

# Urban Simulation and Visualization for Urban Sustainability Planning



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**University of California, Berkeley**

# Urban Simulation and Scenario Planning

- **Scenario Planning** (e.g. UrbanFootprint) describes workflow as:

Existing + Change = Scenario -> Analysis

Answers questions like: If we could develop in a particular way, what kinds of impacts might that have?

- **Urban Simulation** (e.g. UrbanSim) workflow is:

Existing + Policy Scenario -> Analyze -> Evaluate

Answers questions like: Given a set of objectives, what combination of policies might help us achieve them? How would people and businesses respond in real estate markets? What kinds of trade-offs are involved?

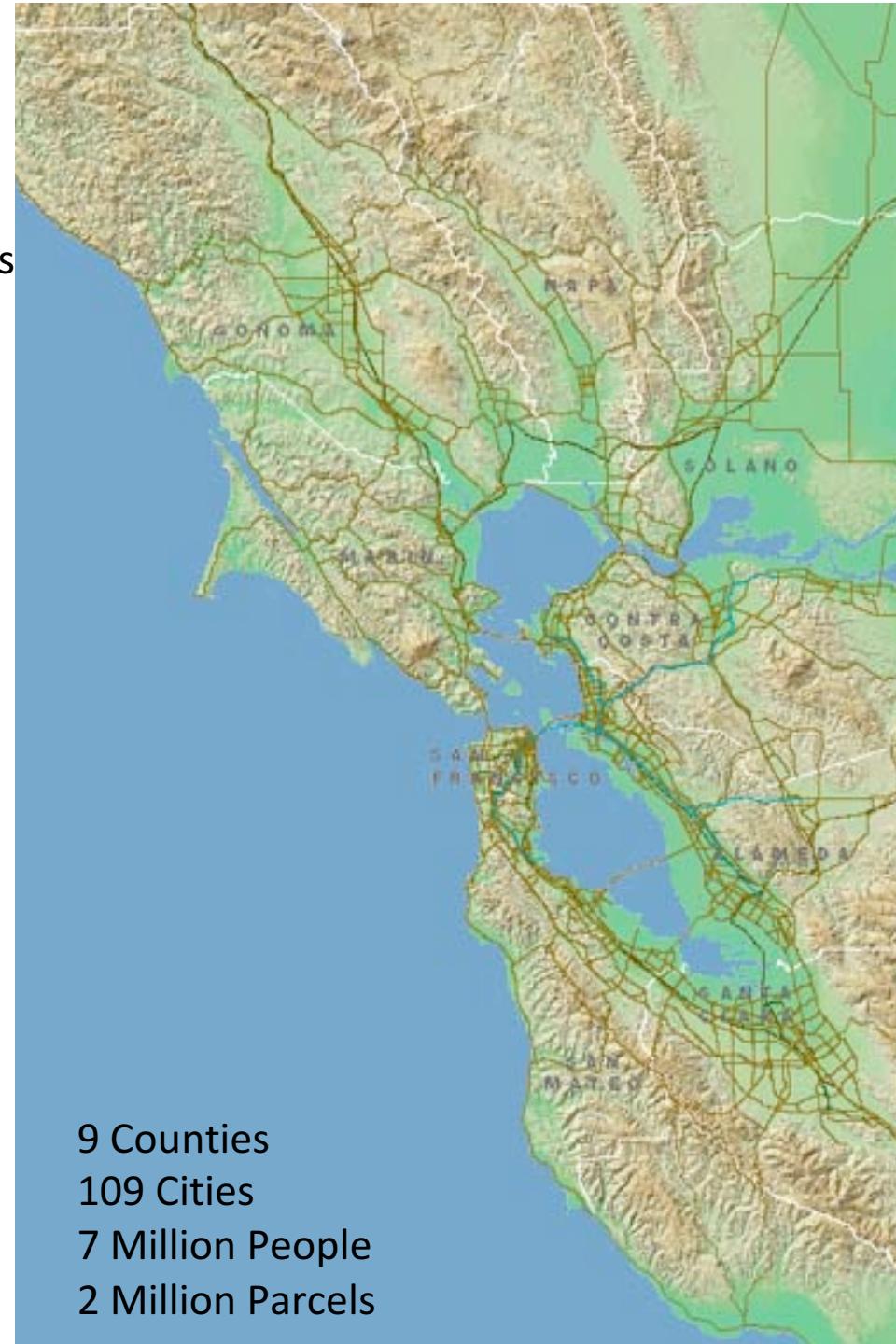
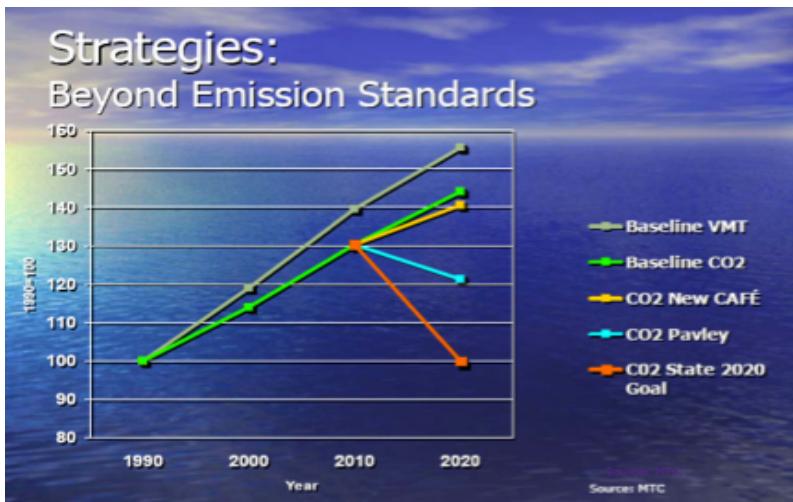


# BayArea Plan

- First regional plan to integrate transportation, land use, and housing (*Sustainable Communities Strategy*)
- Initiated by California Senate Bill 375

# The Regional Task

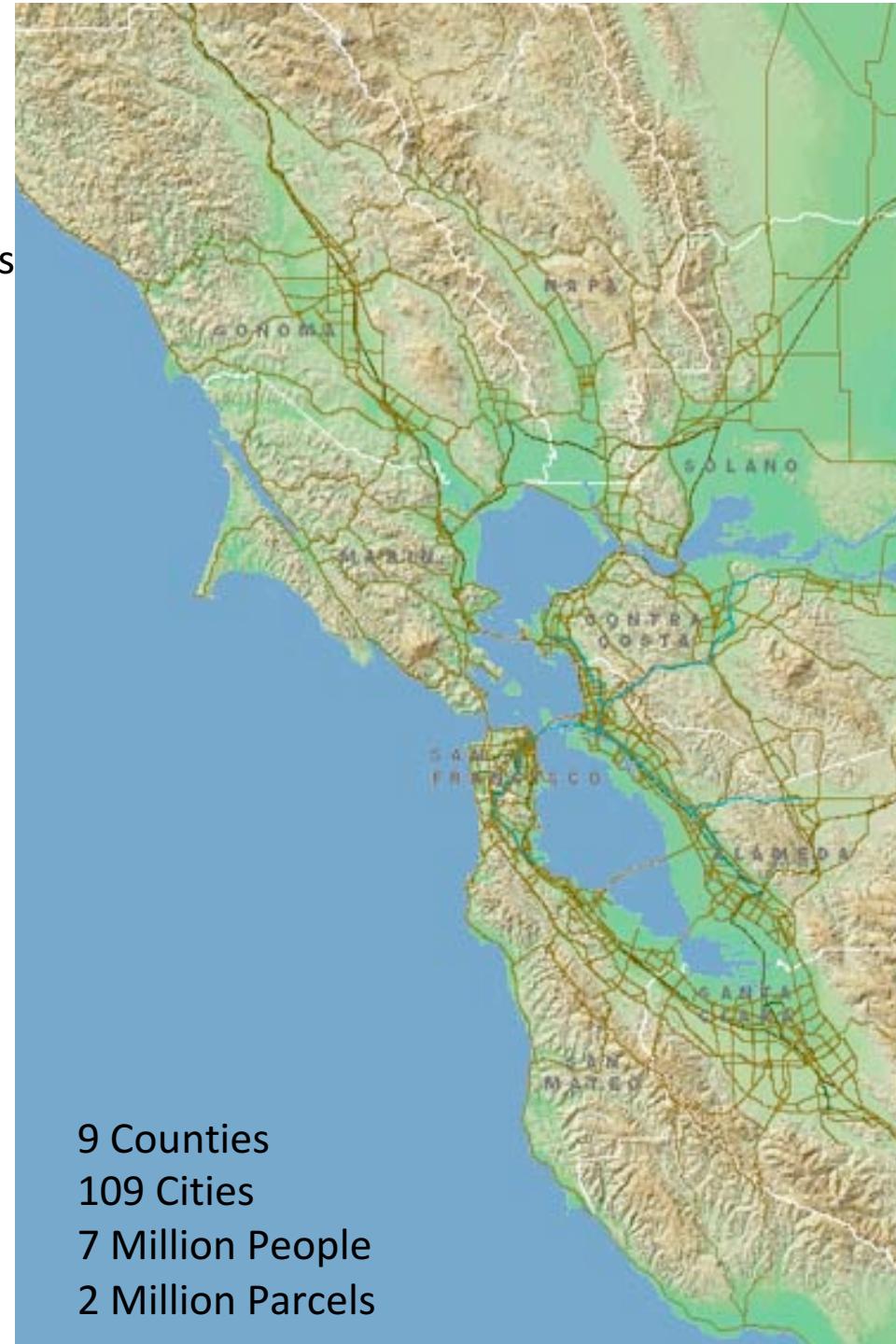
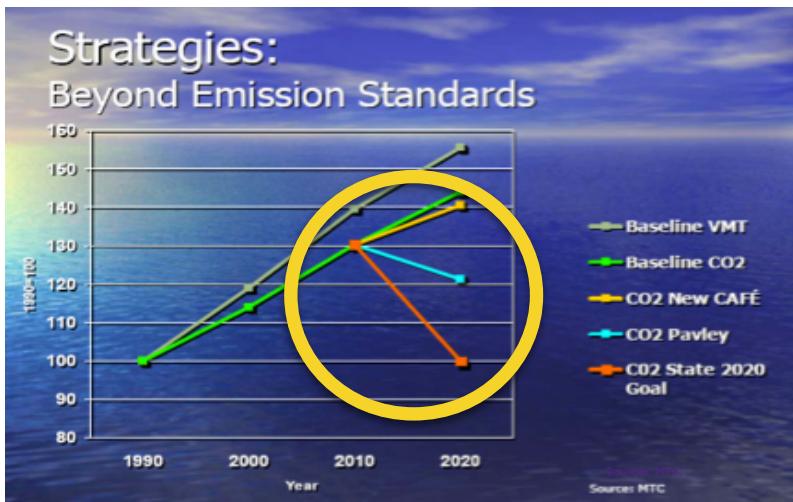
- Reduce per capita greenhouse gas emissions by 15% from 1990 levels by 2035
- House the region's population at all income levels
- Embody local visions
- Stretch tax revenues through smart investments
- Increase economic competitiveness
- Preserve the natural environment
- Sustain a healthy, vibrant region for our children and grandchildren



9 Counties  
109 Cities  
7 Million People  
2 Million Parcels

# The Regional Task

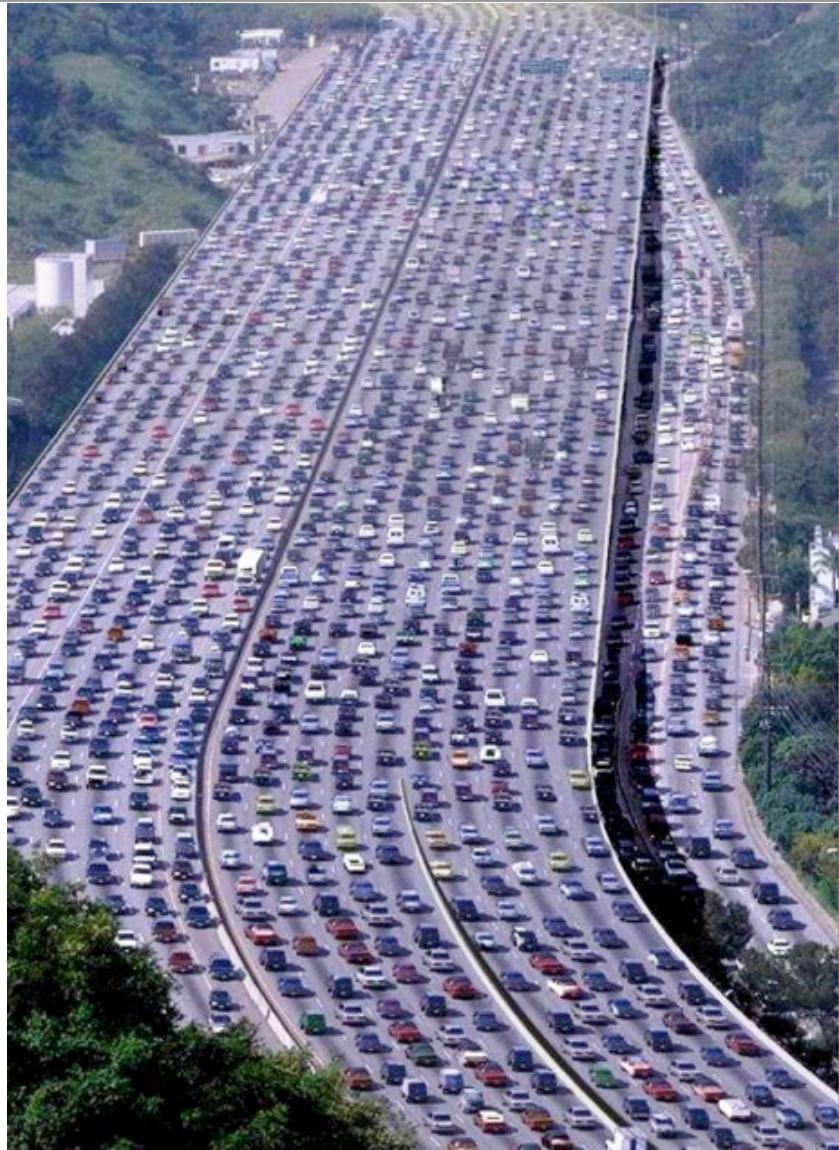
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# Plan Reflects Shifting Paradigm: Mobility to Accessibility

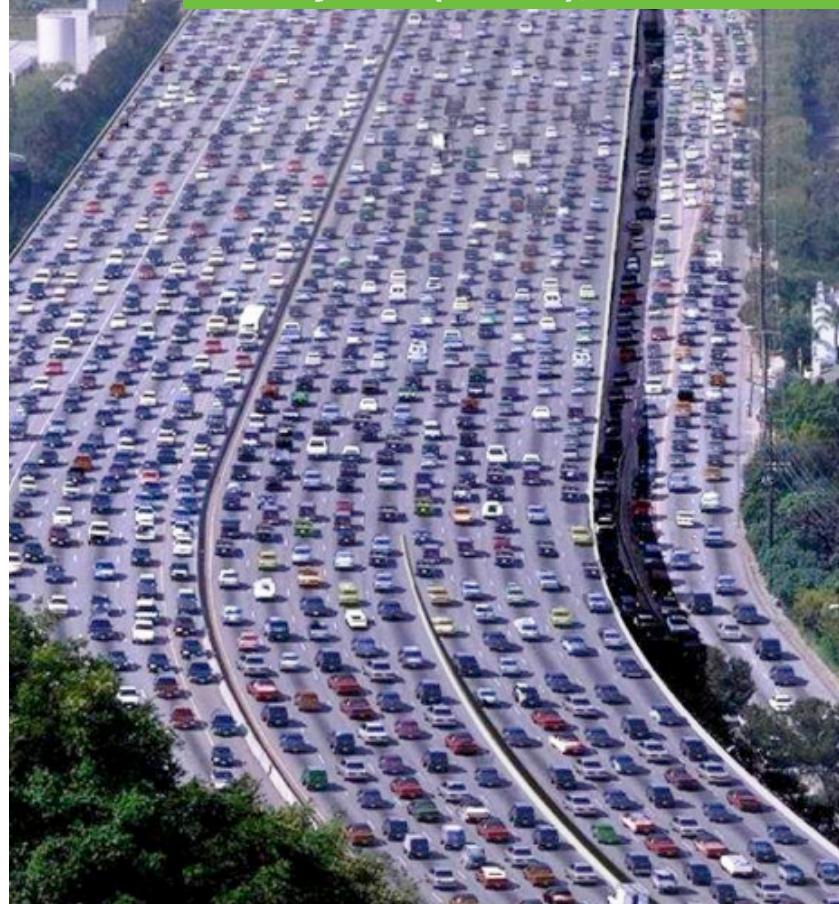
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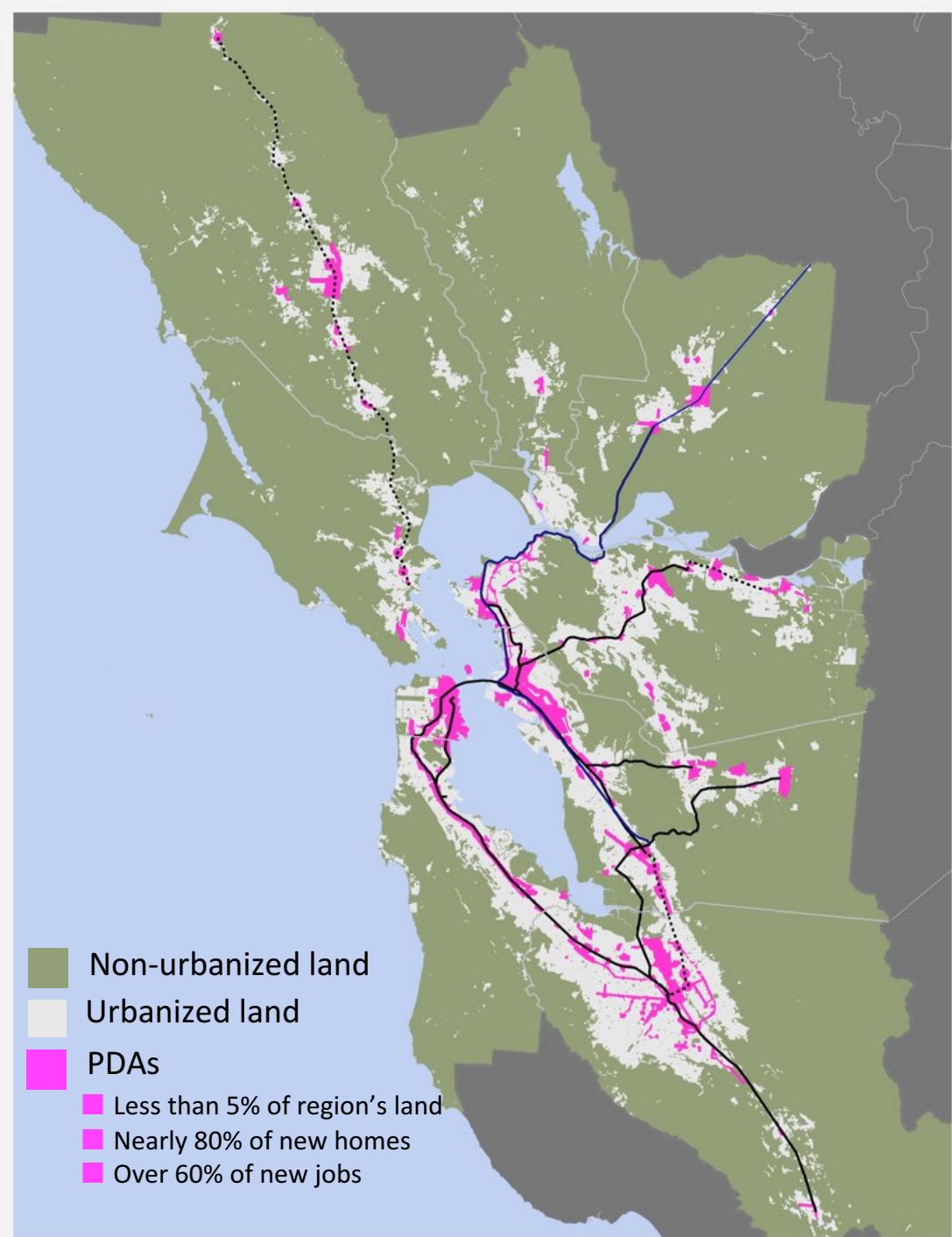
# Plan Reflects Shifting Paradigm: Mobility to Accessibility

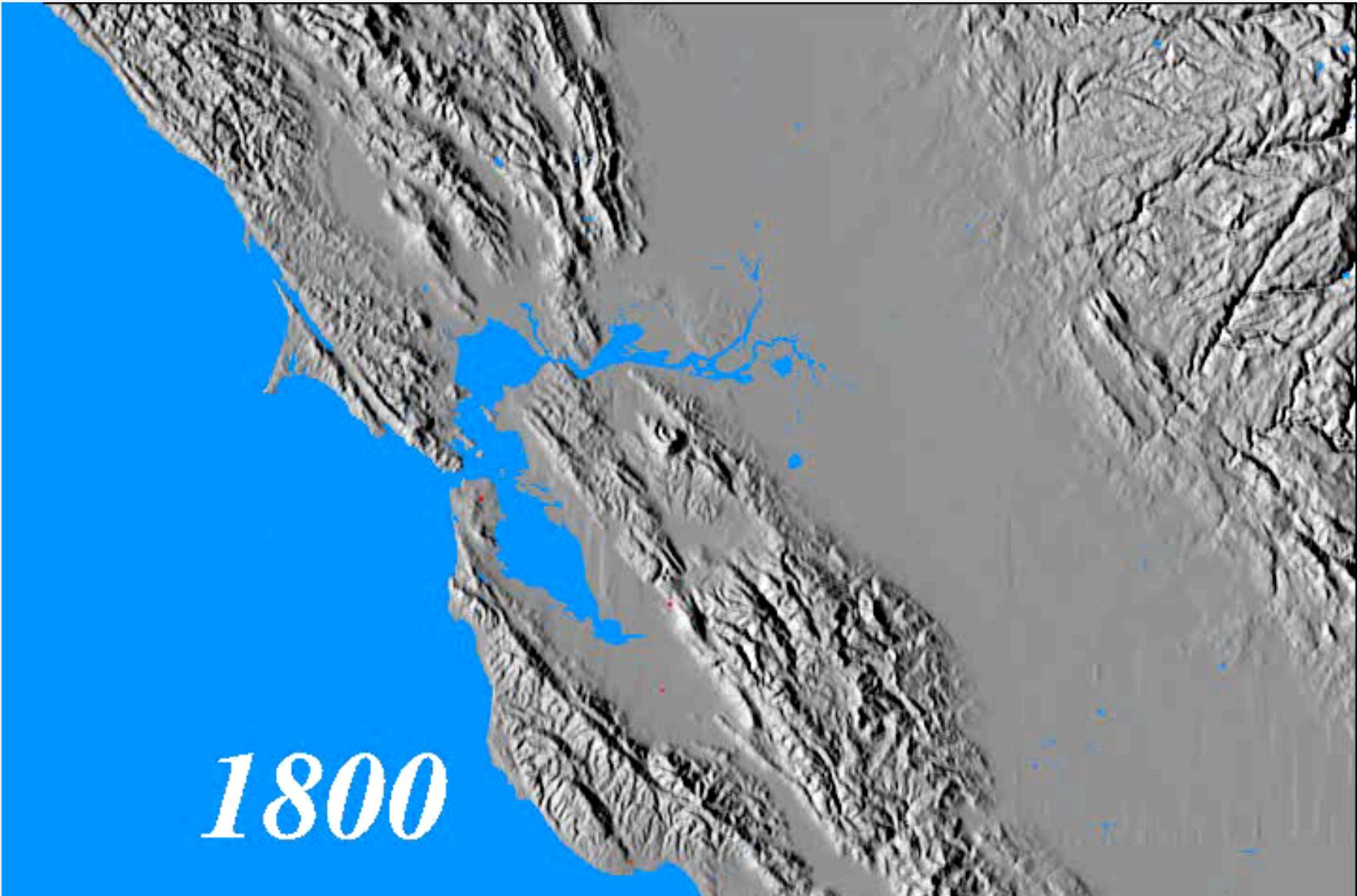


**California has just eliminated Level of Service (LOS) as its metric for assessment of conformity with the California Environmental Quality Act (CEQA), in favor of VMT reduction..**



# Regional Growth Strategy: Focused Growth





1800

Historical land use change



# BayArea Plan

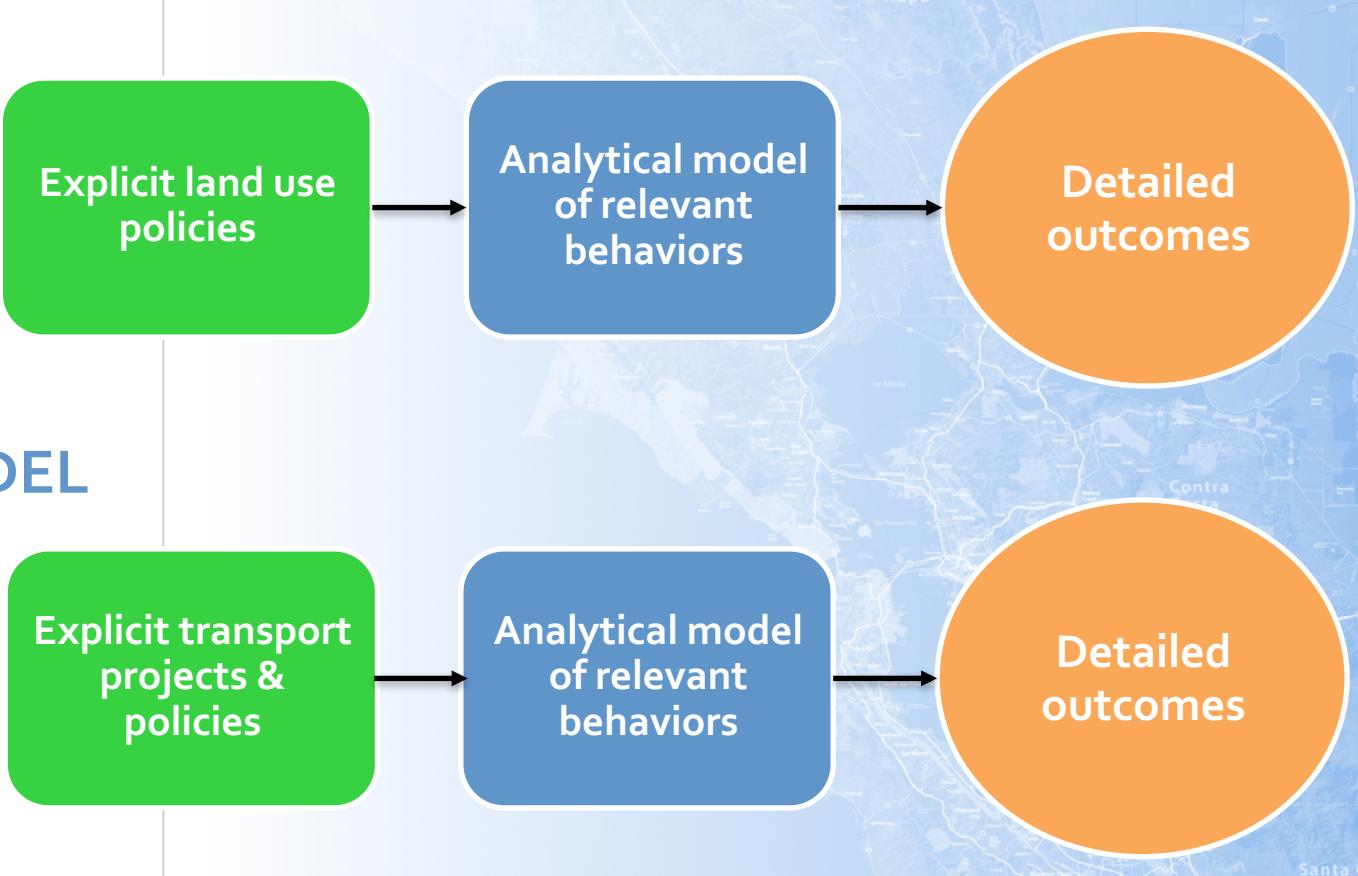
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- Initiated by California Senate Bill 375

# Modeling Scenarios Regionally for EIR

URBANSIM

Integrated

TRAVEL MODEL



Largest MPOs should “build formal microeconomic land use models, as soon as is practical, so that they can be used to analyze and evaluate the effects of growth scenarios on economic welfare (utility), including land prices, home affordability, jobs-housing fit, the combined housing-transportation cost burden, and economic development (wages, jobs, exports).”

Source: California Transportation Commission's 2010 RTP Guidelines

# Policy Inputs to Model System

- **Transportation**

- Transit investments (Rail, Bus)
- Roadway investments (GP, HOV, HOT, Bike, Pedestrian)
- Pricing (Tolls, Congestion)

- **Land Use Regulations**

- City comprehensive Plans
- Transit Oriented Development, Urban Villages & Centers
- Subsidies, Impact Fees
- Urban Growth Boundaries
- Protection of Environmentally-sensitive Areas



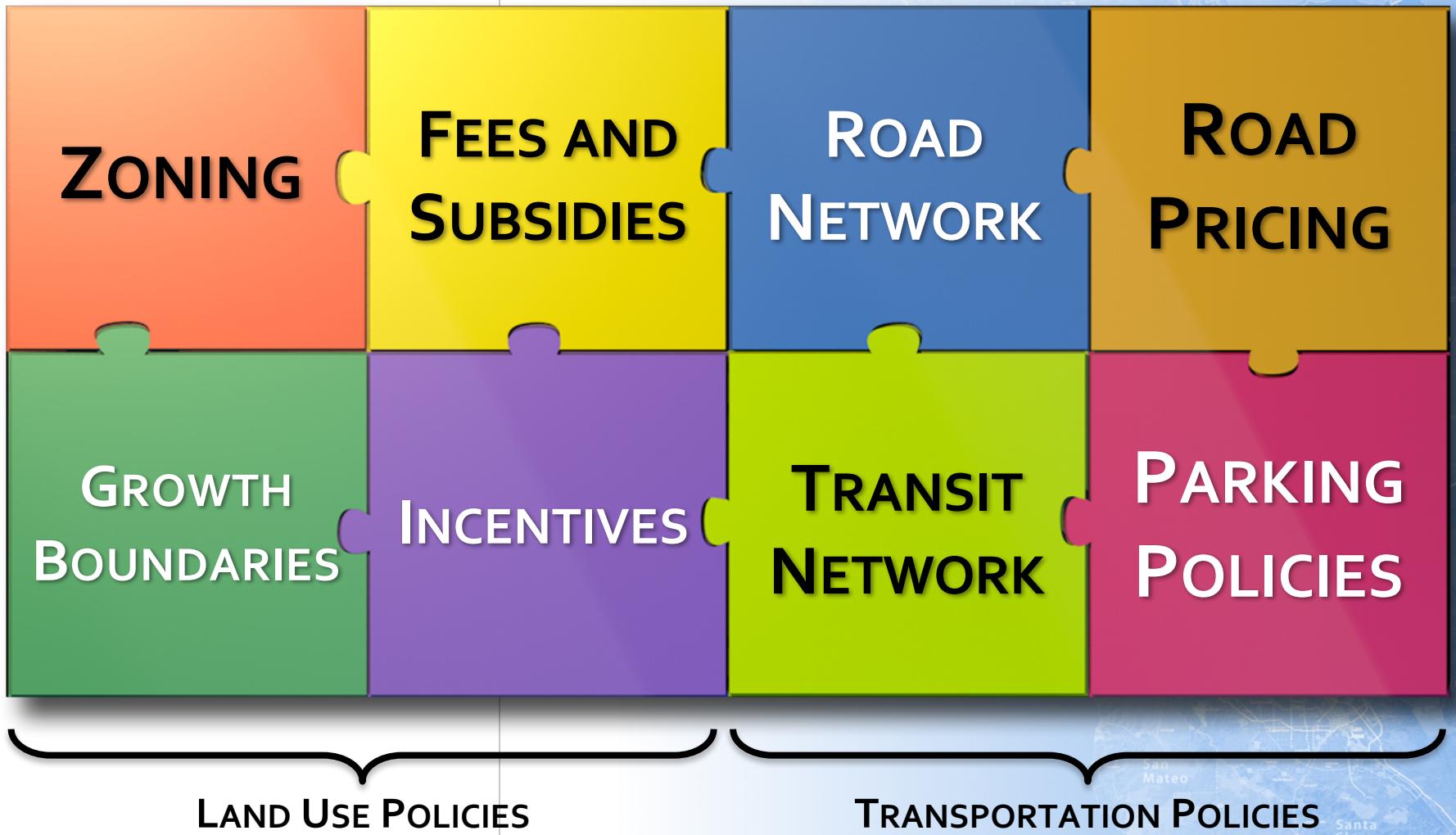
# Land Use Data

	Count of Objects
Parcels	2,023,915
Single Family Houses	1,479,511
Non-SF Buildings	456,749
Establishments	464,302
Jobs	3,395,967
Households	2,608,023
People	6,996,929

# Network Data

	Source	Count Of Nodes	Count of Edges	Ave Nodes in 15 mins	StdDev of Nodes in 15 mins	Ave Nodes in 30 mins	Ave Nodes in 45 mins
Local Street Network	OpenStreetMap	226,060	287,161	122	85	432	900
Auto Network Model	MTC Travel Model	11,999	33,136	1,154	678	3,628	6,565
Transit Network	Bay Area GTFS Feed	421,491	660,914	143	213	1,063	3,729

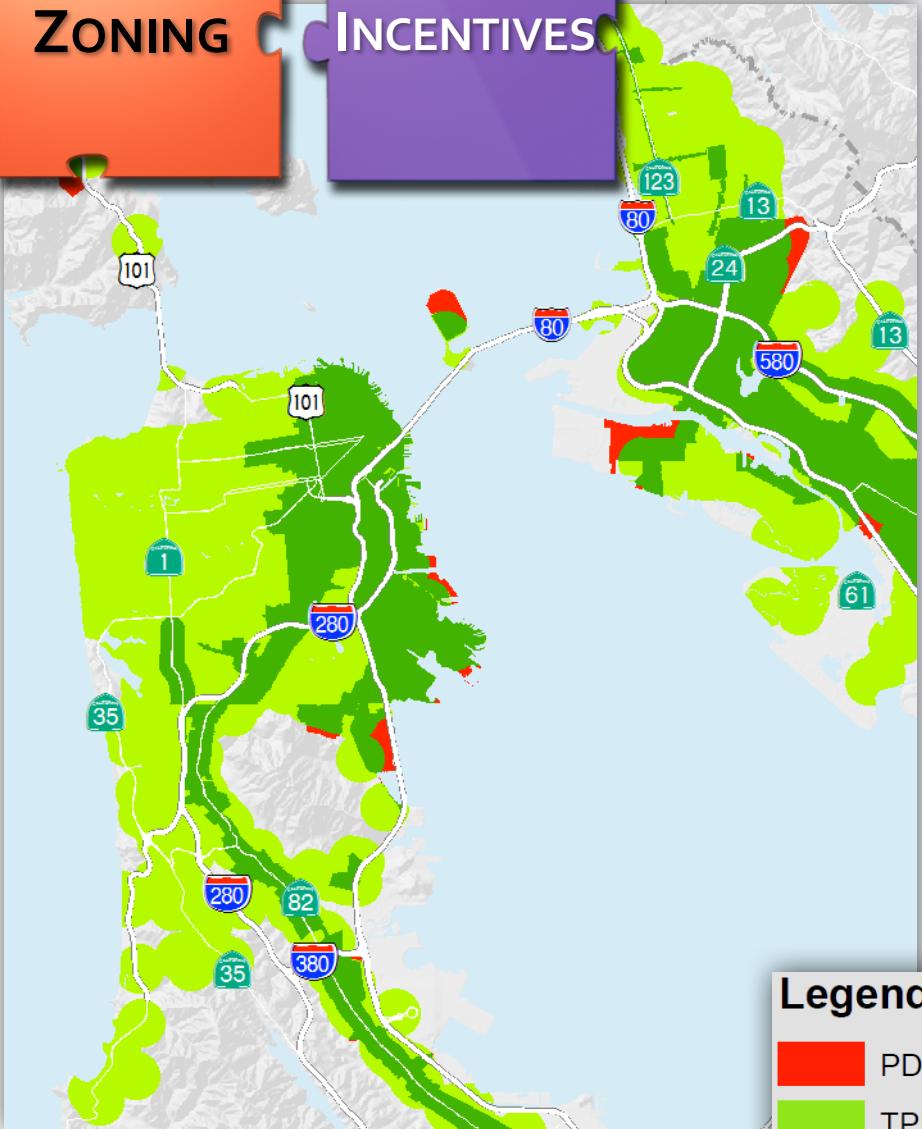
# Policy Inputs for Bay Area EIR Alternatives



# Comparison of TPPs and PDAs

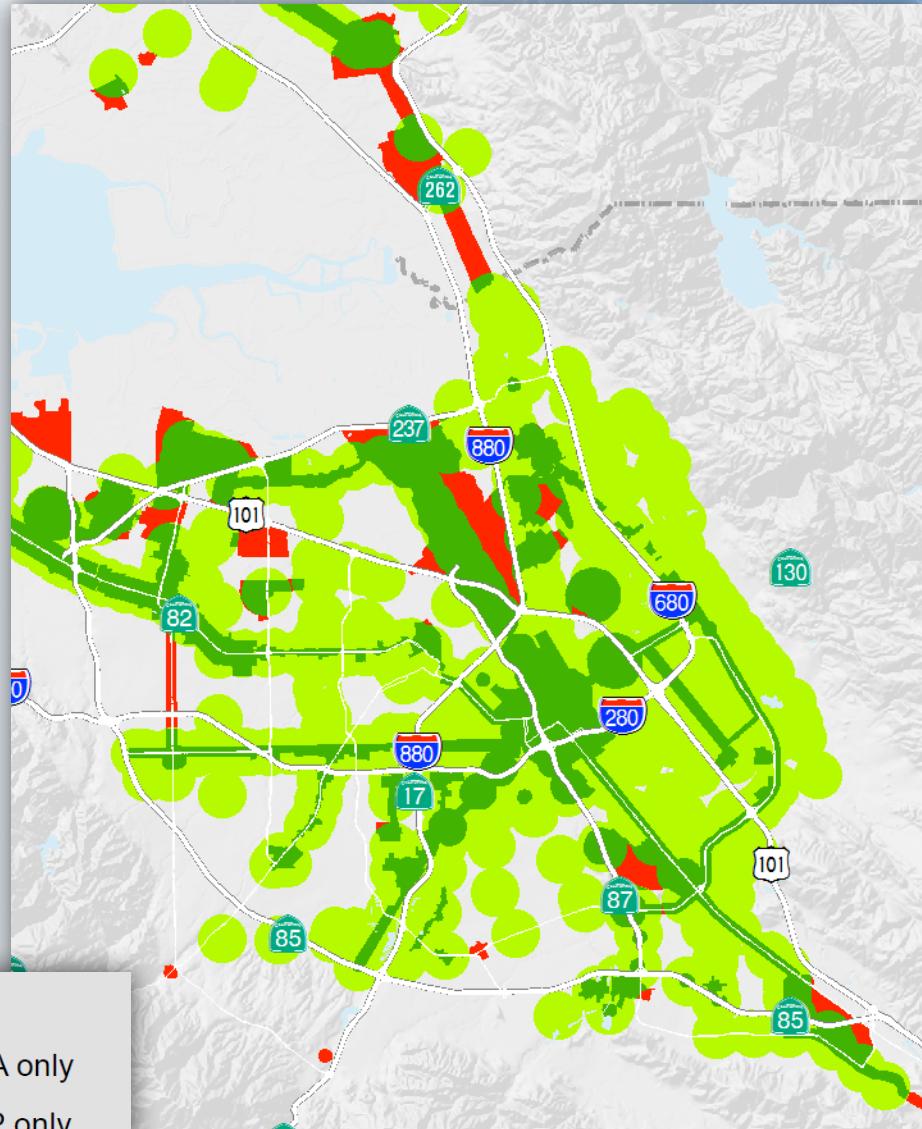
ZONING

INCENTIVES



## Legend

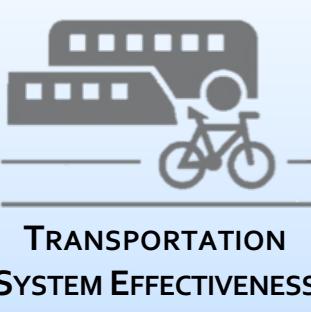
- PDA only
- TPP only
- TPP & PDA



## ECONOMY



Increase gross regional product



Increase non-auto mode share

Reduce VMT per capita

Maintain the transportation system

## ENVIRONMENT



CLIMATE PROTECTION

Reduce per-capita greenhouse gas emissions from cars and light-duty trucks



OPEN SPACE AND AGRICULTURAL PRESERVATION

Direct all non-agricultural development within the urban footprint



HEALTHY AND SAFE COMMUNITIES

Reduce premature deaths from exposure to particulate emissions

Reduce injuries and fatalities from collisions

Increase average daily time spent walking or biking

## EQUITY



ADEQUATE HOUSING

House all of the region's projected housing growth



EQUITABLE ACCESS

Decrease housing and transportation costs as a share of low-income household budgets

# EIR Alternatives Analysis:

## Performance Targets

achieves or exceeds performance target

falls short of performance target

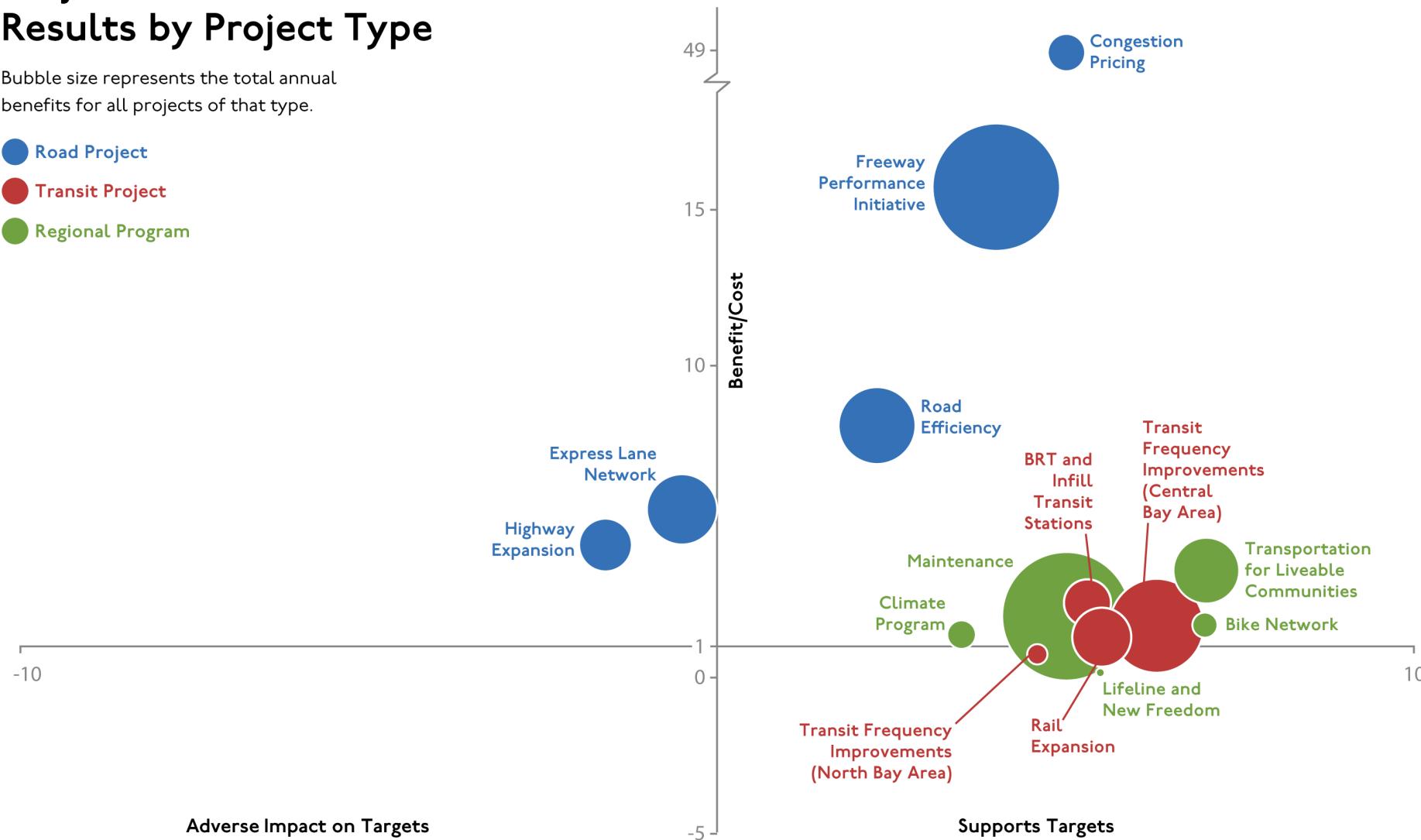
moving in the wrong direction

Target	Goal	No Project	Preferred	Transit Priority Focus	Network of Communities	Equity, Environment & Jobs
1 Reduce per-capita CO <sub>2</sub> emissions from cars and light-duty trucks	<b>-15%</b>	-8%	-18%	-16%	-16%	-17%
2 House the region's projected growth	<b>100%</b>	100%	100%	100%	118%	100%
3a Reduce premature deaths from exposure to fine particulates (PM <sub>2.5</sub> )	<b>-10%</b>	-71%	-71%	-72%	-69%	-72%
3b Reduce coarse particulate emissions (PM <sub>10</sub> )	<b>-30%</b>	-16%	-17%	-17%	-14%	-18%
3c Achieve greater particulate emission reductions in highly impacted areas	<b>Yes</b>	Yes	Yes	Yes	No	Yes
4 Reduce the number of injuries and fatalities from all collisions	<b>-50%</b>	+18%	+18%	+17%	+23%	+16%
5 Increase the average daily time walking or biking per person for transportation	<b>+70%</b>	+12%	+17%	+18%	+13%	+20%

# Project Performance Assessment: Results by Project Type

Bubble size represents the total annual benefits for all projects of that type.

- Road Project
- Transit Project
- Regional Program



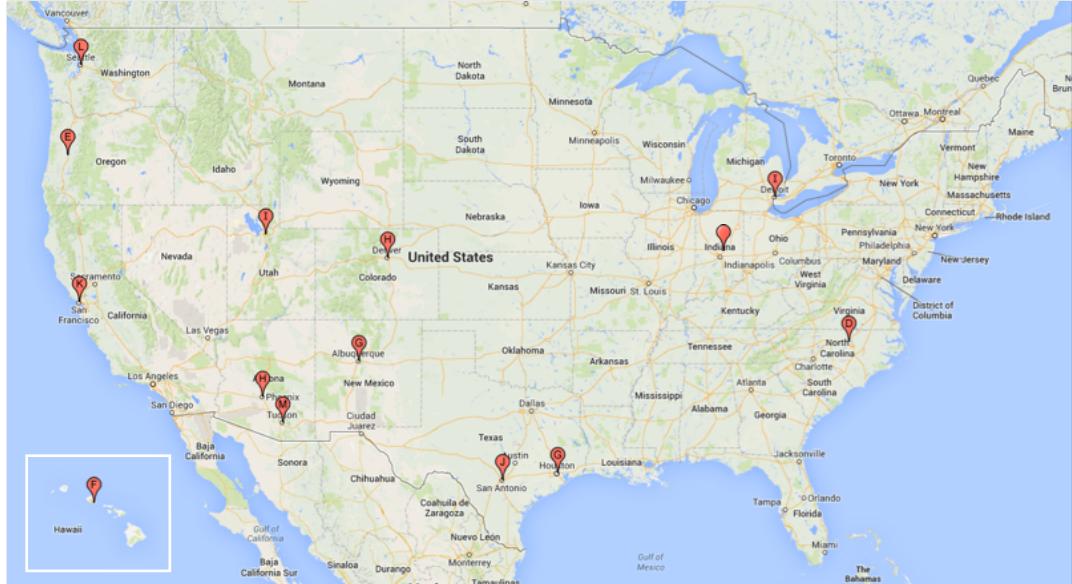
# UrbanSim

Open source, transparent model system to project the outcomes of city and metropolitan land use, transportation and environmental plans and policies

Funded mainly by grants from NSF

Most widely used land use model system by Metropolitan Planning Organizations (MPOs) in the United States

# UrbanSim

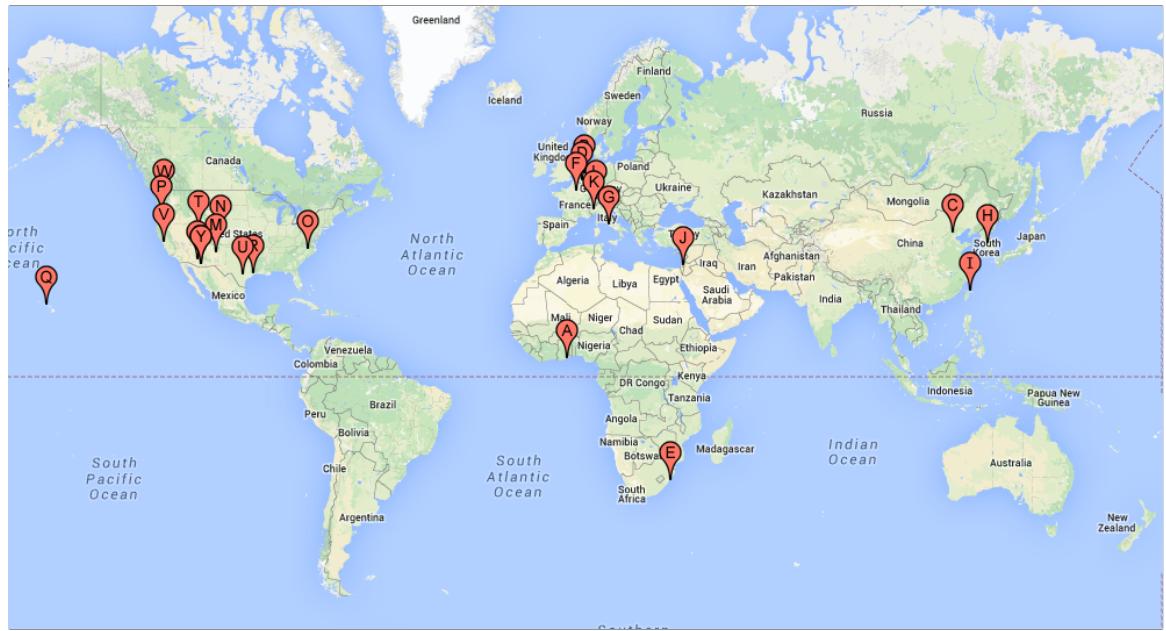


Albuquerque, NM  
Denver, CO  
Detroit, MI  
Durham, NC  
Eugene-Springfield, OR

Honolulu, HI  
Houston, TX  
Madison County, IN  
Phoenix, AZ  
Salt Lake City, UT

San Antonio, TX  
San Francisco, CA  
Seattle, WA  
Tucson, AZ

# UrbanSim



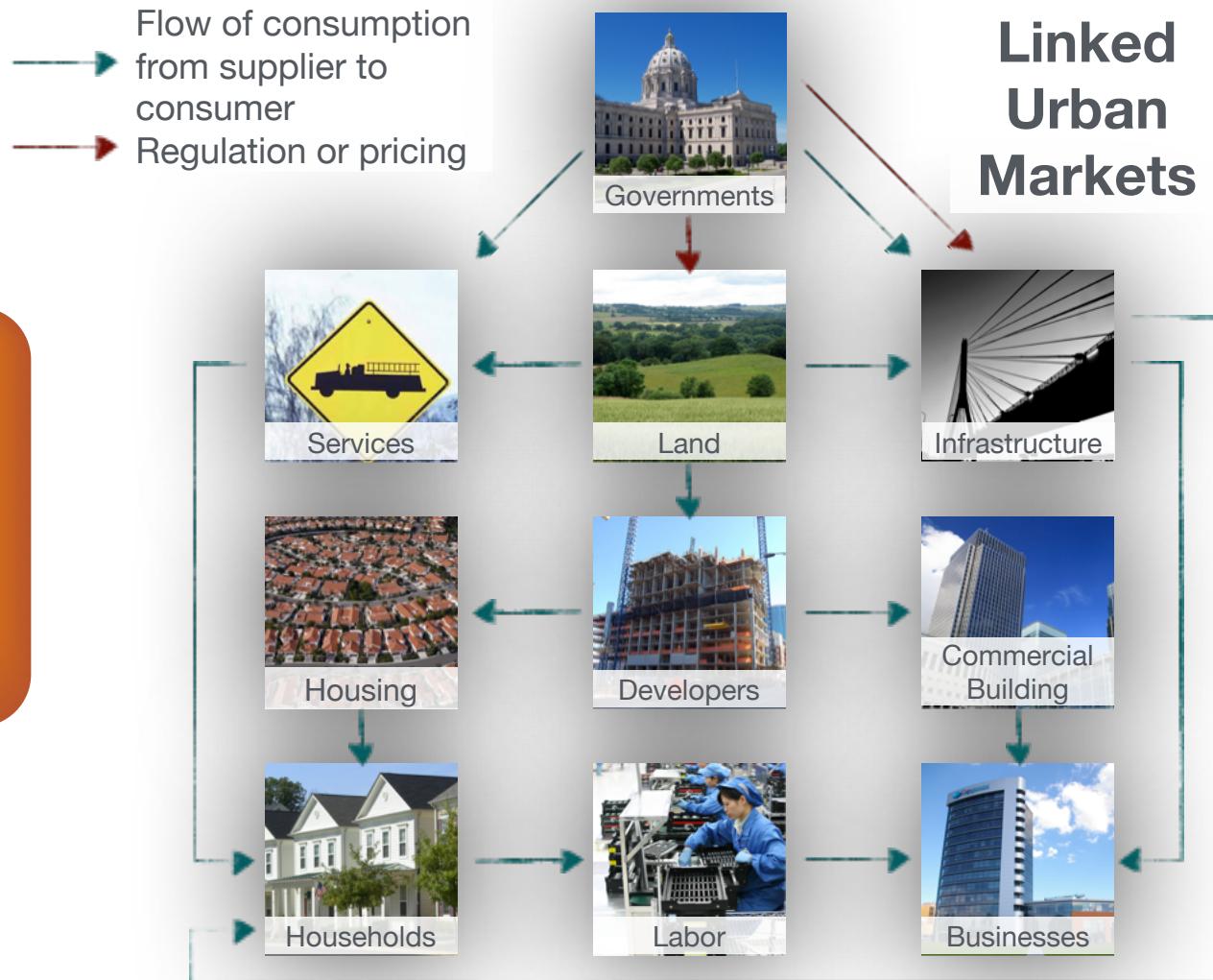
Accra  
Amsterdam  
Beijing  
Brussels

Durban  
Paris  
Rome  
Seoul

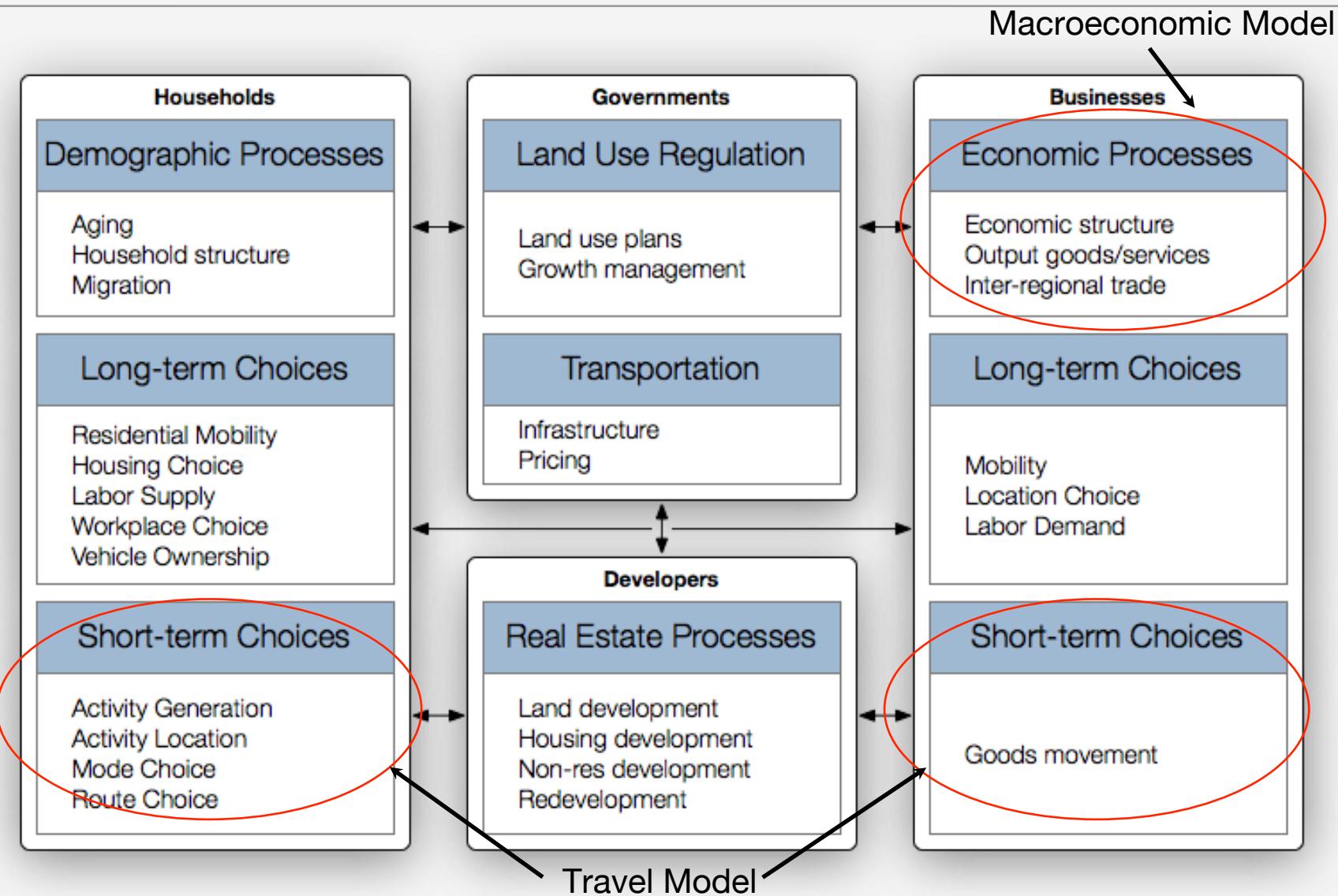
Taipei  
Tel Aviv  
Turin  
Zürich

**Users in 70+ countries**

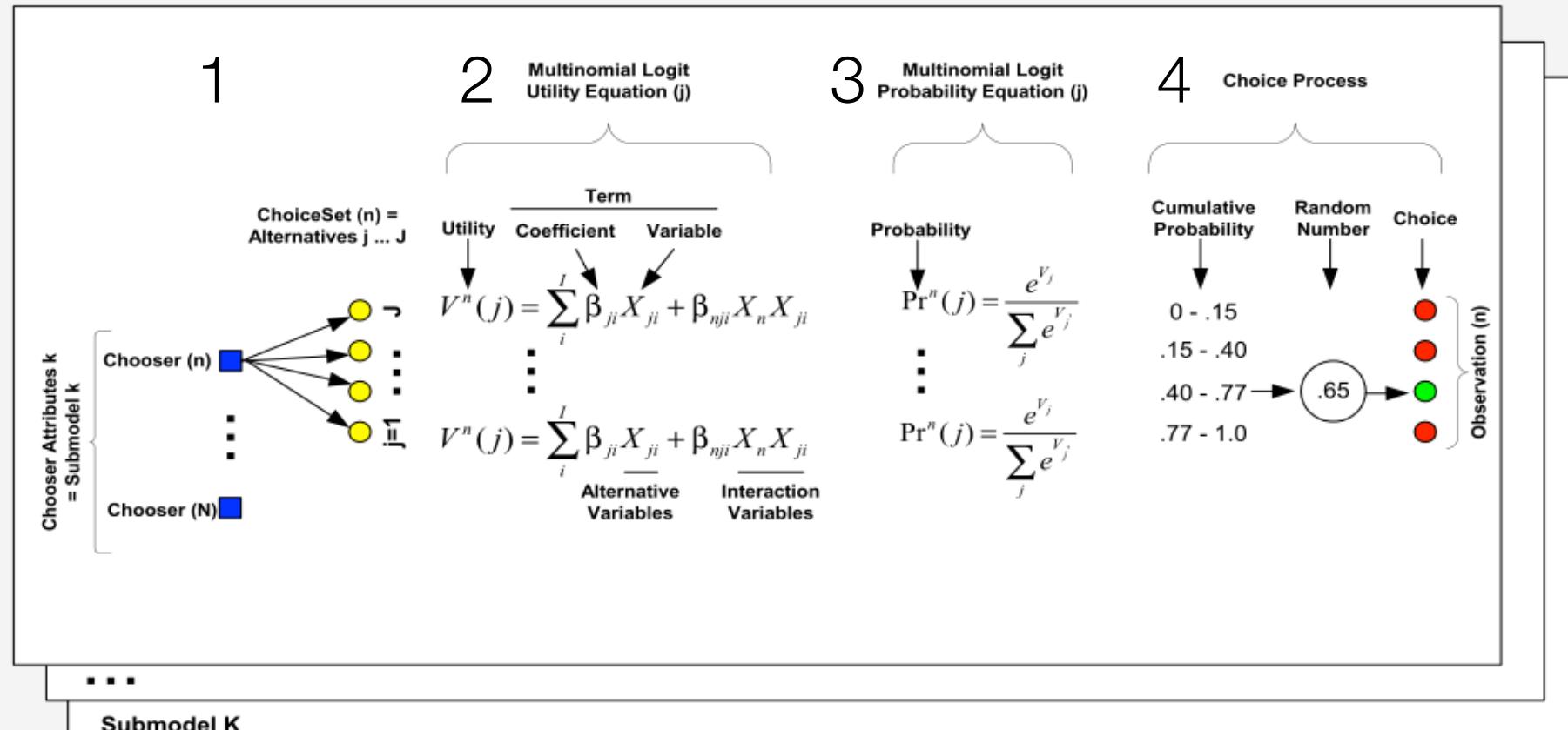
# UrbanSim



# UrbanSim Models Choices of Agents in Urban System

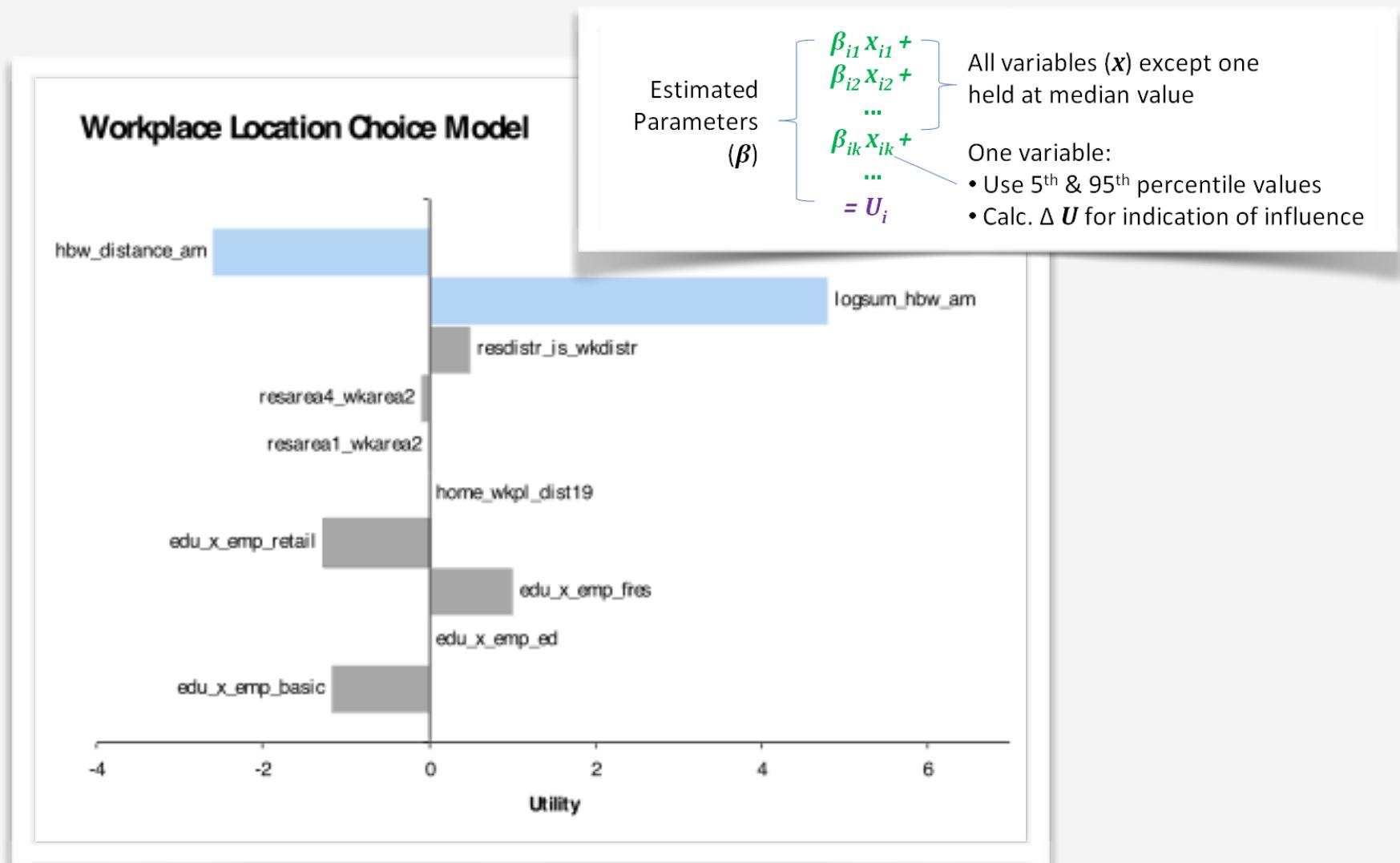


# Software Architecture for UrbanSim: Modular Choice Models



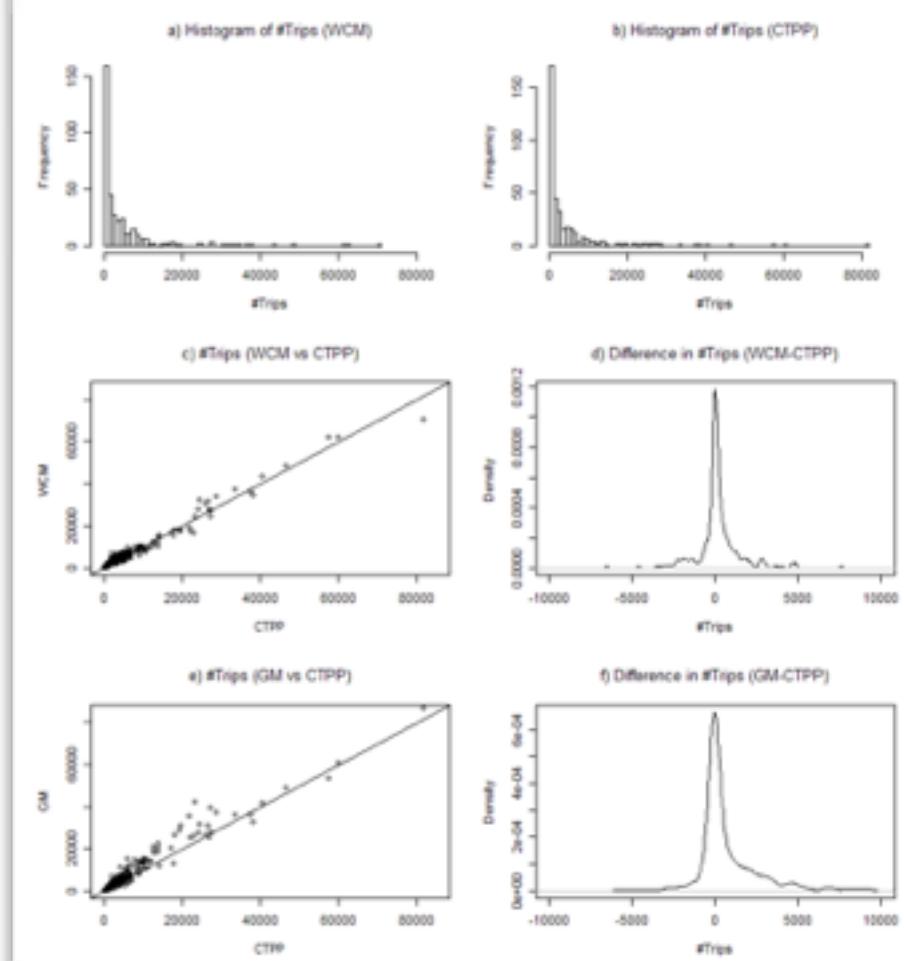
Implementation of a choice model involves selecting options for each step in the model process, and setting its configuration. In most cases, this can be done in the GUI, without the need to edit program code. New models can be created from templates, specified, and estimated interactively.

# Sensitivity Analysis: Relative Influence of Variables

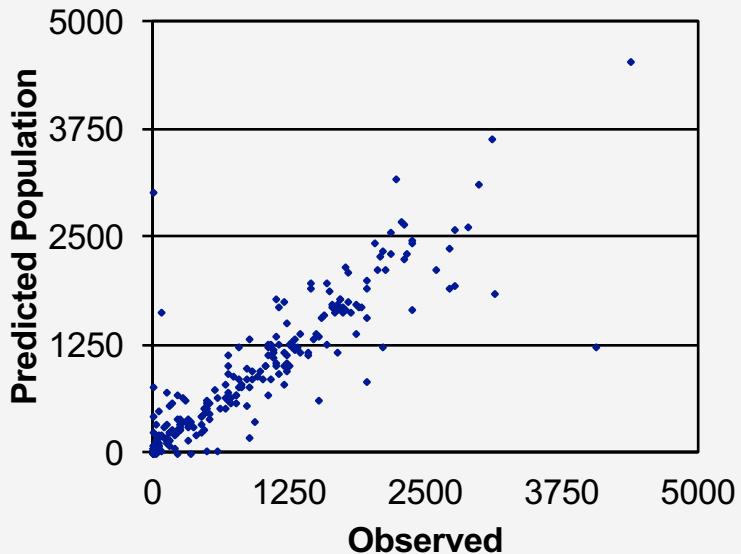


# Calibration and Validation of Workplace Choice Model

- 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



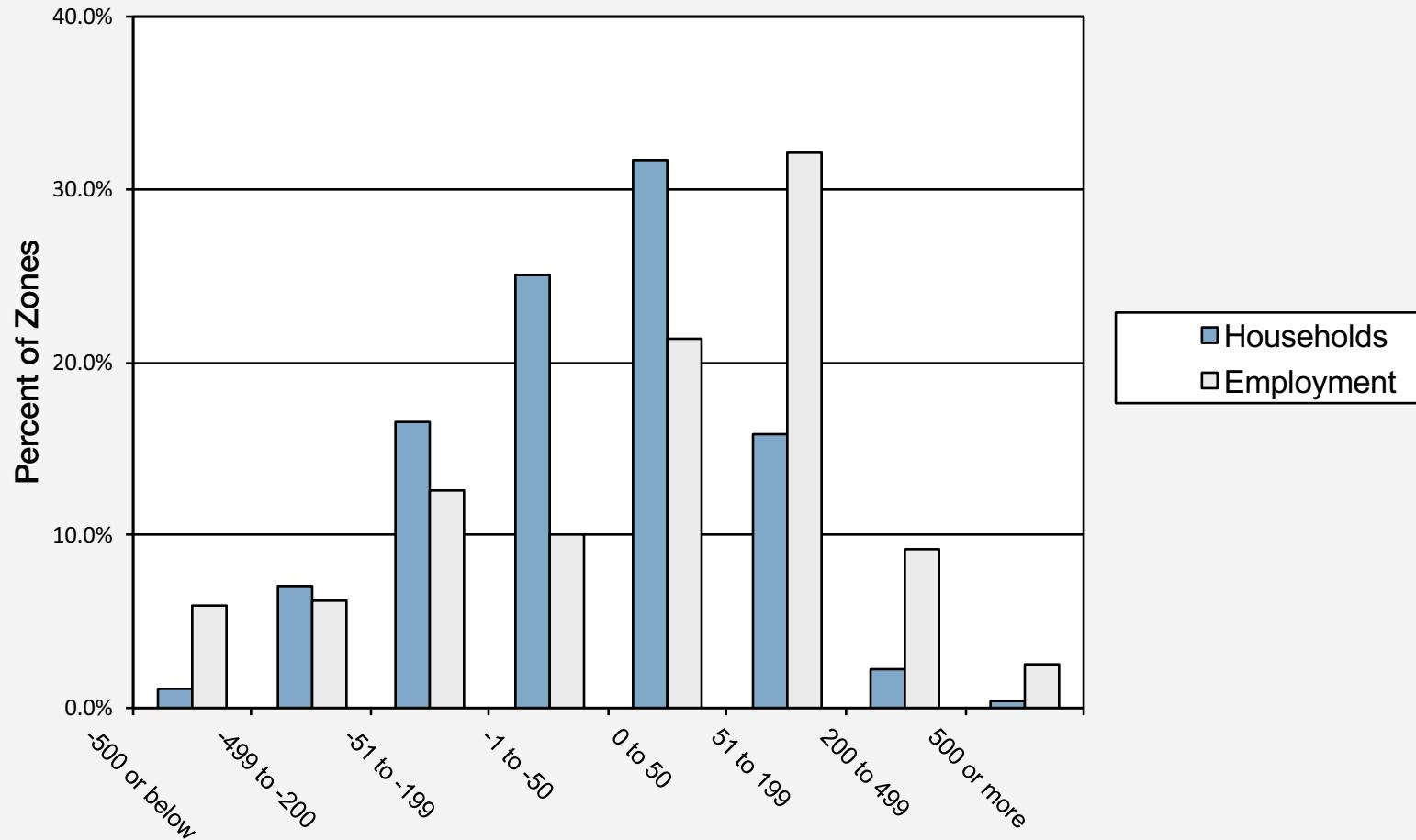
# Longitudinal Validation of Full Model System



Comparison of predicted to observed values in Lane County, Oregon, from 1980 to 1994

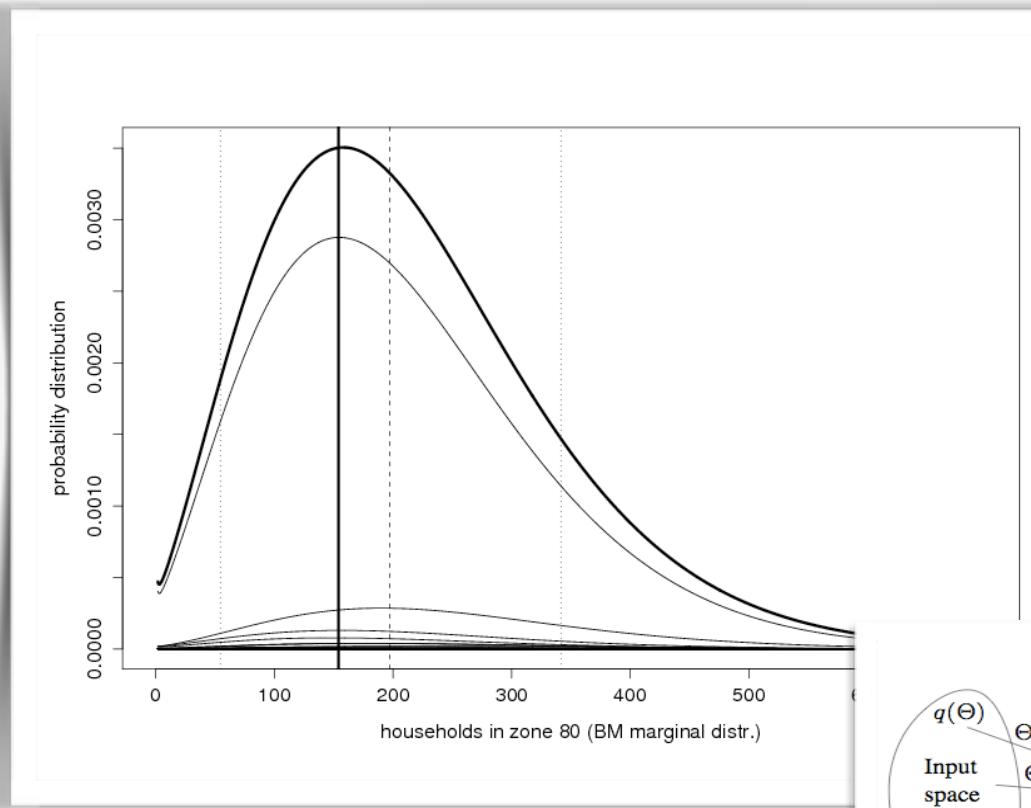
	Cell	Zone	1-Cell Radius
Employment	0.805	0.865	0.917
Population	0.811	0.929	0.919
Nonresidential Sqft	0.799	0.916	0.927
Housing Units	0.828	0.927	0.918
Land Value	0.830	0.925	0.908

# Longitudinal Validation of Full Model System



Predicted - Observed Change from 1980 to 1994, Lane County, Oregon

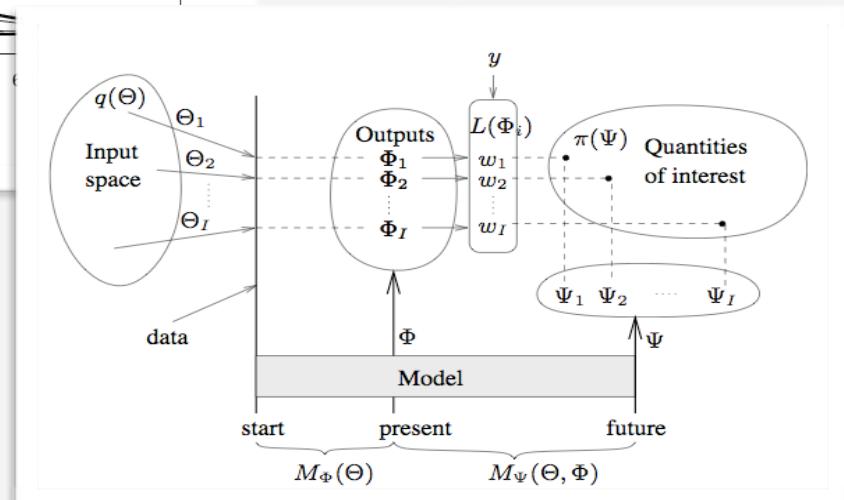
# Calibrating Uncertainty in UrbanSim Model Application



## Bayesian Melding

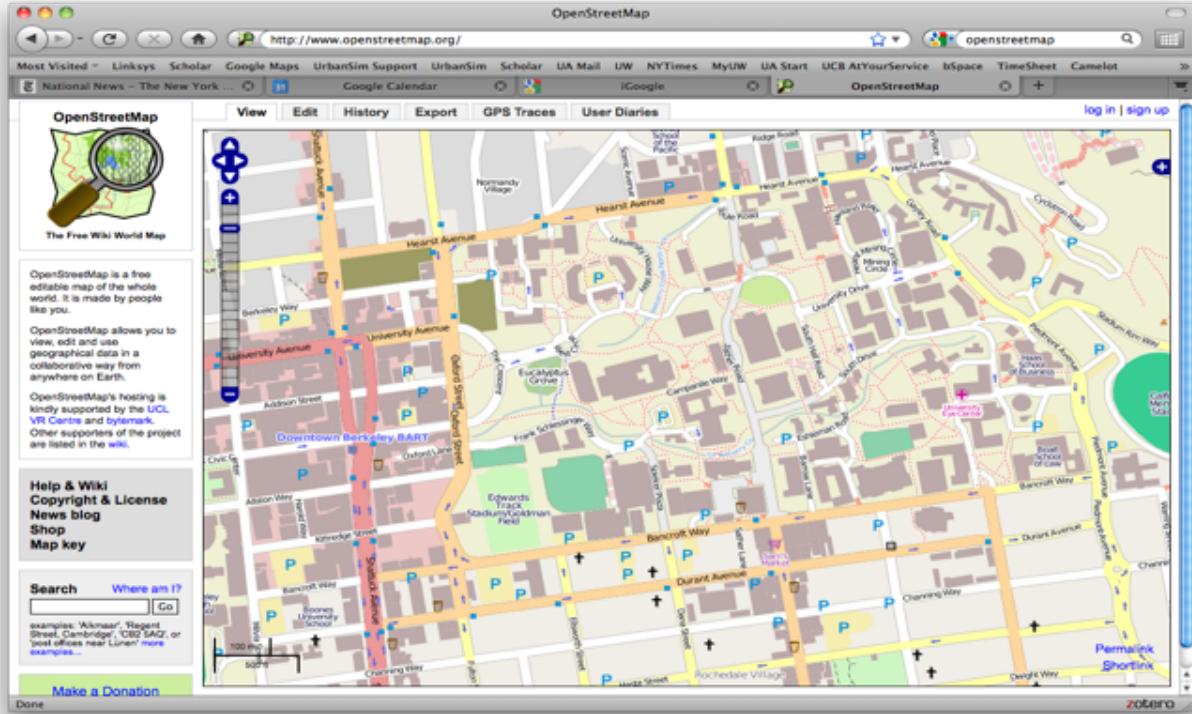
Results from Eugene-springfield  
in Transportation Research B, 2007

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

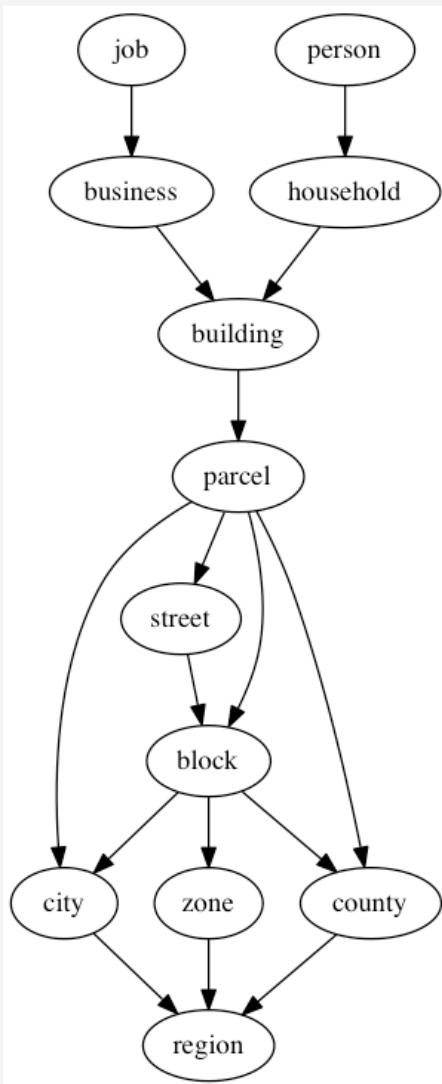


# UrbanSim Data Sources

- Digital terrain models
- Digital orthophotos
- Street Network
- Parcels
- Property sales transactions
- Building attributes
- Google buildings where available and of good quality
- Zoning
- General Plans
- Planned Developments
- Business establishments
- Synthesized population
- Planning boundaries



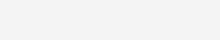
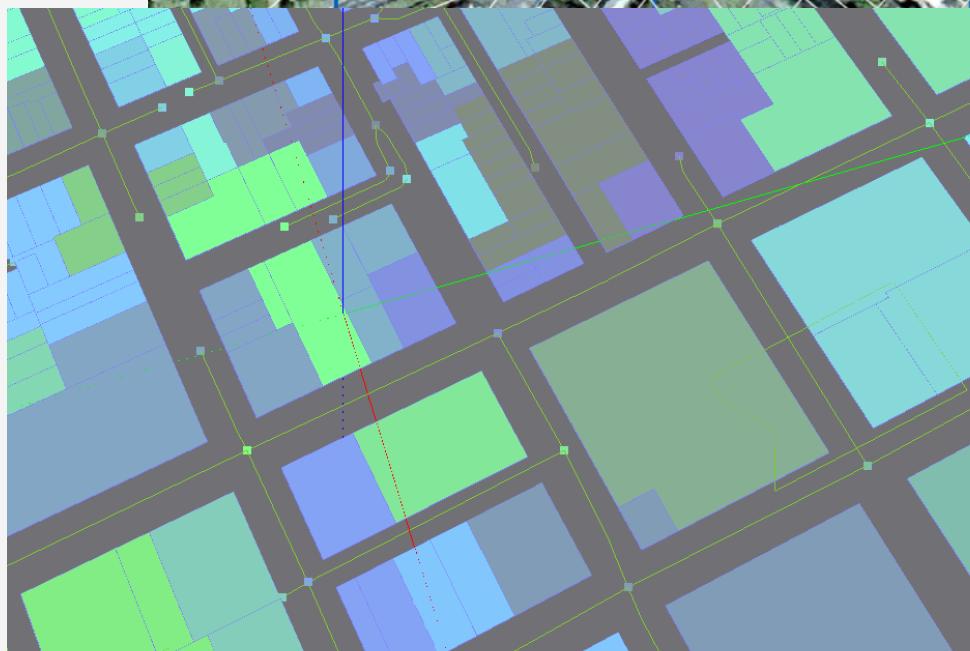
# UrbanSim Leverages Big Urban Data: Modeling A Unified Urban Graph of the Metropolis



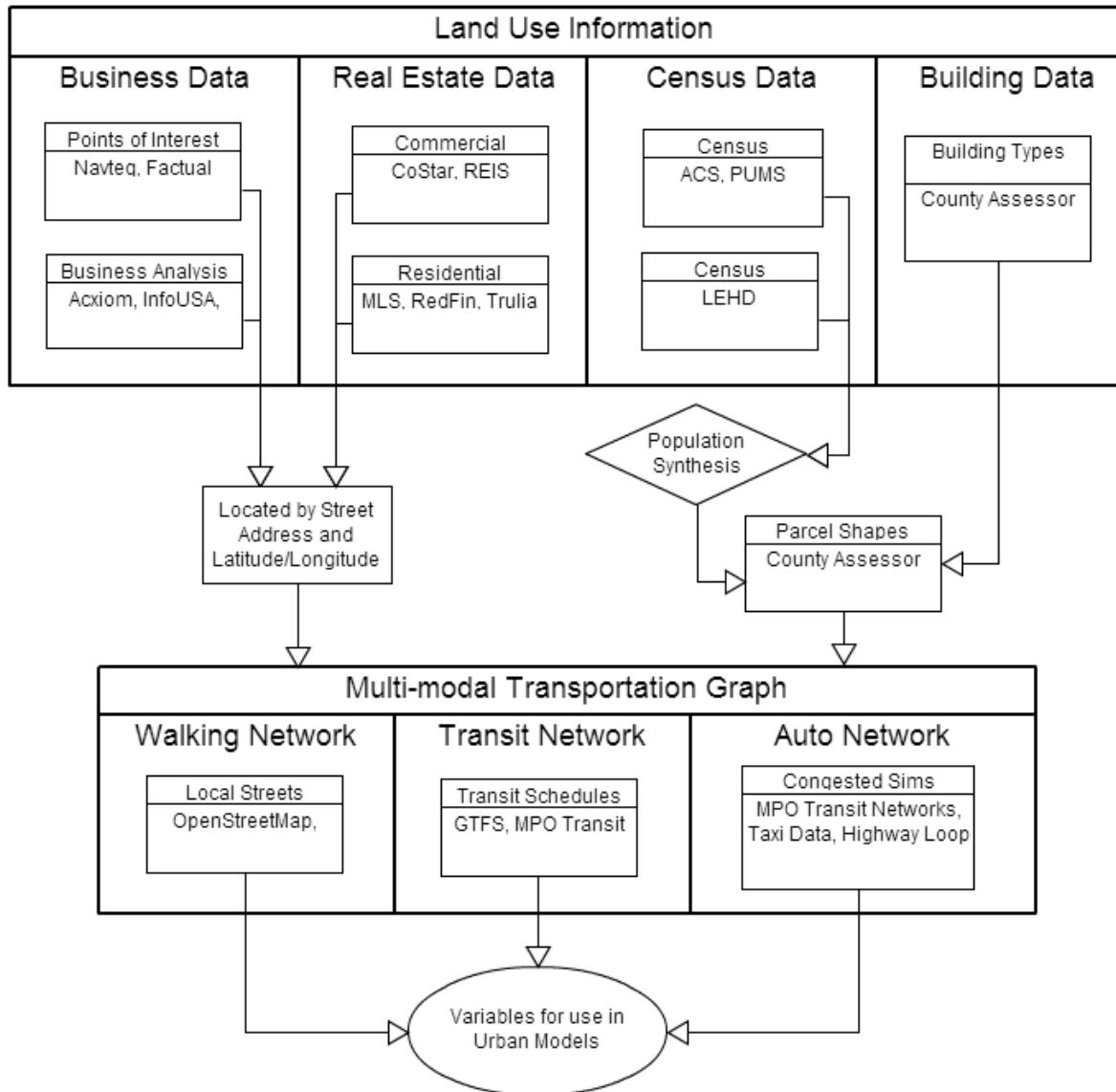
Micro



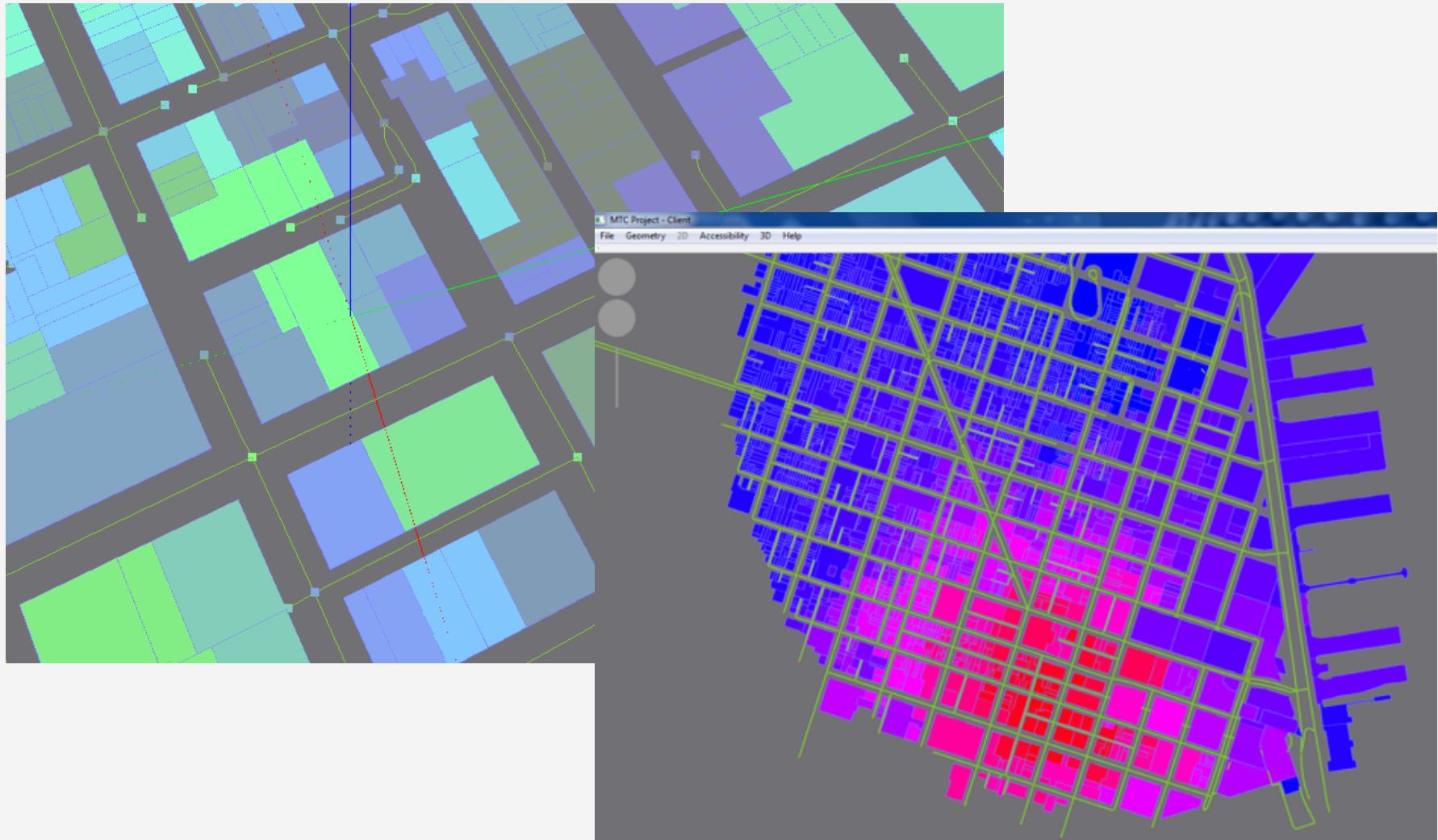
Macro



# The Urban Information Ecosystem



# UrbanSim: Fast Accessibility Analysis



# Accessibility API: Density

Choice of decay function

- Point
- Flat
- Linear
- Exponential

Choice of aggregation

- Sum
- Ave
- Stddev
- Percentile

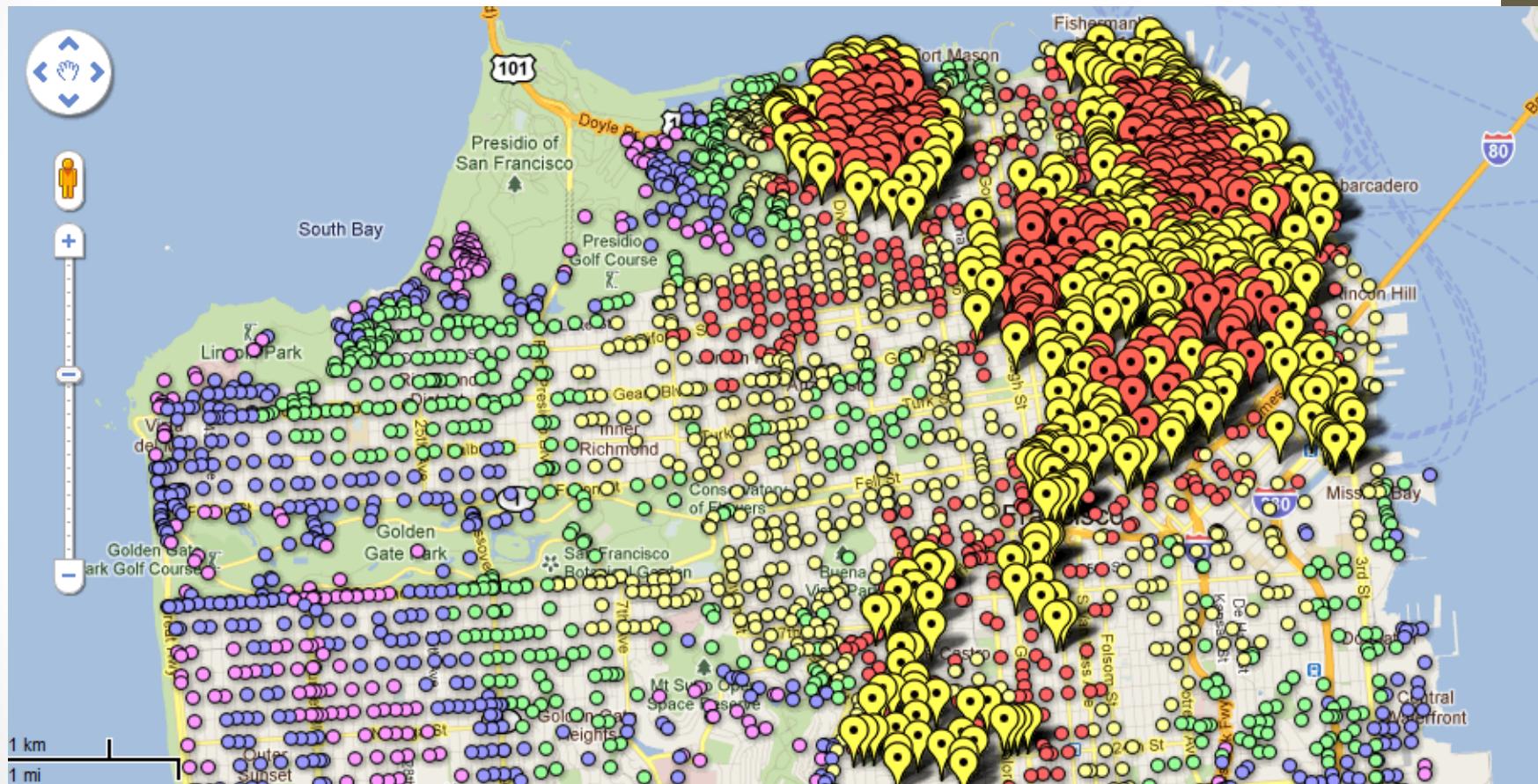
# Accessibility API: Diversity

- Entropy – use Shannon Entropy
- Can support any categorical variable
- Currently:
  - Jobs / Housing
  - Residential / Non-residential
  - Building types
  - Job sectors
  - Housing / tenure types

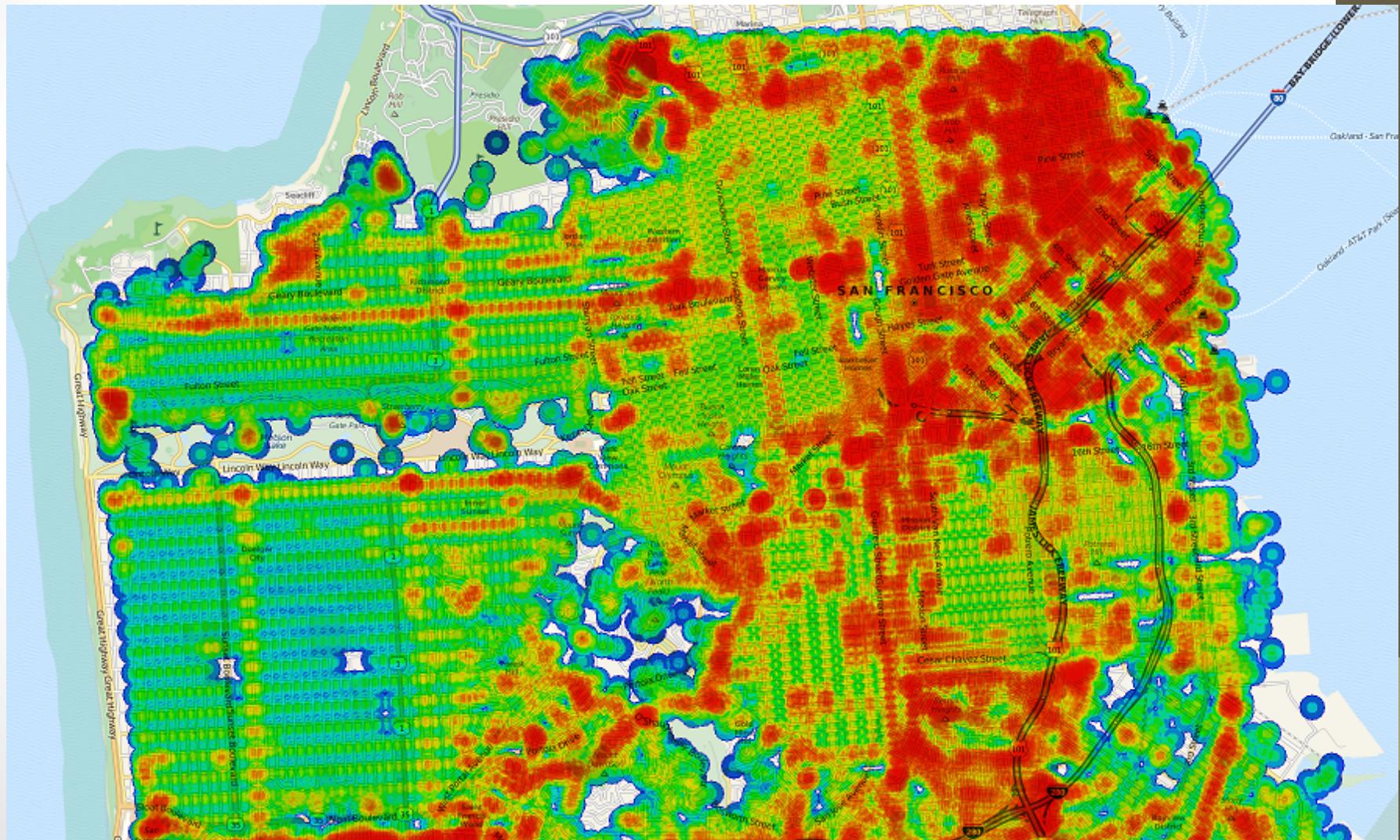
# Accessibility API: Design

- Number of nodes (intersection density)
- Number of parcels
- Size of parcels
- Block length
- Percentage of < 4-way intersections

# Complete “walkscore” using OSM data



# Walkscore as Heatmap



# Analyze Development Feasibility

Penciler   New   Save   Browse   Report   planner@city.gov -

**Parcel Options**   **Mid-rise Generic Parcel**

**Zone**   **RH-3 - Residential, Multi-fami...**

**Development Type**   **Full Site**

Block with Rear Yard    Full Site    Setback all sides    L shaped    Tower and Base

DevType Preset: [ ]

stories: 5   textures: Shingles   layout: nine   type: flat

**Unit Mix**   **Typical Mix**

**Costs**   **Bay Area Average**

**Revenues**   **July 2014, San Francisco**

**Parking**   **Low Parking**

**Development Parameters**   **Dev Preset Two**



Size & Use			136,179 SqFt
Area Takeoffs and Zoning Conformity			
Proposal	Zoning	Compliance	
Parcel Area (gsf)	27,236	-	-
Building Footprint (gsf)	27,236	-	-
Building Total Area (gsf)	136,179	-	-
Lot Coverage (%)	100	85 max	No
Stories	6	5 max	No
Height (ft)	72	60 max	No
Floor Area Ratio (FAR)	6	7 max	Yes
Housing			122.0 Units
Parking			92.3 Spaces
Revenues			\$108,904,000.00
Costs			\$46,128,000.00
Feasibility			1.36



UrbanSim  
Cloud Platform



## What is the UrbanSim Cloud Platform?

The UrbanSim Cloud Platform is a cloud-based urban simulation and visualization platform that leverages state-of-the-art urban simulation, 3D visualization, and shared open data allowing users to explore, gain insights into, and develop and evaluate alternative plans to improve their communities.

### Design



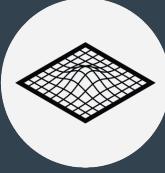
Design scenarios based on existing and proposed policies interactively and visually to simulate variations of land use and transportation plans. These scenarios can be compared across various attributes to allow regional planners to make calculated and informed decisions.

### Simulate



Simulate the regional real estate market at the level of individual decision-makers such as households, employers, and real estate developers. UrbanSim runs on the cloud, for one or many scenarios, and rapidly generates results.

### Visualize



Use a large and flexible portfolio of indicators to gain insight into existing conditions and the effects of alternative scenarios. Visualize existing conditions and indicators in a dynamic 3D web mapping environment, and invite users to review results, or share them with the public.



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### UrbanSim

Harness the power of the UrbanSim microsimulation-based engine.



### Input Data

Use our precompiled national datasets and upload your own local data.



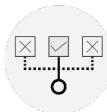
### Track Developments

Incorporate future developments.



### Edit Constraints

Incorporate future zoning constraints.



### Create Scenarios

Compose multiple scenarios representing a suite of land use and transportation policies.



### Run Multiple Simulations on the Cloud

Harness the processing power of the cloud.



### Visualize Indicators

Visually interrogate simulation results.



### Model Adjustments

Incorporate stakeholder feedback.



## What is UrbanSim?

UrbanSim is an open source simulation platform for supporting planning and analysis of urban development, incorporating the interactions between land use, transportation, the economy, and the environment.

### Parcel - Level Model



The most detailed and powerful model applications of UrbanSim using individual buildings and parcels.

Users of the block or zone versions can convert to the parcel version easily when uploading local parcel data.

Coming Soon

### Census Block – Level Model

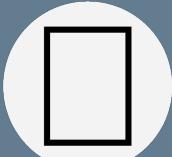


The census block models are pre-built from public data for most metropolitan areas in the United States.

This is the fastest way to begin using UrbanSim.

November 2016 Release

### Zone - Level Model



Users are required to upload zonal data whereby they will be able to build and calibrate an UrbanSim model.

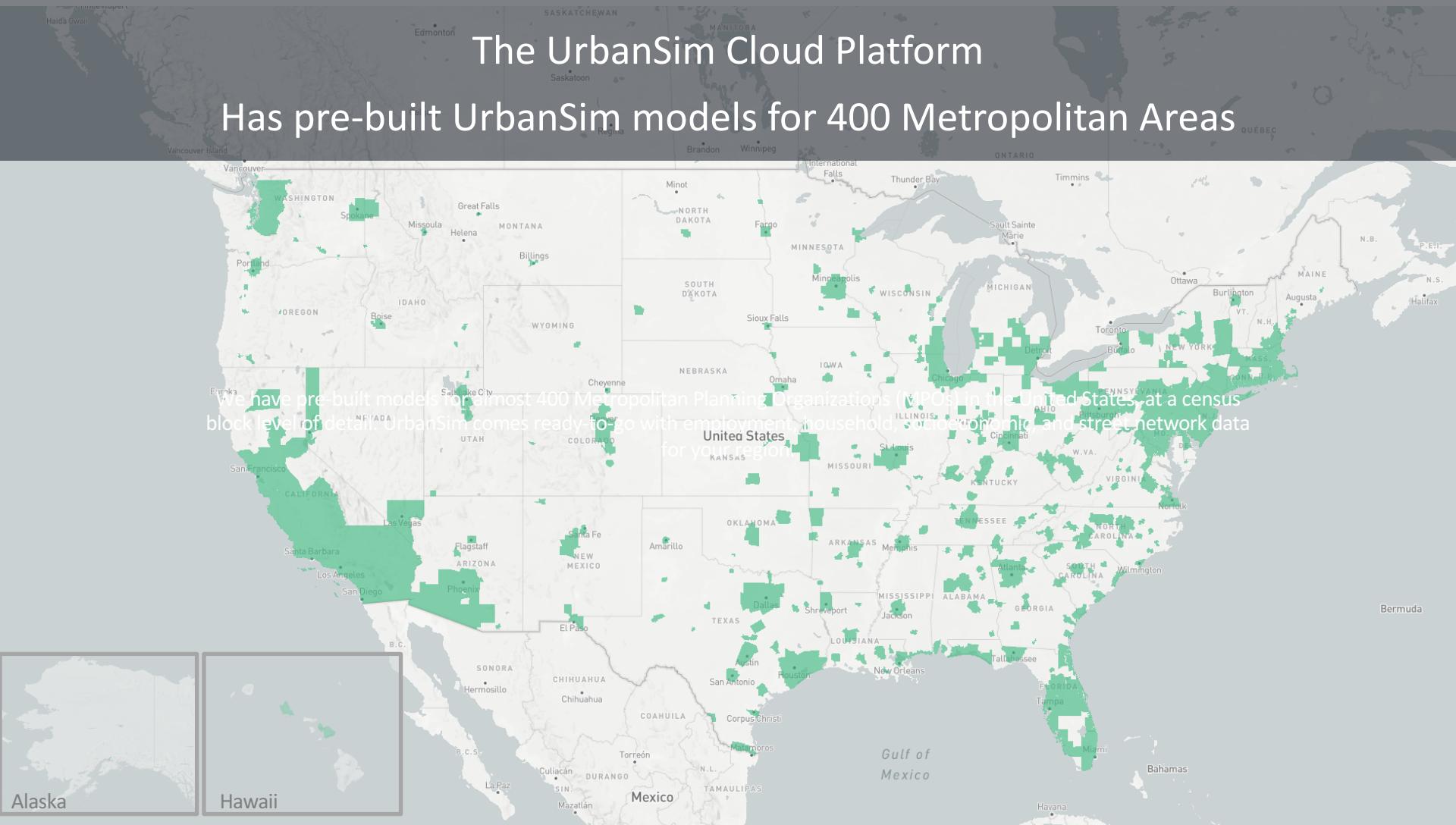
For metropolitan areas outside the United States, this is the fastest way to build an UrbanSim model.

Coming Soon

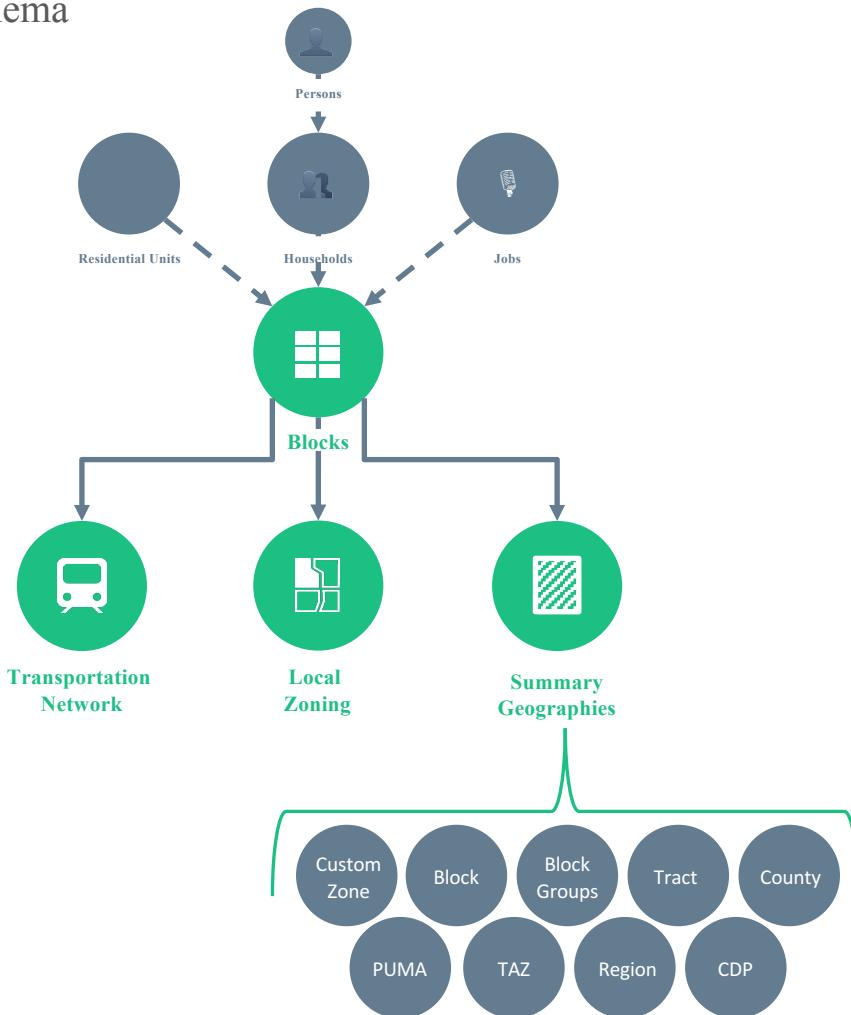
# The UrbanSim Cloud Platform

Has pre-built UrbanSim models for 400 Metropolitan Areas

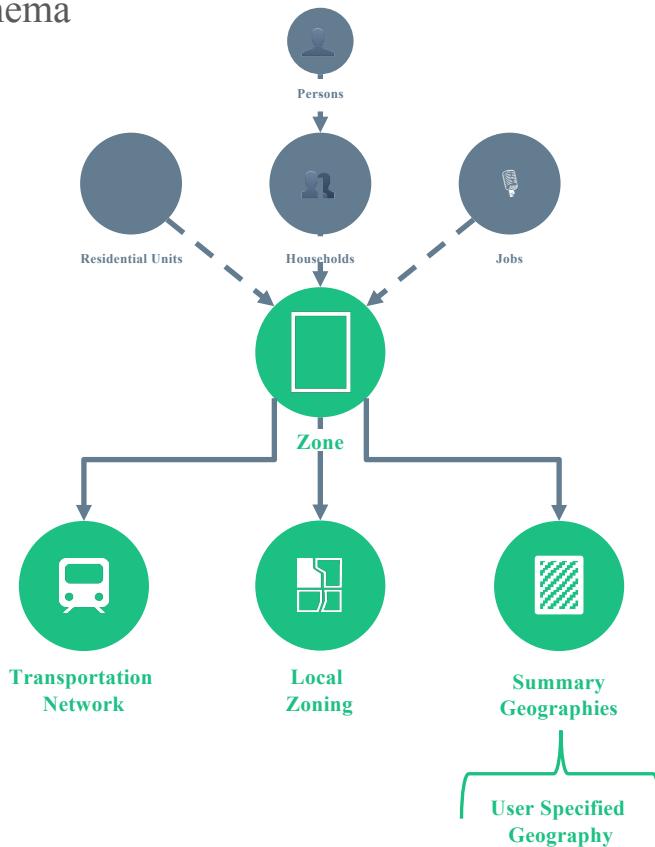
We have pre-built models for almost 400 Metropolitan Planning Organizations (MPOs) in the United States, at a census block level of detail. UrbanSim comes ready-to-go with employment, household, socio-economic, and street network data for your region.



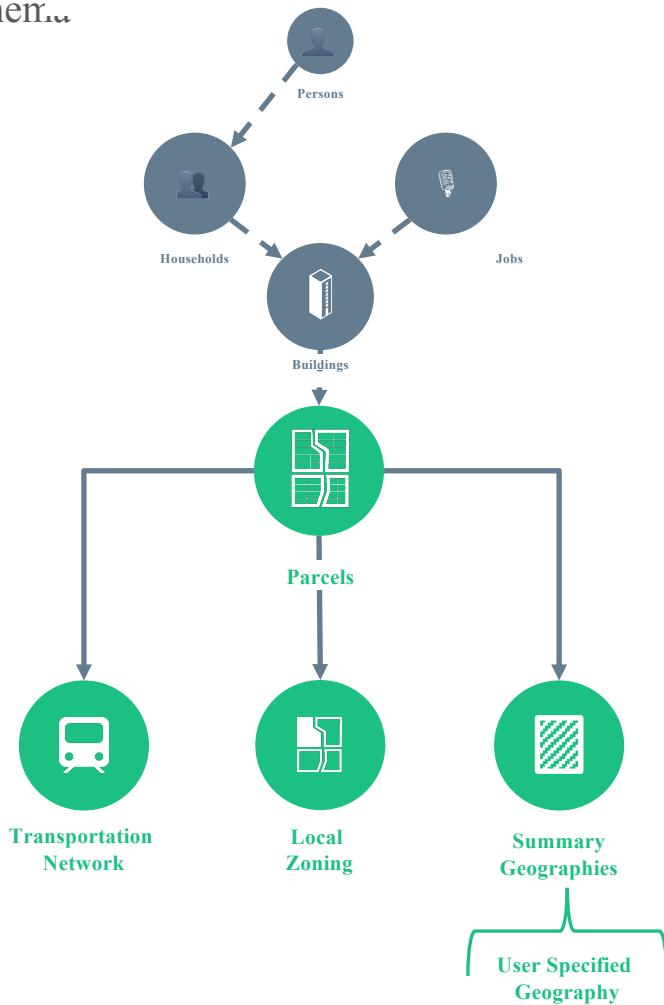
## UrbanSim Block Model Data Schema



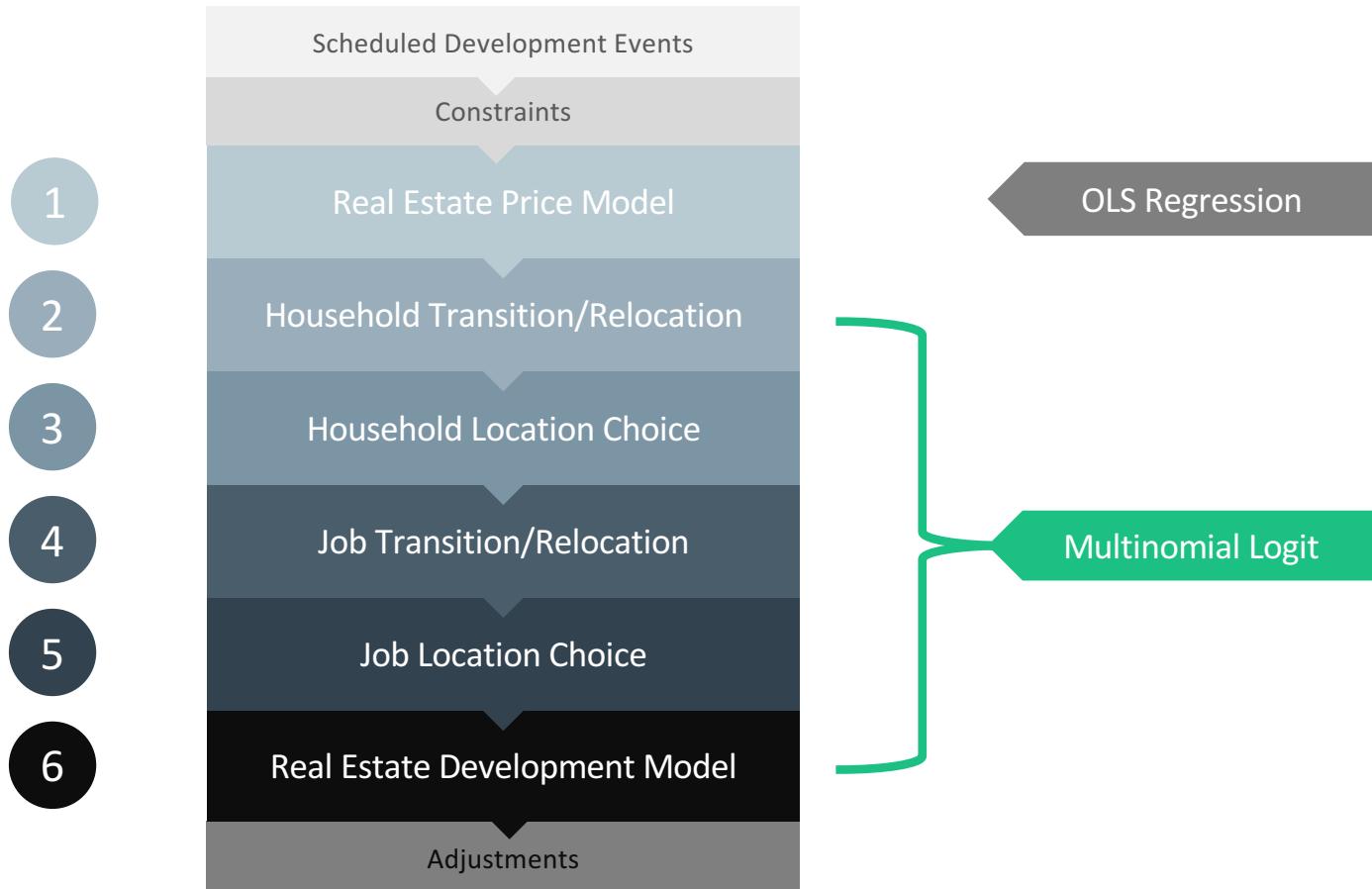
## UrbanSim Block Model Data Schema



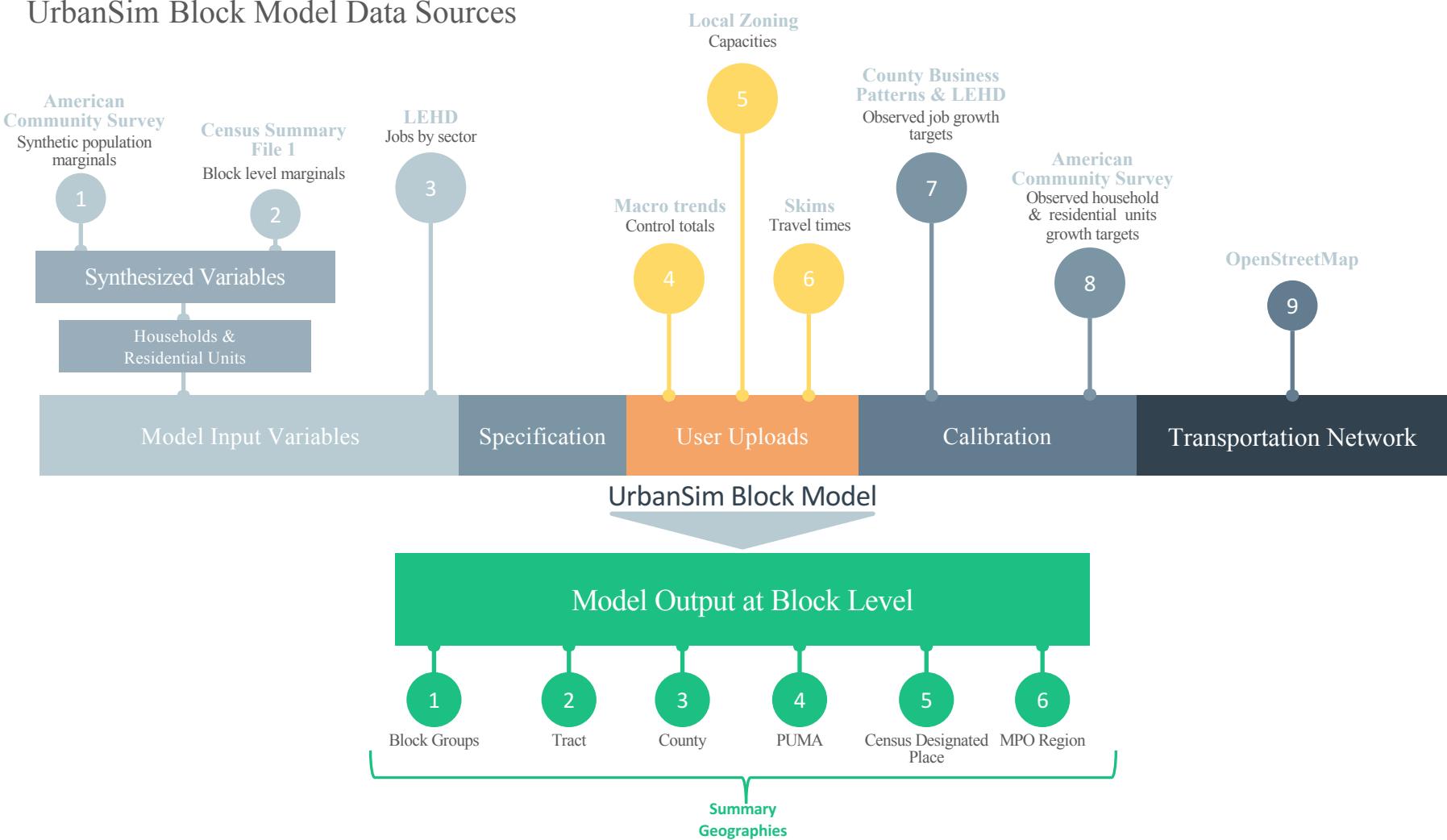
## UrbanSim Block Model Data Schema



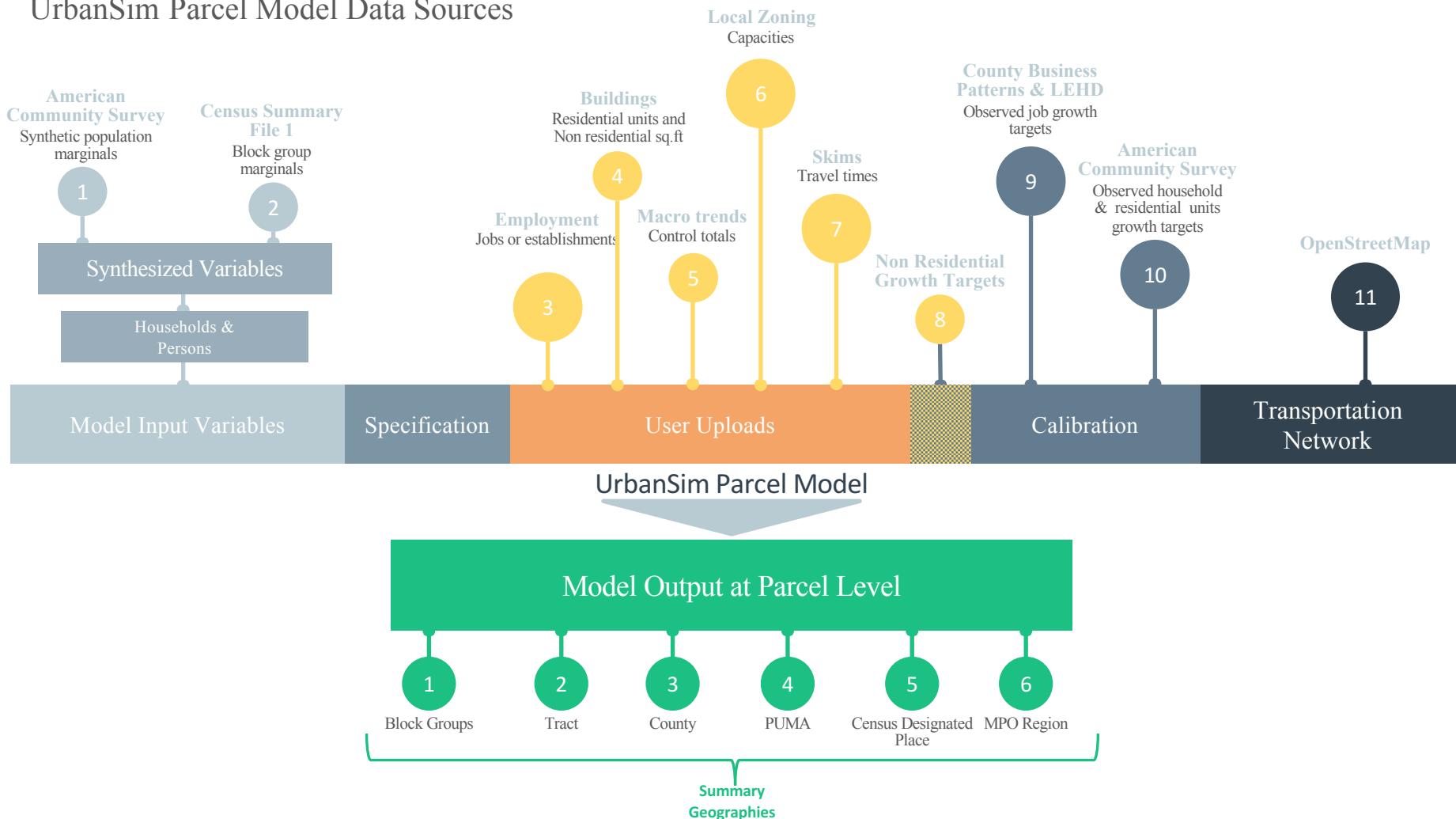
## UrbanSim Block Model Sequence with Scenario Inputs



## UrbanSim Block Model Data Sources



# UrbanSim Parcel Model Data Sources



# What is an UrbanSim scenario?

An UrbanSim scenario is a bundle of policies and assumptions. A user can specify which of the uploaded input data (i.e. travel model skims, household control totals (or growth rate), development projects, development constraints, and model adjustments) to apply to a given scenario through the new scenario composer.

## Household Control Totals

Specify which of the user uploaded household control totals to use (representing detailed demographic information) or specify household growth rate.



## Employment Control Totals

Specify which of the user uploaded employment control totals by sector to use or specify employment growth rate.



## Travel Model Skims

Specify which of the user uploaded travel model skims to use and to what range of years they will be applied.



## Development Projects

Select which of the development projects to consider in this scenario by selecting the relevant development tags



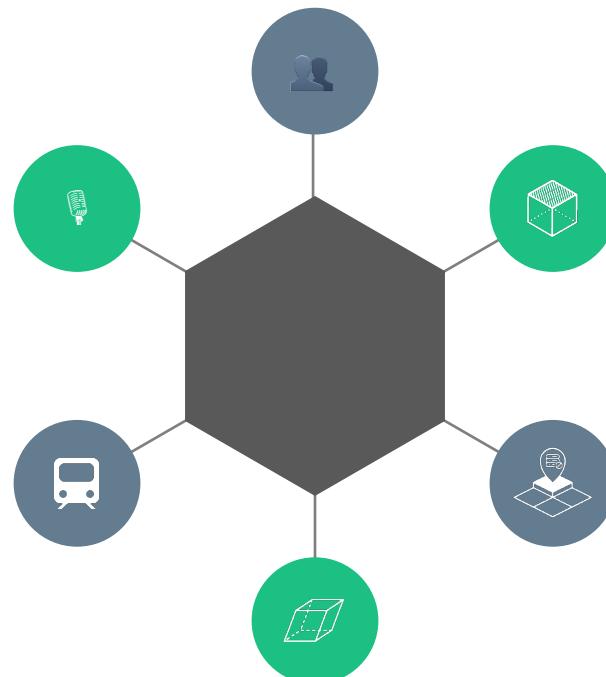
## Zoning Constraints

Select which of the defined zoning constraints to apply in this scenario by selecting the relevant constraints tags.

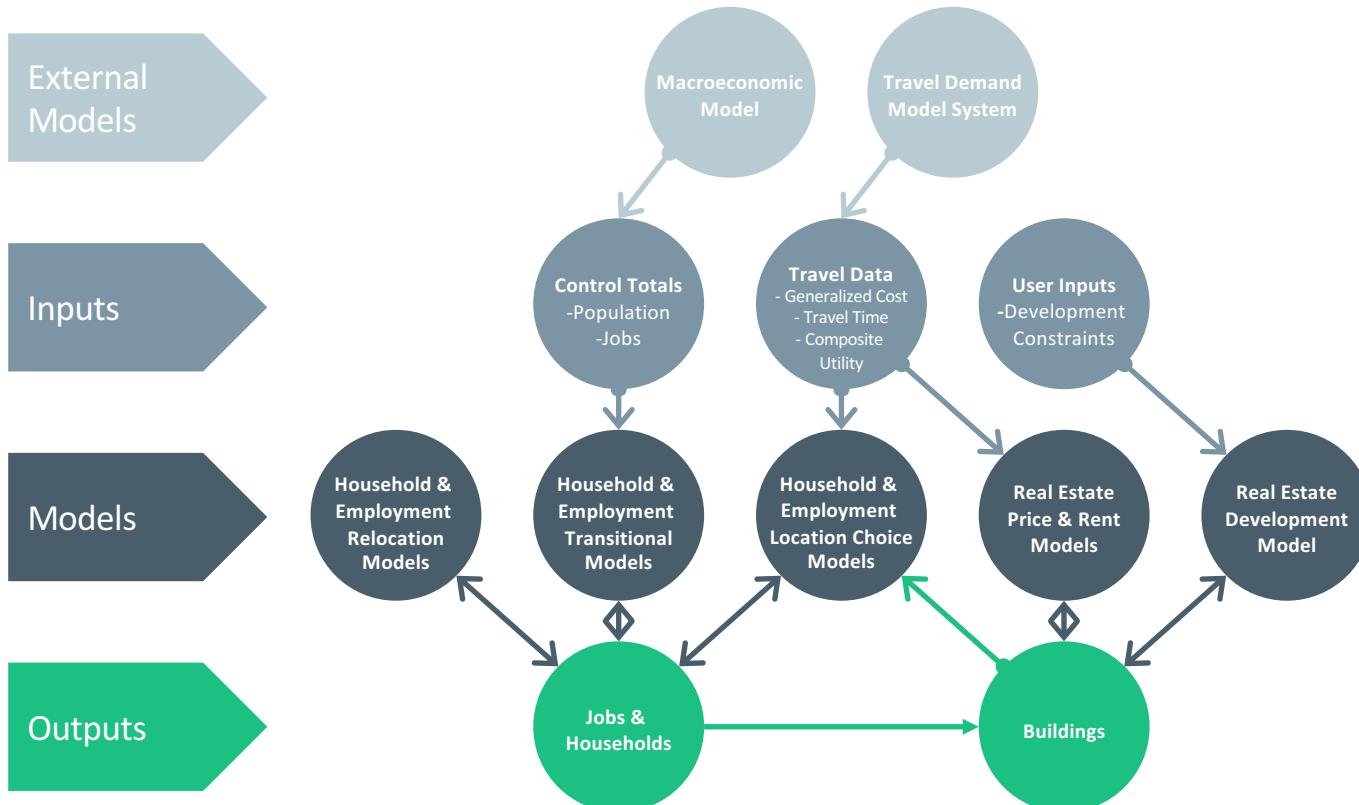


## Model Adjustments

Select which of the model adjustments incorporated through stakeholder feedback to apply in this scenario by selecting the relevant Adjustment tags.



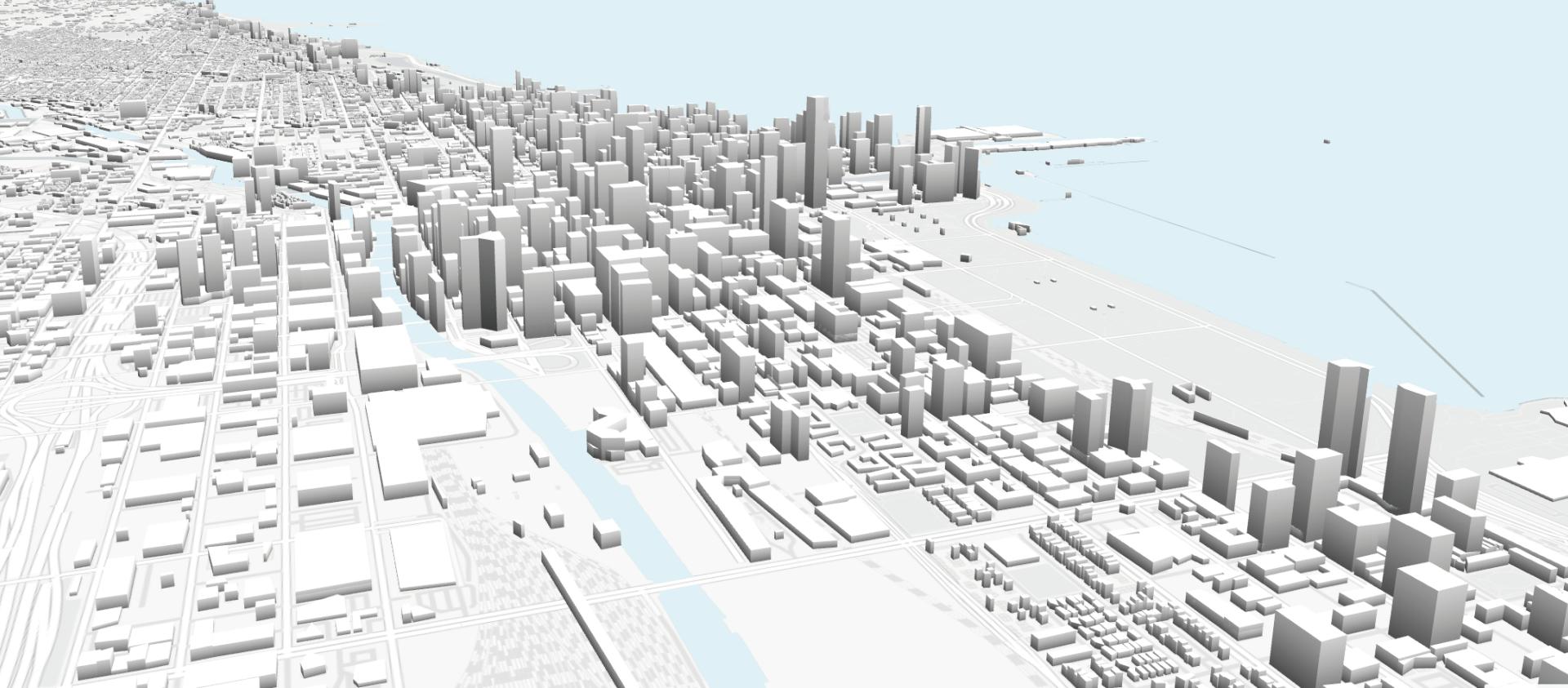
# UrbanSim Data Flow



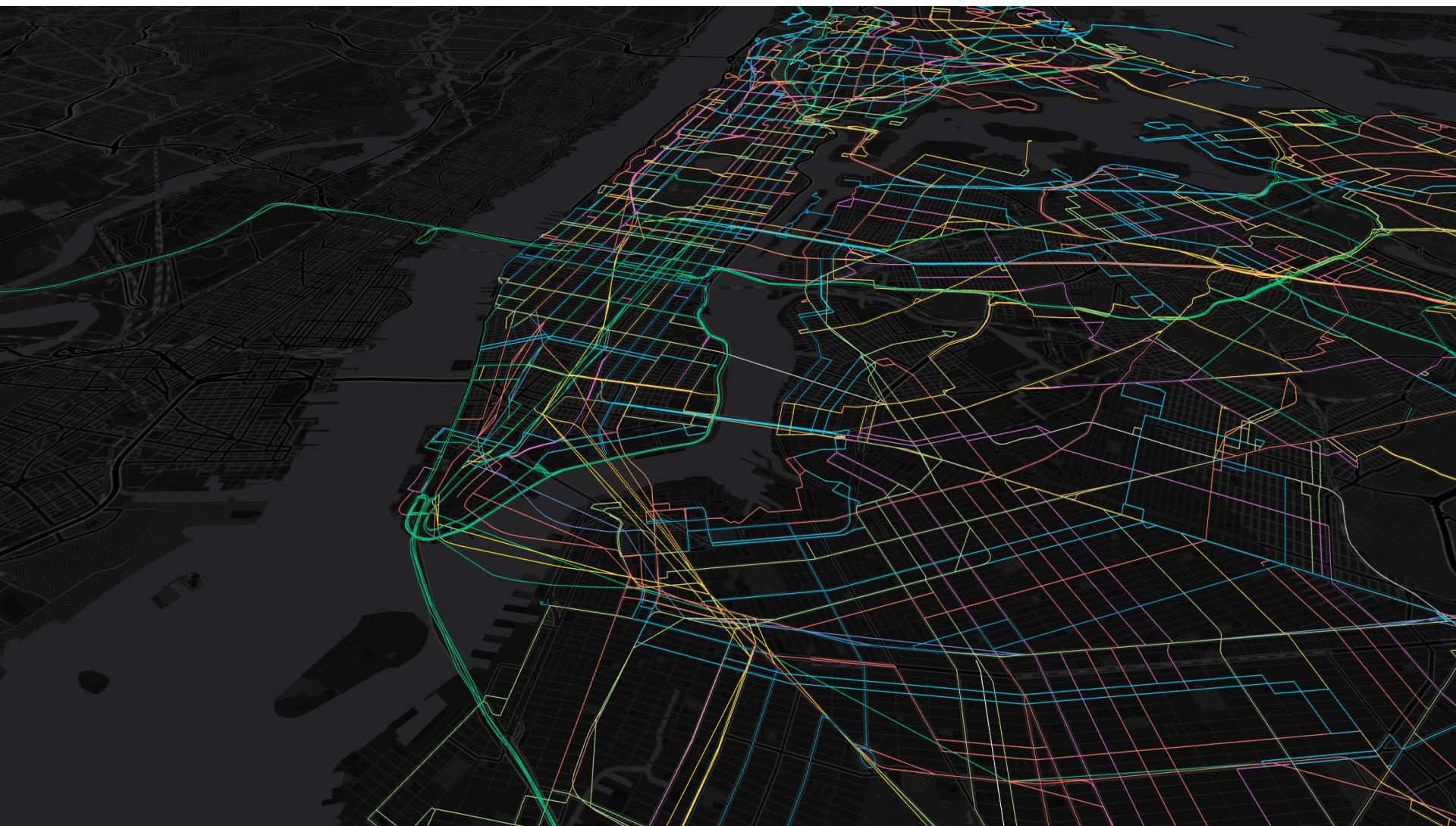


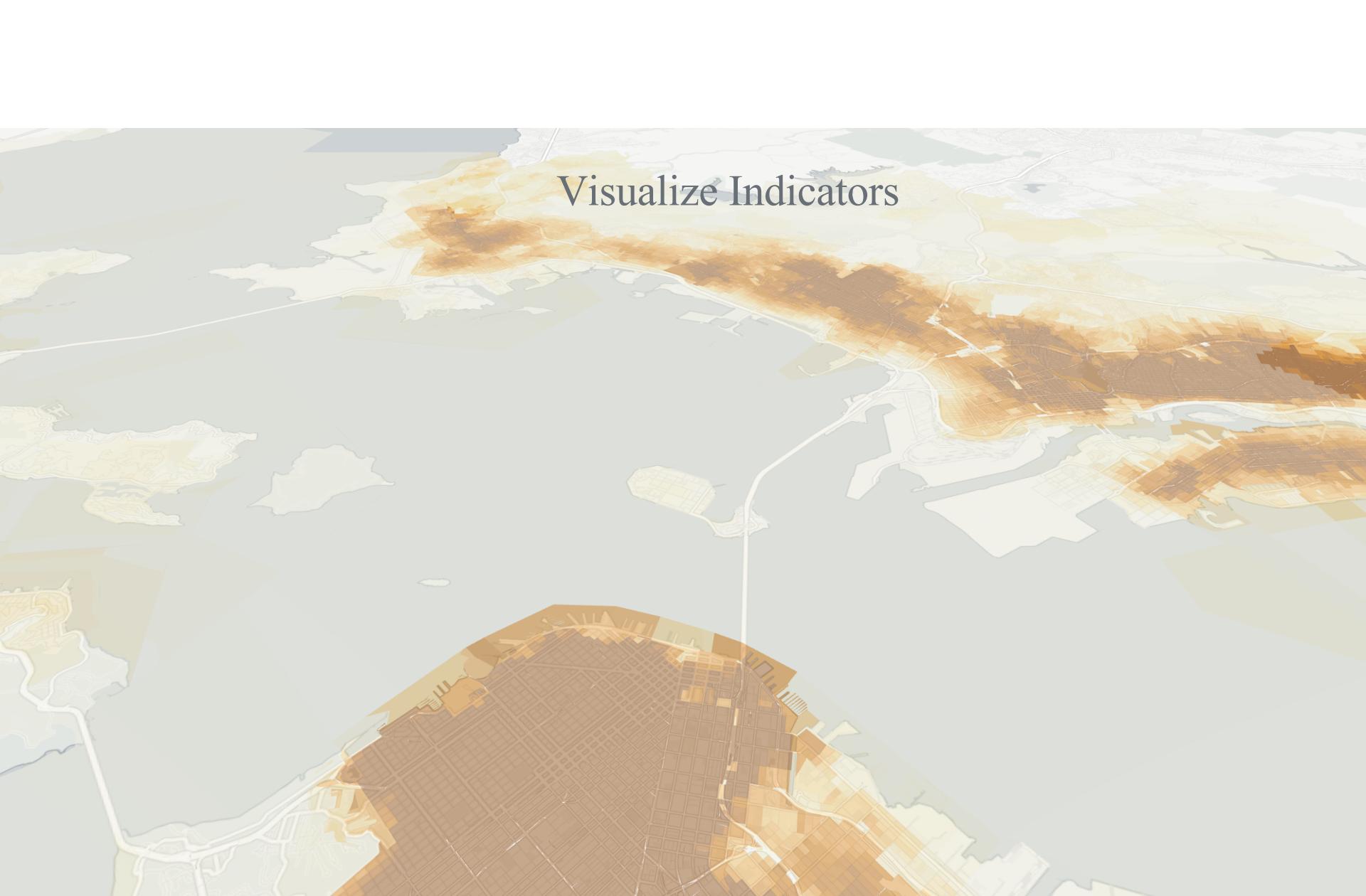
UrbanSim  
Cloud Platform

# 3D Visualization

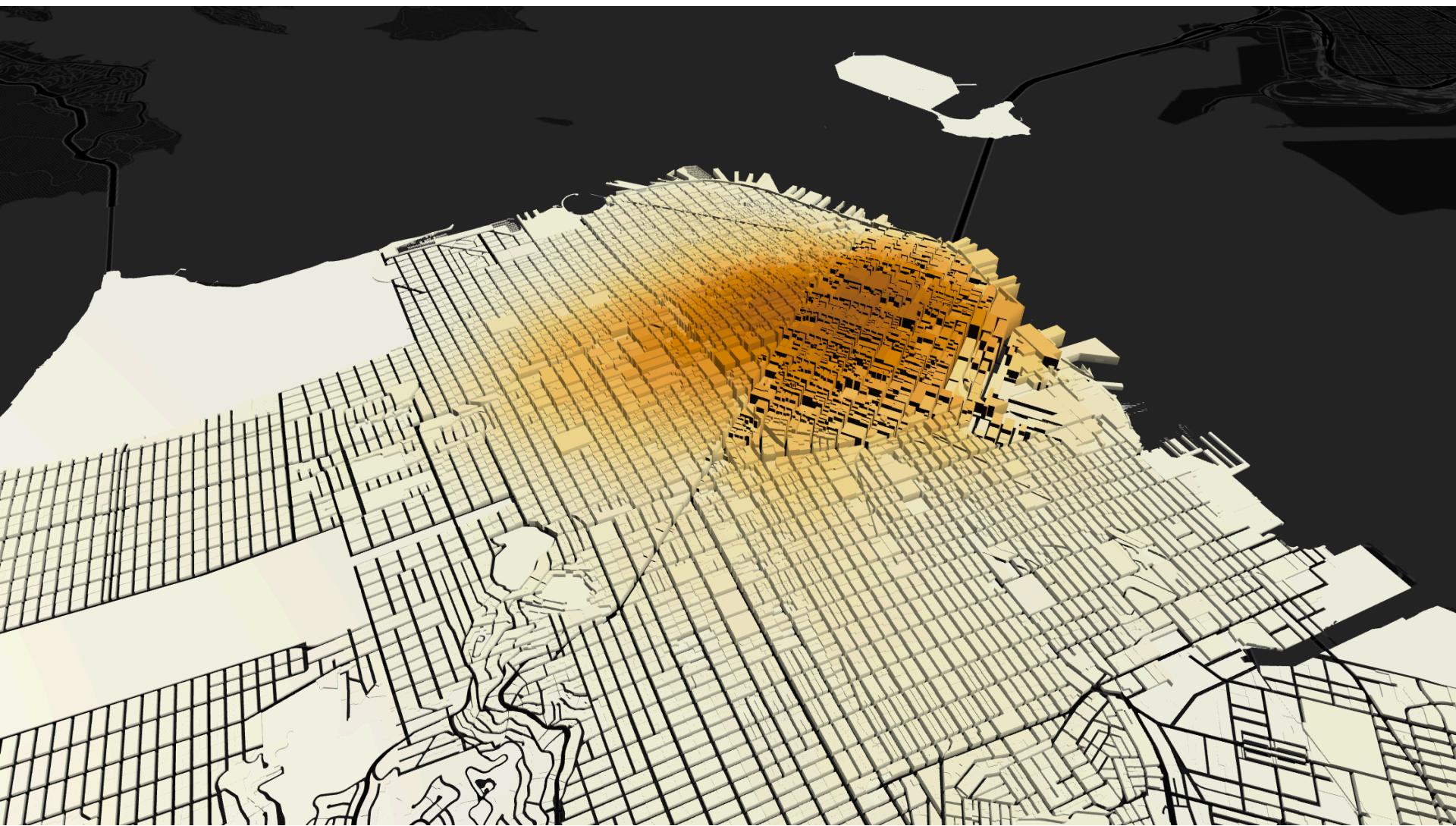


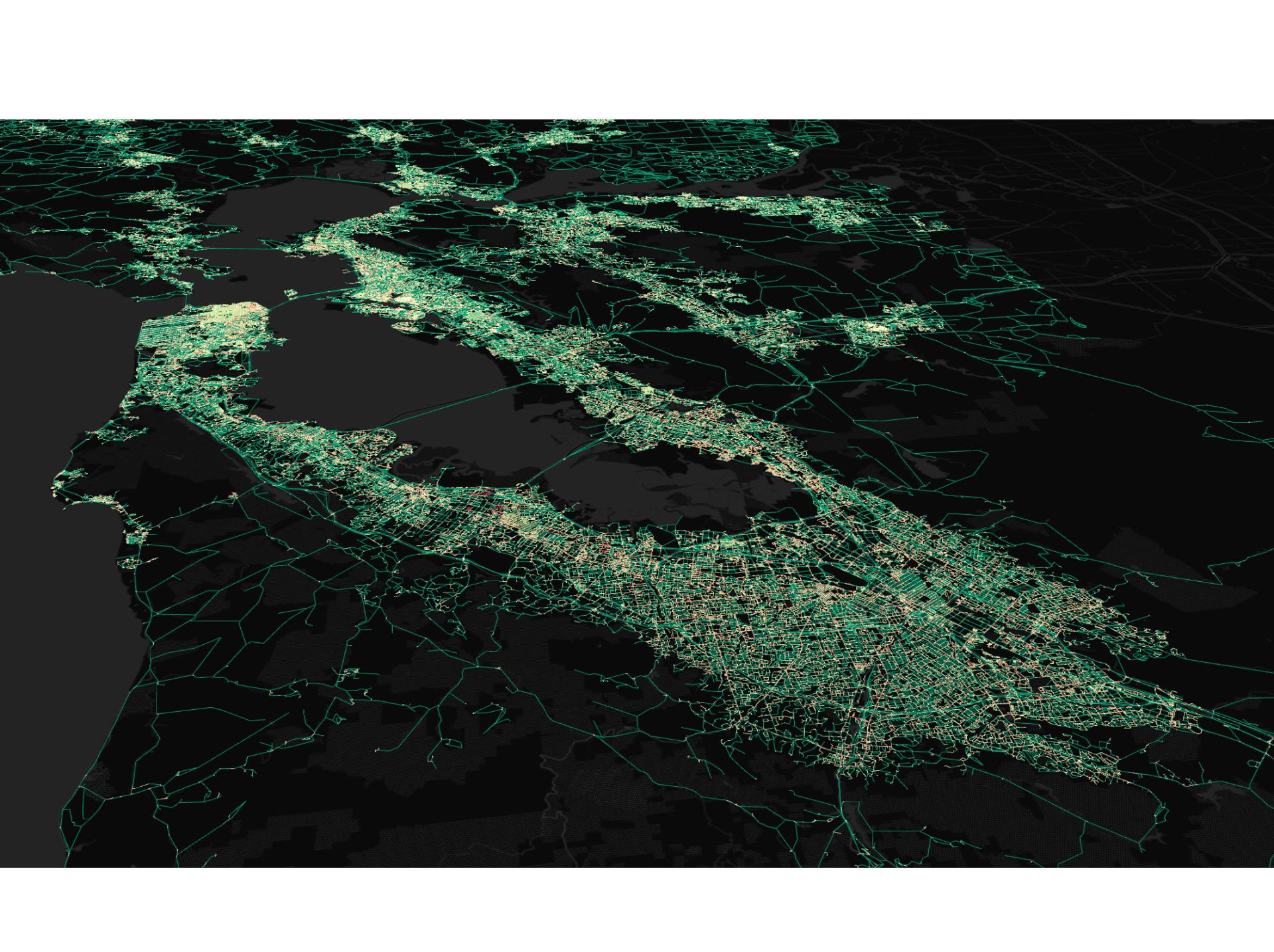




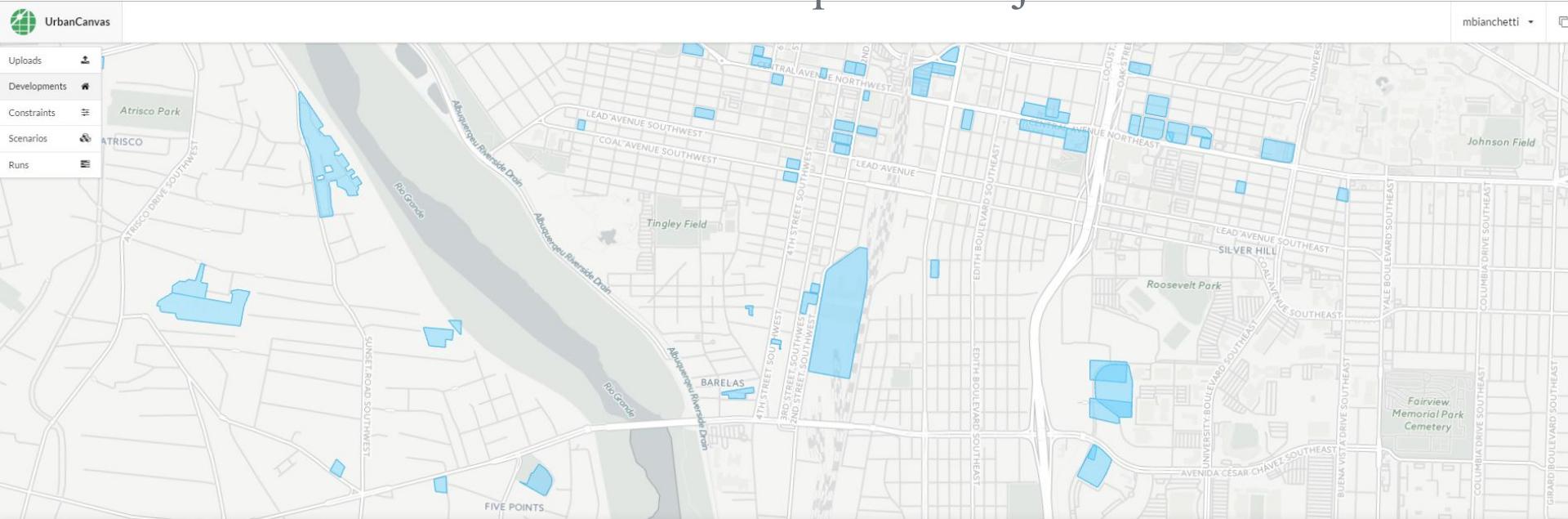


Visualize Indicators





# Track Development Projects



Development Projects perm| Add Project

	Project ID	Name	Block IDs	Address	Start Date	Duration	Residential Units	Average Unit Size	Employment Capacity	Non-residential Sq. Footage	Square Feet per Job	Notes
	305	restaurant and retail			2013	1		0				DRB case, 2 phase building permit approved, this dev project includes both phases bc landuse indicate vacant, #1000870
	1205	RV and Boat Storage			2013	12		0				#1001523, Bldg Permit,
	1209	Sunport Park Hotel			2015	12		0				#1009344, Bld Permit
	1211	restaurant			2014	12		0				#1008134, Bldg Permit
	1212	Applebees			2014	0		0				#1004772, Bld Permit

# Track Development Projects

UrbanCanvas

Uploads Developments Constraints

mbianchetti

Create new Development Project

Name \* Based on Square-feet per job

Project name

Square-feet per job

Attributes

Duration (months) \* Start Date \*

Project duration Start Date

Status Redevelopment

Building type \*

Building type

Residential units \* Average Unit size \*

Residential units Unit size

Employment capacity

Employment capacity

Non-res. Square Footage

Non-res. Square Footage

OR

Development tags

Select blocks \*

Start selection 0

Source

Notes

Cancel Add project

Confirm selection Clear selection Cancel selection

350010012004001

Map showing a selected area with a black box containing the ID 350010012004001. The map includes street names like Colorado Boulevard, Lead Avenue, and Johnson Field.

Job	Notes
	DRB case, 2 phase building permit approved, this dev project includes both phases bc landuse indicate vacant, #1000870
	#1001523, Bldg Permit,
	#1009344, Bld Permit
	#1008134, Bldg Permit
	#1004772, Bld Permit

	1211	restaurant		2014	12	0				
	1212	Applebees		2014	0	0				

# Create Multiple Scenarios

## Create new scenario

### Scenario name

### Travel model skims



### Based on

### Input data

#### Residential vacancy rate

#### Household growth rate

OR

#### Households controls totals

#### Employment growth rate

OR

#### Employment controls totals

### Notes & tags

#### Notes

#### Development tags

#### Zoning proposal tags

#### Adjustments tags

# Create Development Constraints

Create new Constraint

Constraint name  Based on

Notes & tags  
Constraint tags  Select constraint tags

Location  
Start selection 0

Attributes  
Start Year 2015 End Year 2015

Residential capacity 0.05

Employment capacity  Enter employment capacity

# Run Simulations

Create new Run Simulation

Select Scenario to run  All Scenarios

Run Setup  
End Year 2015  
Random Seed (optional) 0.1  
Calibrated Coefficients

Notes



UrbanSim  
Cloud Platform  
Generating and Visualizing Indicators



## Design



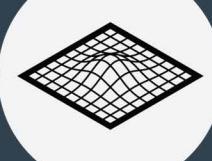
Design scenarios based on existing and proposed policies interactively and visually to simulate variations of land use and transportation plans. These scenarios can be compared across various attributes to allow regional planners to make calculated and informed decisions.

## Simulate



Simulate the regional real estate market at the level of individual decision-makers such as households, employers, and real estate developers. UrbanSim runs on the cloud, for one or many scenarios, and rapidly generates results.

## Visualize



Use a large and flexible portfolio of indicators to gain insight into existing conditions and the effects of alternative scenarios. Visualize existing conditions and indicators in a dynamic 3D web mapping environment, and invite users to review results, or share them with the public.



## Design



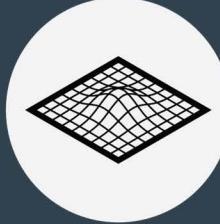
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## Visualize



Use a large and flexible portfolio of indicators to gain insight into existing conditions and the effects of alternative scenarios. Visualize existing conditions and indicators in a dynamic 3D web mapping environment, and invite users to review results, or share them with the public.



- Where might we see **household, job, and residential unit growth**?
- How could **densities of jobs and people** change from year to year?
- How might **accessibility to jobs** change throughout the region?
- How would **lower-income households** respond to land use policies?
- Where might **new employment clusters** emerge? In what sectors?

	serialno	persons	cars	income	race_of_head	age_of_head	workers	children	tenure	recent_mover	block_id
household_id											
2899	2.011001e+12	1	1	35000	1	43	1	0	2	0	060750263011005
5570	2.010000e+12	5	2	121500	1	54	2	2	2	0	060750264041002
5602	2.012000e+12	3	1	58000	2	30	1	0	2	1	060750264022019
10213	2.013000e+12	2	0	80800	1	50	1	0	2	0	060750263011003
19836	2.013001e+12	2	1	40760	8	83	0	0	1	0	060750263012018
23228	2.012000e+12	2	3	91300	1	58	1	0	2	0	060750605022001
23528	2.009001e+12	3	1	29700	1	34	1	1	2	1	060816003001016
23732	2.009001e+12	3	2	52200	1	81	1	0	1	0	060750264041001
24950	2.013000e+12	4	3	29200	6	55	2	1	2	1	060750263012015
33078	2.010001e+12	4	2	69000	1	46	1	2	1	0	060750263012014
35306	2.010001e+12	3	2	251000	1	44	2	1	1	1	060750263012013
37323	2.012001e+12	1	1	17000	9	50	0	0	2	0	060750263012013
37599	2.010001e+12	7	3	21000	8	38	0	3	2	1	060750264041000
38304	2.010001e+12	5	3	121600	8	25	3	2	2	1	060750264041004



## Frequently Asked Questions

- Household, job, and residential unit growth
- Job and household density
- Accessibility to jobs and workers
- Income profiles
- Job and housing growth
- Change in housing by type
- Greenfield vs. brownfield development
- Housing prices
- Household demographics
- Change over time
- Change at different geographic levels
- Comparison between scenarios
- Etc.



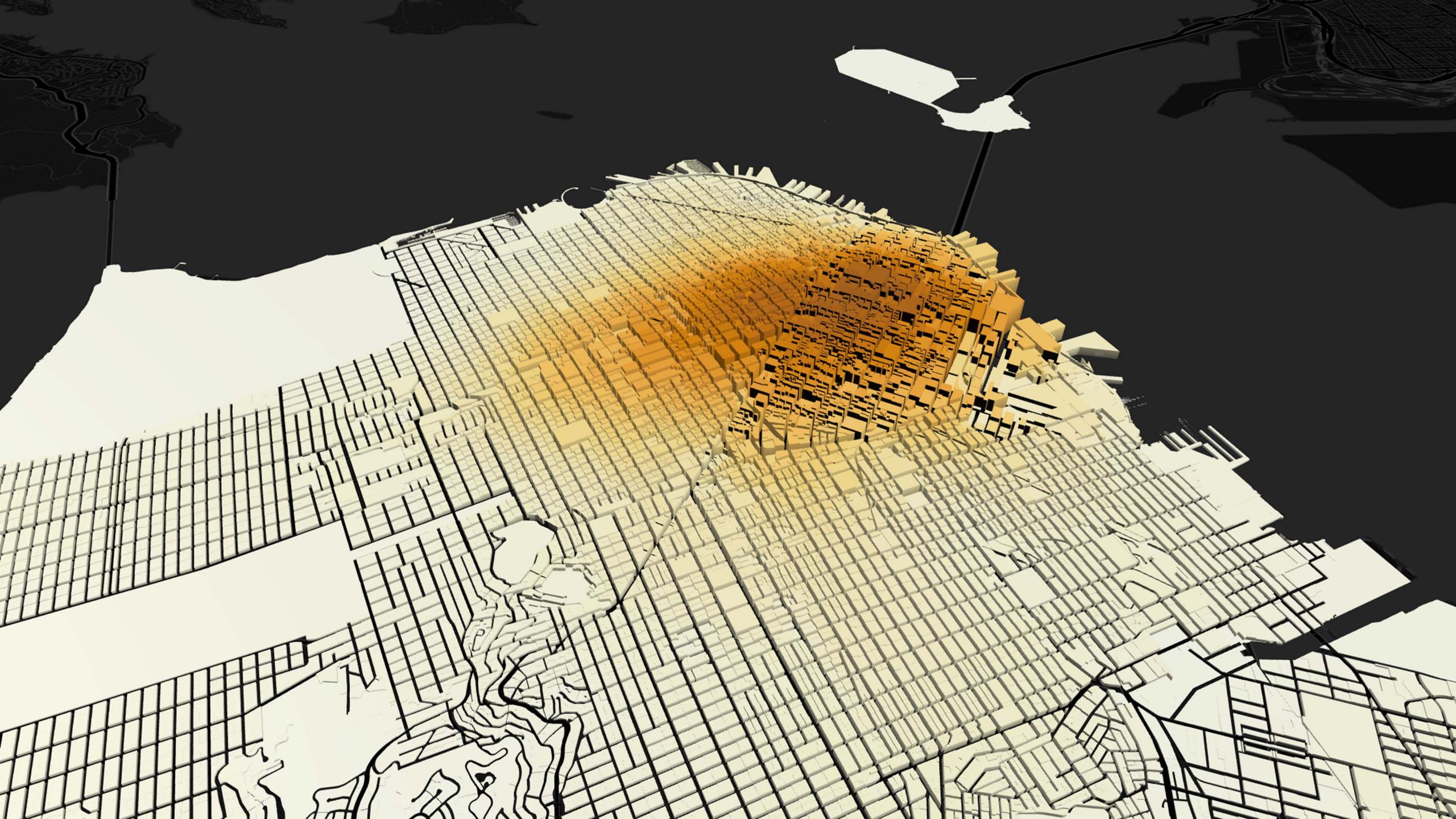
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- Etc.

Common  
Calculations

## UrbanSim Indicators

- Descriptives**
- Proportions**
- Density**
- Accessibility**





## Overall Features: Works for all model templates

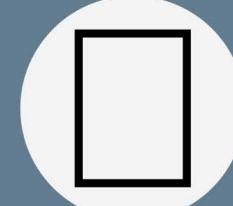
Parcel - Level Model



Census  
Block – Level Model



Zone - Level Model





## Overall Features: Multiple geographies

Counties

Census Tracts

Block Groups

Blocks



## Overall Features: Filtering

- *Where might we see job growth in the manufacturing sector?*
- *On average, how many workers in households without a car are within a 30-minute transit commute of this block?*
- *What is the remaining capacity for residential units in multifamily buildings?*



## Overall Features: Comparisons

### Between Years

*How many jobs will be added from 2016 to 2020 in this county?*

### Between Scenarios

*Which land use scenario results in more job growth by 2020 in this county?*



## UrbanSim Indicators

Descriptives

Proportions

Density

Accessibility



## UrbanSim Indicators

<b>Descriptives</b>	Blocks
<b>Proportions</b>	Block Groups
<b>Density</b>	Tracts
<b>Accessibility</b>	Counties
	Years
	Scenarios



## UrbanSim Indicators

Descriptives	Blocks
Proportions	Block Groups
Density	Tracts
Accessibility	Counties
	Years
	Scenarios

- Number of households, jobs, residential units
- Number of persons, workers
- Median income
- Number of jobs in a given sector
- Median income for households of a certain demographic



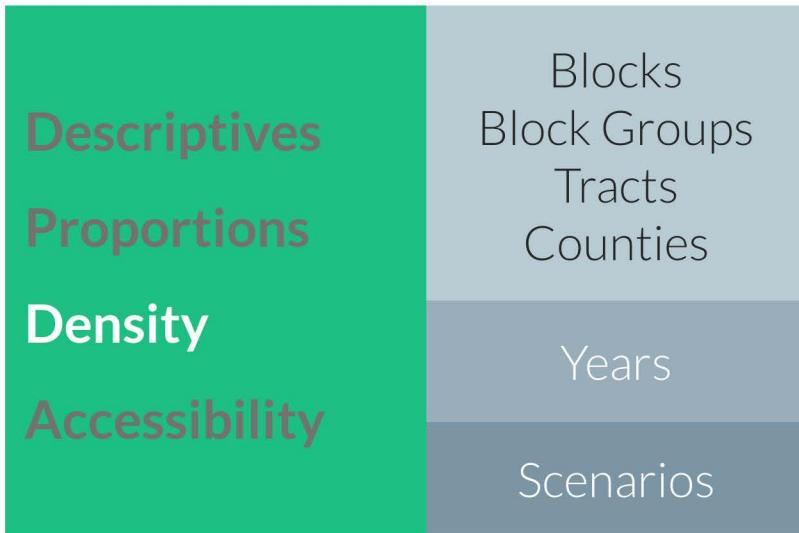
## UrbanSim Indicators

Descriptives	Blocks
Proportions	Block Groups
Density	Tracts
Accessibility	Counties
	Years
	Scenarios

- Proportion of jobs that are in a given sector
- Proportion of households that have an income above/below:
  - A given threshold (\$60,000)
  - The regional median
  - The 25<sup>th</sup> percentile of the region



## UrbanSim Indicators



- *Job or population density*
- *Density of jobs in a given sector*
- *Population density for households of a certain demographic*



## UrbanSim Indicators

Descriptives	Blocks
Proportions	Block Groups
Density	Tracts
Accessibility	Counties
	Years
	Scenarios

- Average number of jobs, persons, or workers within 1000 meters network distance from locations in each block, tract, or county
- Transit network accessibility
- Uses Pandana library, options for distance, aggregation methods
- Depends on network data available



## UrbanSim Indicators

Descriptives

Proportions

Density

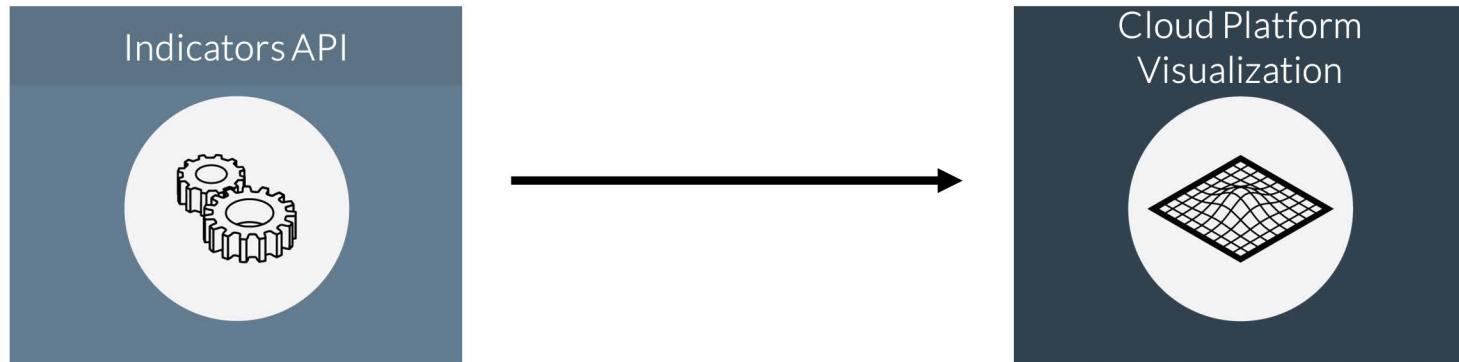
Accessibility

Model Validation

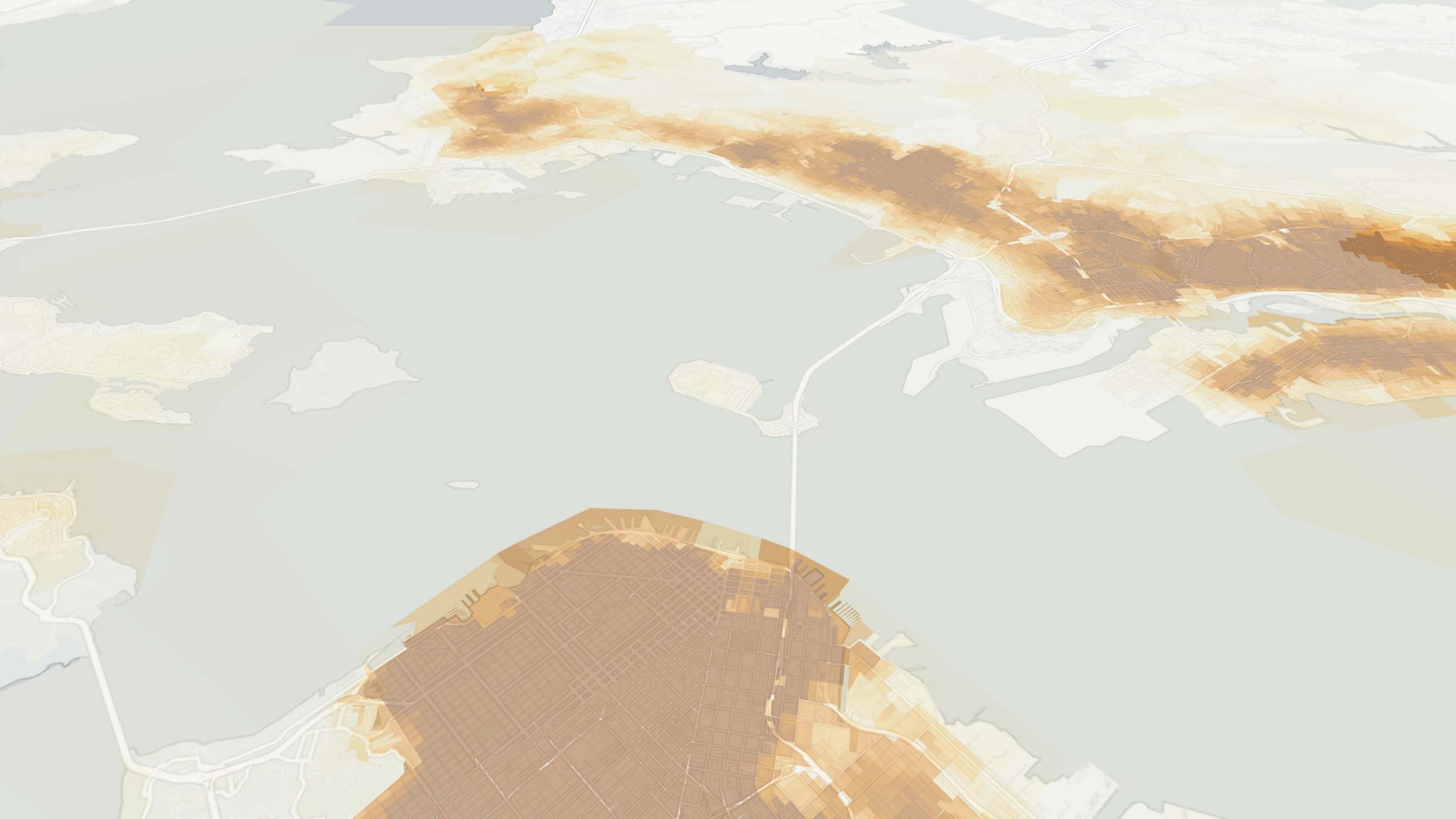
- *Remaining capacity for jobs, residential units*
- *Number of unplaced jobs, households*



## Under the Hood



- Python back end
- Flask API
- Orca/Pandas
- ViziCities maps
- Interactive charts
- Menu-driven workflow





UrbanSim  
Cloud Platform

# Concluding...

- Data Science + Urban Modeling + Design + Visualization has potential to change urban planning in profound ways:
  - More informed by open, shared data
  - More participatory
  - More evidence-based
  - More agile
  - More democratic

# Thank You

