
  - Extensions for high-speed numerical processing: Numpy, Scipy
- **Integrated model estimation**
  - Multinomial and Nested Logit, using Maximum Likelihood Estimation
  - Multiple Regression
  - Bayesian Model Averaging
- **Graphical User Interface** using Qt4 with Python bindings
- **Database interfaces** to multiple database platforms transparently
  - MySQL, Postgres, SQLite, MS SQL Server

# Web Site for UrbanSim Download and Documentation

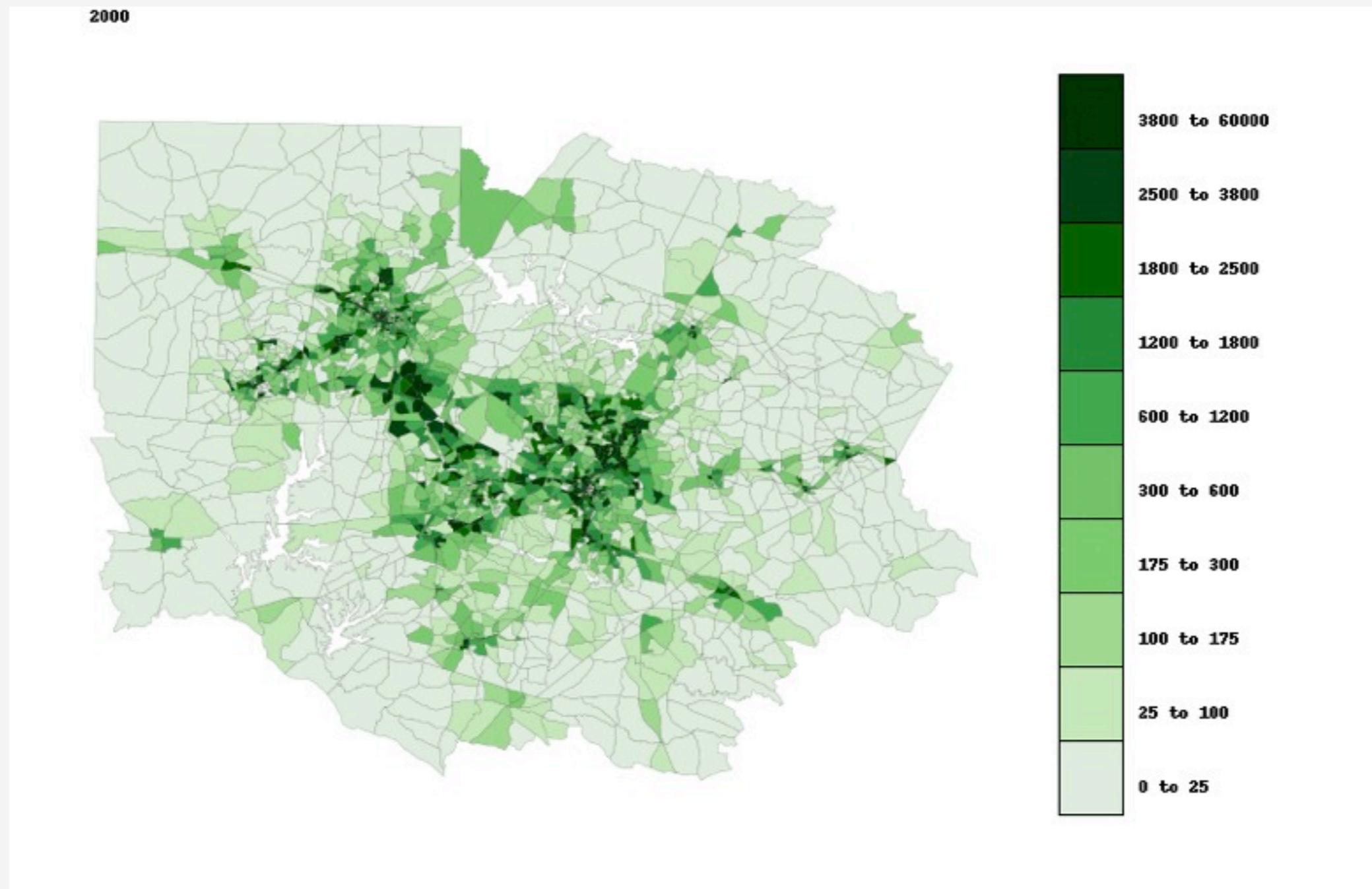
www.urbansim.org



The screenshot shows the UrbanSim website with a blue header bar. The header includes the UrbanSim logo, a 'Jump' menu, and a navigation menu with links to Home, Documentation, Download, Community, Research, and Forums. Below the header, a breadcrumb trail shows 'You are here: Documentation/Zone Web > WebHome (16 Apr 2010)'. To the right of the breadcrumb trail are several small icons. The main content area has a green header 'A Zone-Based Version of UrbanSim'. The text describes the zone-level model configuration, mentioning zones as irregular polygons, cities, and neighborhoods. It notes the flexibility of the OPUS platform to adapt from a parcel level to a zone level, specifically mentioning the location\_set for household and employment choice models being set to building level in the parcel version but aggregated data in the zone version. The text also describes the composite of individual buildings of the same type within a zone. Below this, a section titled 'Models in the Zone Version of UrbanSim' lists two models: the Scheduled Development Events Model (SDEM) and the Scheduled Employment Events Model (SEEM), each with a brief description.

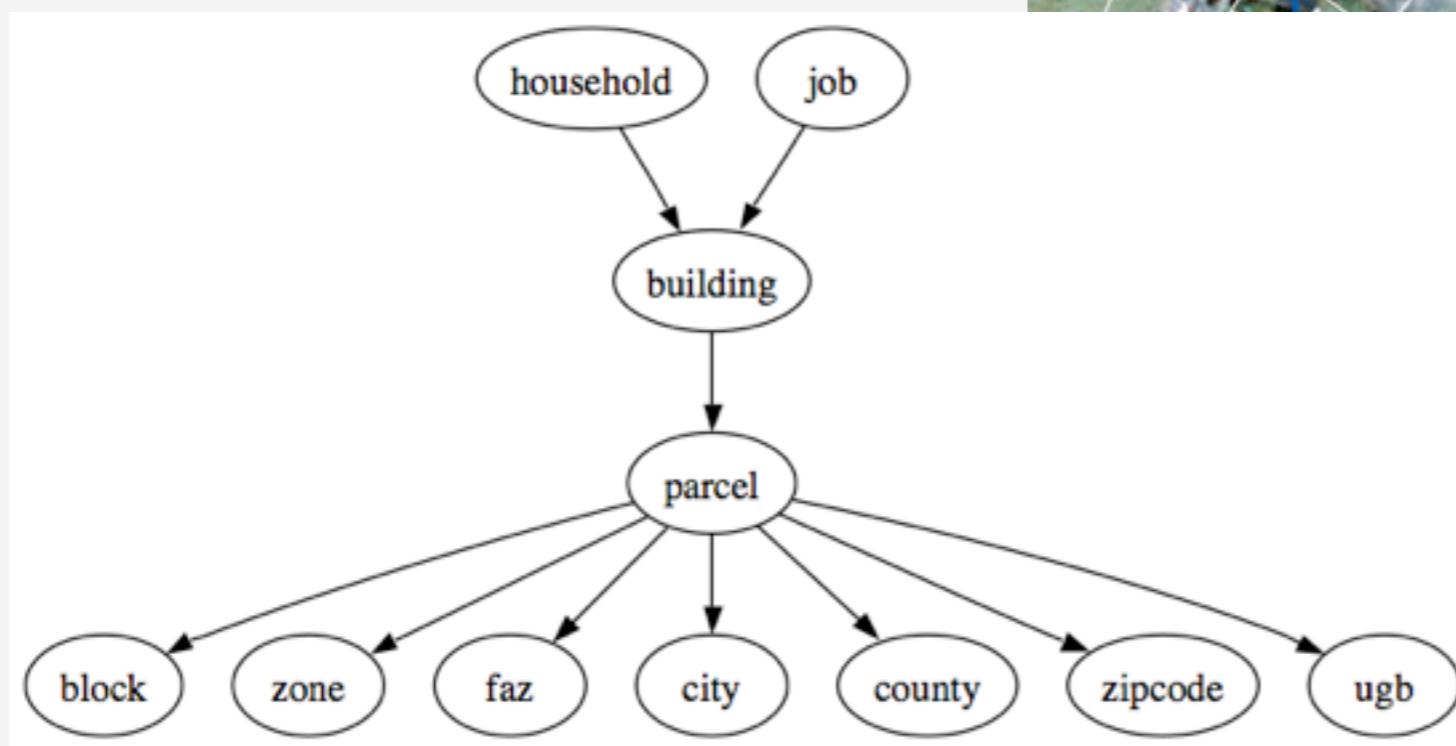
Model Name	Abbreviation	Description
Scheduled Development Events Model	SDEM	Handles Scheduled Development Events
Scheduled Employment Events Model	SEEM	Handles Scheduled Employment Events

# UrbanSim Maps and Animated Maps of Indicators



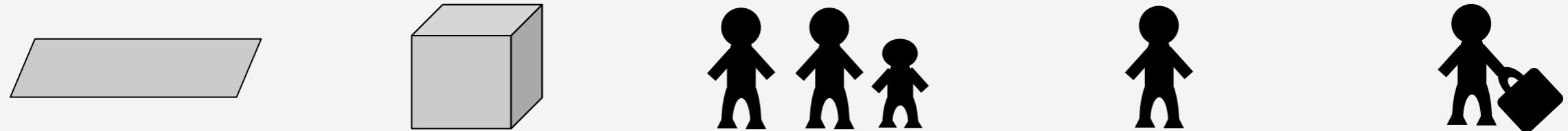
Maps and Animated Maps produced Using OPUS GUI

# Model System Based on Parcels and Buildings



# Primary UrbanSim Databases for Microsimulation

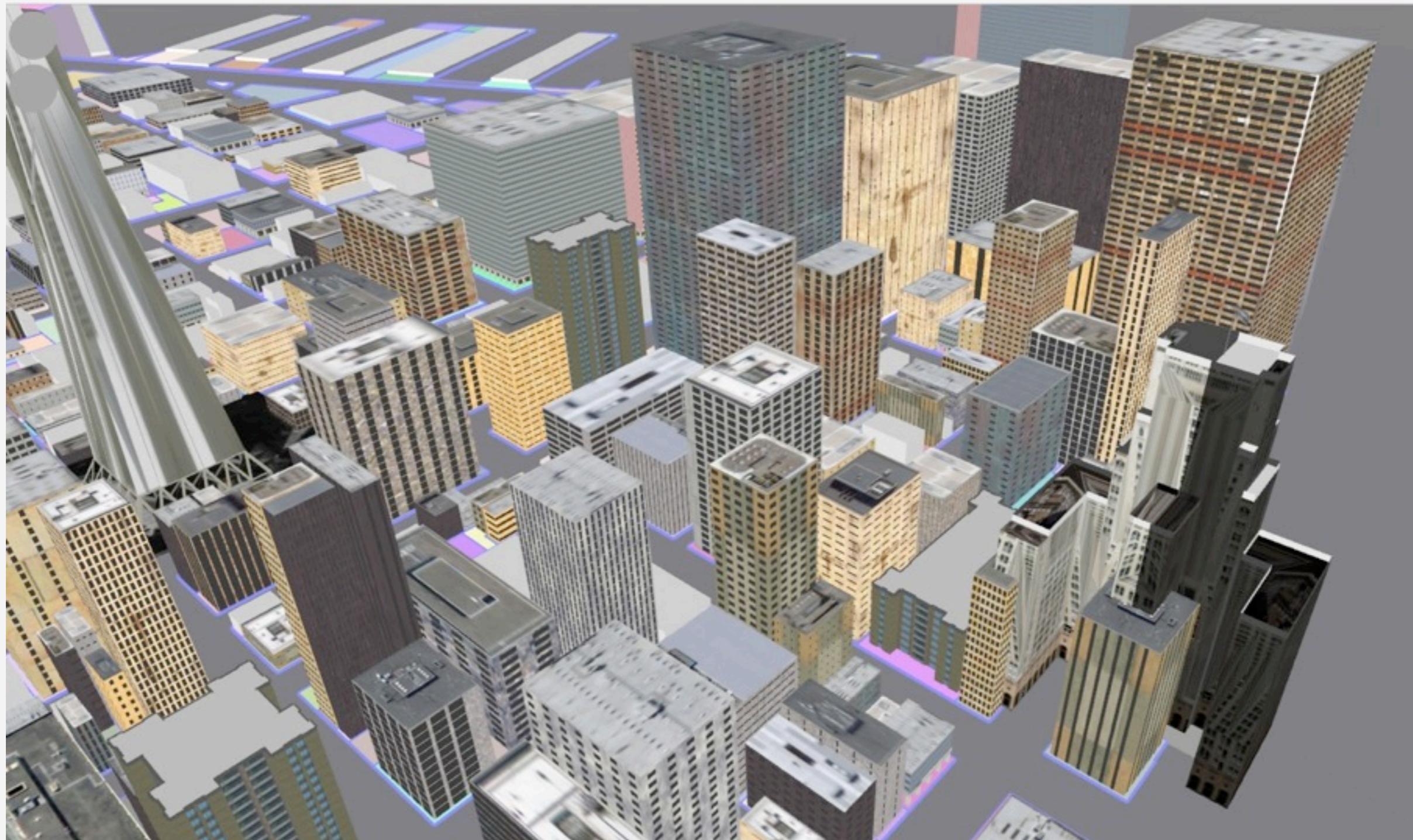
Primary inputs and outputs



<b>Parcels</b>	<b>Buildings</b>	<b>Households</b>	<b>Persons</b>	<b>Jobs</b>
Parcel id	Building id	Household id	Person id	Job id
Zones, cities, zip code, etc.	Parcel id	Building id	Household id / Job id (if worker)	Building id
1.18 million parcels	1.0 million buildings	1.28 million households	3.2 million people	1.85 million jobs

Counts are from Puget Sound model application

# Initial Work on UrbanSim 3D Visualization: UrbanVision

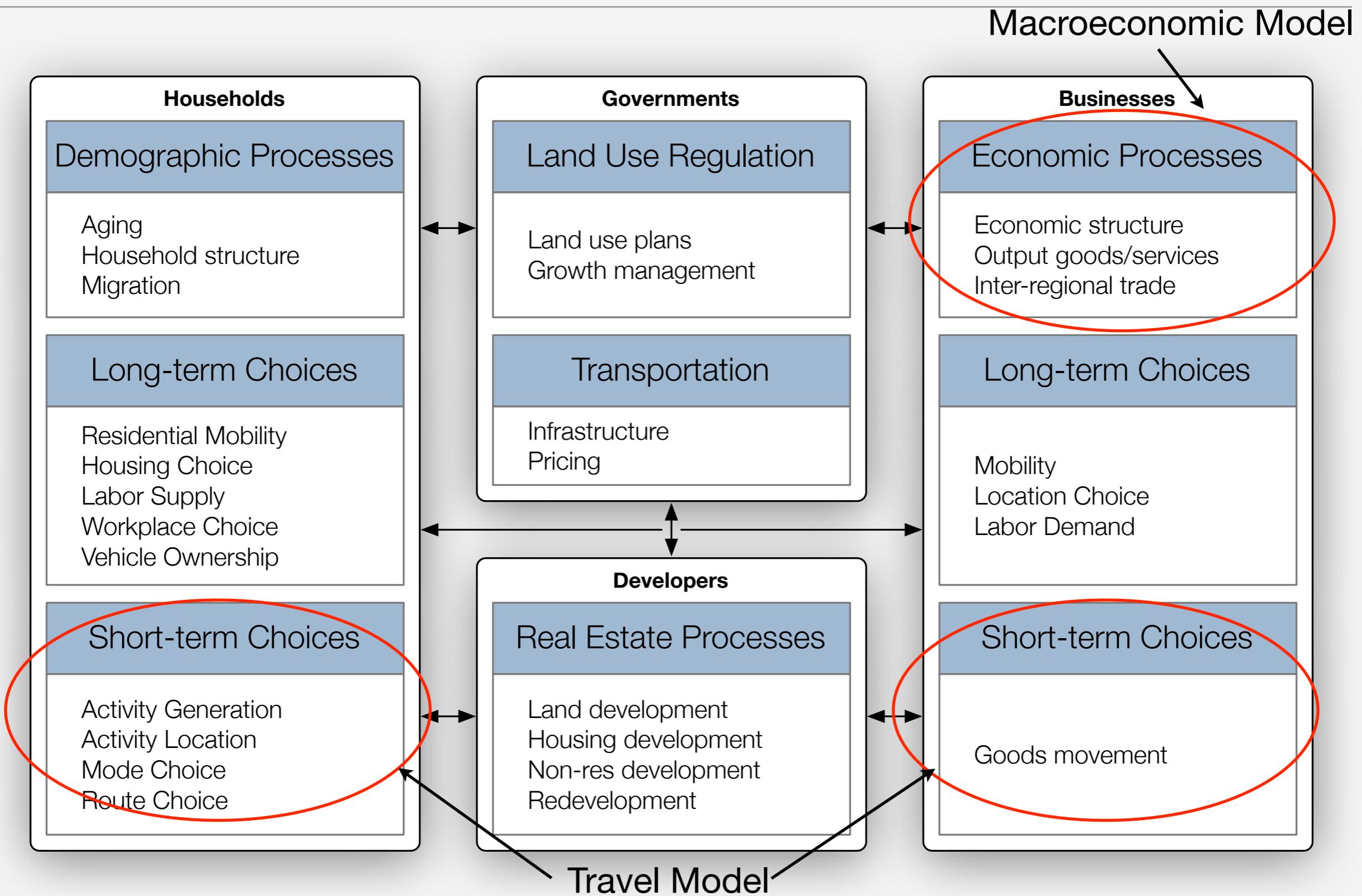


1. UrbanSim Overview

## **2. Anatomy of the System**

- a. Model Design
  - b. Software Architecture
  - c. Implementation Process
  - d. Geographic Configuration
  - e. Estimation, Calibration and Validation
3. Application in Practice
  4. Assessment

# UrbanSim Integrated Microsimulation Implementation



# Software Architecture for UrbanSim: The Open Platform for Urban Simulation (OPUS)

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Opus Core

Python

Opus Packages

Python

External Libraries

C/C++

# Opus External Libraries

## (C/C++ with Python Interface)

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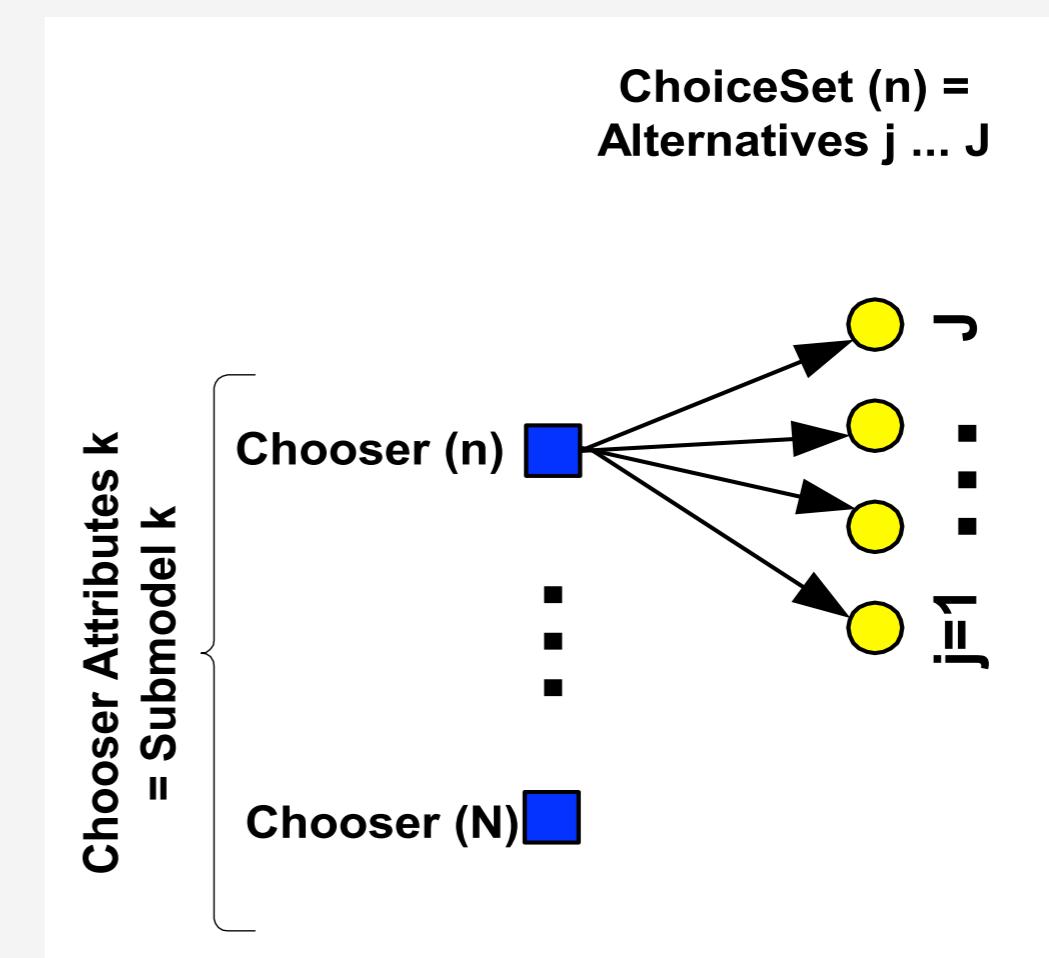
Statistical and Numeric	Data Management and GIS	Travel Models
Biogeme	MySQL	Emme
R	Postgres	Transcad
Numpy	PostGIS	VISUM
Scipy	ArcGIS	MATSIM
BLAS	QGIS	MALTA
Lapack	GDAL	AMOS

Packages in Bold have already been interfaced to Opus, remainder in progress

# Software Architecture for UrbanSim: Modular Choice Models

- Agents making a choice must be selected to begin the process:
  - Households making residence location choices
  - Businesses locating jobs
  - Persons choosing shopping destinations
- Agents may be stratified by type in order to estimate separate models
  - Households by income group, or number of persons
  - Businesses by industrial sector
- Choice set of feasible alternatives for each agent must be constructed

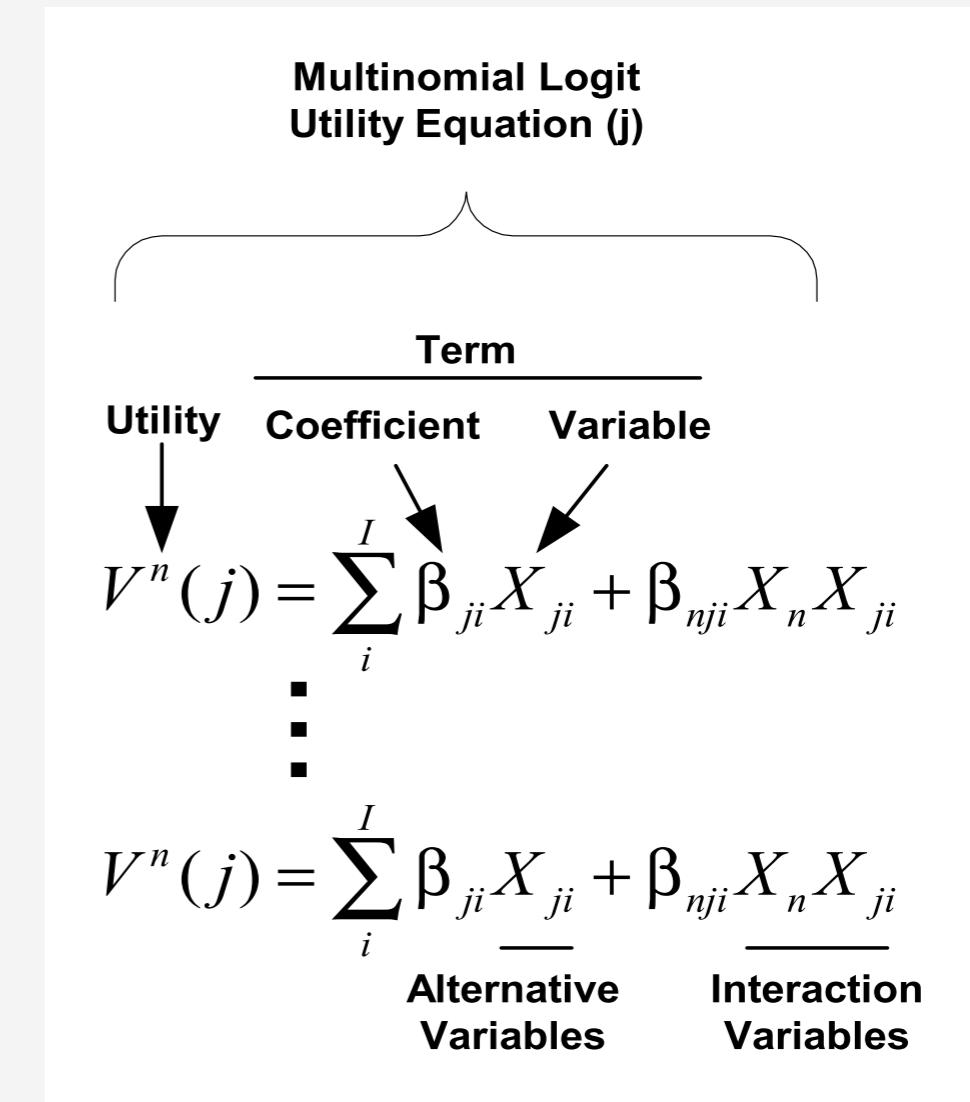
## Step1: Set Up Agents, Choice Sets



# Software Architecture for UrbanSim: Modular Choice Models

- Choice outcomes are based on comparing relative utility of the available options
- Utility has systematic component and a random component
- Systematic component is modeled as a linear function of:
  - Characteristics of alternatives
  - Characteristics of choosers interacted with characteristics of alternatives
- Random component (error) assumed to have a Gumbel distribution: multinomial logit model

## Step 2: Compute Utilities

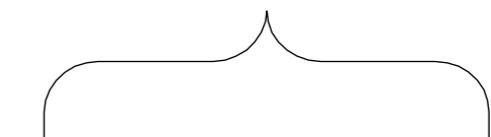


# Software Architecture for UrbanSim: Modular Choice Models

- Given utilities, compute probabilities of making a choice
- Multinomial Logit Model (MNL) has several nice properties:
  - Closed form, easy to compute
  - Probabilities sum to 1
  - Independence of Irrelevant Alternatives (IIA) allows consistent estimation using sample of alternatives
- But IIA also has a downside:
  - Correlation in unobserved attributes violates IIA assumption
  - Nested logit, Mixed logit and other options relax IIA property

## Step 3: Compute Probabilities

Multinomial Logit Probability Equation (j)



Probability

$$\Pr^n(j) = \frac{e^{V_j}}{\sum_j e^{V_j}}$$

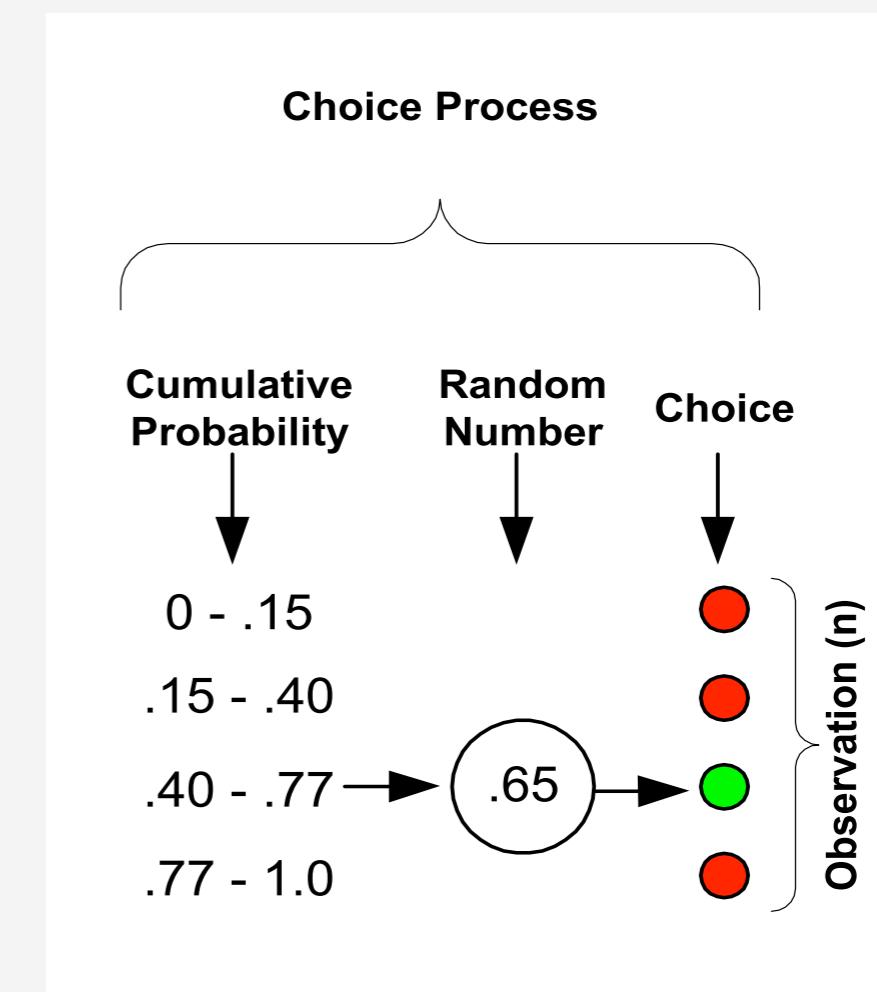
⋮

$$\Pr^n(j) = \frac{e^{V_j}}{\sum_j e^{V_j}}$$

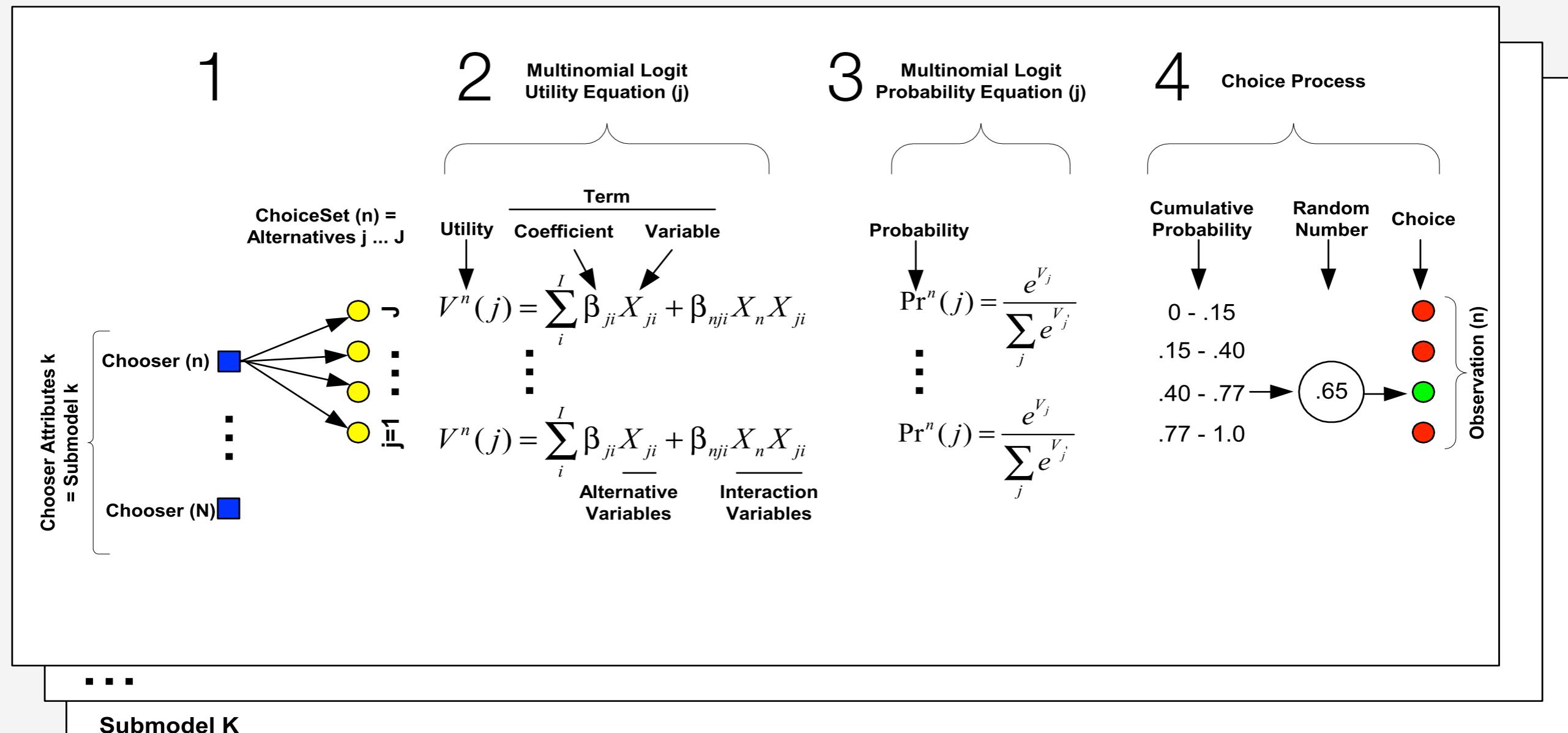
# Software Architecture for UrbanSim: Modular Choice Models

- Probabilities in a microsimulation model need to be acted on: a choice must be made
  - Aggregate models just use the probabilities and multiply by the number of agents to get rough market shares
- Options for modeling choices:
  - Unconstrained: compare random number to cumulative probabilities
  - Constrained (1): first come, first served
  - Constrained (2): bias from availability constraints corrected

## Step 4: Select Choice Outcomes



# Software Architecture for UrbanSim: Modular Choice Models



Implementation of a choice model involves selecting options for each step in the model process, and setting its configuration. In most cases, this can be done in the GUI, without the need to edit program code. New models can be created from templates, specified, and estimated, all in the GUI.

# Recommended UrbanSim Development Approach: Start Simple, Then Add Details

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- **Experience has demonstrated that an incremental development path may be most productive:**
  - Begin with a very simple zone model configuration
  - Begin using and assessing the model
  - Add detail to the model incrementally, targeting most pressing needs
- **Incremental development using a single platform**
  - Open Platform for Urban Simulation (OPUS) and UrbanSim
  - Use microsimulation of agents and explicit representation of time, just vary geographic detail
  - Modular configuration and estimation of models
  - Zonal model configurations
  - Synthesizing parcel details
  - Parcel model configurations
  - Exploiting parcels and local streets

# UrbanSim: Start From the Simplest Zonal Configuration

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## Household Location Models

**Household Transition Model**

**Household Location Choice Model**

## Employment Location Models

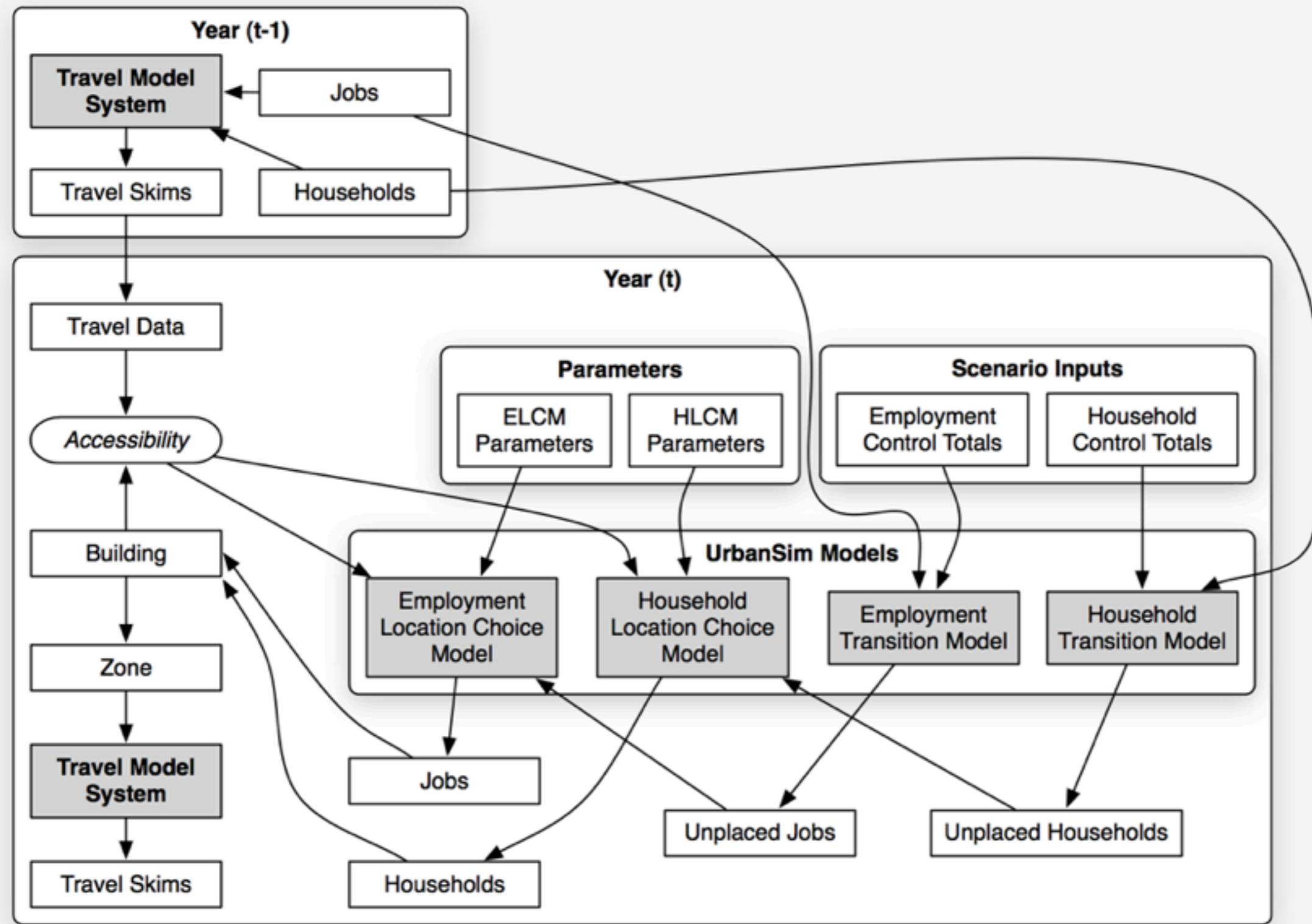
**Employment Transition Model**

**Employment Location Choice Model**

No representation of supply side of real estate market, or prices. No relocation of agents once placed. Becomes an ‘incremental’ model, allocating growth.

Assessment: probably too simple to be very realistic, but improves over many prior models

# The Simple Zone Configuration of UrbanSim: In Detail



# UrbanSim: Add Relocation Dynamics

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## Household Location Models

**Household Transition Model**

**Household Relocation Model**

**Household Location Choice Model**

## Employment Location Models

**Employment Transition Model**

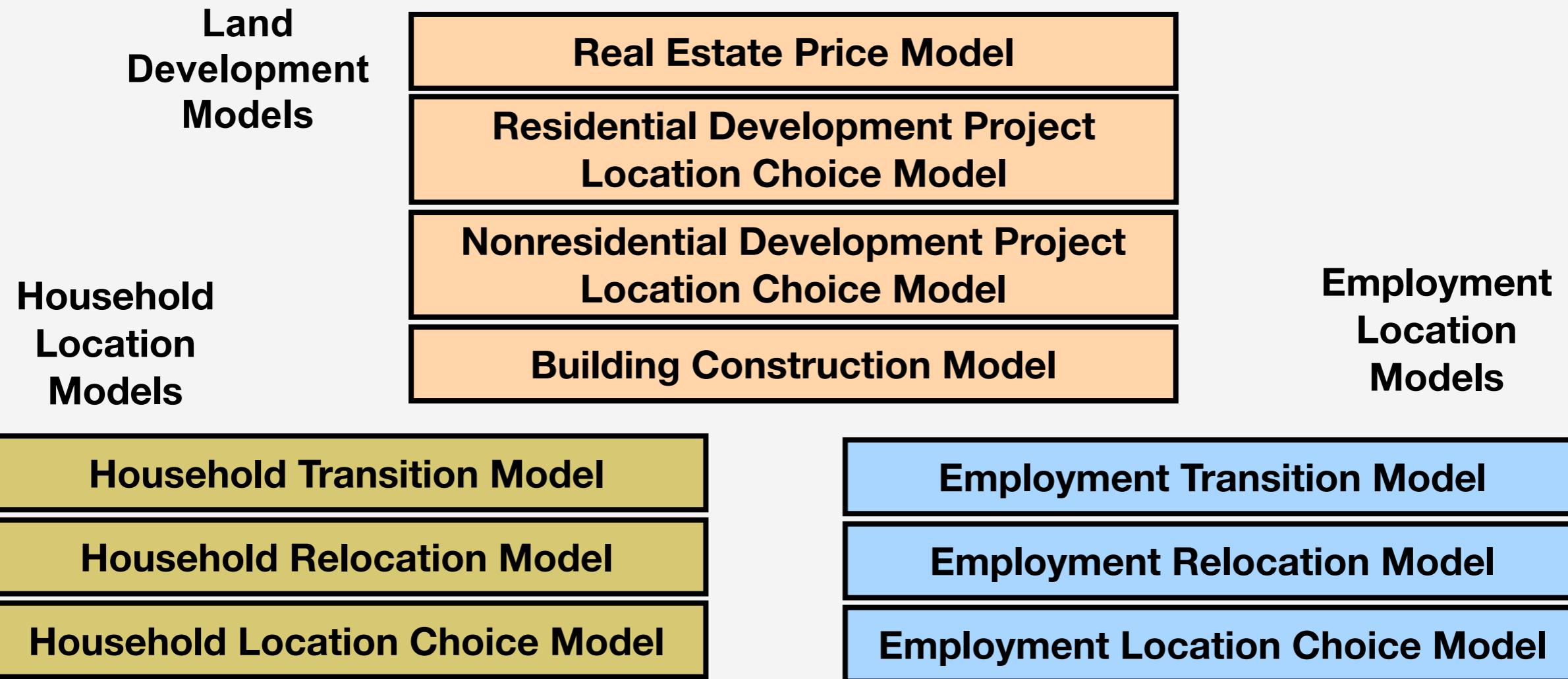
**Employment Relocation Model**

**Employment Location Choice Model**

Being used in Durham, North Carolina. No representation of supply side of real estate market, or prices. Last resort when there is no data on supply.

Note that this allows decline to occur, not just growth.

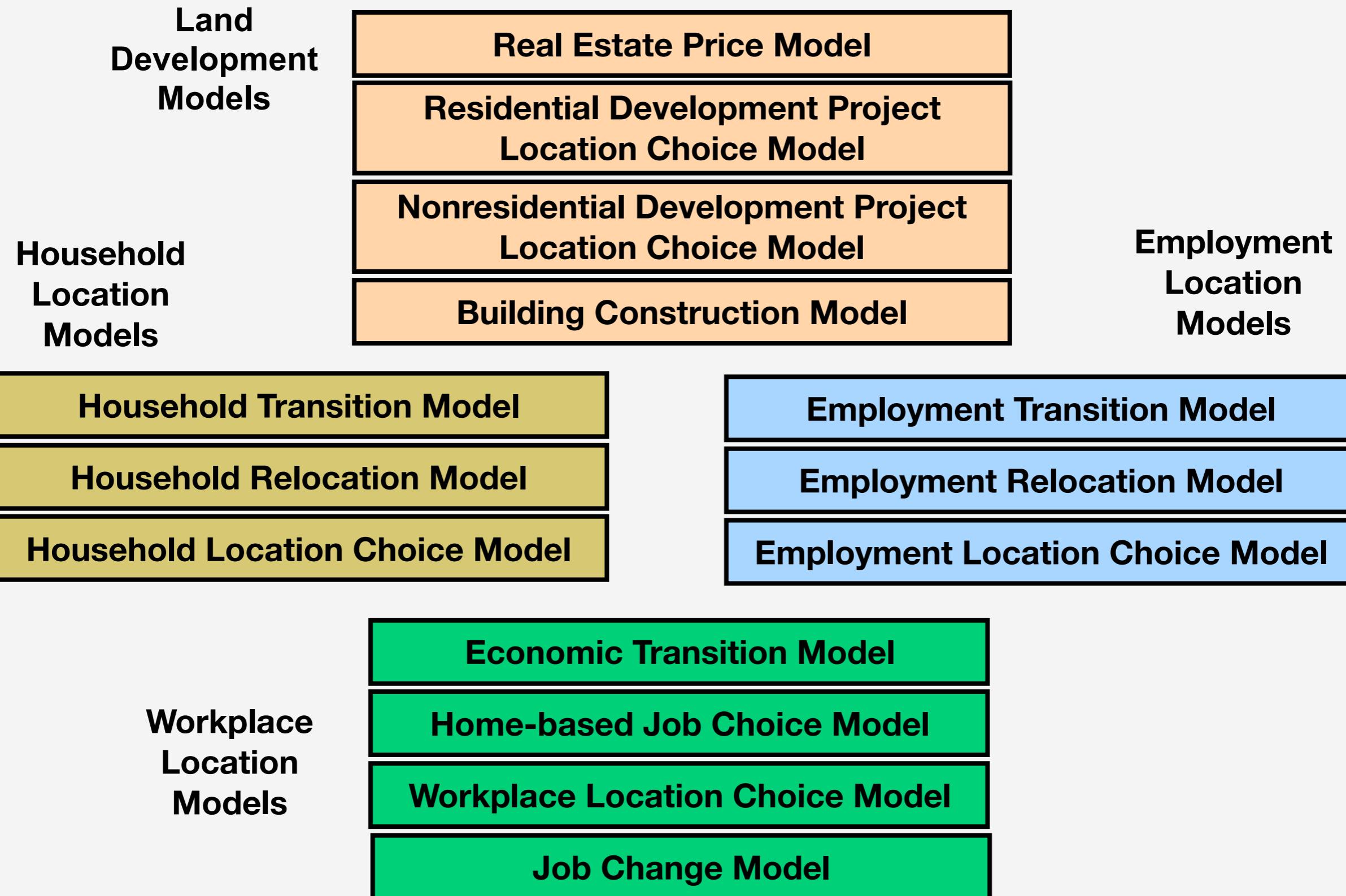
# UrbanSim: Add Real Estate Supply and Price



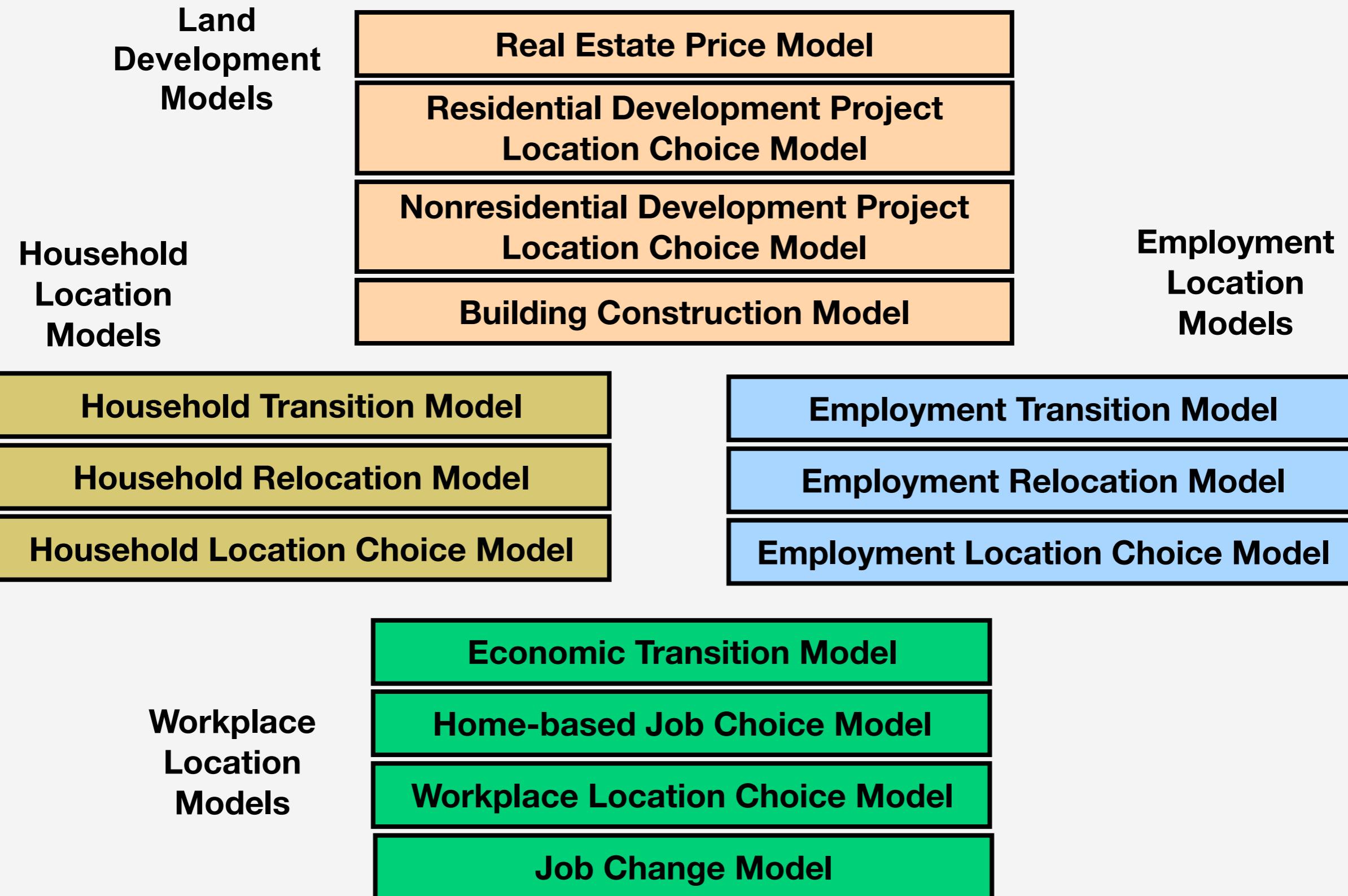
Being used in Maricopa County (MAG). Two different levels of geography being tested: travel model zones, and 'super-parcels' or aggregated parcels by land use/block.

More on this a bit later...

# UrbanSim: Add Labor Market & Workplace



# UrbanSim: Shift From Zones to Parcels as Locations

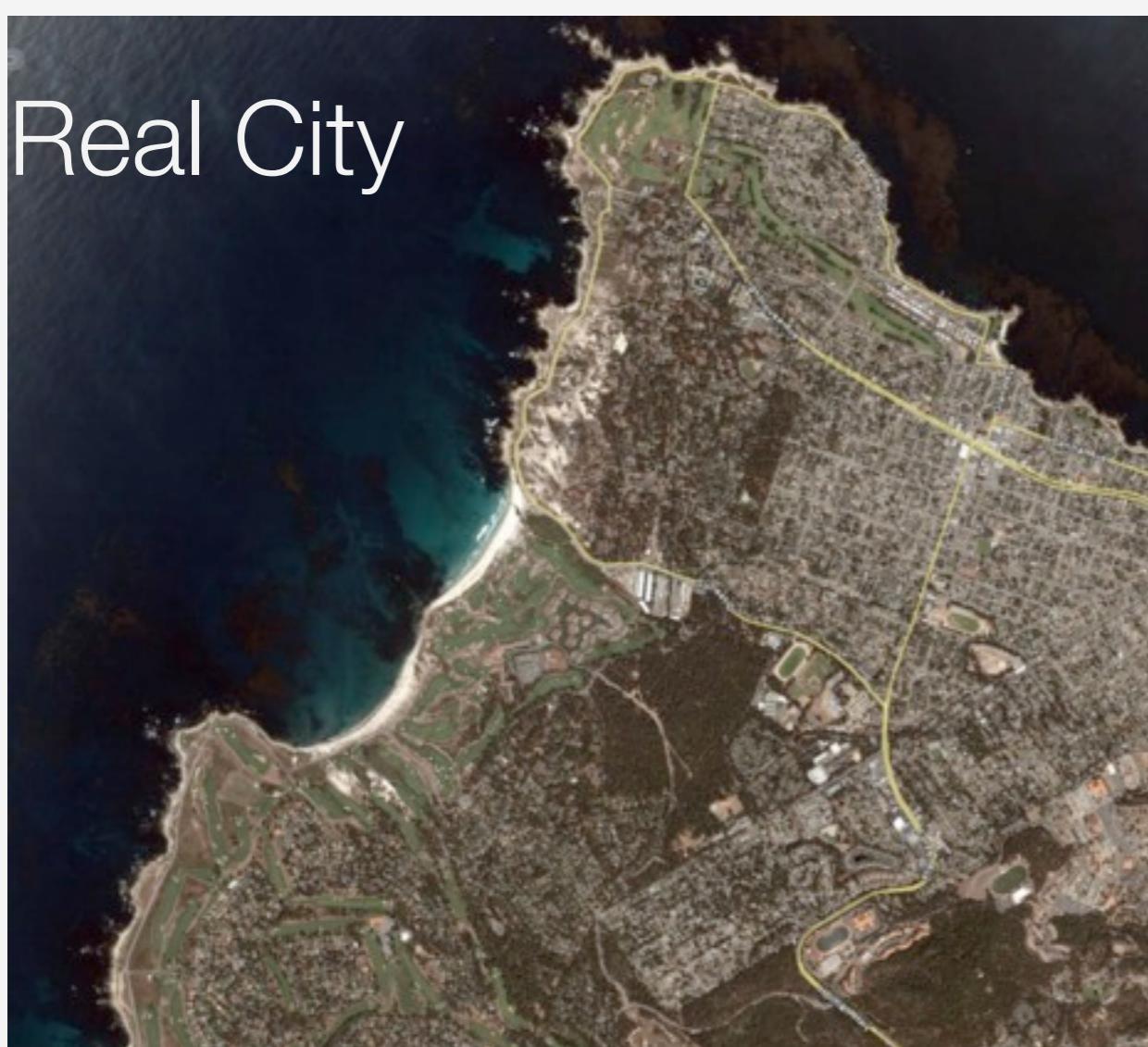


# Tools for Database and Model Development

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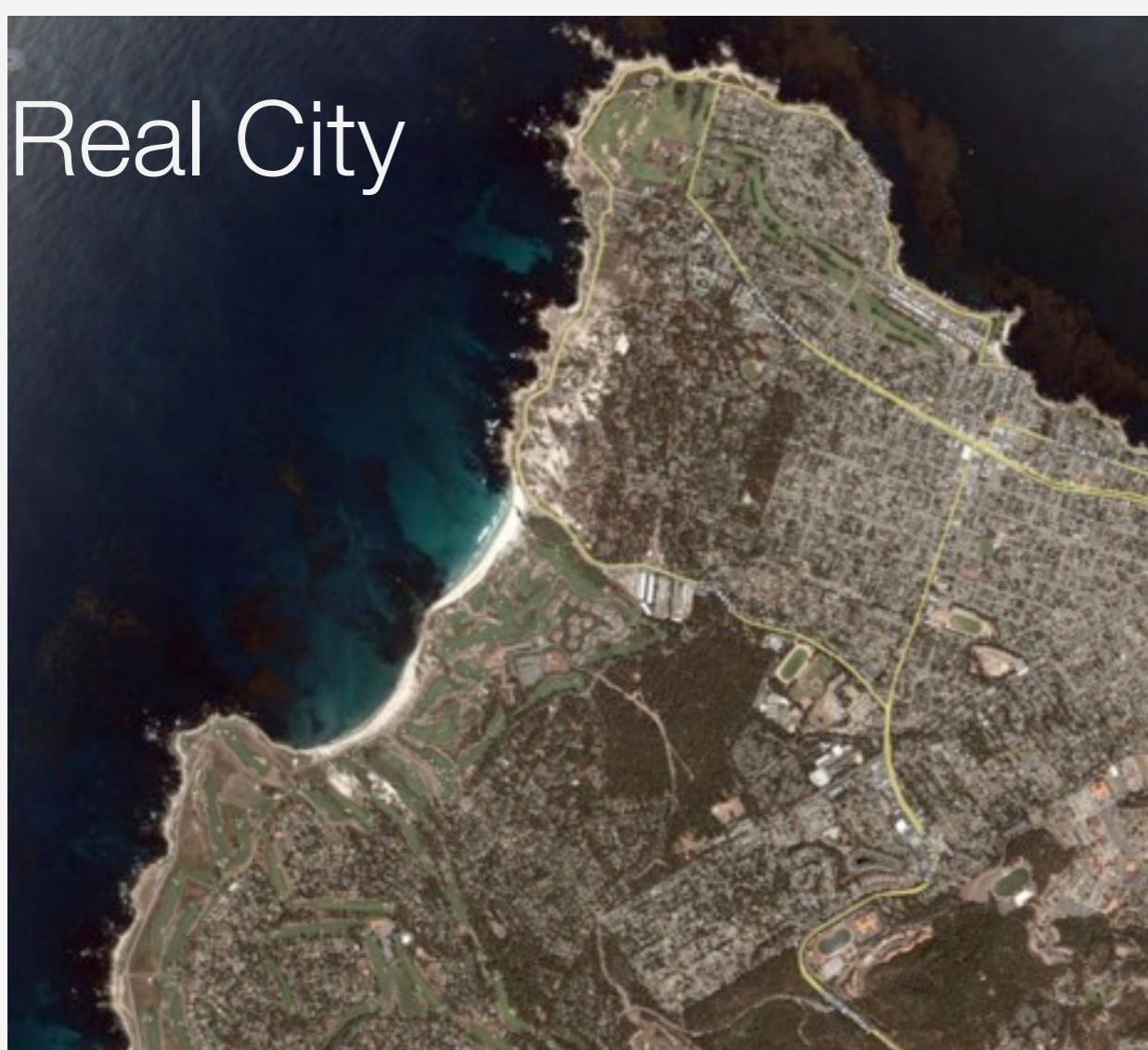
- **Database tools**
  - Schema generator for multiple platforms (MySQL, Postgres, SQLite...)
  - Python scripts for converting and loading data into the database
- **For zonal models, can start with aggregate zone-level data**
  - Zonal input file for Trip Generation
  - Travel skims
- **Zonal models can use traffic analysis zones, or other units of geography**
  - Paris uses Communes (~ 1,300 for Ile de France region)
  - Association of Bay Area Governments currently using traffic analysis zones (~1,450)
  - Maricopa Association of Governments experimenting with Super-parcels (~70,000)
- **Overcoming parcel data messiness**
  - Data synthesis and visualization
- **Multi-level modeling (county, district, zone, parcel)**

# Synthesizing Detail with Procedural Geometric Models



As a test, we created Monterey Peninsula streets, parcels, buildings in 3D using only 5 minutes of user input of the highways, coastline, undevelopable areas, center of jobs, total population and jobs.

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# Database Schema, Data Loading, Browsing, Editing

UrbanSim Parcel Database Manager

Core tables

- Buildings
- Development Event History
- Development Templates
- Development Template Com...
- Households
- Households for Estimation
- Jobs
- Jobs for Estimation
- Parcels
- Travel Data**
- Zones
- Development Projects

Scenario tables

Core tables

Category lookup tables

Geographic lookup tables

Preliminary tables

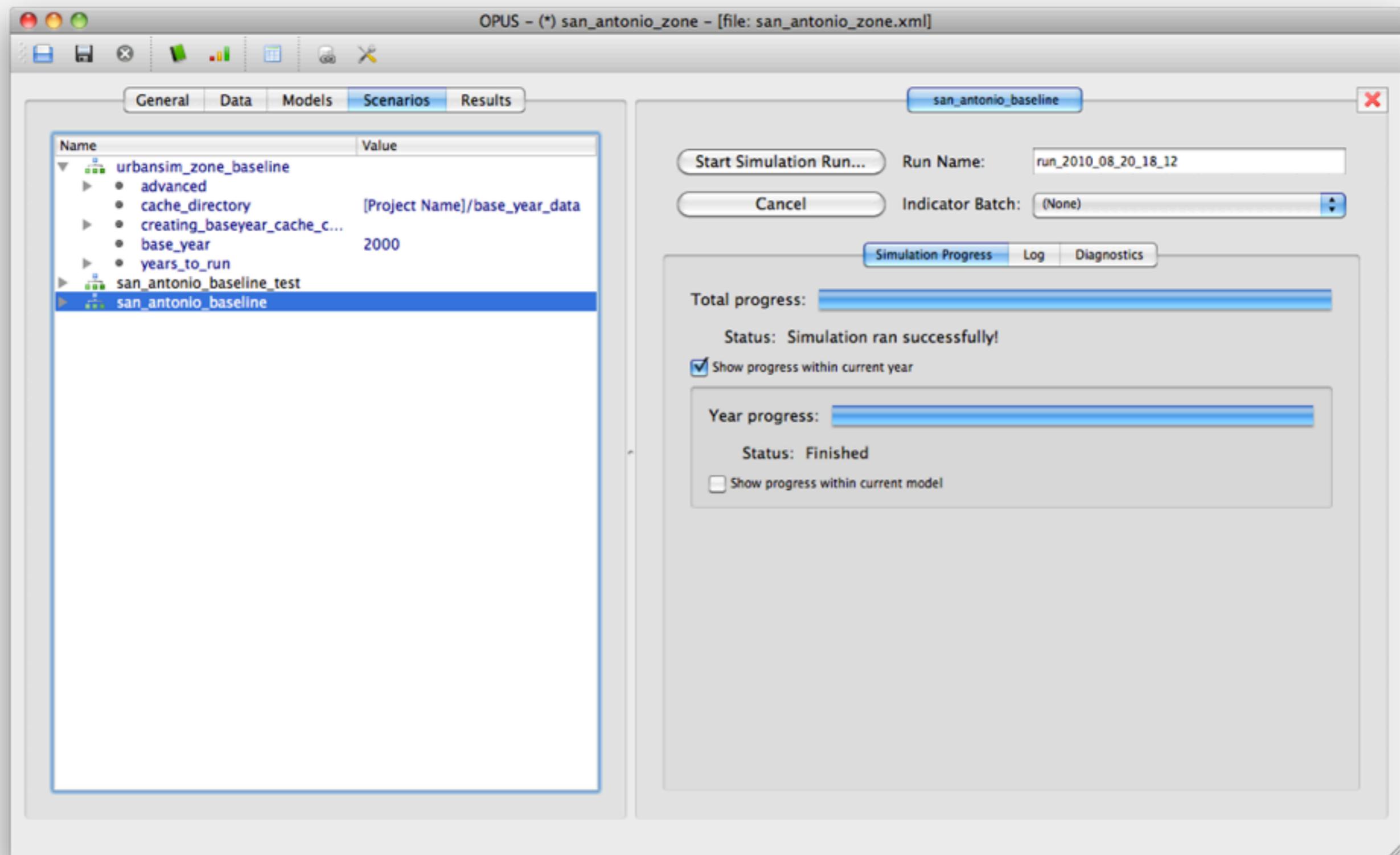
Travel Data

Search...

(583696 rows)

	<b>Id</b>	<b>From zone id</b>	<b>To zone id</b>	<b>Hwy am distance</b>	<b>Hwy am sov time</b>	<b>Hwy mid sov time</b>
1	1	1	1	1.98	3.09	3.01
2	2	1	2	3.56	5.68	5.60
3	3	1	3	1.75	2.75	2.68
4	4	1	4	2.64	4.17	4.09
5	5	1	5	2.94	4.64	4.54
6	6	1	6	3.87	6.25	6.13
7	7	1	7	3.46	5.62	5.51
8	8	1	8	2.21	3.43	3.35
9	9	1	9	4.50	7.04	6.89
10	10	1	10	5.13	7.95	7.77
11	11	1	11	5.10	7.78	7.60
12	12	1	12	4.73	7.68	7.52
13	13	1	13	5.25	8.11	7.93
14	14	1	14	4.41	6.88	6.72
15	15	1	15	4.62	7.08	6.91
16	16	1	16	4.93	8.38	8.27
17	17	1	17	3.66	6.14	6.02
18	18	1	18	3.93	6.57	6.45
19	19	1	19	4.41	8.02	7.90
20	20	1	20	5.25	8.67	8.52

# Interface for Developing, Estimating, Running Models



# Measuring Progress: Benefits and Costs

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- **Incremental model development ideally will monitor and evaluate progress:**
  - How much better is a new innovation compared to the best available version?
  - How much more costly is it in terms of computational expense or data effort?
- **How to measure progress**
  - Model estimation results
  - Model sensitivities
  - Calibration of model uncertainty over time

# Estimation of Workplace Choice Model in GUI

OPUS – psrc.Parcel – [file: psrc.Parcel\_test.xml]

General Data Models Scenarios Results

workplace\_choice\_model\_for\_resident estimation

Start Estimation... Estimation finished successfully

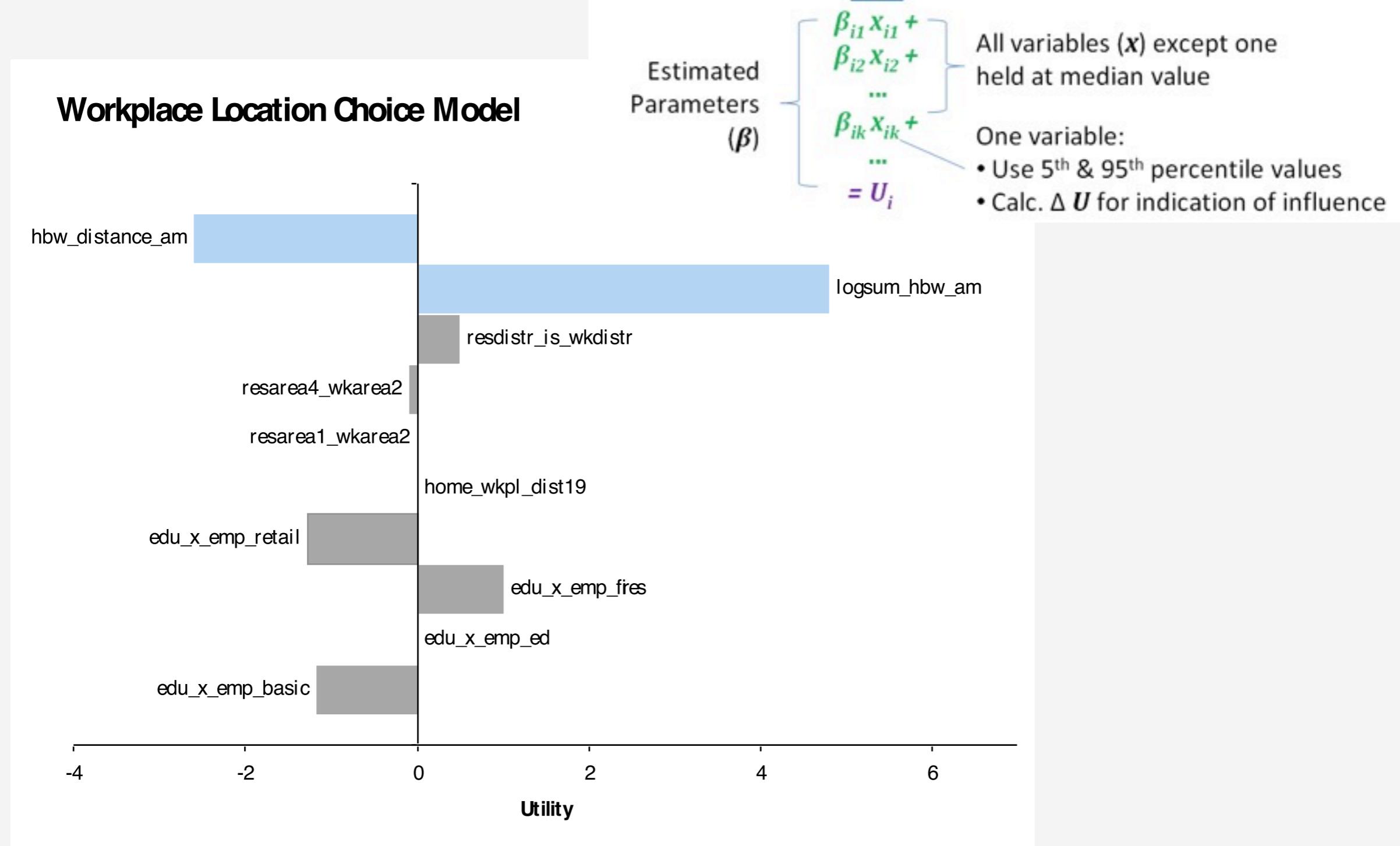
Estimation result log

```

psrc.Parcel.person_x.job.logsum_hbw_am_from_home_to_work: completed...0.4 sec
psrc.Parcel.person_x.job.network_distance_from_home_to_work...0.8 sec
Choice set size: 30
submodel: -2
Convergence achieved.
Akaike's Information Criterion (AIC): 18936.3528676
Bayesian Information Criterion (BIC): 18999.9652765
Number of Iterations: 10
*****
Log-likelihood is: -9458.17643382
Null Log-likelihood is: -14550.3223987
Likelihood ratio index: 0.349967913107
Adj. likelihood ratio index: 0.349280643113
Number of observations: 4278
Suggested |t-value| > 2.89158103633
Convergence statistic is: 0.000305533799711
-----
Coeff_names estimate std err t-values
edu_x.job_is_in_employment_sector_group_basic -0.177369 0.0127099 -13.9552
edu_x.job_is_in_employment_sector_group_edu 0.224213 0.0155413 14.4269
edu_x.job_is_in_employment_sector_group_fires 0.144304 0.010768 13.4012
edu_x.job_is_in_employment_sector_group_retail -0.191668 0.014026 -13.6651
home_dist_19_workplace_dist_19 0.466456 0.205951 2.26489
home_area_type_1_workplace_area_type_2 0.0125937 0.0681605 0.184766
home_area_type_4_workplace_area_type_2 -0.123488 0.113273 -1.09018
home_district_is_same_as_workplace_district 0.569024 0.0499707 11.3871
logsum_hbw_am_from_home_to_work 1.28446 0.0639487 20.0858
network_distance_from_home_to_work -0.0381675 0.0037057 -10.2997
-----
Elapsed time: 1.55 seconds
Estimating Non-home-based Workplace Choice Model for residents (from
urbansim.Parcel.models.workplace_choice_model): completed...2 min, 3.1 sec
Simulate year 2000: completed.....2 min, 14.1 sec

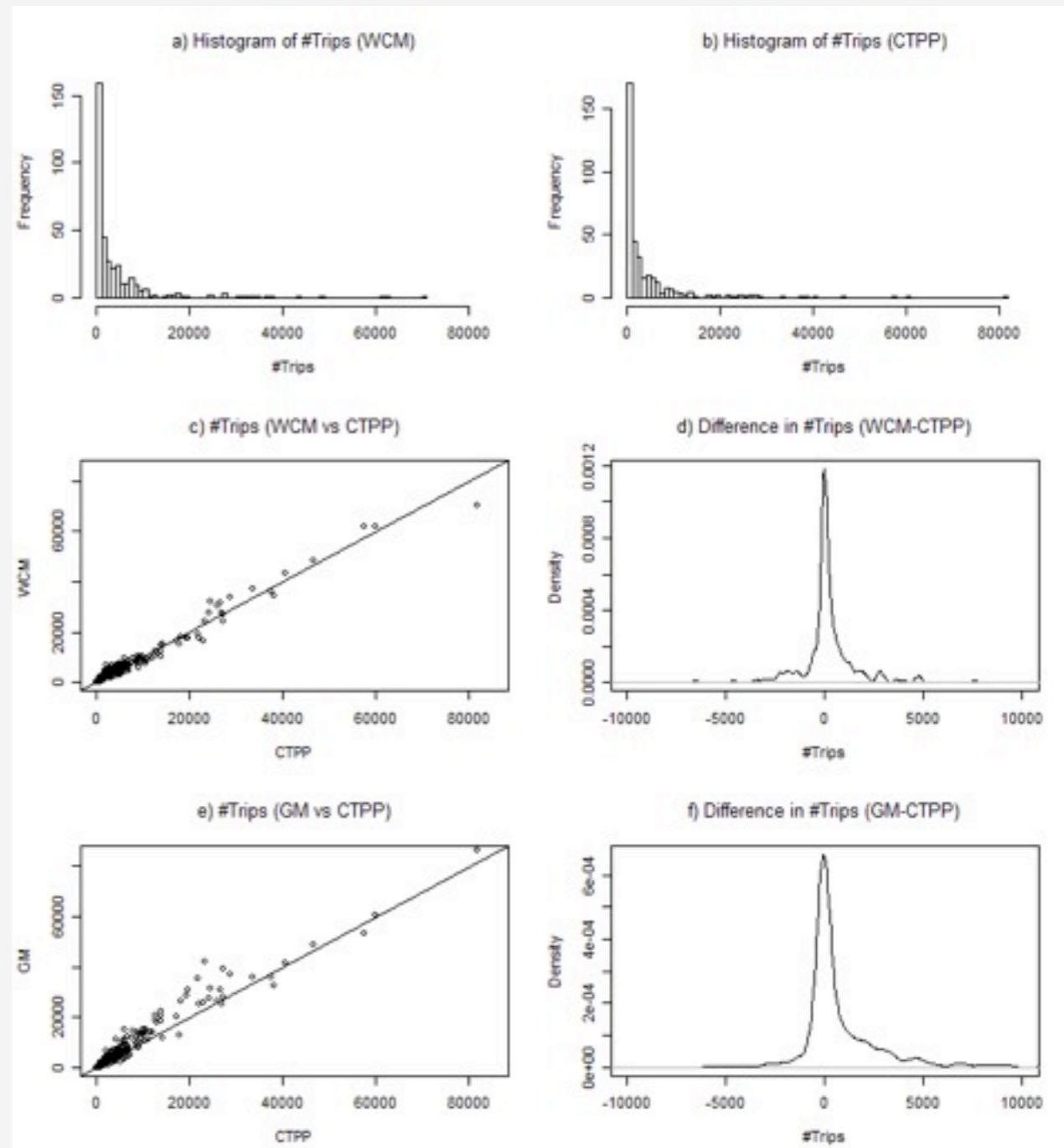
```

# Sensitivity Analysis: Relative Influence of Variables



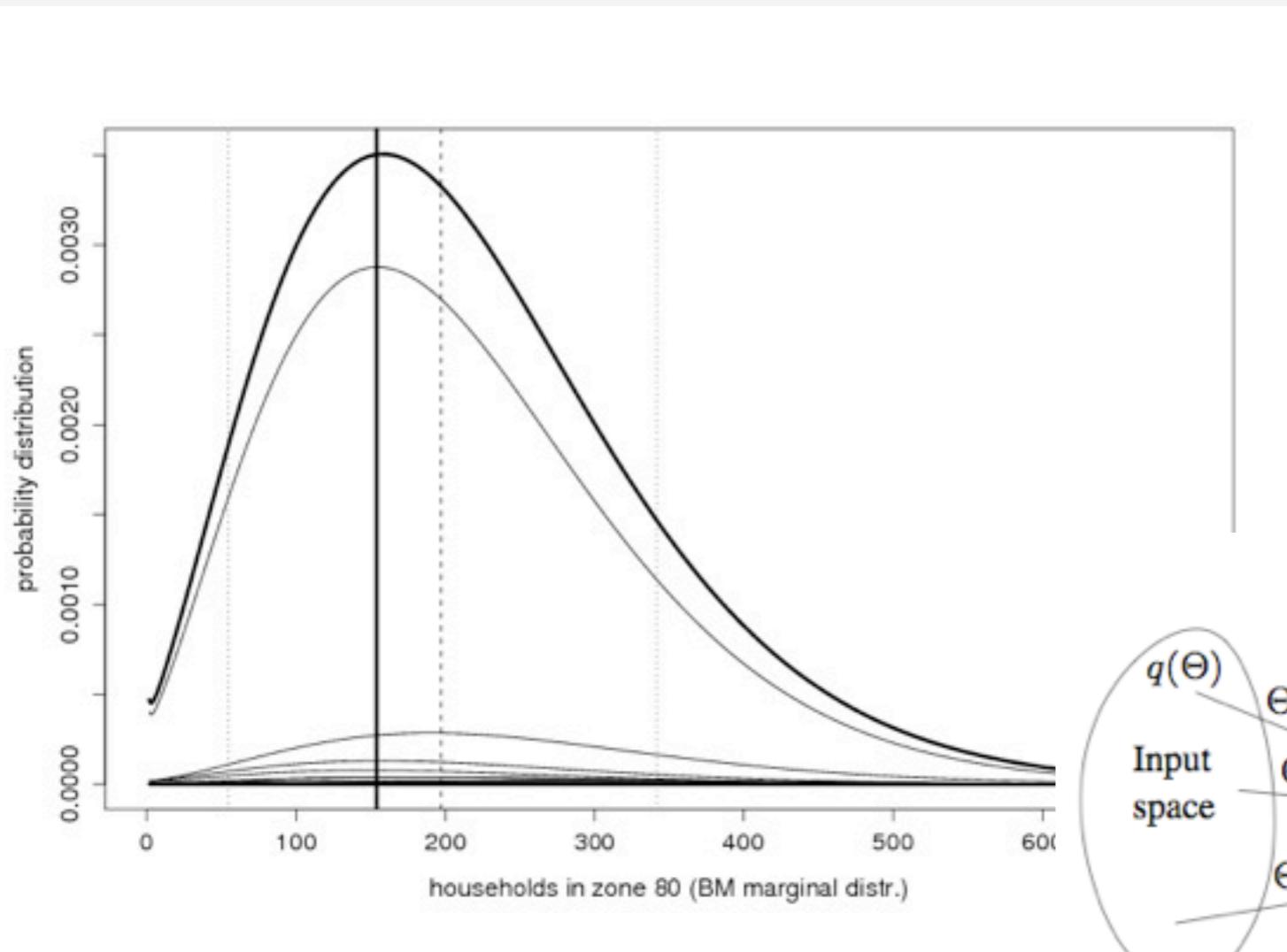
# Calibration and Validation of Workplace Choice Model

- Model predicts individual workplace (attaches a job to a person) at parcel and building level
- Comparison of predicted values (commute trips) to observed values from CTPP to compute errors
- Calibration: Adding variables to specification to reduce errors.
- Errors compared to previous HBW Trip Distribution Model (gravity model)
  - RMSE Gravity Model = 2558.65
  - RMSE New Model = 1440.01



Application: Puget Sound Regional Council

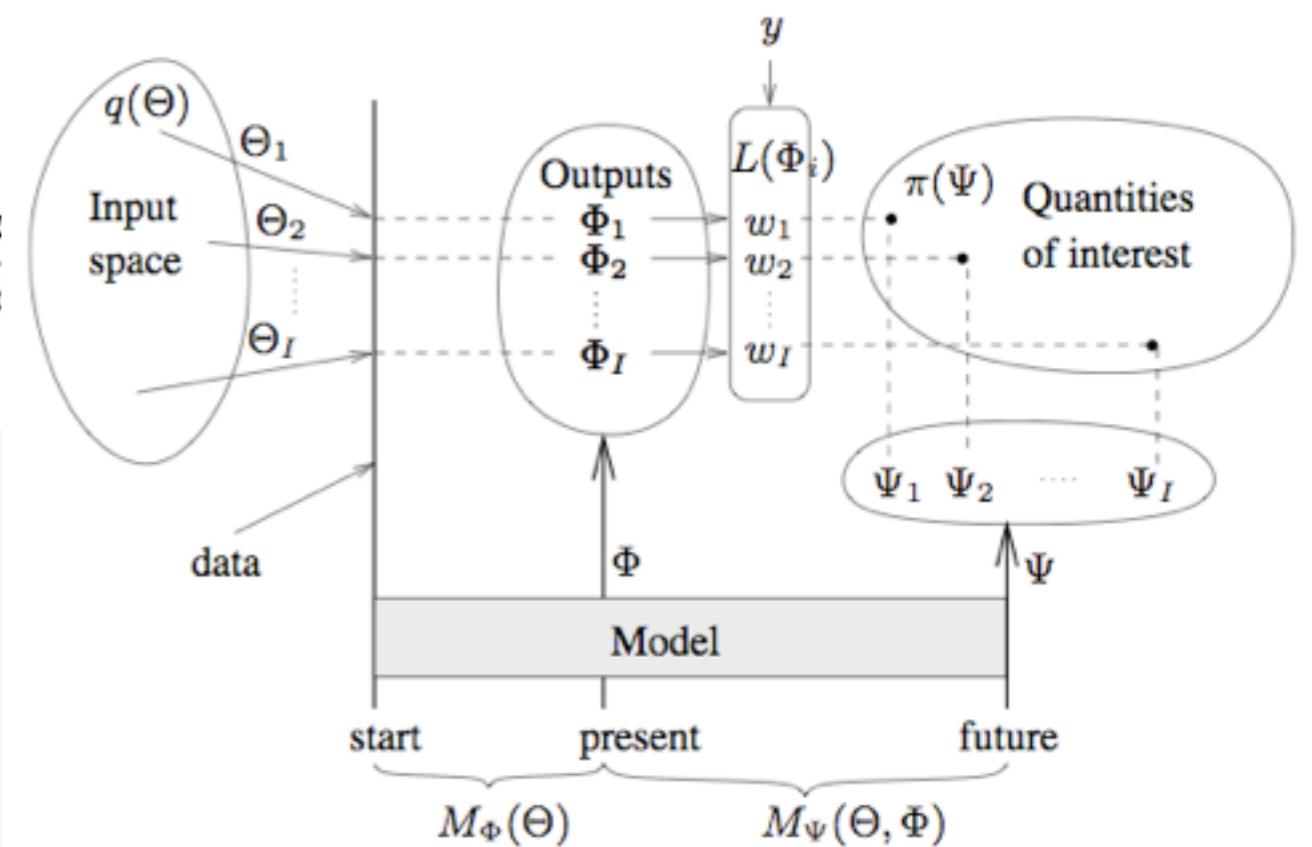
# Calibrating Uncertainty in UrbanSim Model Application



## Bayesian Melding

Results from Eugene-springfield in Transportation Research B, 2007; Seattle Viaduct application in Transportation Research A, 2011.

Method	# Cases Missed by 90% Confidence Interval	Percent Covered Cases
Bayesian Melding	31	88%
Multiple Runs	163	38%



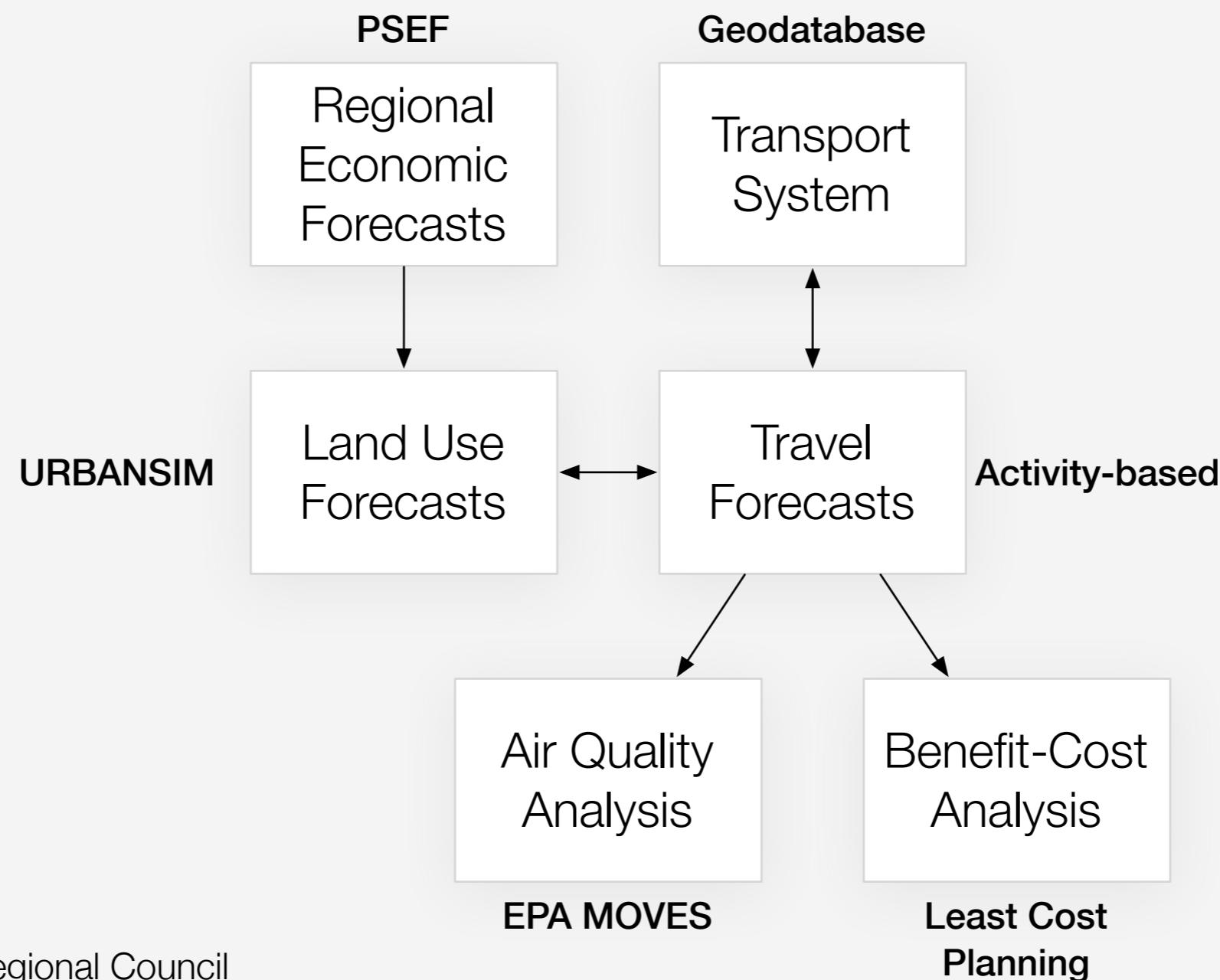
1. UrbanSim Overview
2. Anatomy of the Model

### **3. Application in Practice**

- ❖ Puget Sound Regional Council (parcel level)
  - ❖ Maricopa Association of Governments (zone level)
4. Assessment

# Puget Sound Regional Council: Integrated Models

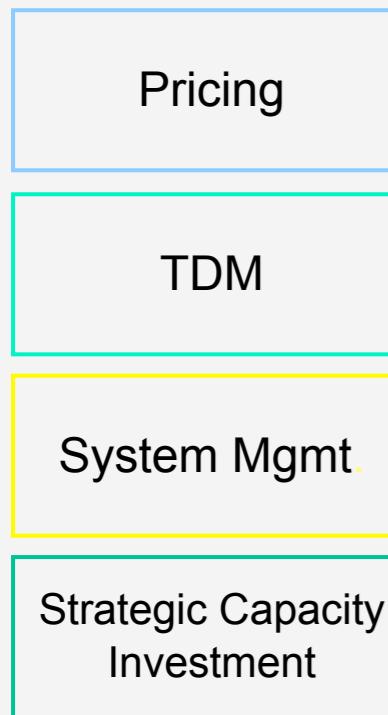
Simulates persons and households at a parcel level



Source: Puget Sound Regional Council

# Destination 2030 Update and Regional Growth Strategy

## Transportation Concepts & Strategies

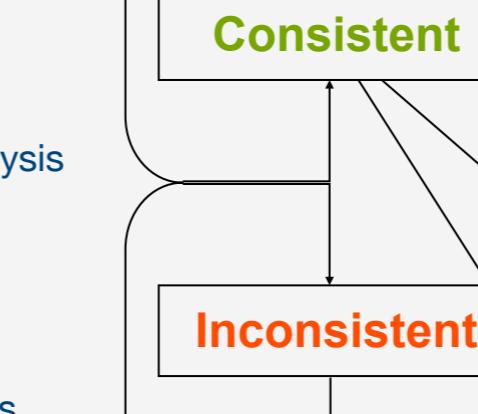
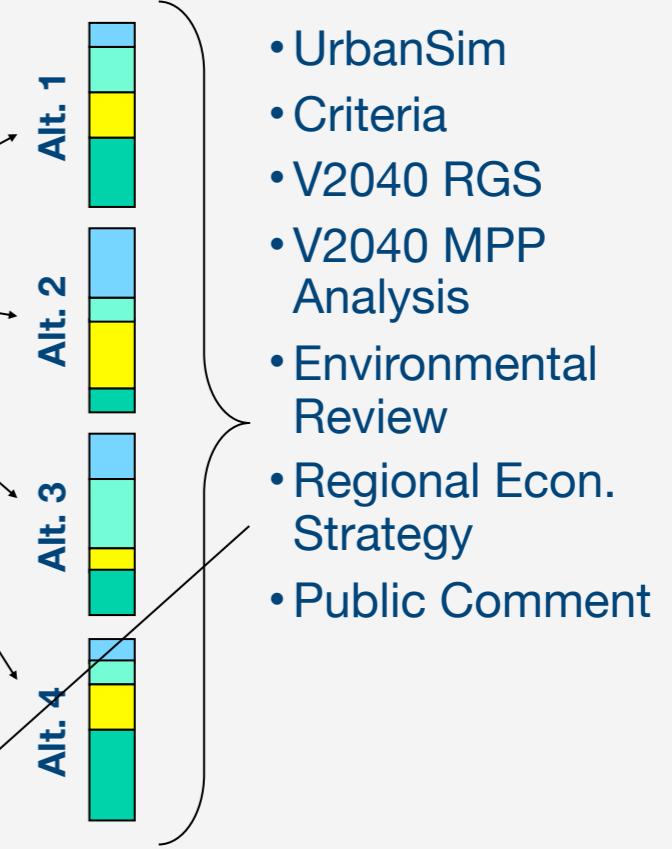


## Screening

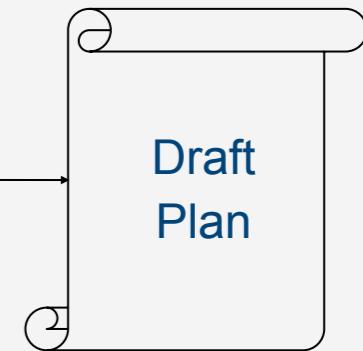
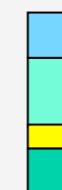


- Growth Distribution
- Policy Analysis
- EIS Impacts

## Alternatives Analysis

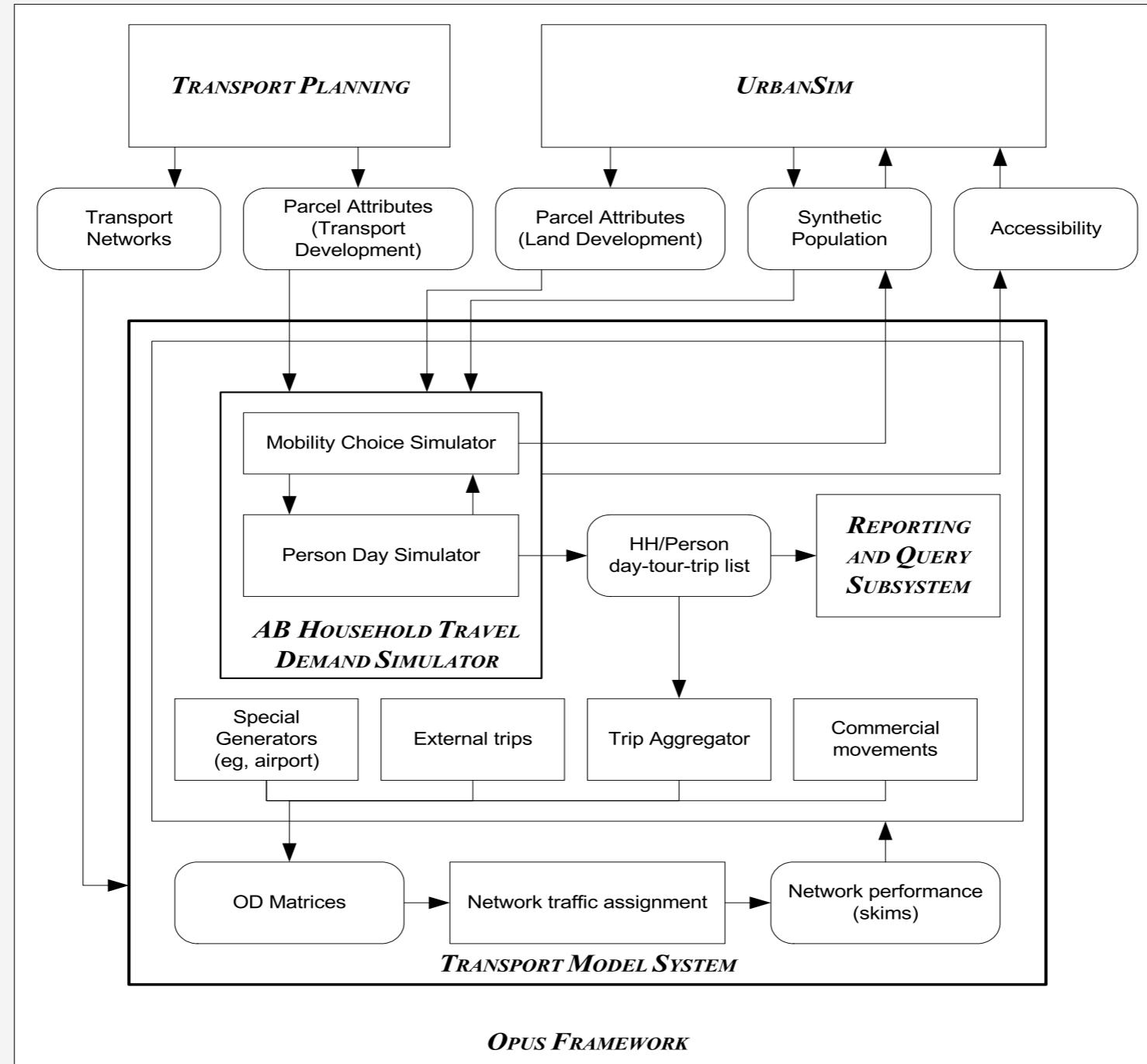


Preferred Alternative



Source: Puget Sound Regional Council

# Model Design for Integrated Activity Models



Source: Puget Sound Regional Council

# PSRC Land Use Model - UrbanSim

---

- Micro-simulation of actions of actors on parcels and buildings:
  - Households and Workers
  - Jobs
  - Developers / Landowners
- Primary Inputs include:
  - Allowable development (comp plans)
  - Transportation system
  - Major planned developments (pipeline developments)
  - Regional economic forecasts
- Many operating assumptions:
  - Relocation rates
  - SQFT needed per job by sector
  - Construction costs
  - Vacancy rates
- Simulates each year from 2001-2040

Source: Puget Sound Regional Council

# Scenario and Alternative Analysis

---

- Land use plan assumptions:
  - Type of development (residential, commercial,...) and density
- Transportation system:
  - Accessibility measures from zone to zone, jobs 10-30 minute travel times
- Critical area buffers:
  - Restrictions on parcels near streams, wetlands, slopes, shorelines, floodplains, etc.
- Planned / Pipeline Developments:
  - Predetermine number of housing units, non-residential SQFT on parcels, year
- Costs factors:
  - Land development variables

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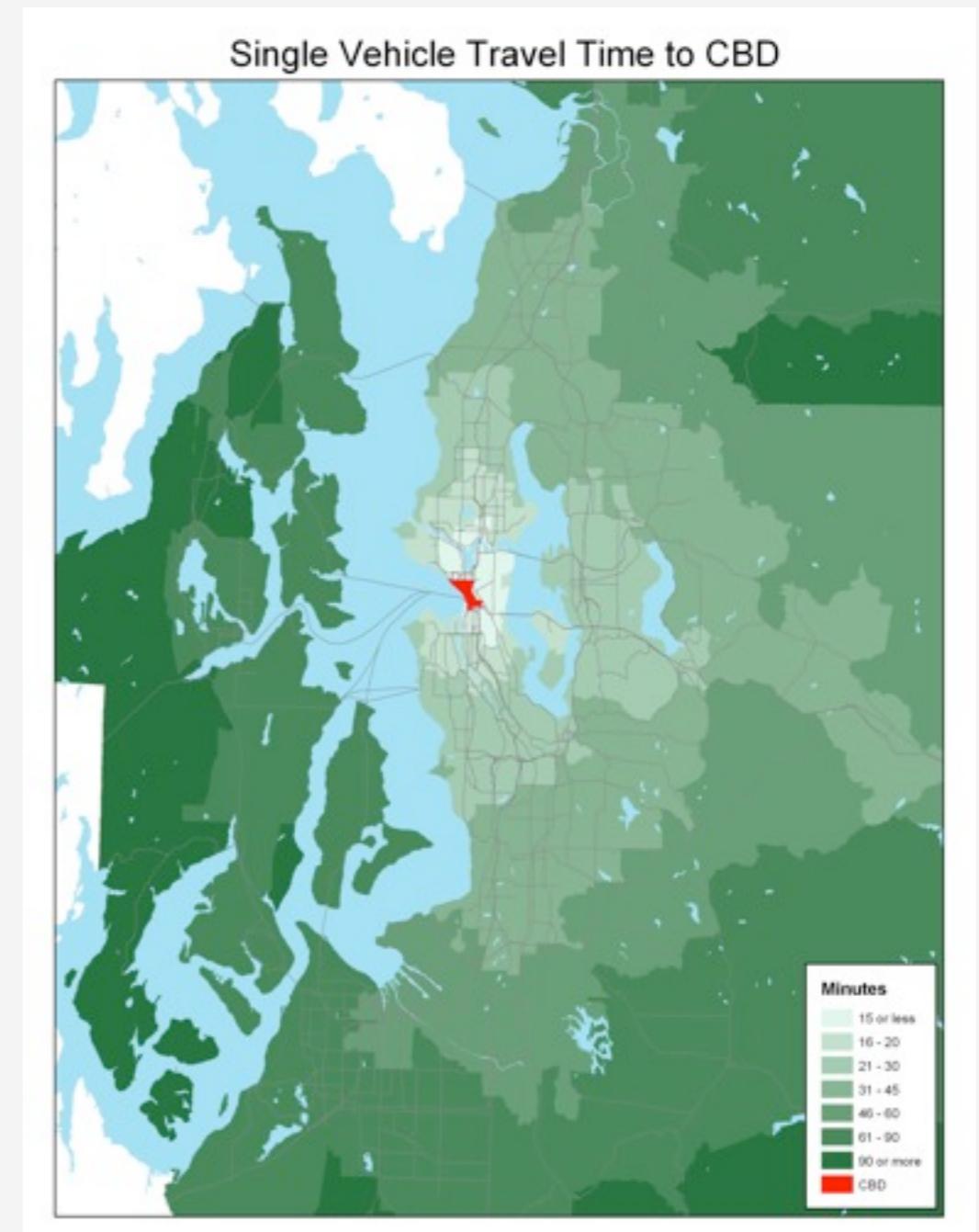
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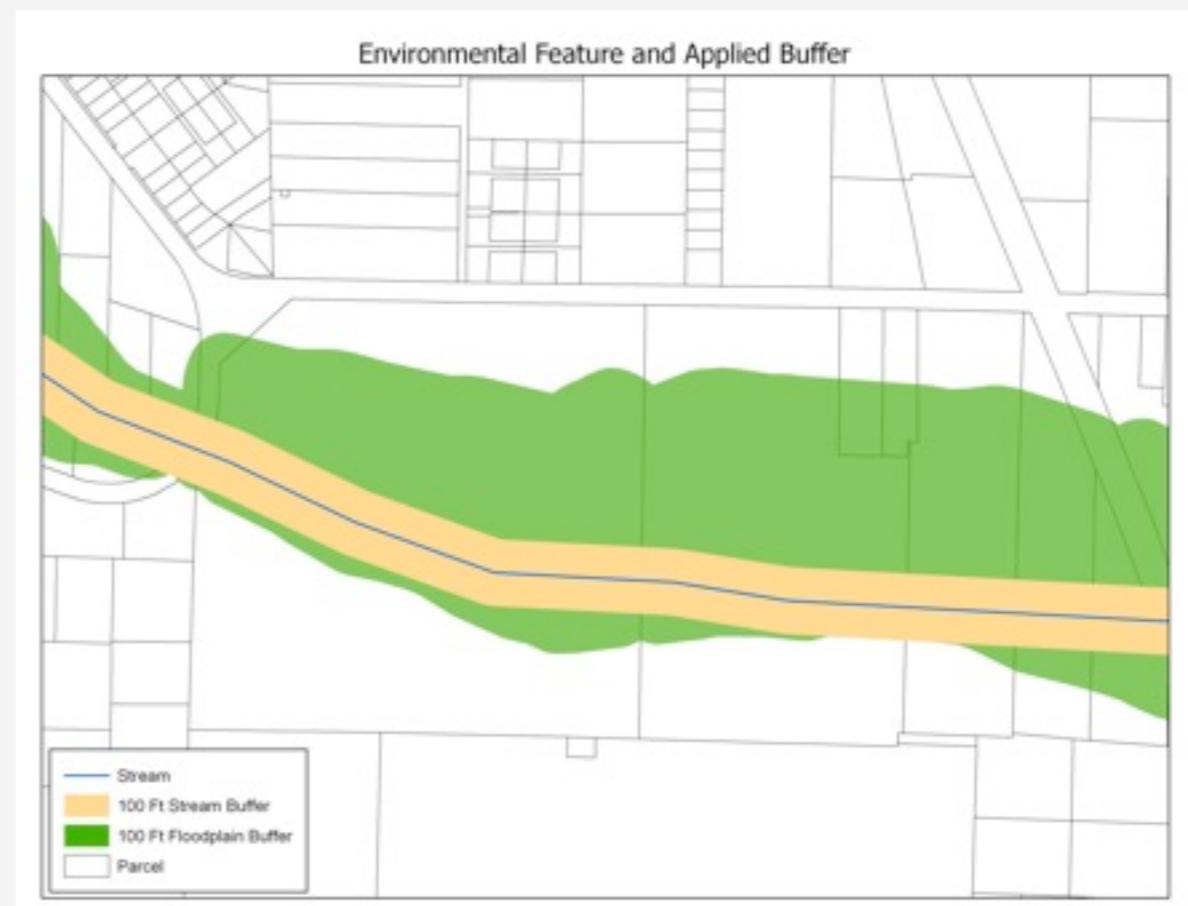
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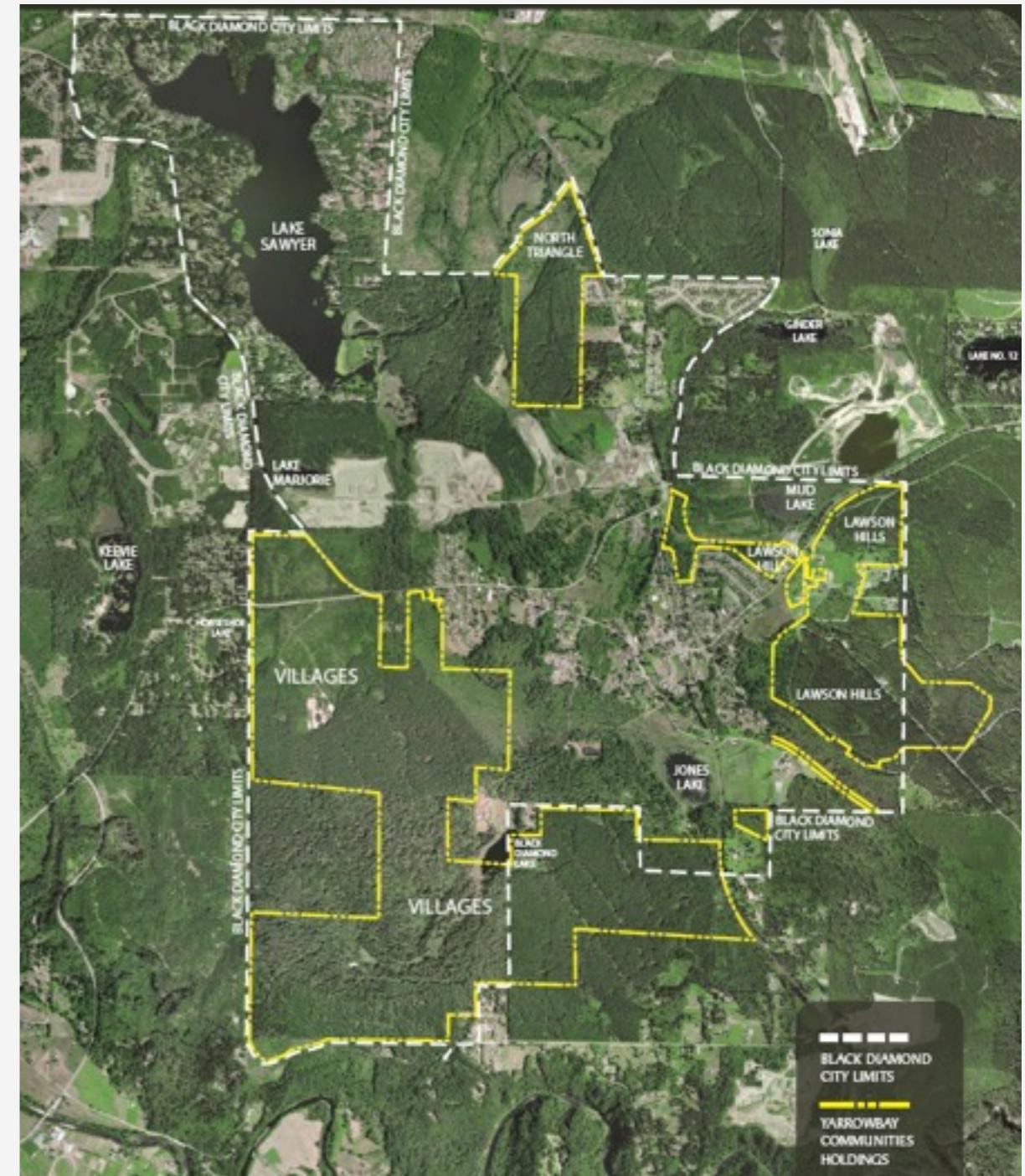
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# Scenario and Alternative Analysis

---

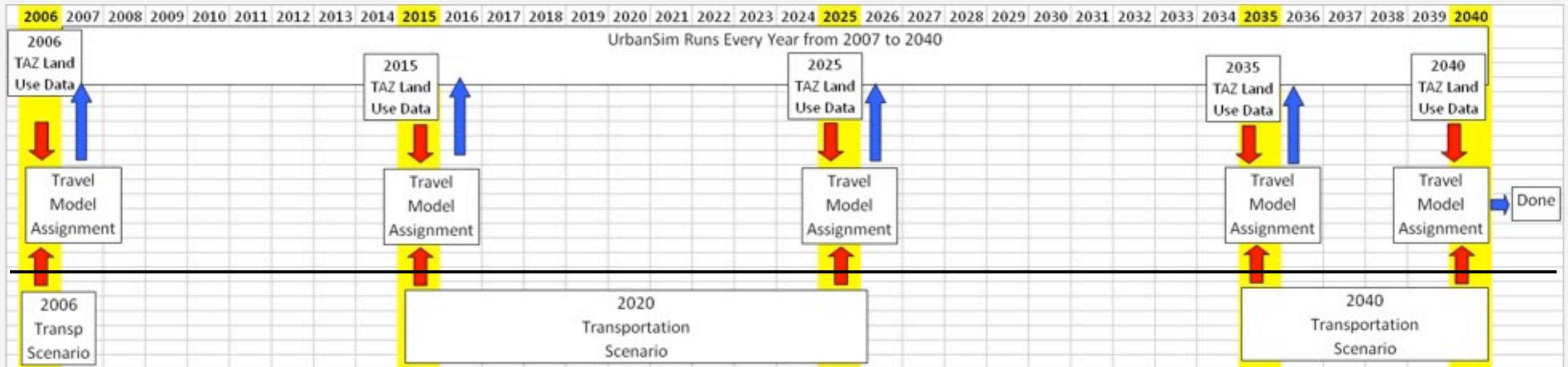
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- Planned / Pipeline Developments:
  - Predetermine number of housing units, non-residential SQFT on parcels, year
- Costs factors:
  - Land development variables
- Developer Model Costs (Per Square Foot)
  - Acquisition of land (and existing buildings)
  - Demolition
  - Construction
- Developer Model Profits (Per Square Foot)
  - Expected sales price
  - Return on Investment (ROI)
- Varying these factors would require some additional programming / testing work

# Model Handshake – Current Setup



Model Inputs and Integration	Analysis Year				
	2006 (base)	2015	2025	2035	2040
<b>Land Use Model Runs, using accessibilities from:</b>	a previous travel model run for land use model run 2006	2006 travel model for land use model runs 2007 through 2015	2015 travel model for land use model runs 2016 through 2025	2025 travel model for land use model runs 2026 through 2035	2035 for land use model runs 2036 through 2040
<b>Travel Model Runs, using population and employment from:</b>	2006 land use model run	2015 land use model run	2025 land use model run	2035 land use model run	2040 land use model run

Source: Puget Sound Regional Council

# Accessibility Measures – passed to UrbanSim

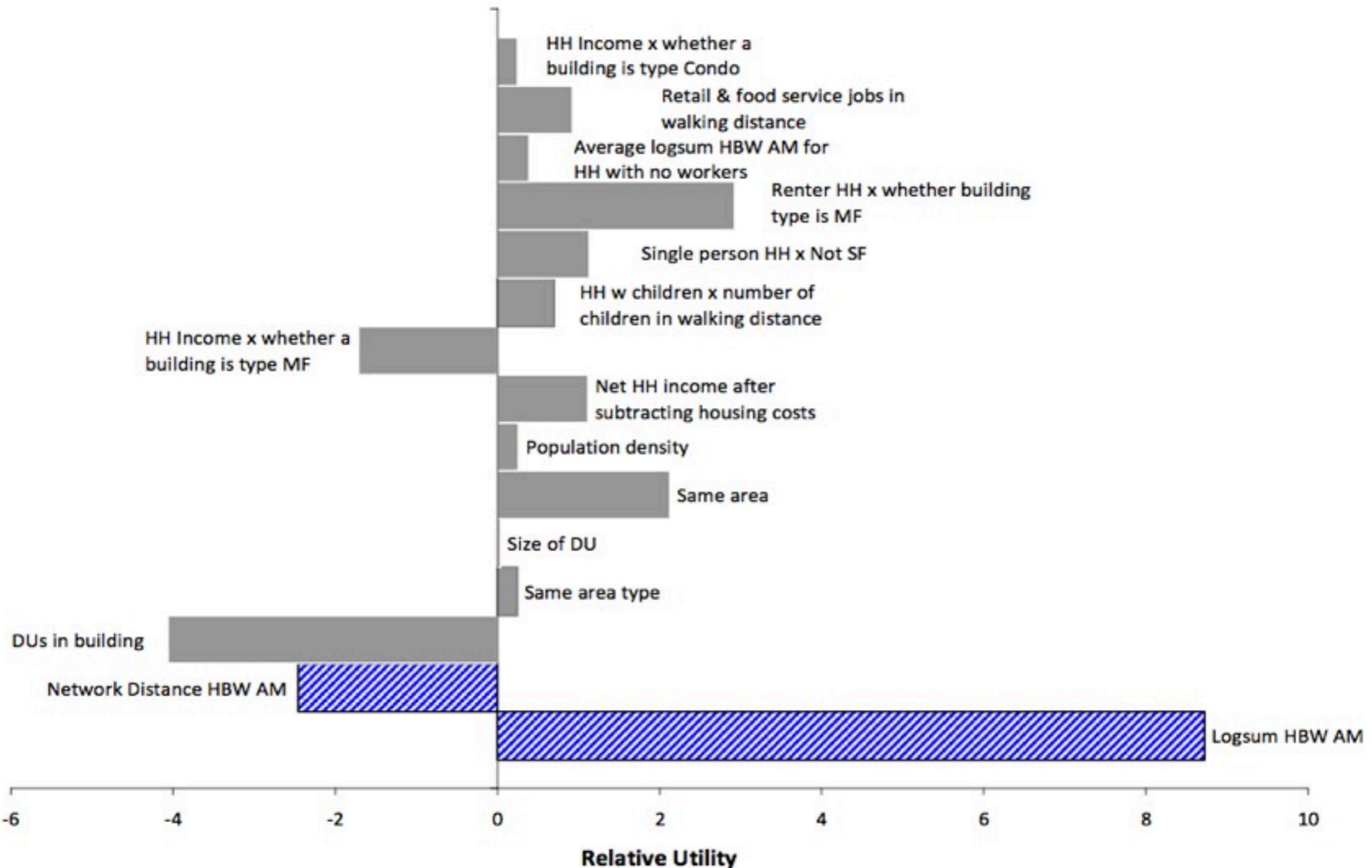
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- Zone-based, measured to a downtown location
  - Generalized Cost to Seattle CBD, HBW AM SOV
  - Generalized Cost to Bellevue CBD, HBW AM SOV
- Zone-based
  - Average Travel Time, Trip-weighted, AM, SOV, HBW
  - Jobs within 30 minutes travel time, AM, SOV
- Person-based, Home to Work Zones
  - Network distance from Home to Work
  - Log Sum, HBW AM from Home to Work

Source: Puget Sound Regional Council

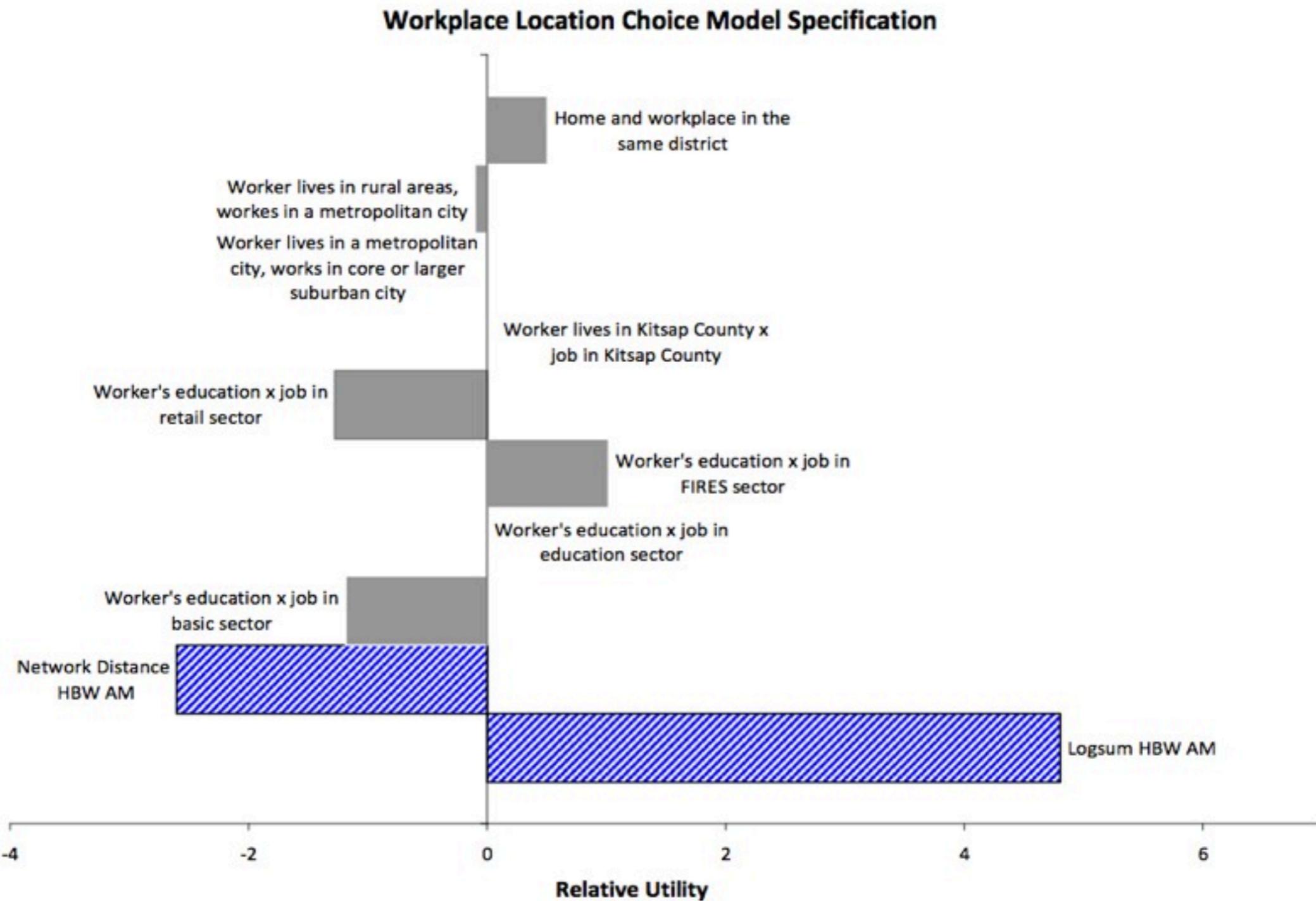
# Household Location Model Sensitivities

## Household Location Choice Model Specification



Source: Puget Sound Regional Council

# Workplace Location Choice Model Sensitivities



Source: Puget Sound Regional Council

# Sensitivity Tests

---

- Base Case Scenario
  - Transportation Networks (2020, 2040)
  - Modest investments in roads and road-based transit
  - Near-term voter-approved rail transit extensions
  - Very limited tolling (two bridge crossings)
  - No real growth in vehicle operating costs
  - Modest real growth in parking costs
- Alternative Scenarios
  - Lower parking costs in selected neighborhoods (zones)
  - Higher vehicle operating costs forecast
  - Major extensions of rail transit
  - Major investments in highway capacity

Source: Puget Sound Regional Council

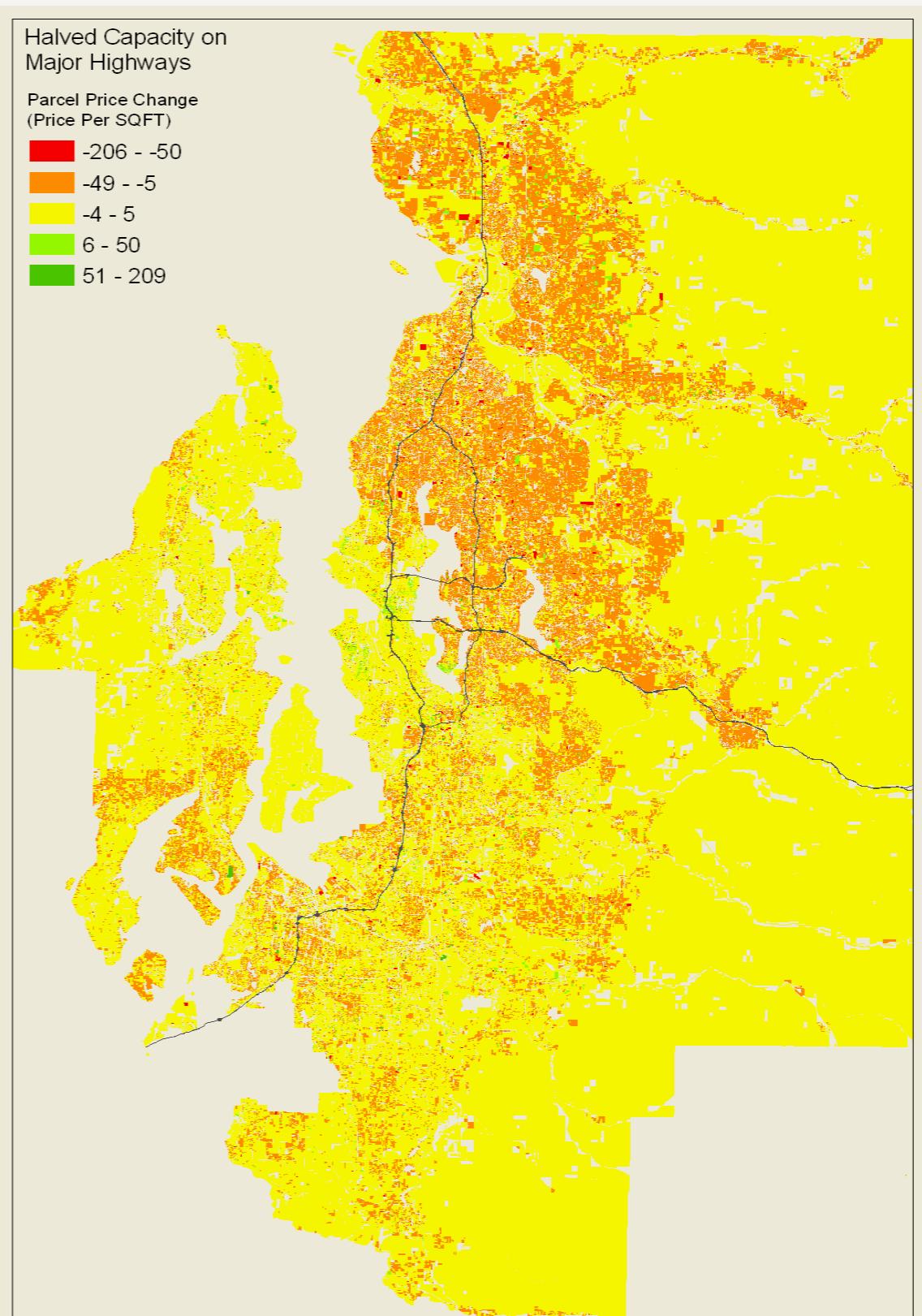
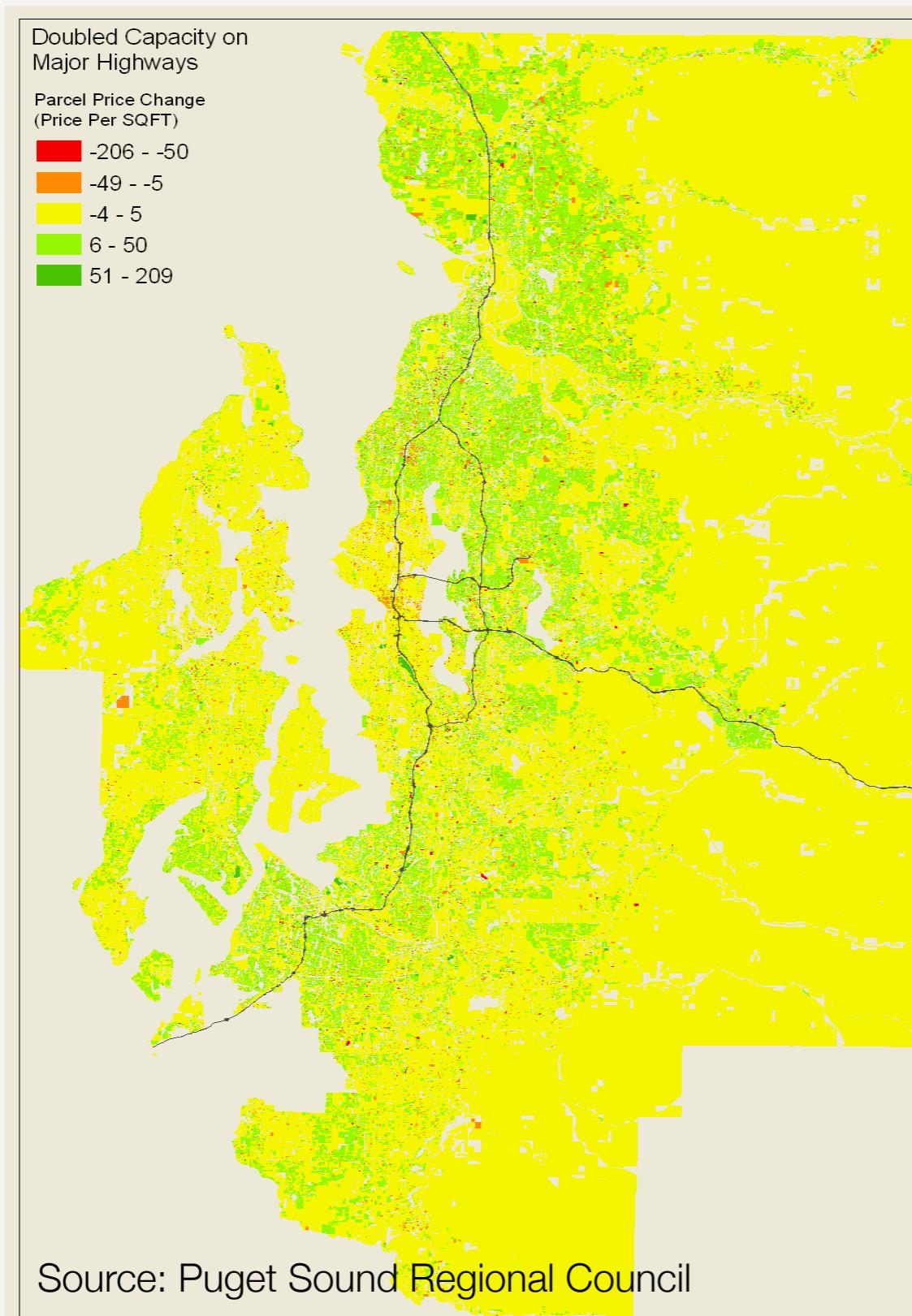
# Selected Travel Sensitivities

---

Travel Measure	Sensitivity Tests				
	Baseline	Higher Vehicle Operating Costs	Rail Transit Extension	Doubled Capacity on Major Highways	Halved Capacity on Major Highways
<b>Daily Trips by Mode:</b>					
Auto	15,976,212	15,545,197	15,925,068	16,061,269	15,684,200
Transit	818,805	832,134	841,256	805,186	850,746
Walk & Bike	2,272,961	2,560,918	2,257,955	2,157,318	2,462,635
<b>Vehicle Miles Traveled:</b>					
Daily	105,976,212	94,195,933	106,185,529	115,030,228	95,213,034
<b>Average Daily Speeds:</b>					
Freeway	37.76	42.24	37.71	46.7	23.93
Arterial	20.43	21.18	20.47	20.04	20.55
Connectors	16.07	16.12	16.07	16.05	16.09
<b>Average Trip Lengths</b>					
Home-Based W	13	12.41	12.98	13.42	12.41
Home-Based S	4.48	3.86	4.5	4.89	4.09
Home-Based O	5.64	4.94	5.67	6.19	5.16

Source: Puget Sound Regional Council

# Real Estate Price Sensitivities



# Findings

---

- **Land Use Response to Transportation Scenarios**

- A modest response is in line with theoretical expectations
- Accessibility measures from the travel model do change across scenarios and reflect route and destination choices (and to a more limited degree mode choice).
- Short-run substitution and activity sorting across sites likely limits the effects on development
- The influence of access on site values is probably a central feature in proper simulations.

- **User Benefits Results Compared to Land Value Change:**

- Valuation of travel time savings for non-commercial vehicles compared to baseline, valued at respective values of time from the mode choice models
- Compared present value of stream of these user benefits to changes in land values from UrbanSim, based on expectation that travel time savings are capitalized into land values
- Expanded Highway Capacity: User Benefits: \$27.7 Billion vs. UrbanSim Land Value Change: \$31.4 Billion
- Reduced Highway Capacity: User Benefits (Costs): -\$42.8 Billion vs. UrbanSim Land Value Change: -\$36.0 Billion

Source: Puget Sound Regional Council

# MAG Region

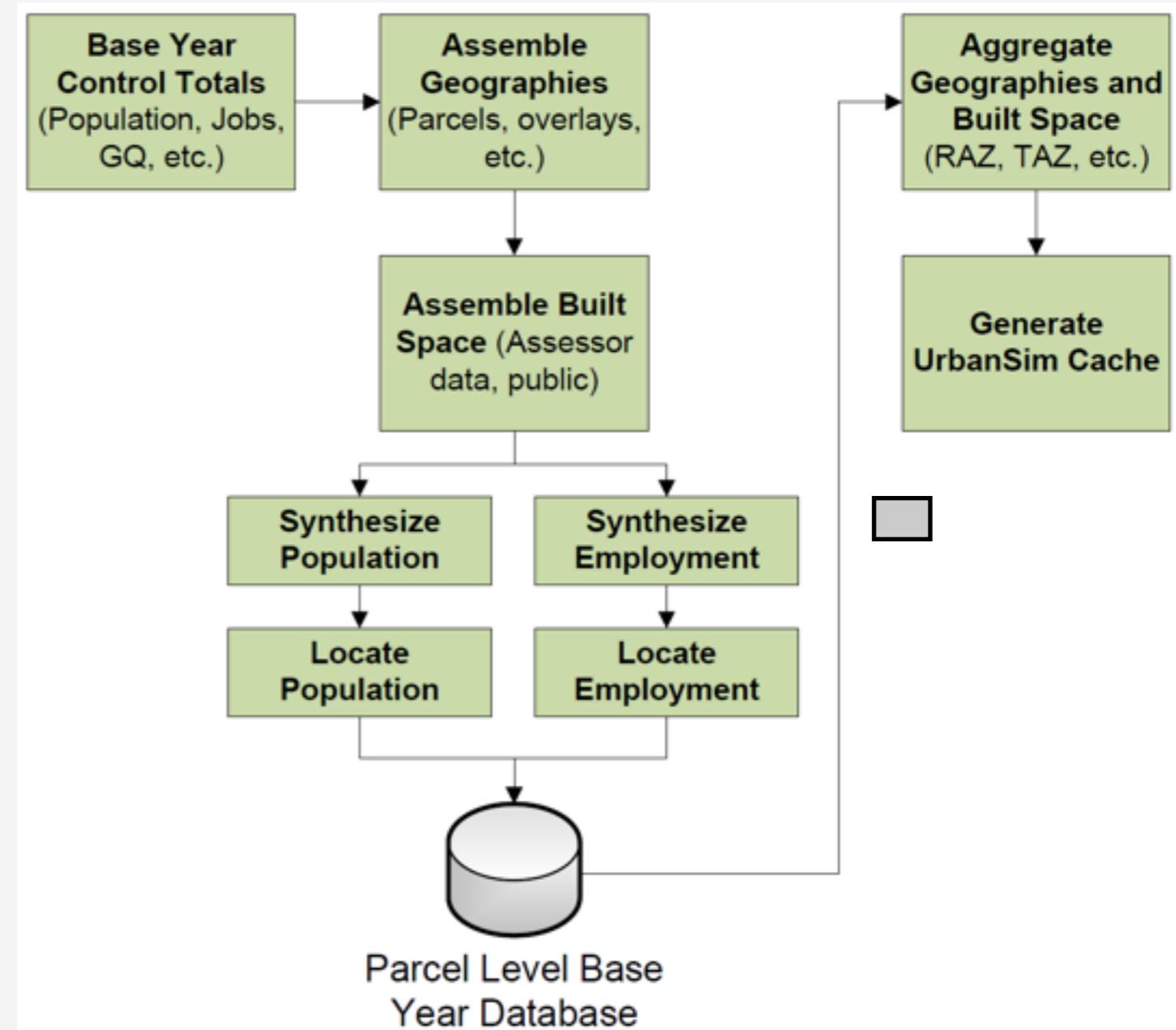
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- MPO for Maricopa County
  - Members include: 25 cities and towns, 3 Native American communities, Maricopa County, ADOT, and CTOC
- Maricopa County:
  - 9200 Mi<sup>2</sup> (<24k Km<sup>2</sup>)
  - Population: 3.9 million
  - Jobs: 1.9 million



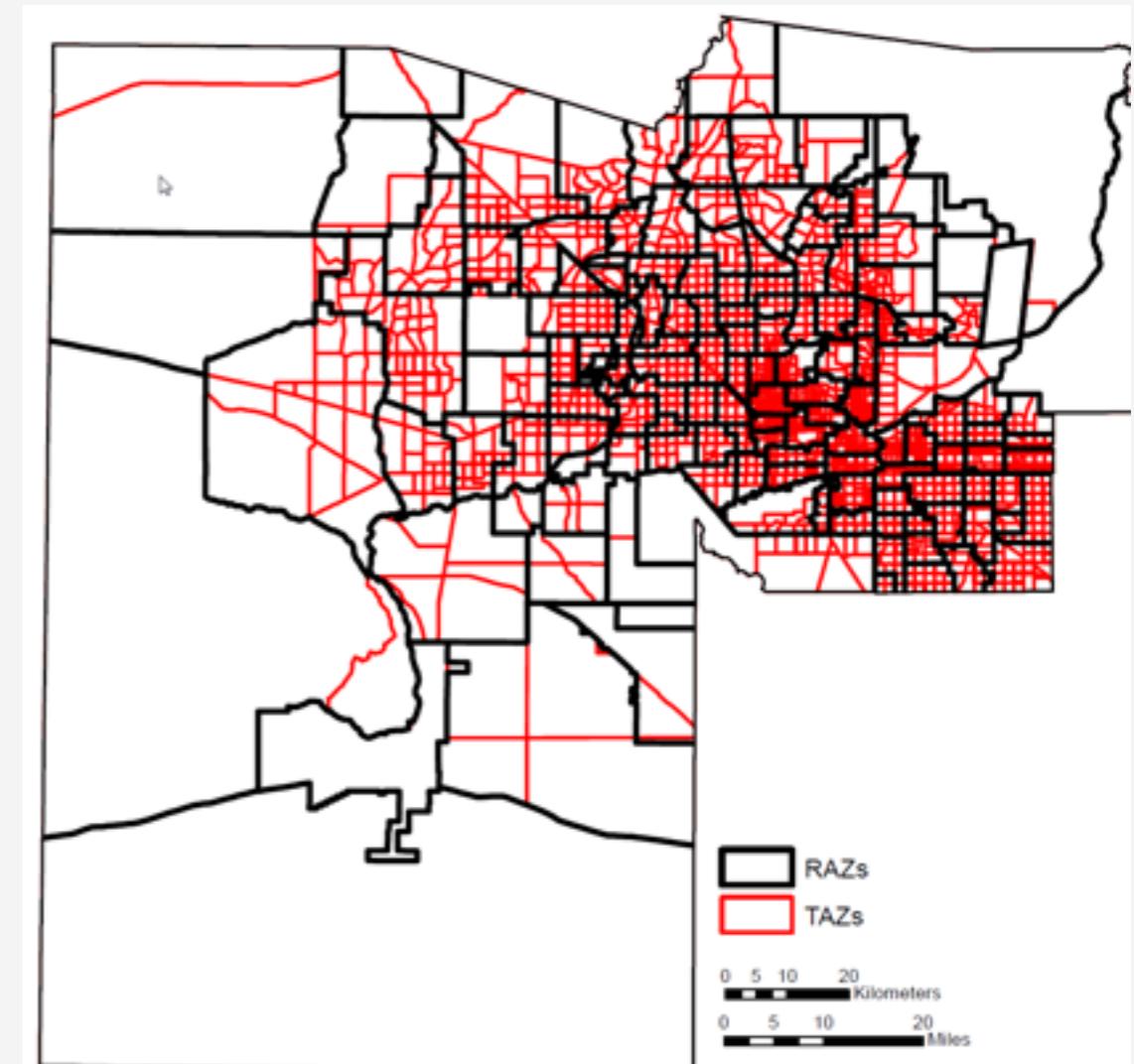
# UrbanSim Data Preparation

Data are prepared, maintained, and synthesized at the Parcel level, then aggregated as necessary

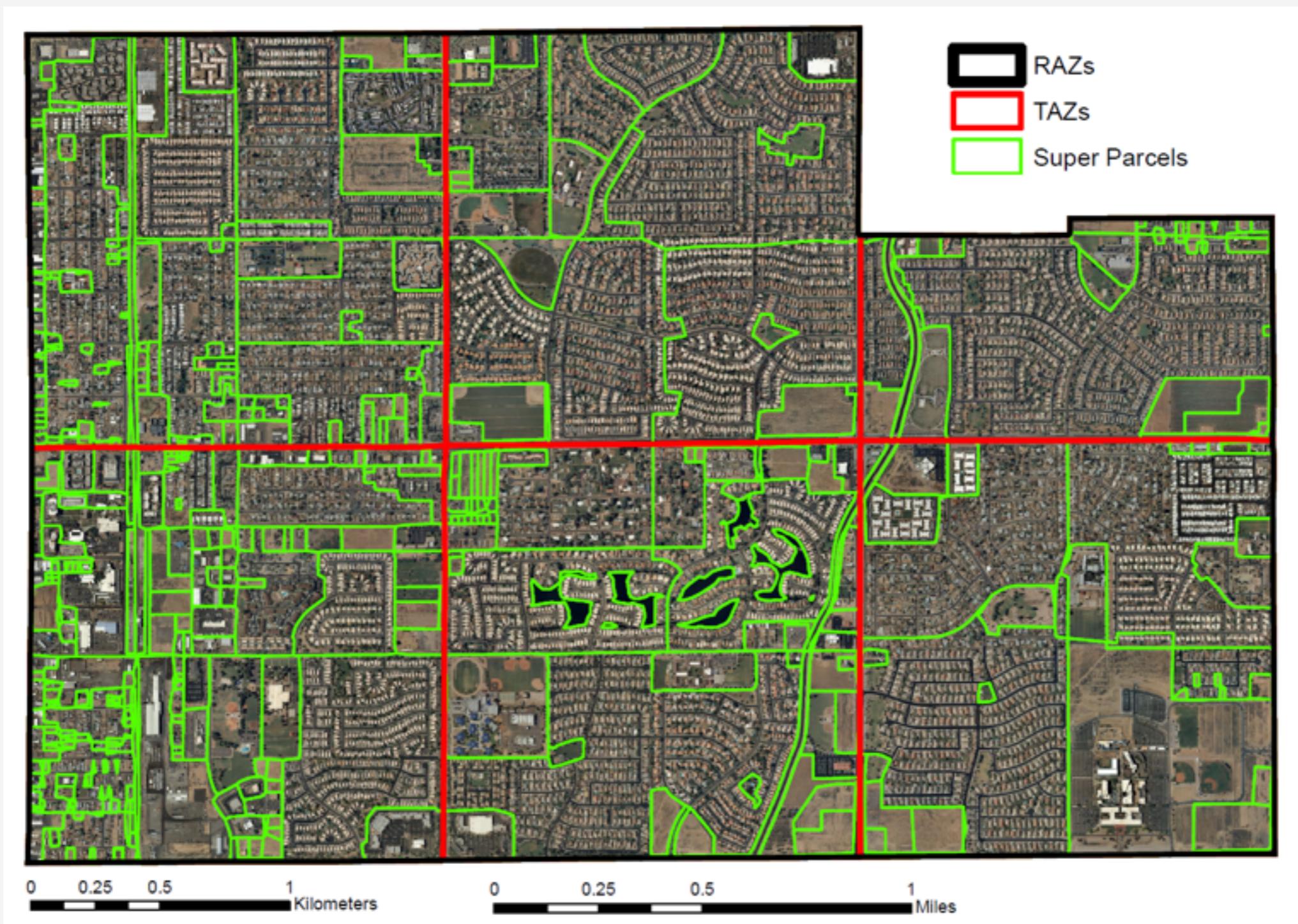


# Zone Model Evaluation - Geographies

- RAZs (Regional Analysis Zones, 148)
- TAZs (Traffic Analysis Zones, 1864)
- “Super-Parcels” (Parcel Aggregations, ~70k)
  - Most super parcels are a single land use type
  - Aggregate to TAZs, RAZs, Census Boundaries, etc.



# Zone Model Geographies – 1 RAZ



# MAG Zone Model System – Current Test Configuration

---

- **Real Estate Price Model**
  - 5 separately estimated submodels out of 15 building types
- **Real Estate Development Models**
  - 5 separately estimated location choice submodels
- **Household and Employment Transition Models**
  - Household Control totals stratified into 3 income classes
  - Employment Control totals stratified into ~15 sectors, aggregations of 2 digit NAICS codes with some special sectors pulled out
- **Household and Employment Relocation Models**
  - Relocation rates currently set to 0% for testing
- **Household and Employment Location Choice Models**
  - Household LCM stratified into 3 income classes for testing
  - Employment LCM stratified into the same sectors as the control totals
- **Several allocation or “pro-rating” models** for some special areas of interest to the travel model
- **Complete model system running at 3 levels of geography:** RAZ, TAZ, Super-Parcel

# Zone Model Evaluation

---

- **Simulation performance:**

- High end workstation (Dual Quad Core Xeon, 64bit Windows 7, 24GB RAM, 15k RPM RAID Array):
  - RAZ based model: 1 - 1.5 minutes/year
  - TAZ based model: 1 - 2 minutes/year
  - Super-parcel based: 3 - 4 minutes/year
- All runs with fully disaggregate decision-making agents

- **What's next?**

- New model development
  - Subarea based target vacancy rates for Real Estate Development Models
  - Demographic Evolution
  - Known / Active development information
- Improve input data quality: the source of most issues we have seen to date
- Testing, testing, testing, and more testing

1. UrbanSim Overview
2. Anatomy of the Model
3. Application in Practice

## **4. Assessment**

# UrbanSim: Strengths

---

- **Behavioral realism** and transparency: agents and choices are clear to modelers and to stakeholders
- **Strong and internally consistent theoretical basis** drawing on urban economics and random utility
- **Consistent and unified microsimulation framework;**
- **Can be configured to reflect different behavior at different scales**
- **Flexibility and modularity** to allow users to adapt and extend the system
- **Substantial and growing user community** in the US, Europe, and elsewhere;
- **Rapidly growing base of experience in operational planning** among MPOs
- **Extensive documentation and web site** (wiki allowing users to add content)
- **Migration path from very simple to more complex models**
- **Extended and ongoing support** from NSF, EPA, FHWA, States and MPOs, and the European Research Council

# UrbanSim: Weaknesses

---

- **Parcel version of the system has high data requirements**
  - Difficulties with data preparation: large and messy databases, missing data
  - Have had to resort to synthesizing some of the detailed data in some cases
- **Zone version of the model system has diminished capacity to represent detail**, though is quite fast to run, and easy to interface with travel model
- Although model specification and estimation are straightforward, **calibration and validation are still fairly complex and time consuming** iterative processes
- Documentation, though extensive, could still be improved
- Some still not comfortable moving away from static equilibrium assumptions, even with rigorous longitudinal validation

# UrbanSim Software Platform (OPUS): Strengths

---

- **Well developed Graphical User Interface** in close collaboration with users
- **Flexibility**
  - Geography: zones (any size), gridcells (any size) or parcels
  - Models: can be created from templates for regression, choice models and others
  - Travel models: interfaced with many 4-step and activity-based demand models, and DTA
  - Supports experimentation and extension by users
- **Expression language** to simplify addition of variables and indicators
- **Integrated tools for model estimation and calibration**
- **Integrated spatial analysis and visualization, and new tools for 3D visualization**
- **Tools for database schema generation, data loading, data imputation**
- **High computational performance**
- **Extensive software testing and automated build system**
- **Software and documentation are open source and freely downloadable**
- **Entire system and web community open to engagement and contributions** (code, documentation, tutorials, case studies, etc.)

# UrbanSim Software Platform (OPUS): Weaknesses

---

- **Graphical User Interface still has excessive detail** presented to user; can be confusing
- **Some learning curve is required to become proficient in creating variables** and indicators using the syntax of the OPUS expression language
  - e.g. to create a zone population indicator: zone.aggregate(households.persons)
- **Needs more user-friendly error handling and error messages**
- **Tools for data imputation and synthesis need to be better integrated**
- **Tools for calibrating the model system need to be better integrated**
- **3D visualization not yet integrated into the OPUS GUI**
- **Limited built-in indicators**, and the GUI framework for indicator reports is limited
- **Generating new scenarios is not easy to do in the GUI**; new platform for release this fall to address this

# UrbanSim: Recommendations

---

- Improve tools to develop database: imputation, synthesis
- Create a more integrated and user-friendly interface to create scenarios
- Integrate 3D visualization into GUI
- Tighten integration with new activity-based travel demand and dynamic assignment models, preserving microsimulation information consistently
- Improve capacity to support more interactive use in stakeholder settings

# Questions and Discussion

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## UrbanSim Links:

<http://www.urbansim.org>

## Presenters:

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University of California Berkeley  
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Jesse Ayers

Maricopa Association of Governments  
email: jayers at azmag.gov