Land Use Model

Introduction

The Mid-Region Metropolitan Planning Organization (MRMPO) uses the UrbanSim land use model to forecast the growth of employment and people moving into and within the region. This socioeconomic forecast is then used to forecast travel demand and the impacts on transportation infrastructure. MRMPO has used UrbanSim since 2011.

UrbanSim is a microsimulation land use model, designed for analyzing the potential effects of land use policies and infrastructure investments on the development and character of the region. The modeling system relies upon a data-driven, transparent, and behaviorally-focused methodology that is designed to attempt to reflect the interdependencies in dynamic urban systems, focusing on the real estate market and the transportation system, and on the effects of individual and combinations of interventions on patterns of development, travel demand, and household and job location. UrbanSim has become the operational modeling approach for a variety of metropolitan areas in the United States and abroad, and is actively used by planning organizations in Austin, Chicago, Denver, Detroit, Honolulu, Phoenix, Minneapolis, Salt Lake City, San Diego, San Francisco, Eugene-Springfield, Seattle, and Paris among others.

UrbanSim has been developed for more than a decade of research led by Paul Waddell, currently Professor of City and Regional Planning at the University of California, Berkeley, from multiple grants from the National Science Foundation and from a number of MPOs in the United States. UrbanSim has consistently emerged as one of the most sophisticated and credible land use modeling methodologies. The core model code has been developed in the Python programming language as Open Source software and is publicly available on the Urban Data Science Toolkit GitHub page.

UrbanSim Overview

UrbanSim works at the microsimulation level representing individual people and households, and individual parcels, buildings and housing units within buildings. UrbanSim simulates the interactions among households, businesses, and developers within real estate markets. By modeling how households trade off housing costs, accessibility, and housing and neighborhood amenities, UrbanSim microsimulates households' choices to move within a year, make a new location choice. UrbanSim also microsimulates employment dynamics, including a firms' location choices. Furthermore, the model microsimulates developers' choices of what kind of buildings to build, where, and when, and whether to redevelop existing properties. Land use policies constrain what developers can build, and transportation plans modify accessibility patterns, which influence the attractiveness of different locations for households and firms. This influences prices and rents and the market conditions for new development or redevelopment.

UrbanSim is different from prior operational land use models that are based on cross-sectional, equilibrium, aggregate approaches in that UrbanSim models individual households, jobs, buildings and parcels, and their changes from one year to the next as a consequence of economic changes, policy interventions, and market interactions. UrbanSim simulates changes for each year, and the results of one year provide the starting point for the next simulation year. This method closely replicates the way that urban areas evolve, year over year, with mismatches between the supply and demand of housing and jobs. Typically, metropolitan areas see only a small fraction of the housing stock added in a given year. Development of real estate proceeds slowly in response to rapid changes in demand, leading to swings in vacancy rates and prices, and to the commonly observed booms and busts in real estate cycles.

Key conceptual underpinnings of UrbanSim include:

- Representation of individual decision-making agents such as households, employers, people and jobs.
- Representation of the supply and characteristics of land and of real estate development.
- The adoption of a dynamic perspective of time, with the simulation proceeding in annual steps, and the urban system evolving in a path dependent manner.
- The use of real estate markets as a central organizing focus, with consumer choices and supplier choices explicitly represented, as well as the resulting effects on real estate prices. The relationship of households or employers to real estate tied to specific locations provides a simple accounting of space and it's use.
- The use of Multinomial Logit Models to represent the choices made by households, employers and developers (principally location choices).
- Integration of the urban simulation system with existing transportation model systems, to obtain information used to compute accessibilities and their influence on location choices, and to provide the raw inputs to the travel models.

Model System Design

In the UrbanSim model, buildings are located on parcels that have particular characteristics such as value, land use, and developable area. Local municipalities set policies that regulate the use of land, through the imposition of zoning or through pricing policies such as development impact fees. Municipalities also build infrastructure, including transportation infrastructure, which interacts with the distribution of activities to generate patterns of accessibility at different locations that in turn influence the attractiveness of these sites for different consumers. Households have particular characteristics that may influence their preferences and demands for housing of different types at different locations. Businesses also have preferences that vary by industry and size of business (number of employees) for alternative building types and locations.

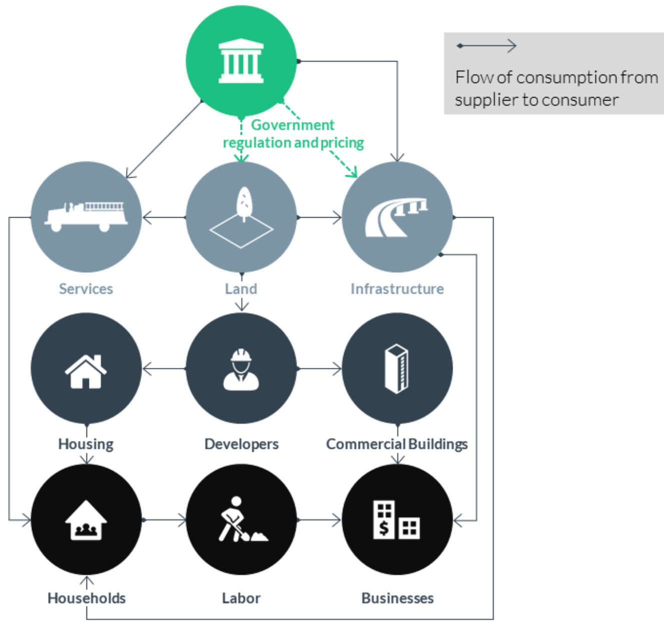

Figure 1. UrbanSim simulates households and employers interacting within real estate markets.

UrbanSim predicts the evolution of households, employers and their characteristics over time, using annual steps to predict the movement and location choices, the development activities of developers, and the impacts of governmental policies and infrastructure choices. The land use model is interfaced with MRMPO's travel model system to deal with the interactions of land use and transportation. Access to opportunities, such as employment or shopping, are measured by the travel time or cost of accessing these opportunities via all available modes of travel. See the travel model integration section for details.

MRMPO uses exogenous regional employment and population forecasts as control totals, meaning that these are inputs that are not predicted directly by UrbanSim or MRMPO. The University of New Mexico Bureau of Business and Economic Research (UNM-BBER) uses a macroeconomic model to predict short term future employment by sector which is supplemented by a long-term employment forecast from Regional Economics Modelling Inc. (REMI) to create a regional employment control total. The University of New Mexico Geospatial Population Studies (UNM GPS) creates a population projection using the cohort component method which relies on predicting births, deaths and migration that is used as a population control total.

UrbanSim Inputs

- Employment data from New Mexico Department of Workforce Solutions and InfoGroup
- Household data, merged from multiple U.S. Census sources and ESRI Business Analyst Online
- Municipal and County plans and zoning
- Undevelopable land, Federal land, Tribal land, and State land boundaries
- Congested travel times from the travel model

- Parcel database, with acreage, land use, housing units, nonresidential square footage, year built, land value, and improvement value developed using data from County Assessors, CoStar, Metrostudy, municipal, county and state building permits.
- Average construction costs from RSMeans
- Employment control totals (regional forecast) provided by UNM BBER and REMI.
- Population control totals (regional forecast) provided by UNM GPS, which is then converted to a household control total using Woodes and Poole Inc's household-size forecast.

Discrete Choice Models

UrbanSim makes extensive use of choice models where individual households and employers choose buildings. First multinomial logit models are estimated based on current data (see household and employment location choice model descriptions in the next section). For example, households that moved to the region in the last 5 years are evaluated by the Census Tracts that they picked to move to. The estimated model is then used as the probability that a particular household (with different incomes and characteristics) picks a particular unit (of different sizes, prices and characteristics). In order to predict choices given the predicted probabilities, the choice algorithm uses a sampling approach. As illustrated in the figure below, a choice outcome can be selected by sampling a random number from the uniform distribution in the range 0 to 1, and comparing this random draw to the cumulative probabilities of the alternative housing units. Whichever alternative the sampled random number falls within is the alternative that is selected as the 'chosen' one. This algorithm has the property that it preserves in the distribution of choice outcomes a close approximation of the original probability distribution, especially as the sample size of choosers becomes larger.

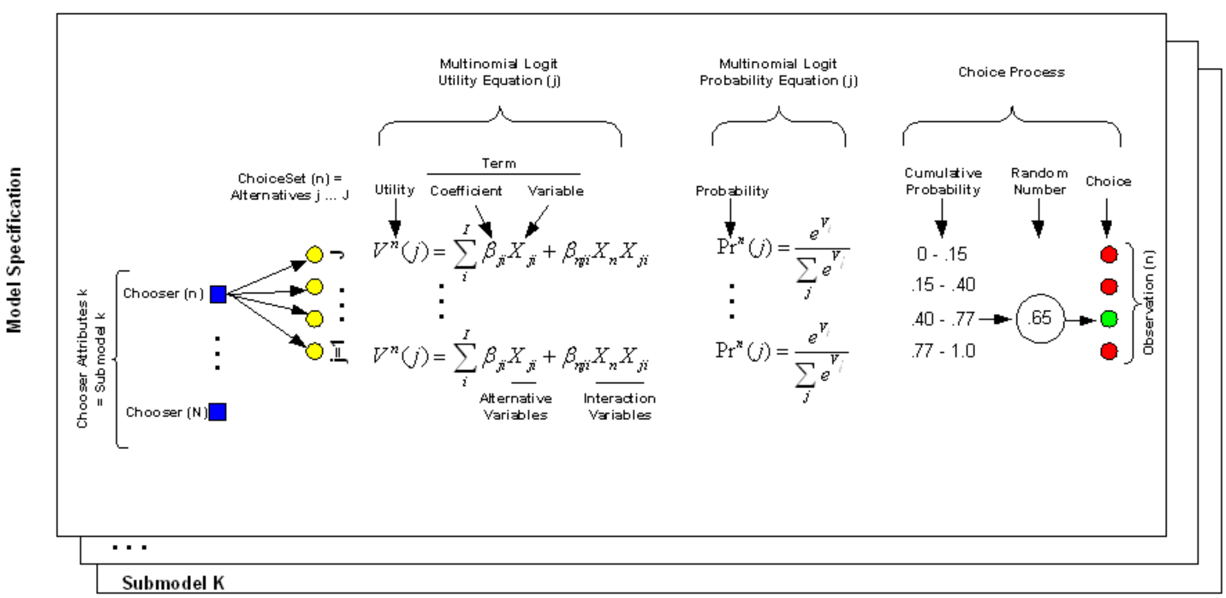

Figure 2. UrbanSim Choice Models.

The figure below shows an example of the probability of an employer selecting a particular parcel in the Albuquerque Metropolitan area, yellow indicates areas that are more attractive for employers.

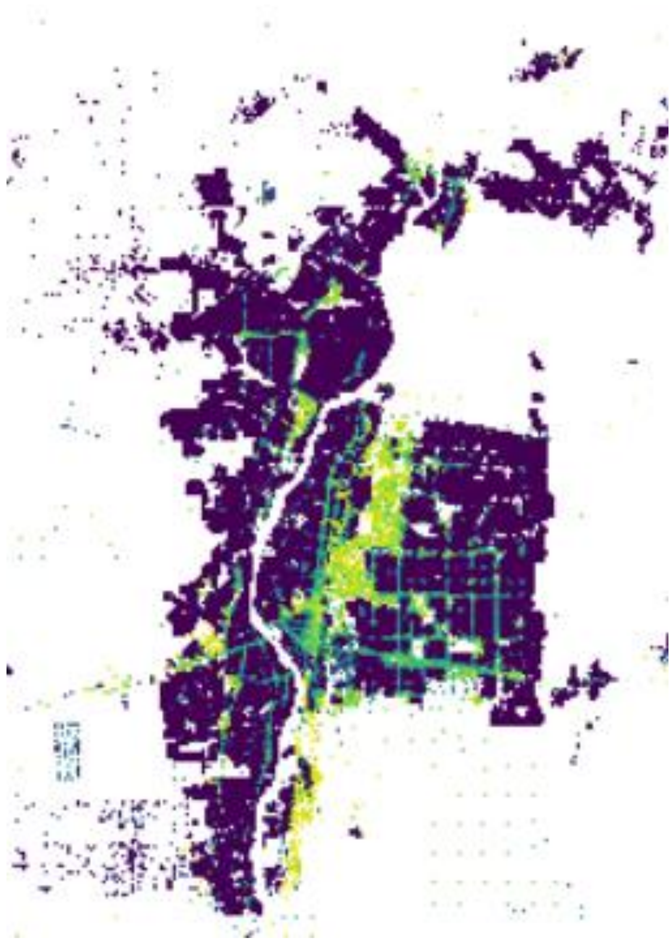

Figure 3. Example of the probability of a manufacturing firm selecting a particular parcel within the greater Albuquerque metro area (Yellow is high probability, purple is low).

Model Steps

Each simulation year follows the steps seen below in figure 1. First, the control totals developed externally by UNM and REMI determine how many new households and jobs are introduced to the region. Next, the known scheduled developments are built. Next, the Price Models update real estate prices followed by the proforma and developer steps calculating costs of potential sites and then building new buildings that are profitable. Next, the Household and Employment Location Models place households and jobs into empty buildings based on the predicted attractiveness of each site. Finally, because the spatial allocation of people and jobs has been altered, the Travel Model is updated and calculates new congested travel times. The updated travel times will affect the next year's prices and location choices (see Travel Model Integration section for more details).

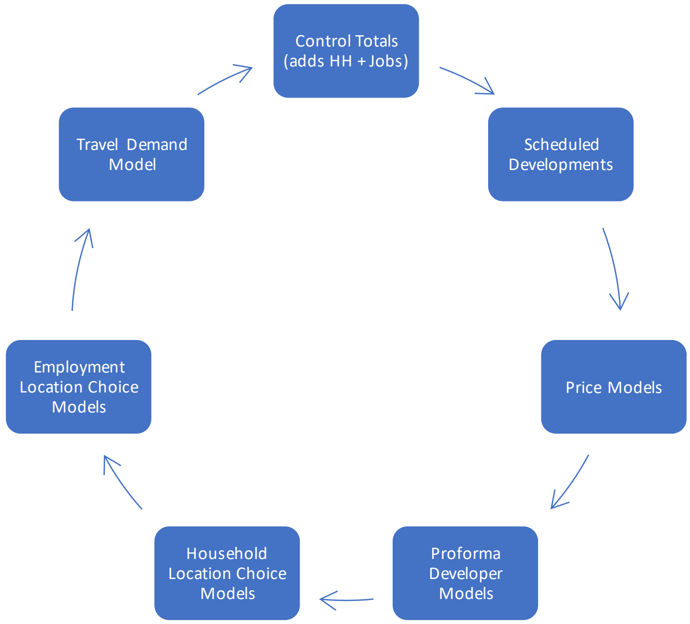

Figure 4. Each step of 1 year of simulation.

Developer Steps

- **Scheduled Developments:** Known development projects that are either currently under construction or set to begin building within the first 5 years of simulation are added to the simulation. This allows areas of current growth to be seeded with real projects and updates the base year data from 2016 to current conditions.
- **Proforma:** Computes the costs and revenues of feasible development projects allowed by zoning and creates new buildings. Costs include: construction costs, demolition costs (if parcel is not vacant), financing costs, and parking construction costs. Using the modelled prices from the Price Models to estimate potential revenue of different developments, the most profitable development projects are built in each simulation year.

Price Models (Ordinary Least Squares Regression)

- **Commercial Price Models**: segmented into office, retail, and industrial. Important estimation variables include: accessibility to workers (based on travel model outputs), year built, proximity to freeway exits, size of parcel or building, within 'key center', accessibility to other employers (clustering effect).
- **Residential Price Model**: important estimation variables include: accessibility to jobs (based on travel model outputs), proximity to industrial sites (negative coefficient), income level of neighborhood, access to transit, year built, and access to retail or food services.

Location Choice Models (Multinomial Logit)

- **Employment Location Choice Models**: segmented by sector. Important estimation variables include: commercial rent/price per square foot, size of parcel or building, type of commercial building, year built, accessibility to other employers (clustering effect) and accessibility to workers.
- **Household Location Choice Models**: segmented by income. Important estimation variables include: rent or price per residential unit, unit square feet, year built, accessibility to jobs (based on travel model outputs), access to transit, access to retail or food services, average household size of neighborhood, and income level of neighborhood.

Target Scenario

The Target Scenario is created by adjusting some inputs to the UrbanSim model in order to simulate how policy changes may affect future regional growth. The Target Scenario goals are to increase transit mode share by increasing density in "Key Centers" and along high capacity transit corridors, reduce single occupancy vehicle trips across the river by encouraging job growth on the Westside; reducing the jobs-housing imbalance on the Westside, and to reduce urban expansion into agricultural land and open-space. The three components that are adjusted in UrbanSim to create the Target Scenario are: zoning in Key Centers and along future transit corridors, incentives for development in Key Centers and transit corridors (east and west centers are treated differently in order to remediate the jobs-housing imbalance), and disincentivizing greenfield development in order to preserve agricultural land and open space.

- The zoned densities for parcels in Key Centers or transit corridors is increased by 20% to encourage density in areas served by transit.
- Revenues of commercial development in westside Key Centers and transit corridors are increased by 20% to help address job-housing imbalances east and west of the river.
- Revenues of residential development in eastside Key Centers and transit corridors are increased by 20% to help address job-housing imbalances east and west of the river.
- Revenues of residential and commercial development in Valencia County Key Centers are increased by 20% to encourage density existing employment centers.
- Revenues of greenfield development are decreased by 20% ("greenfield" is approximated by selecting parcels that do not currently have municipal sewer service) to preserve agricultural and open-space land.

Assumptions and Limitations of UrbanSim

UrbanSim is a model system, and models are abstractions, or simplifications, of reality. Only a small subset of the real world is reflected in the model system, as needed to address the kinds of uses outlined above. Like any model, or analytical method, that attempts to examine the potential effects of an action on one or more outcomes, there are limitations to be aware of.

- *Boundary effects are ignored.* Interactions with adjacent metropolitan areas pose modeling difficulties due to boundary effects. For example, MRMPO does not model interactions with Santa Fe even though residents of the Mid-Region work in Santa Fe and vice-versa.

- *Zoning regulations are assumed to be binding constraints on the actions of developers.* Parcels are constrained by their zoned densities with the exception of the known scheduled developments which are always built, and master planned areas which are updated to reflect the intended densities shown in the plans.

- *UrbanSim is a Regional Model and is less accurate at smaller geographies.* MRMPO aggregates results to the Data Analysis Sub Zone (DASZ) level geography and larger geographies to avoid the inaccuracy inherent at smaller geographies.

- *Behavioral patterns are assumed to be relatively stable over time.* The Model assumes that behavioral patterns will not change dramatically over time. Models are estimated using observed data, and the parameters reflect a certain range of conditions observed in the data. If conditions were to change dramatically, such as fuel prices tripling and continuing to increase, it is probably the case that fundamental changes in consumption behavior, such as vehicle ownership and use, would result.