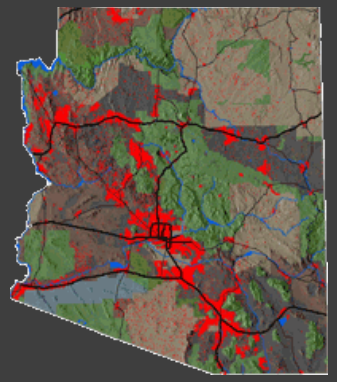


AZ-SMART

ARIZONA'S SOCIOECONOMIC MODELING, ANALYSIS, & REPORTING TOOLBOX

AZ-SMART POPTAC WORKSHOP
FEBRUARY 26, 2019

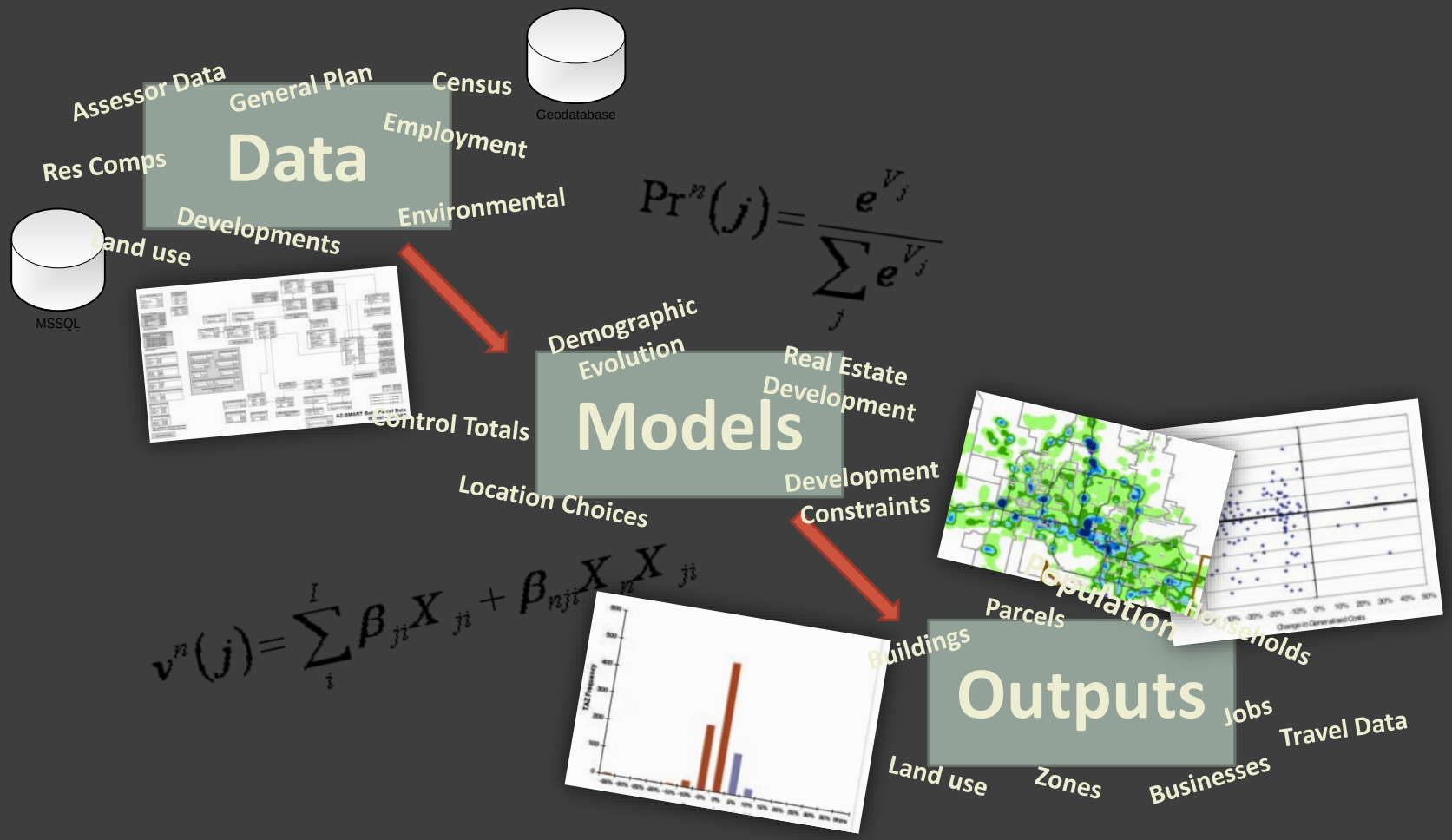
AZ-SMART – overview

AZ-SMART: What and why?

Input and Base Year Data

Models: Simulation Sequence & Description

AZ-SMART – WHAT IS IT?



AZ-SMART – WHAT IS IT REALLY?

An open source framework for developing socio-economic projections

Tools for data development and maintenance

- Land use, general plan, inventories, etc.
- Population and employment synthesis

Tools for data analysis

Tools for configuring, estimating, calibrating, and running simulation models

Makes use of UrbanSim \ Urban Data Science Toolkit (UDST)

All software written in Python and hosted publicly on GitHub

AZ-SMART – WHY DO IT?

We are required to produce population projections (AZ Executive Order 2011-04)

Travel demand model requirements

- Travel models depend on socio-economic data
- Socio-economic models are improved by travel model feedbacks

We are getting asked questions that previous models were less equipped to answer, e.g.

- Corridor studies
- Activity-based travel models

Policy analysis, what happens if:

- Employment sector X is predicted to grow or decline substantially?
- Several cities change land use policies to encourage density?

AZ-SMART INPUT AND BASE YEAR DATA

TARGET DATA MODEL

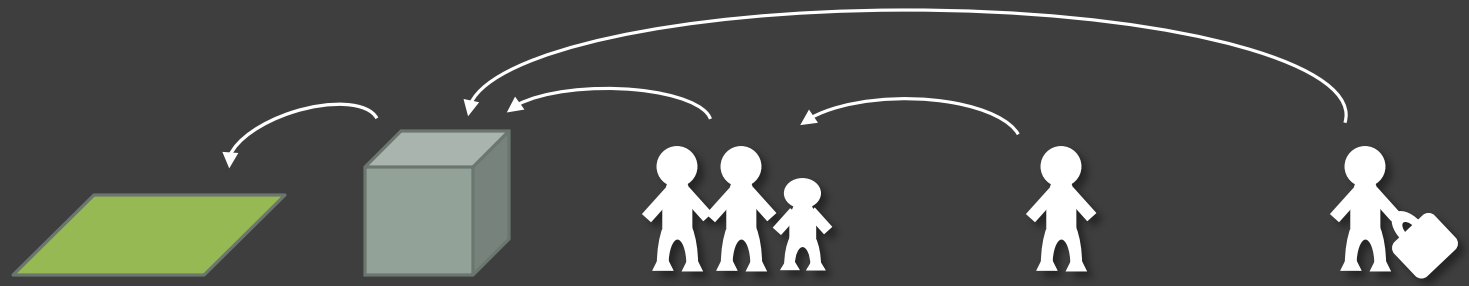


Table	Parcels	Buildings (built space)	Households	Persons	Jobs
Primary Key	zone_id	building_id	household_id	person_id	job_id
Foreign Key	taz_id, mpa_id, tract_id, etc.	zone_id	building_id	household_id	building_id
# Records	~1.84 million	~1.53 million	~1.71 million	~4.56 million	~2.12 million

PRIMARY INPUT DATABASES - REVIEWED

- Existing Land Use (EXLU) – updated and reviewed annually
- Developments (DEVS) – ongoing updates, reviewed annually
- General Plan (GP) – ongoing updates, reviewed annually
- MAG Employer Database (EmpDB) – data updated and reviewed annually
- Other Inventories (e.g. group quarters, schools, etc.) – updated and reviewed annually

BASE DATABASE: DATA, ASSUMPTIONS, AND FACTORS

Database of observed data representing the region

Database serves as the basis for forecasting, build-out

Base year is 2018

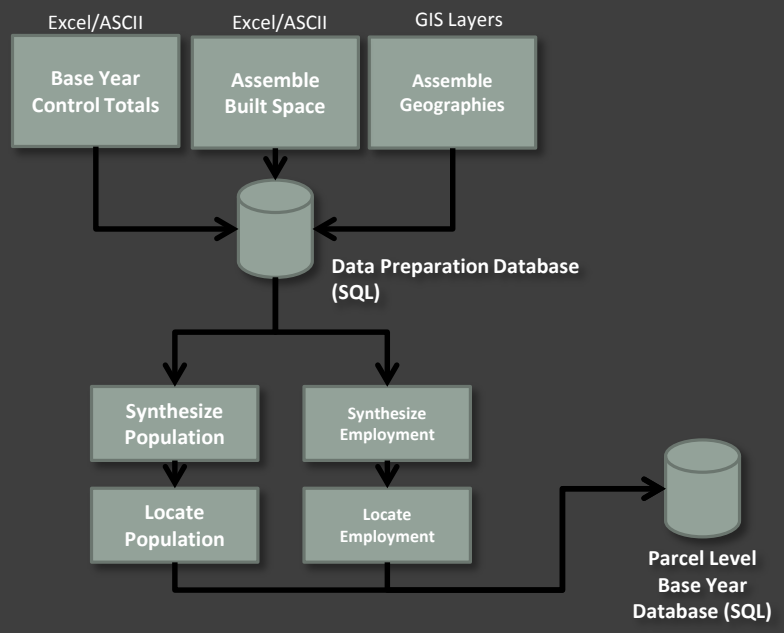
- Note: 2018 will be as up to date as possible as of March 2019.

Population control totals

- 2018 population estimates by jurisdiction

Employment control totals

- 2018 totals based on 2018 Q1 and Q2 QCEW



BASE DATABASE: DATA, ASSUMPTIONS, AND FACTORS

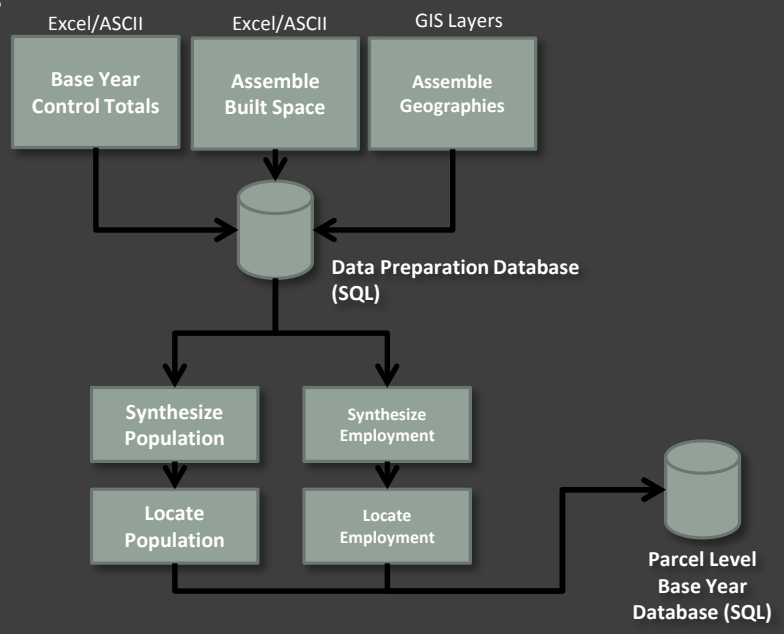
Land: Assessor parcels, filled in w/land use dataset

Built space: Assessor improvements, city and other public data

- Building types: 22 types of built space, aggregated from Assessor "model types" in improvements data
- Residential Completions current to 2018Q4

Building Occupants:

- Households
- Employment
  - Building SQFT / Job, by building type
  - Employment by industrial sectors: NAICS 2 Digit
  - Work at home employment



BASE DATABASE CREATION METHODOLOGIES

Household and population synthesis:

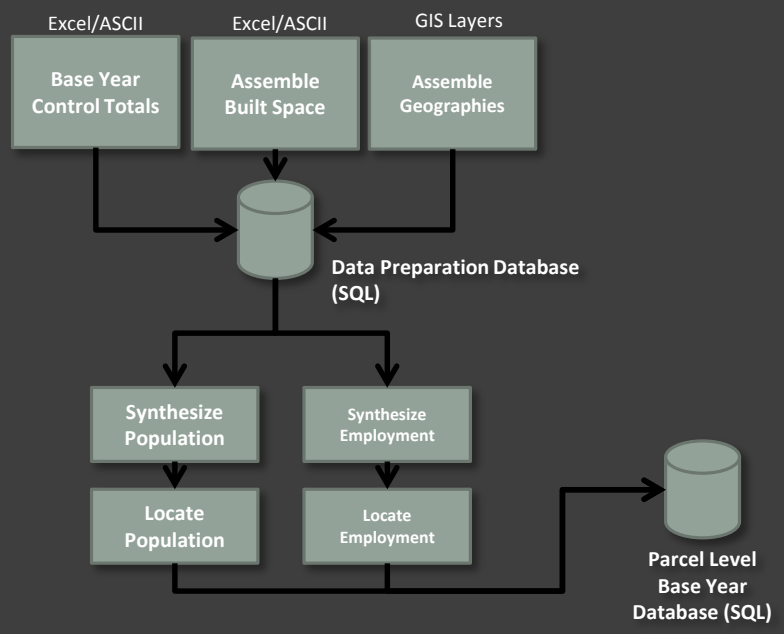
- Based on latest Census ACS 5 year sample and ACS PUMS (2013-2017) released in Jan. 2019
- Synthesized to "pseudo-block groups," controlled population to 2018 Population Estimates from OEO
- Located households to dwelling units

Employment synthesis:

- 2017 (and partial 2018) MAG employer database, parcel level
- Allocated employees to building records proportional to the built space
- Scaled employment up to match 2018 county control total (by NAICS)

Special populations:

- Seasonal households, allocated to vacant units "held for seasonal use" by Census
- Non-site based (NSB) employment, allocated to buildings proportionally by NSB type and building occupants
- Construction employment, allocated to developing land use codes



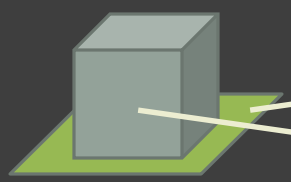
POPULATION SYNTHESIS

1. Given Census Block Group information (e.g. #hh by income categories & size, #pp by age and sex)
2. Generate frequency matrix (via IPF/IPU methodology) of household and person type constraints by block group
3. Draw from Census PUMS data detailed household and person records that match the constraints
4. Use detailed information from PUMS records (structure size, type, value, etc.) to match or "locate" households to Assessor parcels and built-space information with similar attributes

Total Households:		100
Households by Size:	1	30
	2	40
	3+	30
Households by Income:	Low	60
	High	40

Households		**Household Income**		**Total**
		Low	**High**	
Household Size	**1**	23.6	6.4	30
	2	15.2	24.8	40
	3+	21.3	8.7	30
Total		60	40	100

DATA MODEL – RESIDENTIAL EXAMPLE



Parcels

parcel_id	raz_id	mpa_id	county_id	area	freeway_within_qtr_mi	dist_to_phx_cbd	flood_plain
1671	204	26	1	174240	0	185042	0

Buildings

building_id	building_type_id	zone_id	land_area	residential_units	residential_units_capacity	non_residential_sqft	non_residential_sqft_capacity	sqft_per_unit
875	1	1671	174240	10	10	0	0	1964

Households

household_id	building_id	children	age_of_head	income	persons	workers
812943	875	1	60	122616	2	2
812960	875	1	30	79910	2	1
813534	875	0	39	44671	2	0
813556	875	0	38	37990	2	0
814097	875	0	71	74408	2	0
814118	875	0	65	76766	2	1
814258	875	0	31	93010	3	3
814287	875	0	67	129690	2	1
814434	875	0	25	0	1	0
814435	875	0	44	0	1	0

Persons

person_id	household_id	person_no	head_of_hh	age	sex	education	student_status	marriage_status
2170137	812943	1	1	60	1	11	1	1
2170138	812943	2	0	17	2	7	2	6
2170171	812960	1	1	30	1	8	1	1
2170172	812960	2	0	2	1	0	0	0
2171893	813534	1	1	39	1	5	1	1
2171894	813534	2	0	35	2	1	1	1
2171937	813556	1	1	38	1	9	1	1
2171938	813556	2	0	39	2	10	1	1
2173361	814097	1	1	71	1	9	1	1
2173362	814097	2	0	65	2	12	1	1
2173403	814118	1	1	65	2	14	1	1
2173404	814118	2	0	56	1	14	1	1
2173725	814258	1	1	31	1	10	1	6
2173726	814258	2	0	29	1	13	1	6
2173727	814258	3	0	28	1	13	1	6
2173857	814287	1	1	67	1	9	1	1
2173858	814287	2	0	59	2	9	1	1
2174154	814434	1	1	25	1	13	3	6
2174155	814435	1	1	44	1	11	1	6

EMPLOYMENT SYNTHESIS

Relies heavily upon the mag employer database

- Point level (parcel matched) database of employers

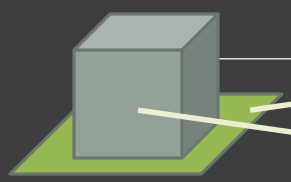
Total employment in the employer database is less than the total employment present in the county

- Employment must be scaled to match the county control

Employer points match to built space / building records, many conflicts between datasets:

- 1 employer point on a parcel with 1 building
- 2+ employer points on a parcel with 1 building
- 1+ employer point(s) on a parcel with 0 buildings
- 2+ employer points on a parcel with 2+ buildings
- Etc…

DATA MODEL NON-RESIDENTIAL EXAMPLE



Parcels

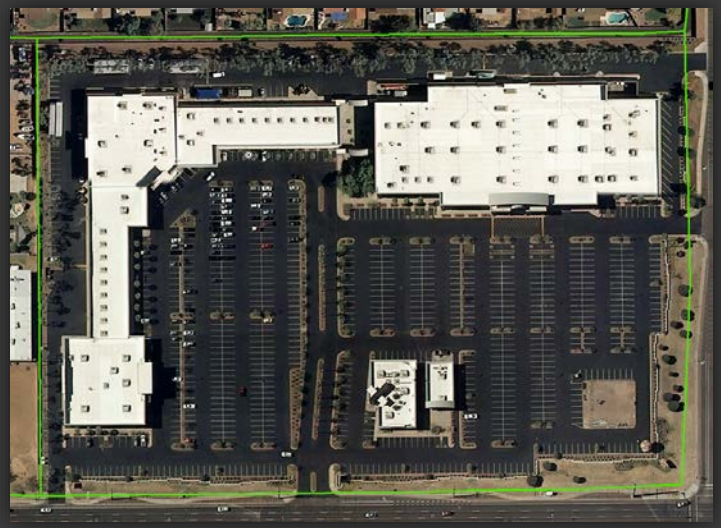
parcel_id	raz_id	mpa_id	county_id	area	freeway_within_qtr_mi	dist_to_phx_cbd	flood_plain
8479	265	27	1	849800	1	86950	0

Buildings

building_id	building_type_id	zone_id	land_area	residential_units	residential_units_capacity	non_residential_sqft	non_residential_sqft_capacity	sqft_per_unit
875	3	8479	849800	0	0	162500	162500	1

Jobs

job_id	building_id	sector_id	home_based_status
814097	875	3	0
814118	875	3	0
814258	875	3	0
814287	875	3	0
814434	875	3	0



building_type_id	building_sqft_per_job
1	150
2	150
3	800
4	400
5	350
6	500
7	500
8	750
9	1000
10	250

building_sqft_per_job

DATA MODEL TARGET DATA STRUCTURE REVIEW

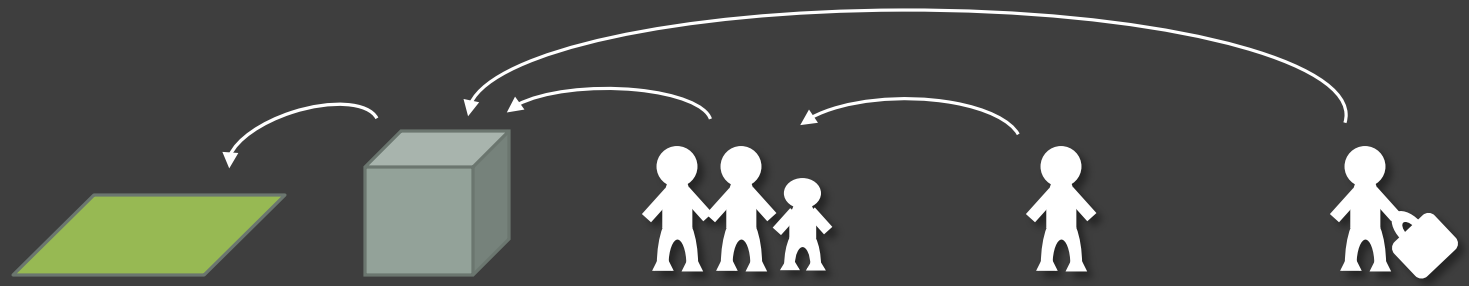


Table	Parcels	Buildings (built space)	Households	Persons	Jobs
Primary Key	zone_id	building_id	household_id	person_id	job_id
Foreign Key	taz_id, mpa_id, tract_id, etc.	zone_id	building_id	household_id	building_id
# Records	~1.42 million	~300 k	~1.44 million	~3.93 million	~1.79 million

MODELS: SIMULATION SEQUENCE & DESCRIPTION

WHAT IS A MODEL ANYWAY?

A mathematical or statistical abstraction to help us understand and make predictions about real world systems, often consists of:

- A set of simplifying assumptions
- Initial conditions
- A range of applicability

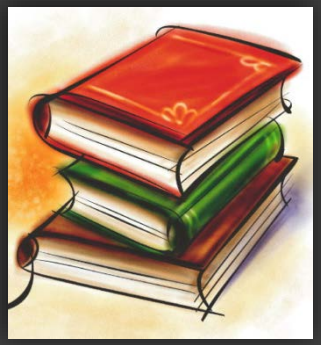
Models can be used to:

- Make predictions about the future
- Understand what variables influence certain outcomes

IMPORTANT: DETERMINISTIC VS PROBABILISTIC models

- Deterministic: given a set of inputs, outputs are consistent over many model runs
- Probabilistic (stochastic): has a random component, results vary some small amount over many model runs
- AZ-SMART uses a combination of both types

AZ-SMART MODELS: THEORETICAL BASES



Random Utility Theory (McFadden)

- Agents choose amongst alternatives based on relative utility

Urban Economics/Bid Rent Theory (Alonso, Mills, Muth)

- Explains land use as a function of willingness to pay for amenities and location trade-offs

Hedonic Price Theory (Rosen)

- Composite goods (housing) can be “disaggregated” into their attributes and priced

Dynamic Market Equilibrium, Disequilibrium

- Real-world markets rarely in equilibrium, imperfect information abounds

Microsimulation (Orcutt)

- Helps avoid aggregation bias and ecological fallacy

GIS and Spatial Analysis (Tobler, Anselin)

Source: P. Waddell, 2010

AZ-SMART SIMULATION: SEQUENCE OF MODELS

Demographic Change Models

Employment Change Models

Simulates demographic change in population and change in employment

↓

Real Estate Development Models

Predicts price, location, timing, and types of real estate development and re-development

↓

Household Location Models

Simulates migration and location choices of households

↓

Employment Location Models

Simulates location choices of regional employment

HOUSEHOLD AND EMPLOYMENT TRANSITION MODELS

Demographic Change Models

Employment Change Models

Simulates county level demographic change in population and change in employment

Adds and removes households and jobs based on control totals developed a priori

Randomly add or remove records until control totals are met, setting location to -1

Results in new agents that need to be located to a building record

HOUSEHOLD AND EMPLOYMENT TRANSITION MODELS

Demographic Change Models

Employment Change Models

- **Step 1: Calculate Simulation Population by bins in Control Totals Table and difference**
- **Step 2: Randomly duplicate or delete population records as necessary**

Annual Population Control Totals Table Example

year	sex	age_min	age_max	Population Control Total	Simulation Population	Difference
2016	1	0	13	53684	52443	+ 1241
2016	1	14	17	52482	53451	- 969
2016	1	18	35	50472	48421	+ 2051
2016	1	36	55	49190	51216	- 2026
2016	1	56	75	48471	50994	- 2523
2016	1	76	-1	49621	48341	+ 1280
2016	2	0	13	48916	47154	+ 1762
2016	2	14	17	51751	50985	+ 766
2016	2	18	35	53478	52187	+ 1291
2016	2	36	55	52971	51924	+ 1047
2016	2	56	75	49168	51369	- 2201
2016	2	76	-1	47154	49271	- 2117

REAL ESTATE DEVELOPMENT MODELS

Generate Development Projects

Residential Unit Demand

Non-Residential "Unit" Demand

Choose Projects to Build

Generate Buildings for Chosen Projects

Real Estate Price Models

In the first simulation year only: generate projects

Parcels are grouped on their presence within a planned development or within a general plan area

Large GP areas are subdivided by PLSS sections, parcels are sometimes split by various boundaries

Only developable parcels are considered

Parcels within a project are assumed to share the same future densities and land use compositions

REAL ESTATE DEVELOPMENT MODELS

Generate Development Projects

Residential Unit Demand

Non-Residential "Unit" Demand

Choose Projects to Build

Generate Buildings for Chosen Projects

Real Estate Price Models

Estimate regional demand: determine how many units should be built county-wide for each development type

Residential:

- Calculate a total regional vacancy rate, compute # units to build based on a year specific target vacancy rate
- Determine share of units going to single vs multi-family

Non-residential:

- Demand is expressed in terms of "job spaces" (building square footage / sqft per job)
- Anticipate demand for building types based on new jobs' building types
- Utilize target vacancy rate to compute # of job spaces to build

REAL ESTATE DEVELOPMENT MODELS

- **Generate Development Projects**
- **Residential Unit Demand**
- **Non-Residential "Unit" Demand**
- **Choose Projects to Build**
- **Generate Buildings for Chosen Projects**
- **Real Estate Price Models**

For each year:

- Filter out complete or ineligible projects
- Compute maximum # of units per project (based on size, type, # built)
- Assign scores or weights to projects based on type and status
- Choose top scoring projects by type

Tier 1 projects: scheduled developments

- have defined start and end years, guaranteed to build out at a linear rate

Tier 2 projects: Active developments

- Currently developing, subject to regional demand
- More likely to be chosen to build, preference given to projects closer to completion and those with higher occupancy rates

Tier 3: non-active projects

- Not currently developing, subject to regional demand, less likely to be chosen

REAL ESTATE DEVELOPMENT MODELS

- Generate Development Projects
- Residential Unit Demand
- Non-Residential "Unit" Demand
- Choose Projects to Build
- Generate Buildings for Chosen Projects
- **Real Estate Price Models**

Primary purpose: prices influence location decisions

Model stratified into submodels by building type

- Different variables influence SFR vs. Industrial prices

Standard OLS estimated regression model with $/sqft as dependent variable

Predicted prices then used as inputs to influence the behavior of other models (e.g. HLCM, ELCM)

price = (β)home sqft + (β)lot sqft + (β)within 1/4mi of landfill

Price	=	β	*	Home Sqft	+	β	*	Lot Sqft	+	β	*	0.25mi landfill?
Price	=	14.63	*	2365	+	2.34	*	43560	+	-5630	*	1
Price	=	34599.95			+	101930.4			+	-5630		
Price	=	$130,900.40										

AZ-SMART SIMULATION SEQUENCE – LOCATION CHOICE

Household Location Models

Simulates location choices of households

Employment Location Models

Simulates location choices of regional employment

LCMs locate households and jobs in vacant residential and non-residential space

- Predicts a specific built-space record for a household or job in need of a location

Different types of households and employment have different variables that influence location decisions

- Household LCM stratified into models by 3 income classes
- Employment LCM stratified into sectors (roughly corresponding to 2 digit NAICS)

AZ-SMART SIMULATION SEQUENCE – LCM VARIABLES

Household Location Models

Employment Location Models

- Accessibility variables using Travel Demand Model Skims:
  - <quantity> of <some variable> within <some travel time> <during some travel period> <on some mode>
  - Examples in current HLCMs / ELCMs:
    - Retail Employment within 20 minutes Peak SOV
    - Number of Jobs in Office buildings within 15 minutes Peak SOV
    - Resident Population within 15 minutes
    - Vacant Job spaces within 10 minutes
- Proximity variables:
  - Distance to nearest bus stop, light rail stop, park and ride, Dist to Phx CBD
- Other variables, examples:
  - HLCM: Interaction of household income with predicted DU price
  - DU sqft / persons in household
  - Zonal median income

LOCATION CHOICE MODEL EXAMPLE

1. Determine household records w/out a location
2. Identify vacant housing units
3. Randomly sample from vacant units for a reasonably sized choice set
4. Calculate utility and probability (based on household and housing unit characteristics)
5. Use random sampling to determine the choice

House	Utility	Probability
A	300	0.259
B	600	0.517
C	200	0.172
D	50	0.043
E	10	0.009

House	Ordered Probability	Cumulative Proability	Random Number
E	0.009	0.009	
D	0.043	0.052	
C	0.172	0.224	
A	0.259	0.483	0.480
B	0.517	1.000	

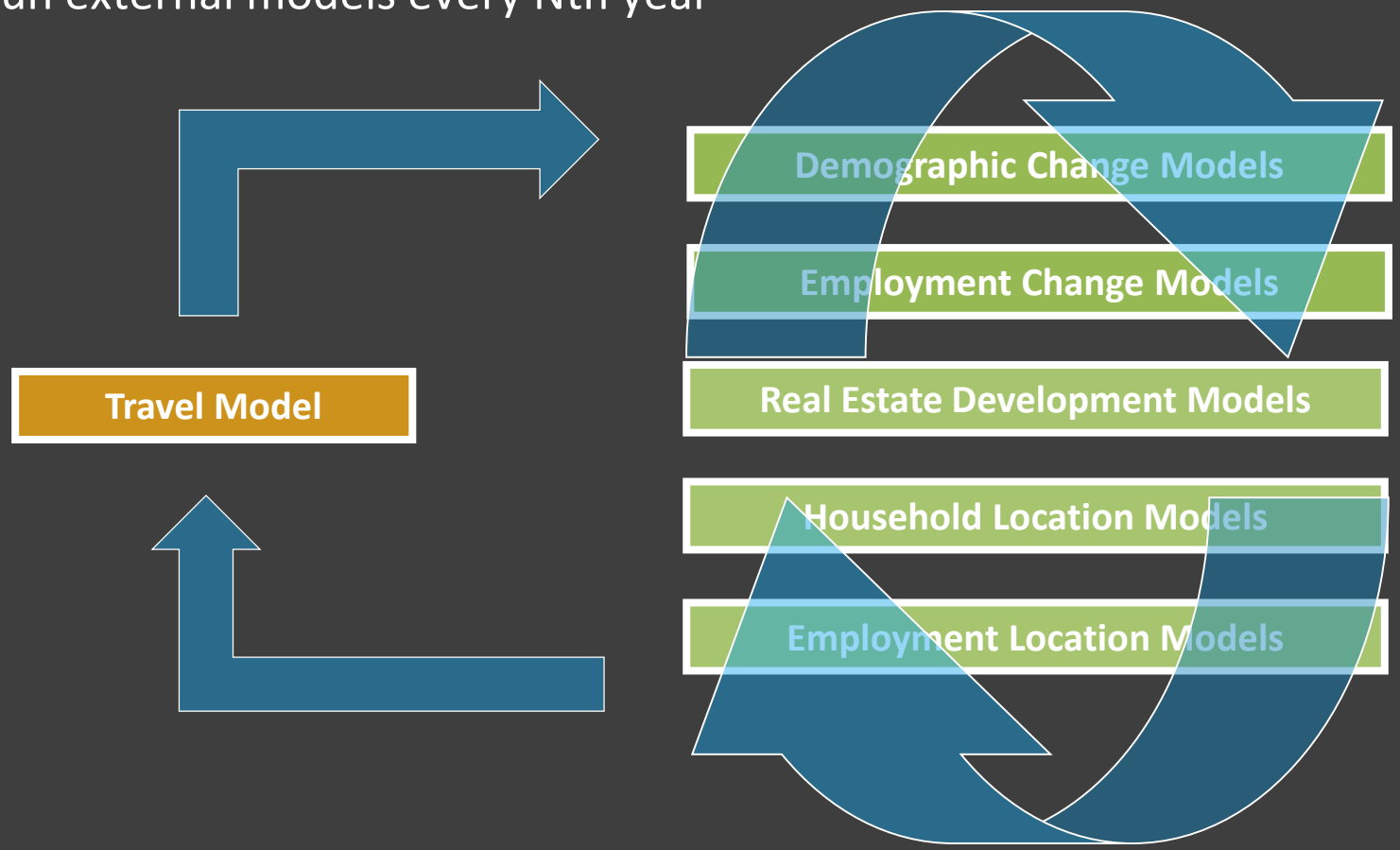
$$v^n(j) = \sum_i^I \beta_{ji} X_{ji} + \beta_{nji} X_n X_{ji}$$

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

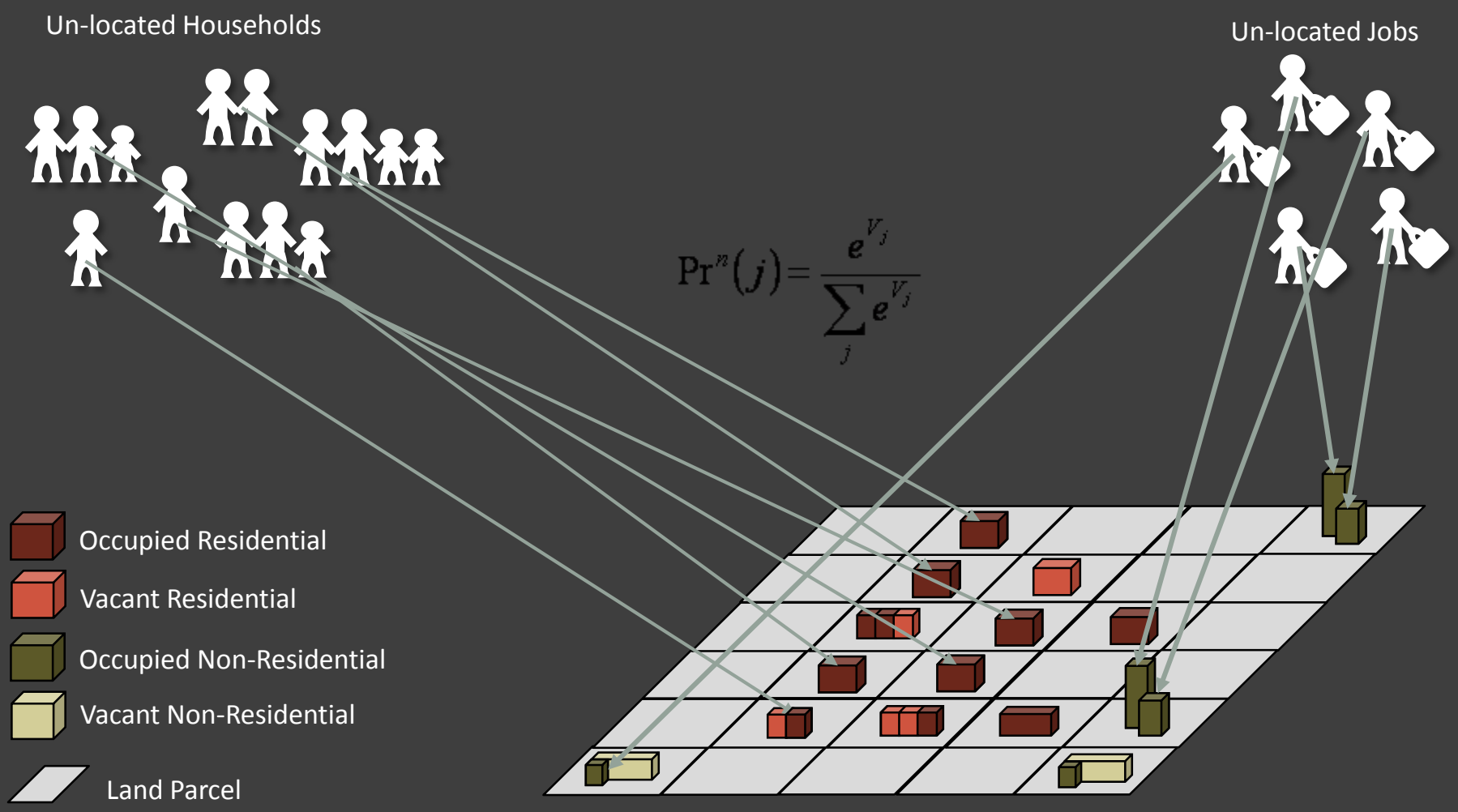
AZ-SMART SIMULATION SEQUENCE – LOCATION CHOICE

Models repeat for every year

Run external models every Nth year



Employment Location Choice Models



QUESTIONS?

Primary Team:

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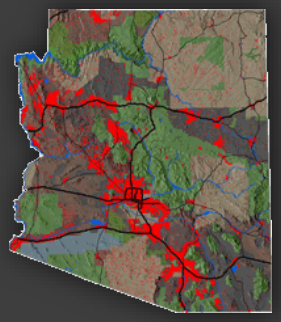
Scott Bridwell

Scott Wilken

Anubhav Bagley



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