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The Oregon Prototype Metropolitan Land Use Model

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Abstract

This paper describes the design of UrbanSim, the Oregon Prototype Metropolitan Land Use Model, and its application to the Eugene-Springfield Metropolitan Area[2]. The model is based on a decision-maker perspective on urban development, representing the choices made by households and businesses of whether and where to move and what type of building to occupy, and the choices made by developers to develop or redevelop particular land parcels into different land uses. These market components are integrated through a land market clearing mechanism that adjusts prices to clear the market. A policy interface provides the user-interface to the model, and supports the development, comparison, and evaluation of policy and infrastructure scenarios.

Introduction

Over the past two years, the Oregon Department of Transportation (ODOT) has invested in the development of new modeling tools for statewide and metropolitan land use and transportation planning. This paper describes the design of the prototype metropolitan land use model, named UrbanSim, and its

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application to Eugene-Springfield[3]. ODOT initiated the metropolitan land use modeling project to develop a land use forecasting model that could be interfaced to the travel demand forecasting models in use by Metropolitan Planning Organizations (MPO) in Oregon. ODOT needed a systematic modeling capacity to analyze the feedback relationships between transportation and land use that have been the subject of much discussion and interest since the passage of the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991.

The state of Oregon has an exceptionally proactive growth management strategy, embodied in such policy initiatives as the Oregon Transportation Plan and the Oregon Benchmarks. Within this context, the model needed to facilitate assessment of the impacts of numerous combinations of land and transportation policies. Urban Growth Boundaries were particularly important planning instruments that the model needed to be able to address, including the assessment of impacts of changes in the UGBs on the location of businesses and households, and on housing and land markets. Other considerations included the impact of comprehensive land use plans and the impact of constraints imposed on environmentally sensitive lands.

The possibility of addressing these planning requirements using existing land use models was addressed as an initial phase of the project. DRAM/EMPAL, developed by Stephen Putman, is the only model in widespread use in the United States (Putman, 1983). The DRAM/EMPAL model does not incorporate a land market component, however, which would make it less appropriate for evaluating the housing price impacts of urban growth boundaries or other market-related planning and policy questions.

Other models that have been in use outside of the U.S. over the past two decades or longer included MEPLAN (Echenique, et al, 1990), and TRANUS (de la Barra, 1995). TRANUS and MEPLAN share overall similarities in their use of Input-Output economic model structures with a spatial disaggregation based on logit techniques, though they differ in important design and implementation details. The nature of these models and their economic structure made them viable candidates for the statewide land use and transportation and land use component of the Oregon project, and TRANUS has been adopted as the foundation for that element. The Input-Output structure of these models, however, and their relatively high level of spatial aggregation, made them less

[3] The Eugene-Springfield application of the model has been made possible through substantial assistance and cooperation from the Lane Council of Governments. In particular, Bud Reiff and Sharon Edwards have provided substantial assistance.

appropriate for meeting the requirements of the Oregon metropolitan land use model.

The decision to proceed with new model development was based on the design of a land use model developed by the author for Honolulu[4]. The design was further extended to address particular planning requirements in Oregon. Key features of the model include:

- The model simulates the key decision makers and choices impacting urban development; in particular, the mobility and location choices of households and businesses, and the development choices of developers;
- The model explicitly accounts for land, structures (houses and commercial buildings), and occupants (households and businesses);
- The model simulates urban development as a dynamic process over time and space, as opposed to a cross-sectional or equilibrium approach;
- The model simulates the land market as the interaction of demand (location preferences of businesses and households) and supply (existing vacant space, new construction, and redevelopment), with prices adjusting to clear market;
- The model incorporates governmental policy assumptions explicitly, and evaluates policy impacts by modeling market responses;
- The model is based on random utility theory and uses logit models for implementation of key demand components;
- The model is designed for high levels of spatial and activity disaggregation, with a zonal system identical to travel model zones;
- The model presently addresses both new development and redevelopment, using parcel-level detail.

Key features of the software implementation of the model include:

- The software is currently compatible with Windows95/NT;
- The user interface focuses on policy assumptions and the creation and evaluation of scenarios;

[4] The Oahu Metropolitan Planning Organization funded the initial design and calibration of the UrbanSim model.

- The model is implemented using object-oriented programming to maximize software flexibility;
- The model integrates a GIS Viewer using MapObjects from Environmental Systems Research Institute;

Theoretical Foundation

The model is based is random utility theory, which provides a consistent economic basis with which to evaluate discrete choices such as residential location or mode choice. While random utility theory may be most familiar in its application to transportation mode choice modeling (see, for example Ben-Akiva and Lerman, 1993), it has also been widely applied to the analysis of residential location choices by Lerman (1977), Anas (1982) and Waddell (1997), among others; and to business location by researchers including Erickson and Wasylenko (1980), Carlton (1983), and Shukla and Waddell (1993).

The application of random utility theory generally takes the form of discrete choice models. The treatment of urban development as a dynamic outcome of the ongoing interactions between the choices of households, businesses, developers and governments is at the same time intuitively simple and consistent with random utility theory. Households and businesses make choices about whether and where to move within a metropolitan area, and what kind of buildings to occupy. Developers make decisions about where to construct new buildings and where to redevelop existing ones. These choices represent the market components of the urban development dynamic. The urban land market is a highly regulated market, and in addition is heavily influenced by the infrastructure decisions made by governments. The model treats these market and government components of the urban dynamic as separate but interacting elements. Governmental choices regarding infrastructure and land policy are taken as exogenous to the model, but the model design attempts to capture the market behavior in response to exogenous changes in these governmental inputs.

A key theoretical and implementation feature of the model is that it is not based on a full equilibrium theory of urban land markets. The model is based on the recognition that urban dynamics occur at the margin: changes occur through the relocation choices of businesses and households and through the marginal development and redevelopment efforts of developers. The existing stock of buildings is assumed to be durable, and should be explicitly accounted for. Similarly, not every business or household moves in any given time period, and significant bias will likely result by ignoring the differential rates of mobility of different kinds of households or businesses. The mobility rate of young persons is an order of magnitude higher than that of retired persons, for example. By recognizing that urban change occurs at the margin, we can undertake more realistic tests of the impacts of policy changes on residential and business location and on new construction and redevelopment.

Model Structure

The flowchart in Figure 1 presents a graphical view of the key components of the model system, each of which is described briefly in this section. The model components represent the behavior of households, businesses, developers, and governments, all interfaced through the land market. In extending the discrete-choice modeling framework to households and businesses, the model employs a framework that is behaviorally transparent, theoretically sound, and computationally tractable.

Exogenous inputs to the model include base year land use, population and employment, regional economic forecasts, transportation system plans, land use plans, and land development policies such as density constraints, environmental constraints, and development impact fees. The user interacts with the model through the user interface to create scenarios that combine alternative packages of assumptions and exogenous inputs. The model is then executed using a given scenario, and the results of one or more scenarios can be examined and compared in the viewer component of the user interface.

The model endogenously predicts the location of businesses and households; the location, type, and quantity of new construction and redevelopment by developers; and the prices of land and buildings. Two modules, demographic and economic transition, predict changes in the distribution of households and business by type (e.g. age, income, and businesses by industry) at the regional level, consistent with the aggregate control totals.

In the household mobility and location module, the model simulates household decisions about whether to move or remain in their current residence and if they choose to move their selection of a housing type and zone. These choices are modeled in much the same way as mode choices of commuters, using multinomial or nested logit estimation techniques. In the business mobility and location module, businesses make similar choices regarding mobility, building type and location choice. Household and business characteristics influence choices, as do location attributes such as accessibility and prices.

In the development component, the model simulates developer choices to convert vacant or developed land to urban uses, including the type of improvements and density, based on their profitability expectations and subject to constraints imposed by governmental policies such as zoning and infrastructure

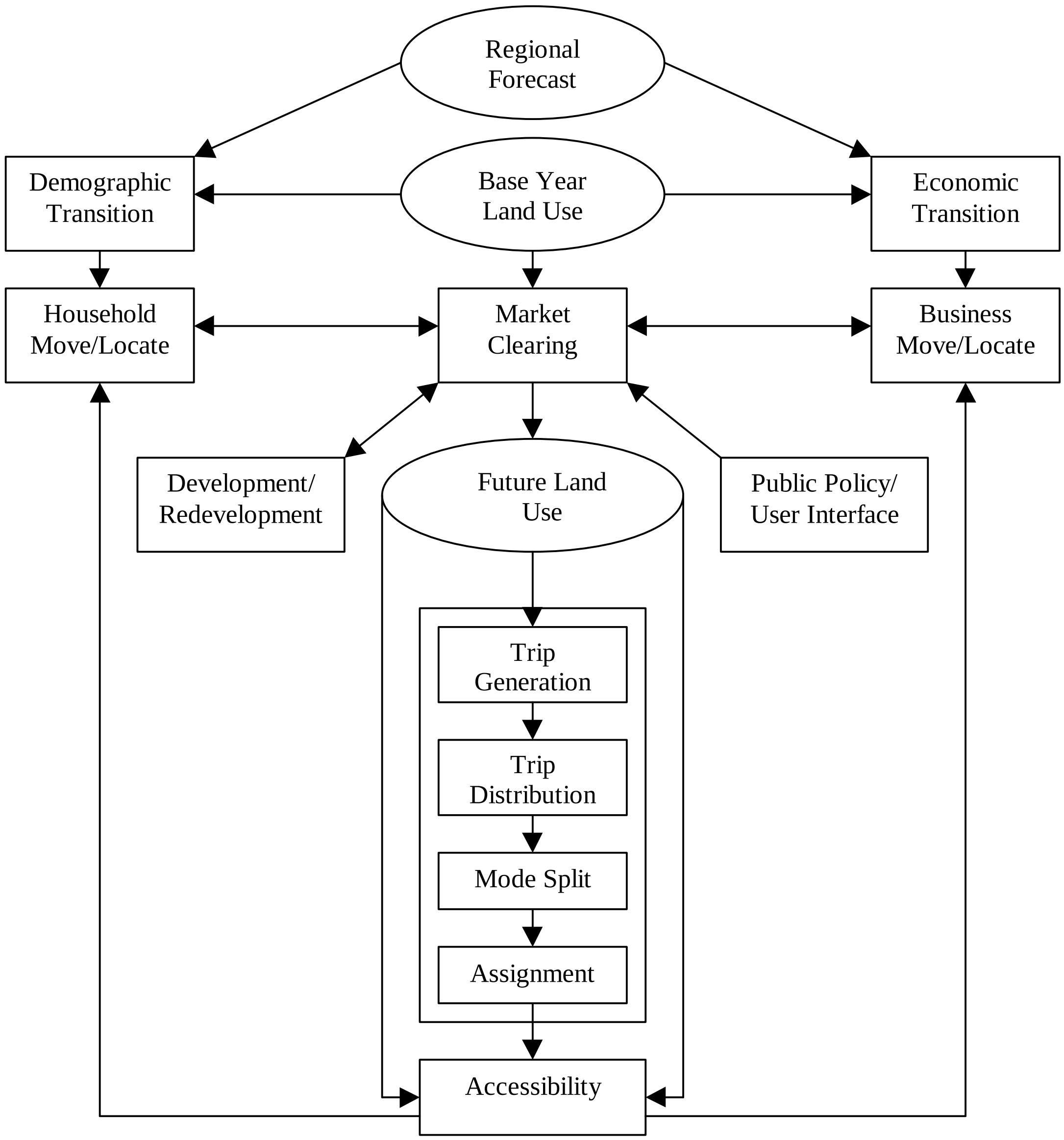


Figure 1. UrbanSim Structure

availability. These profitability expectations are influenced by prior prices and revealed demand in the location and building type preferences of businesses and households.

The model simulates land market clearing by adjusting prices to reconcile the competing demands for locations and structures among households and businesses against the supply of space in each zone. The ratio of demand to supply in each zone for each type of space (housing and commercial structures by type) induces proportional price adjustments for these structures. The adjusted prices produce new market signals to demanders in the subsequent year, thereby influencing preferences for zones and building types.

These interactions of households, businesses, developers, and governments produce outcomes representing the distribution of population and employment, as well as the prices, uses, and density of land development. These results are written out for any desired year that the travel models will be run. The data are input to the traditional four-step travel models to produce new travel times, costs and patterns by mode. The analysis then uses these travel times to compute new accessibility indices in subsequent years, until the travel models are run for the next target year.

The model is based on a one-year timetable, which has several advantages. First, many of the actions modeled take place over a duration of less than or approximately one year, including household and business location changes. Longer time frame actions, such as the introduction of major transportation system changes, are handled by introducing them in a particular year, from which time the model can account for the influence of this change over subsequent years. Figure 2 illustrates these dynamics.

Households and businesses are assumed to be price takers, as are developers. The implications of this assumption for the temporal dynamics of the model is that, with a one year increment, the model adjusts prices once each year, after computing the total demand for each location and building type within the location choice components of the model, and before developers estimate profitability of alternative construction projects. Developers then undertake new construction and redevelopment based on current market information, including current demand, and priced as adjusted to reflect the current period supply and demand. New construction then becomes available at the beginning of the next year, for new and moving businesses and households. Land development decisions are presently assumed to occur within one year, although multi-year construction timetables for large construction projects would be more realistic, and will be implemented in later planned enhancements to the basic model.

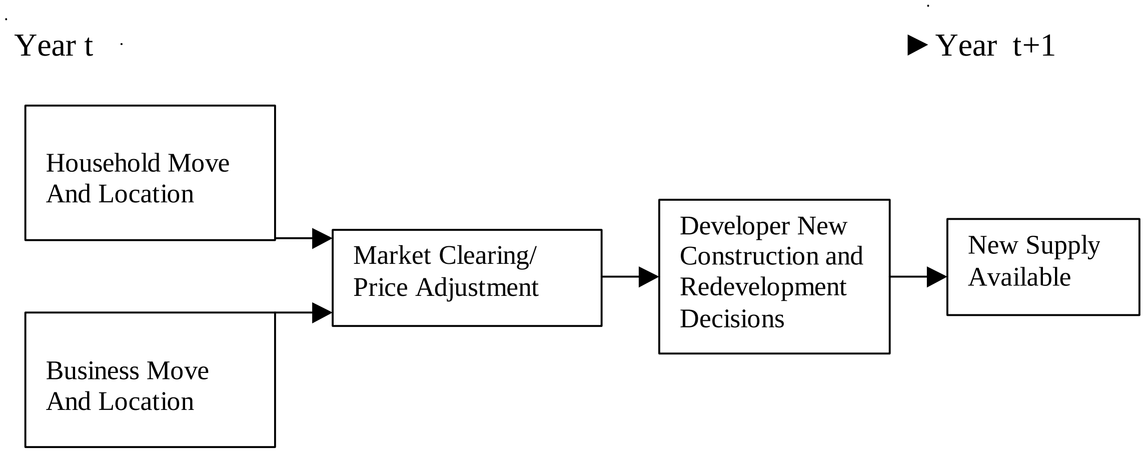
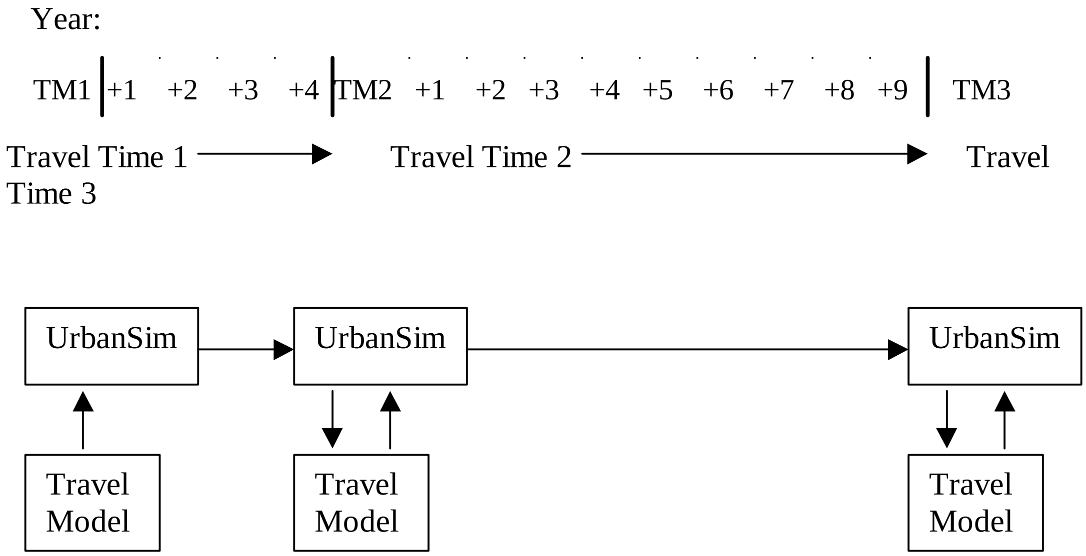


Figure 2. Temporal Dynamics

Integration with Travel Demand Models

UrbanSim integrates with existing travel forecasting models through a longer-term temporal dynamic to account for changes in the transportation system, and reflect these through accessibility indices in the model. Figure 3 illustrates this sequencing.

Note that although travel times are only updated for years in which the travel models are run, two considerations apply. First, the urban model uses accessibility indices to measure the relative accessibility to various activities from each potential location, which are computed as entropy measures of the activity at each location discounted by the travel time between the source and each potential destination for the activity, such as shopping. The activity levels are updated annually by the model, so that although the travel times remain constant until the subsequent travel model run, the accessibility indices change according to the changing distribution of activities. Second, major transportation improvements are likely to be fairly discrete in time, such as the opening of a new section of a freeway. It is up to the user to determine the appropriateness of the travel model years with respect to the significance of the transportation system changes in intervening years. If the user desires to run the travel model for every year, the urban model is capable of accommodating it, though this is likely to be unnecessary.



(TM = Travel Model Year)

Figure 3. Integration with Travel Demand Models

Application to Eugene-Springfield

The development of the model as a prototype required a site for testing of the model. Eugene-Springfield was selected as the site for the case study application on the basis of the availability of data and the manageable size of the metropolitan area. The case study has been coordinated with the assistance of the Lane Council of Governments, the MPO for the Eugene-Springfield area. Like other metropolitan areas in the state of Oregon, this region is dealing with the impacts of an Urban Growth Boundary, and is attempting to coordinate land use and transportation plans and policies. Lane COG is distinguished by a highly developed GIS database. In particular, the availability of geocoded business establishment data made the development of the input data for the model feasible within the constraints of the model development project.

Parcel data, business establishment data, and census data were the primary data sources required for the calibration of the model. For model application, GIS layers representing environmental constraints, the comprehensive land use plan, and the Urban Growth Boundary were integrated with the parcel layer to reflect the development constraints on each parcel. The calibration of the model components is now complete, and is being followed by validation and sensitivity testing. A unique historical simulation is being developed as a validation exercise, to test the ability of the model to reproduce the major dimensions of change over the period from 1980 to the present. An extended research agenda for the further development of the model and application to other metropolitan areas is now being prepared. Once the model testing in the current phase is completed, it will be made available for distribution.

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