Development and Calibration of the Prototype Metropolitan Land Use Model

Transportation and Land Use Model Integration Program
Final Report on Phase II

Prepared for

Transportation Development Branch
Oregon Department of Transportation
555 13th Street, NE
Salem, Oregon 97310

Prepared by

Paul Waddell
Urban Analytics
1022 1st Ave W.
Seattle, WA 98119
waddell@uanalytics.com

And

Parsons Brinckerhoff Quade & Douglas, Inc.
ECONorthwest
KJS Associates, Inc.

April 20, 1998

1 Model overview

1.1 Preface

This document describes *UrbanSim*, the Oregon Prototype Metropolitan Land Use Model, and its application to Eugene-Springfield, Oregon. The report presents the results of Phase II of the metropolitan component of the Oregon Department of Transportation (ODOT) Transportation and Land Use Model Integration Project. The report is organized as follows: Section 1 provides an overview of the model, its behavioral formulation, and its implementation as a software tool for integrated land use and transportation planning; Section 2 focuses on the use of the model for planning and policy analysis. Section 3 describes the data requirements of the model. Section 4 relates the model theory and design to prior research in land use modeling. Section 5 provides detailed model specifications. Section 6 describes the application of the model to the Eugene-Springfield planning area, and deals with issues of data preparation and the calibration of the model components. The report includes several appendices with more detailed information. Appendix 1 provides State policy requirements, and Appendix 2 describes local policy requirements.

1.2 Overview

UrbanSim is a software-based system designed to be used for integrated planning and analysis of urban development, incorporating the interactions between land use, transportation, and public policy. It is based on the land use model described in this document, and is designed to interface to existing travel modeling procedures in use by a Metropolitan Planning Organization.

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 (locational 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;
- 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;
- Model results are written as dBase files for external use.

1.3 Behavioral Foundation and Motivation

The UrbanSim model is based on a view of urban development as it evolves over time and space as the composite outcome of the interactions of individual choices and actions taken by households, businesses, developers, and governments. The structure of this model includes components reflecting the behavior of households, businesses, developers, and governments, all interfaced through the land market. This behavioral approach provides a transparent theoretical structure that is much less like ‘black-box’ or abstract urban models that do not clearly identify agents and actions being modeled. As such, it becomes much more straightforward to explicitly incorporate policies and evaluate their effects.

Table 1 presents some of the key decision-makers and their decisions or actions that pertain to urban development in general and to land use and transportation in particular. The decisions made by households, workers, businesses, and developers are modeled, and the decisions by the public sector are treated as exogenous, and are input to the model in the form of policy scenarios.

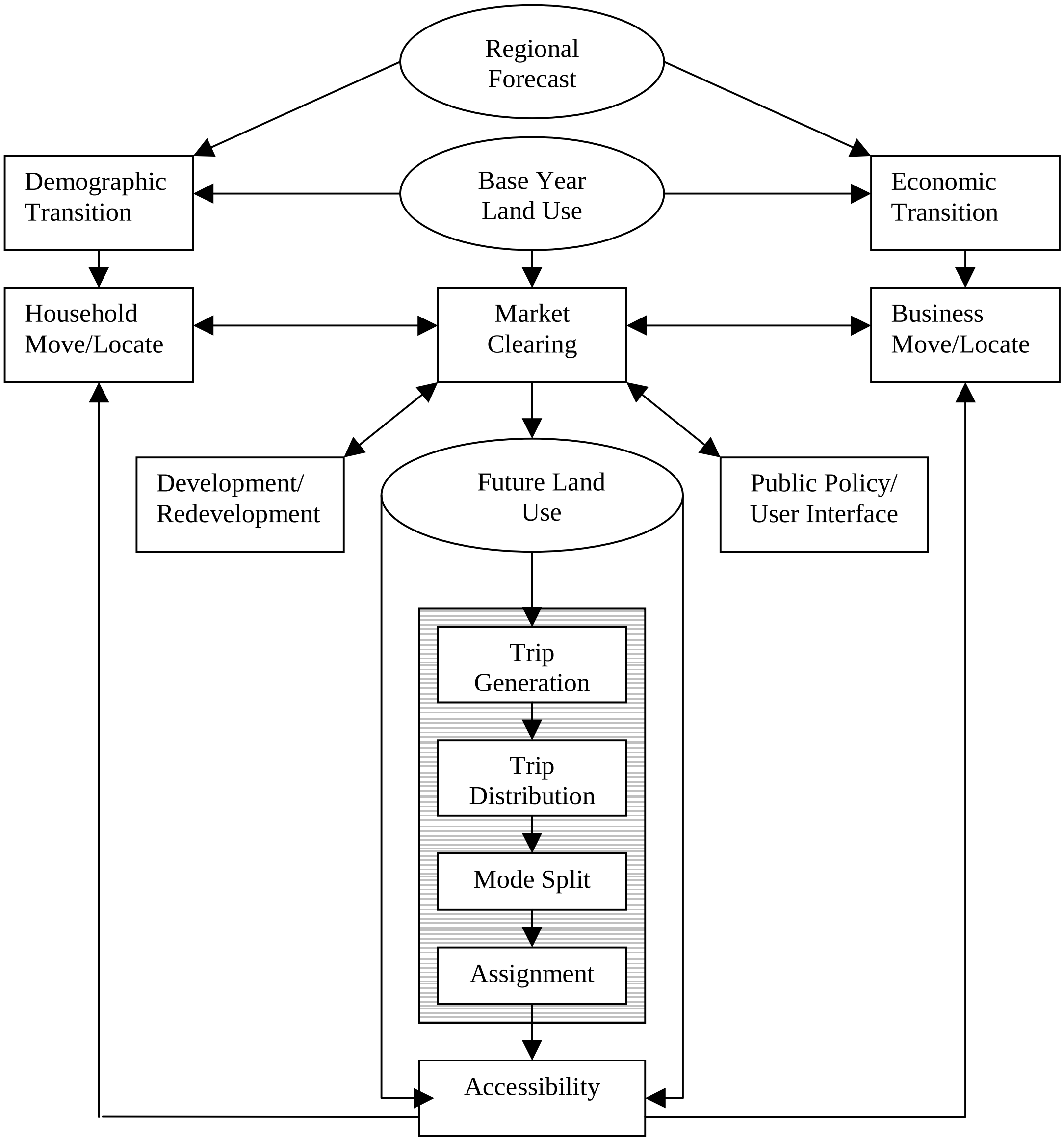
The treatment of urban development as an interaction between market behavior and governmental actions is designed to maximize the realism of the model as well as its utility for assessing the impacts of alternative governmental plans and policies related to land use and transportation. The model design is intended to enhance the strategic planning capabilities of Metropolitan Planning Organizations and other state and local agencies needing to evaluate Growth Management Policies such as urban growth boundaries, assess consistency of land use and transportation plans, and address conformity with respect to air quality implementation plans.

TABLE 1:
Decision-makers and Choices Affecting Urban Development

Decision-makers	**Choices/Actions**	
Market Decisions (Endogenous)		
Household	*Mobility (move or stay)* *Location (where to move)* *Housing Type (single/multi)*	Housing Tenure (rent/own) *Housing Price* Auto Ownership
Worker	Labor Force Participation Job Change Full-time/Part-time Multiple Jobs	Workplace Choice Wage to Accept Mode of Transport to Work Trip Linking
Business	*Number of Employees* Wages to Offer *Type of Space (office, retail, etc.)* Tenure (rent/own)	Lease/Purchase Cost (willingness to pay) *Mobility (move or stay)* *Location (where to move)*
Developer	Land Purchase Infrastructure Investment *New Development*	*Redevelopment* *Land Use* *Density*
Public Policy Decisions (Exogenous)		
Municipality	Tax Rate Tax Abatement/Incentives Zoning *Land Use Plan* Urban Design	*Development Fees* Amenities (Parks) Services (Fire, Police) *Infrastructure* (Transportation, Water, Sewer)
Transit Agency	*Transit Infrastructure*	*Levels of Service* Transit Fares
Lender	Loans for Mortgages	Development Loans Interest Rates
School District	Tax Rates	School Quality
Other Local, State, Federal Agencies	*Fees, Regulations governing land use, transportation, environment*	*Highway*, Rail, Ports, Airports

Note: Choices in *italics* are currently addressed in UrbanSim

FIGURE 1:
Structure of UrbanSim



1.4 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, interfaced through the land market. The model draws on random utility theory for its theoretical foundation, and builds on techniques of disaggregate choice modeling widely used in mode choice models. 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 locational 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 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.

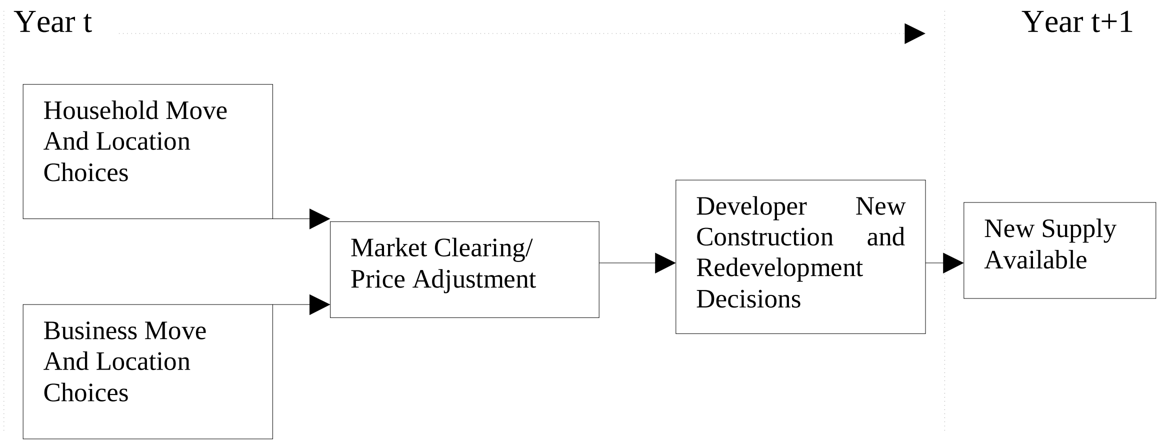
These interactions of households, businesses, developers, and governments produce outcomes representing the distribution of population and employment, as well as the prices, uses, and density of land development. These results are written out for any desired year that the travel models will be run. The data are fed into 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.

1.5 Temporal Dynamics

The model is based on a one-year timetable, which has several advantages. First, many of the actions modeled take place over durations 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 implication of this assumption for the temporal dynamics of the model is that with a one-year increment, the model adjusts prices once each year. This occurs 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

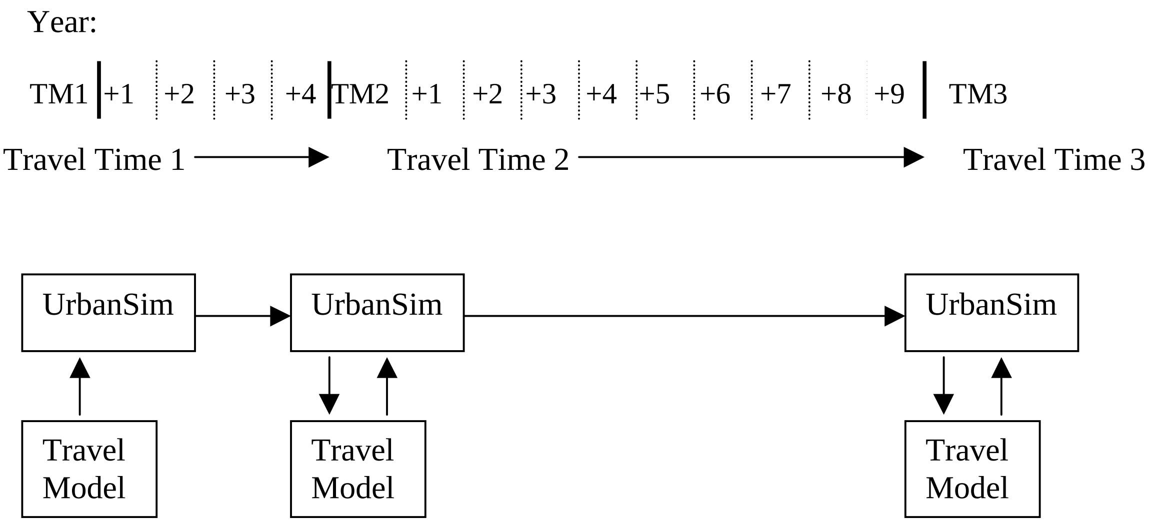


1.6 Integration with Transportation Models

The urban simulation model integrates with 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 highly inefficient and quite unnecessary.

FIGURE 3
Land Use-Transportation Sequence



(TM = Travel Model Year)

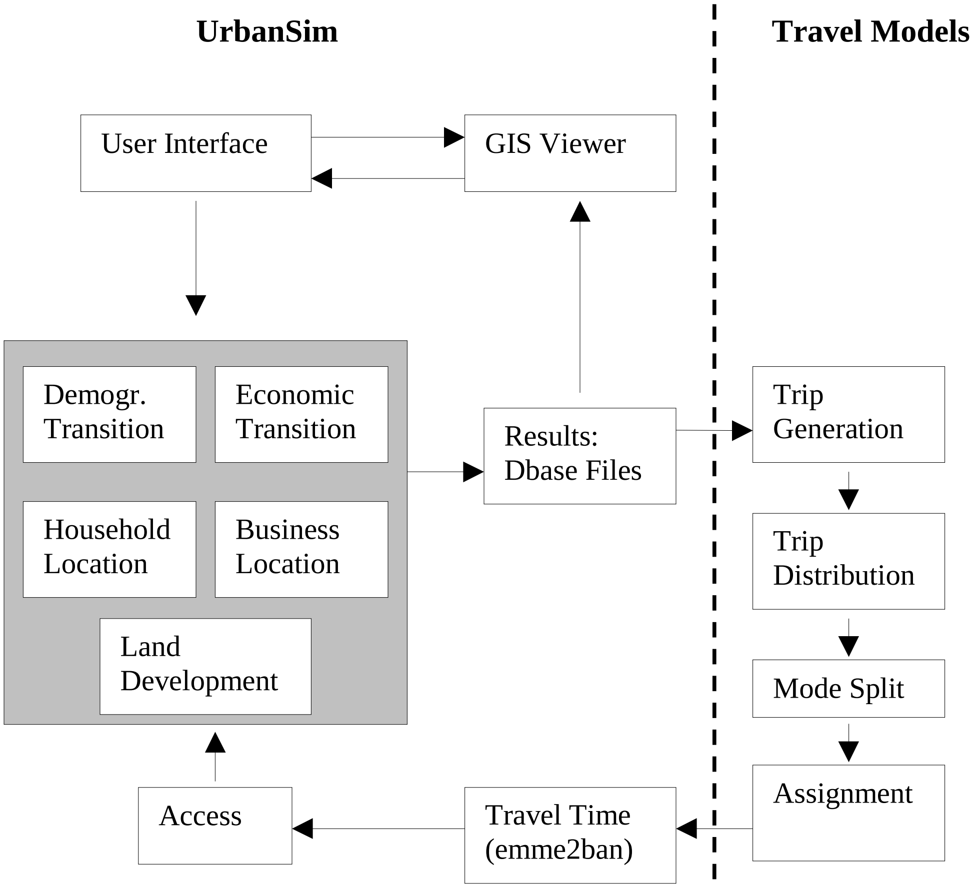
In operation, when the urban model reaches a travel model year, it writes results for that year into external data files in dBase format, and suspends operation until the travel model sequence is executed using the current land use data. Once new travel time matrices are created from the travel model run, the urban model simulation is resumed by the user and proceeds to run until the next travel model year, at which this process is repeated. One would prefer a fully integrated software environment in which both the travel and land use models reside, but this is well beyond the scope of the current project. Beyond the logistical effort required to execute a series of separate programs for the travel model components and the urban simulation model, however, it is not clear that there is a substantial loss of functionality. A truly integrated land use-transportation model would require complete integration of theory, estimation, and software, and most likely a microsimulation implementation. The design of the current land use model has been constructed to support extension to a microsimulation implementation (the developer component is already a microsimulation), and to integrate with activity-based travel forecasting models such as those under development in Portland and Honolulu.

1.7 Software Design

The software implementation of UrbanSim includes the core model components identified in Figure 1, a GIS Viewer, a database interface, and a user interface. The relationship of these components to each other and to the travel model is depicted in Figure 4. The viewer provides basic visualization of the inputs to the model, and outputs from it, in an integrated component that does not require a GIS software package to be installed on the user's computer. The user interface is the focus of the attention for interacting with the model, and is designed to conform to user interface standards in software written for the Windows95/NT platforms.

The model components of UrbanSim are implemented in object-oriented software, using the Java language. The Supercede Java Compiler from Supercede, Inc. was used to compile native executable code for the Windows95/NT platforms. The object-oriented design provides flexibility in reusing software components, and conceptually, fits well the theoretical structure of this model. More detailed software specifications are provided in Appendix 3.

FIGURE 4
UrbanSim Software Components



2 Planning and Policy analysis

2.1 Introduction

The relationship between land use and transportation has been as enduring subject of both theoretical and empirical study. Urban form, whether it is compact, multi-nodal, or sprawling, has enormous impact on the type and cost of transportation systems needed to serve the residents of a metropolitan area. On the other hand, the type and location of major transportation facilities greatly influences urban form. It seems intuitive that land uses and transportation influence each other; that the spatial distribution of activities creates the need for travel; and that the transportation system in combination with this spatial activity distribution creates patterns of accessibility that in turn influence the location choices of households and firms. Although the literature reflects a broad understanding of this complex relationship—and some of the literature dates back several decades—surprisingly little of the learning from the literature has been put into effect in planning practice or analytical models. Transportation planning and local "comprehensive" planning continue to take place quite separately, resulting in combinations of public policies that rarely reinforce one another and that often work at cross purposes (Kelly 1994).

Most metropolitan planning organizations (MPOs), for example, are responsible for preparing long-term forecasts of travel demand—and land use is a critical component of such a process. However, MPOs have historically prepared long-term travel demand forecasts based on land use assumptions about the future that were not influenced by the transportation plan. On a more local level, planning commissions, presumably with the advice of their professional staffs, make decisions about new developments that become new neighborhoods. They recommend new zoning ordinances (traditionally considered the "work horse" for land use plans) to governing bodies. Engineering or public works departments make decisions about the construction of new arterial and other roads, often without consulting either their respective planning commissions or planning staffs (Kelly 1994).

The Clean Air Act Amendments of 1990 and the 1991 federal Intermodal Surface Transportation Efficiency Act (ISTEA) urge such practices to change. Both the CAAA and ISTEA mandate linking land use and transportation planning to ensure that relationships between land use and transportation are accounted for. Increasing interest in developing sound and consistent plans and policies for land use and transportation has resulted in an observable trend over the past decade or longer for MPOs to move beyond the traditional long-term baseline forecasting requirements that have dominated planning practices for decades. Baseline forecasts are now being used for strategic planning and policy analysis; and, there is an increasing need to employ land use and transportation models as a primary tool for such analysis. In fact, as becomes evident from the kinds of policy requirements in many state agencies, the application of the models to strategic planning and policy analysis may become their primary use in the future. As such, the first policy priority for new land use models is to provide a meaningful mechanism to incorporate the impacts of transportation system and travel demand changes on land use outcomes. These impacts include, at a minimum, the spatial distribution of population and employment by type, and the mix and density of land uses. In order to accomplish these objectives, as well as many of the policy analysis objectives identified below, the new models also address impacts on the land market in the form of land and housing.

2.2 Policy Requirements

If urban models are to be used as a tool for strategic planning and policy analysis, then they need to be able to account for myriad policies prescribed by various levels of government. At the federal level, the Clean Air Act Amendments (CAAA) and the Intermodal Surface Transportation Efficiency Act (ISTEA) mandate linking land use and transportation to ensure their relationships are accounted for in the planning process.

Three policy initiatives in the State of Oregon combine to form what is perhaps the most proactive state program in the United States to effectively manage urban growth and its consequences. The Oregon Transportation Plan (OTP) explicitly links transportation and land use and provides a multi-modal context for statewide transportation plans and project development. The Transportation Planning Rule (TPR) specifies the relationships between transportation and land use. It defines the characteristics of acceptable transportation plans, establishes standards for transportation system performance, and requires explicit linkages between local land use and transportation planning processes. The Oregon State Benchmarks (OSB) establish measurable performance standards for a wide range of state and local governmental activities including transportation and land use. These three documents describe the following policy objectives that are particularly germane to the development and use of the urban simulation model[1].

Consistency between transportation and land use planning
Consistency with comprehensive plans and urban growth boundaries
Minimize development pressures on the urban fringe
Support Compact, mixed use development including infill and redevelopment
Evaluate land use alternatives for meeting transportation needs
Limit parking supply in metropolitan areas
Access management
Statewide economic development
Transportation system efficiency
Multi-modal accessibility
Demand and congestion management
Reduction in automobile reliance and state VMT per capita

It is important to draw a distinction between policy objectives and policy instruments. While the objectives listed above are clear, they represent desired outcomes rather than the means for achieving these outcomes. Specific policies and investments are the instruments for achieving these objectives. The relative effectiveness of alternative investments and policies in achieving these policy objectives depends on many factors, including the interaction between policies, and the reactions of individual households and firms to the policies in their locational and travel behavior. It is this interaction between the policies and the marketplace that often produces unanticipated consequences from well-intentioned policies. A key design goal of the UrbanSim model is to provide an analytical tool for strategically assessing the interactions between government actions (land and transportation policies and investments) and urban markets for land and transportation.

---

[1] For a more detailed discussion of these policy objectives and their framing within the three state policy documents, refer to Appendix 1.

Land use and transportation policies can be categorized into regulatory, pricing, and infrastructure actions. Regulatory actions often take the form of restricting actions in some systematic way, such as zoning constraints on the physical development of land that restrict developers to certain land uses and densities. Pricing policies such as taxes, development impact fees, and congestion pricing affect economic decisions made by businesses and households through their individual choices in the markets for land and travel. Infrastructure investments impact accessibility, travel costs, and development costs, and thereby influence physical development and location choices indirectly but significantly.

In the UrbanSim model, policy analysis is focused on the creation and evaluation of policy scenarios, which combine policy assumptions and provide inputs to the model. The following section describes the use of scenarios in the model.

2.3 Scenarios

The policy analysis module allows users to specify policy inputs and assumptions, generate scenarios and compare them, compute evaluation measures, and query the database of results. The user interface is focused on the interaction of the user with the policy analysis module, where the user generates a scenario that consists of a particular combination of development policies represented in appropriate input data such as comprehensive plans, infrastructure plans, development fees, urban growth boundaries, and other policies. These policies are linked to locations at a zonal, municipal, county, or metropolitan scale. If land is represented either by individual parcel or by grid cells, then policies could be specified to this level of detail as needed. Users may edit policy variables imposing constraints (e.g. land use plans) or influencing costs (development fees). The software provides the user reports, charts and maps useful in evaluating policy outcomes or objectives.

A major advantage of the urban simulation model is its use as a tool for comparing different land use policy alternatives—an essential part of planning and a critical tenet of planning theory. The days of working with a single land use forecast must be over (Douglas 1995). For example, what would be the impacts if development was restricted to within a growth boundary? How effective are different policies in encouraging nodal development? The urban simulation model accounts for these alternatives by developing scenarios in which the user alters certain policy functions, together with population projections (some of the exogenous variables mentioned earlier). These scenarios provide the basis for the suitability, growth, and allocation scenarios to be developed in the remainder of the model. Scenario development is done in three stages—configuration, control totals, and growth policy—where growth policy contains all of the land use features.

2.3.1 Configuration and Control Totals

Scenario development requires an estimate of the regional population and employment growth over the desired forecasting time horizon (often 20 years). Aggregate population and employment are exogenous values considered across the metropolitan area of study. The standard procedure for many MPOs is to use state or federal forecasts of regional population and growth. State law may mandate the use of these state forecasts. In other cases, regions make their own estimates of regional control totals because they want to refine state estimates using more local information (i.e. its current size, growth history, and/or growth policies). These estimates may be obtained from another agency (such as a state economic agency) or estimated using one or more techniques such as demographic forecasting and regional economic models. The user prescribes a start year and an end year for the time period of analysis and identifies the reporting years for which model results should be written to external databases in dBase format.

2.3.2 Growth Management Objectives

Broadly speaking, government agencies influence the land development process via two principle means: land use planning (considered here to include land classification and density, environmental protection, tax abatement), and infrastructure provisions. While there are endless permutations and many local conditions to consider when doing an analysis, most alternative scenarios attempt to shape urban structure towards one or more of the following basic forms:

- concentrating development within a specified area,
- focusing growth in transportation corridors or in centers connected by multi-modal transportation,
- locating some of the growth in new or existing satellite communities,
- emphasizing growth in parts of the region with underutilized infrastructure.

The methods for creating policy scenarios to apply to the urban simulation model are described below.

2.3.3 Land Use Plan

Land use plans and the process of land use planning, as described by Kaiser and Godschalk (1995) usually involve the integration of four separate prototypes (land use design, land classification plan, verbal policy plan, and the development management plan). The process results in a contemporary hybrid plan that not only maps and classifies land use in both specific and general ways, but also propose policies and management measures. The process of prescribing land use categories is essentially the land use design plan, the most traditional form of land use planning. It proposes a long-range future urban form as a pattern of prescribed land use designations, within which, various uses are permitted under current zoning. For example, in the City of Eugene, the land use plan identifies almost two dozen different land use designations (i.e. educational, light-medium industrial, medium-density residential). Within each of these designations the urban development is spelled out as a mixture of retail, office, industrial, residential, and open spaces, public land uses, and a circulation system.

The interpretation of the comprehensive land use plan is a part of the construction of a forecasting scenario. Each land use plan designation may be restricted by the user to be convertible into one or more actual land uses. For example, the plan designation of ‘agricultural’ may be allowed to convert to no other urban category under restrictive growth policies, or to single-family residential, or other uses, under less restrictive growth policies. The comprehensive plan guidelines for a local region should spell out the intended interpretation of these plan designations, but the user of the model may wish to assess the impact of altering these constraints as a matter of policy testing.

2.3.4 Density Constraints

In addition to prescribing the types of actual land uses to which land in each plan designation may be converted, density of development may also be constrained. Land use plans usually assign density constraints to each land use category. Residential land uses are usually regulated, simply enough, by the number of units per acre. All other uses that involve development are usually prescribed as a range of densities, most often expressed as a floor area ratio (FAR). This a ratio of the total built area (times the number of levels) to the total site area. The scenario construction involves the user input of minimum and maximum allowable densities for each actual land use.

2.3.5 Environmental Factors

Increasingly, environmental factors are being recognized as valuable resources and processes to be preserved. Land use plans (or more specifically local zoning codes) usually identify areas where such factors are an issue, and adopt additional development constraints. This urban simulation model accounts for development constraints among six types of environmental factors by identifying the parcels which may be affected and adjusting density constraints that apply to the actual land use category.

The six environmental factors implemented at this time are:
- Areas with slopes greater than 25%.
- Areas delimited as part of a stream buffer
- Wetlands
- Areas considered to be in 100 year floodplain areas
- Areas included as part of transmission easements

The model accounts for areas with the above conditions by allowing the user to modify the allowable development densities (in the protected area) as a percentage of the normal densities allowed. For example, if a user wishes to totally exclude an environmentally sensitive type of land use, such as wetlands, from any development, then the density adjustment of zero would eliminate all wetlands from development. If the constraint were to reduce densities by 50% in selected areas such as those with high slope, then the applicable density adjustment input by the user would be 0.5.

2.3.6 Urban Growth Boundary

The second prototype of land use planning described by Kaiser and Godschalk consists of land classification planning which is a proactive effort by governments to specify where and under what conditions growth will occur. It is usually less specific about the pattern of land uses within areas specified for development. Often known as urban containment techniques, it has two principle purposes: (1) to promote compact and contiguous development patterns that can be efficiently served by public services, and (2) to preserve open space, agricultural land, and environmentally sensitive areas that are not currently suitable for development (Nelson and Duncan 1995). It does so prescribing areas where development will be encouraged (referred to as urban, transition or development areas) and areas where development will be discouraged (referred to as open space, rural, conservation, or critical environmental areas). For each area, policies about the type, timing, and density of allowable development and development incentives or constraints apply. The most common form of urban containment and the policy alternative employed in the urban simulation model is use of an urban growth boundary (UGB).

The user may treat the UGB as a policy constraint in much the same way as the environmental constraints, by assigning a density adjustment factor that can reduce density, or totally prevent development, from areas outside the urban growth boundary.

3 Data requirements

The input data used in the land use model system are described in the following sections. The data include:

1. Regional Control Totals
2. Existing Land Use
3. Land Use Plans
4. Households
5. Businesses
6. Environmental Constraints
7. Development Costs

3.1 Regional Forecast

This is an exogenous input to the land use forecasting models, which are designed to allocate regional changes in households and employment. The data items required as inputs to the land use models are employment and total households.

3.2 Existing Land Use

Existing land use is required as a baseline from which the model begins. The level of aggregation of most of the model components, except the land development component, is the cross-classification of zone and land use category. For these ‘building objects’, the model needs the following items in the base year:

- Land use category
- Acres
- Land value
- Improvement value
- Housing units (for residential land categories)
- Square footage of improvements (for nonresidential land categories)

The land development component of the model can consider new construction on vacant land, and redevelopment of existing land uses. For new construction, vacant parcels are overlaid in a GIS with the land use plan, to serve as the basic units of development. If the user wishes to analyze redevelopment, then the full parcel file is needed in order to use information on the improvement value, land value, housing units, square footage and land use of existing parcels that might be redeveloped. This is a considerable data requirement, but redevelopment is a complex phenomenon that requires detailed data for useful analysis.

3.3 Land Use Plans

Comprehensive land use plans are needed for the model, at a minimum to overlay in a GIS on vacant land parcels, but preferably assigned to each existing parcel so that redevelopment can conform to land use plans for each developed area. The user in the user-interface inputs the allowable conversion of land use plan designations to actual (existing) land uses that are modeled.

3.4 Households

In order to capture information about household characteristics needed to predict location, mobility, and travel behavior, households are stratified for example by age of head, whether children are present, household size, and income.

The development of the base year household data at the zone level used in the modeling, and with the required cross-classification of household characteristics, is achieved using a method which is based on an approach developed by Dick Beckman as part of the TRANSIMS project, entitled 'Synthetic Baseline Population Estimation.' In summary, this approach exploits the ability to generate a detailed joint distribution of household characteristics from the Public Use Microdata Sample (5%), and the availability of several marginal distributions (not joint) of household characteristics available at a census block group level. The procedure developed for this project uses seven household characteristics to develop a joint distribution from the PUMS data. It then applies an Iterative Proportional Fitting algorithm to the household weights in order to estimate the joint distributions at a census block group level that are consistent with the geographically-detailed marginal distributions and with the geographically aggregate joint distribution from the PUMS.

These joint distributions are converted from census block group to the zones used in the model by using parcel-based housing data by type of housing. These data are used to proportionally allocate households in block groups that are split by zones into the zone fractions in proportion to the available housing in the appropriate housing type. This process is implemented using a sampling procedure that also scales the household weights from 1990 to the current base year, assuming that the distribution of household types remained consistent over that time.

The advantage of this procedure is that it uses available data sources, so it can be readily replicated, it provides a large sample size for estimation of the residential mobility rates and location and housing type choice components of the model.

3.5 Businesses

Creation of the employment/space/zone allocation uses a business establishment file, ideally address-matched to the parcel file. This provides the joint distribution of employment by industry, nonresidential space, and zone needed as input for the land use models. The employment data are classified into business types by industry by size category. The business is treated as the behavioral unit of the model, as opposed to the individual employee, since this more closely reflects the decision-making units, and size of establishment is important in predicting mobility, location choice, trip attractions, and potentially, policy responsiveness to TDM (Travel Demand Management) measures.

Major businesses, that is, businesses that have 250 or more employees, are likely to be relatively scarce in number, to have large physical capital investments in place, and to have a very low probability of moving. As such, major businesses are excluded from the modeling of business movement and location choice. Accounting of these major employers allows proper reporting of employment by industry and zone.

3.6 Environmental Constraints

As discussed with reference to the creation of planning scenarios earlier, environmental constraints are used in the model to modify the development potential of environmentally sensitive land. These data are captured as GIS themes, and overlaid with vacant parcels to integrate these attributes into the vacant parcels.

3.7 Development Costs

The land development component requires information on the costs of development in order to compute the profitability of alternative development projects at each site. These costs include the hard development costs (replacement costs for the improvements), soft development costs (the aggregation of development impact fees, building permits, and any other costs assigned by a jurisdiction to new construction), and demolition costs, by type of land use. Hard construction and demolition costs are expressed in dollars per unit for residential, and in dollars per square foot for nonresidential uses.

4 Relationship to Prior Research

Reviews of the literature in urban land use modeling are in ample supply, with contributions by Anas (1987), Harris (1985), Kain (1987), Paulley and Webster (1991), Southworth (1995), and Wegener (1994, 1995), among others. This paper does not, therefore, attempt a systematic review of the literature, but presents the UrbanSim model within a context of existing work in land use modeling.

As pointed out by Anas (1982), the concept of 'bid rent' forms the basis of modern urban economic analysis and provides the foundation for most microeconomic models of urban spatial structure. The concept originated from von Thünen's (1826) work on agricultural land use, and became the centerpiece of Alonso's (1964) models of residential location and urban housing markets. This bidding approach, in the microeconomic tradition, assumes perfectly informed and efficient consumers make bids on all properties. Property owners, also fully informed, auction the property to the highest bidder, with steady state long-run equilibrium reached when this bid-auctioning process succeeds in allocating each property to the highest bidder. All consumers are expected to costlessly and instantaneously change residence when any change in conditions occurs that temporarily disrupts equilibrium, by repeating this bid-auction process. The monocentric model and its extensions by Alonso (1964), Mills (1967) and Muth (1969) adopted the constraint that all employment was located in the central business district, and focused on the problem of predicting residential location as a function of transportation and housing costs.

Substantial research activity evolved in the direction of predicting housing prices, and the willingness to pay of consumers for the underlying attributes of housing. This body of work, which draws on Lancaster's (1966) theory of consumer behavior, views housing as a bundle of services, and households as utility maximizing consumers based on some function of these underlying attributed of housing, including locational characteristics. Rosen (1974) developed the hedonic theory of housing markets, in which households choose housing so as to maximize a utility function subject to a budget constraint. Extensions of this body of theory and empirical estimation of hedonic price functions have been widely published, beginning with contributions by Strazheim (1974), Wheaton (1977) and Galster (1977).

A separate stream of research activity emerged in parallel, focusing not on prices but on household residential choice. In particular, the work of McFadden (1973, 1978, 1984), Quigley (1973, 1976) and others on the use of random utility theory to develop multinomial logit models of residential location opened a significant direction for research in this area. This approach was used by Lerman (1977) to assess the importance of accessibility and mode on residential location and by Williams (1977) to examine the effects of neighborhood on location choice.

Some research has emerged that crosses these two streams, notably work by Ellickson (1981) that develops a logit model of the property auction process using the bid rent function rather than the utility function. Essentially, this approach focused on the landowner's problem of selling to the highest bidder, which is the consumer making the highest bid. It differs from the majority of logit models of residential choice, which focus on the consumer's problem of choosing among properties based on maximizing their utility function. Essentially these approaches represent the two sides of the auction: the buyer's perspective and the seller's. Martinez (1992) extended

Ellickson's work by developing a 'bid-choice' model that dealt with both sides of the auction simultaneously, through a nested logit formulation in which the higher level of the model represented the consumer's choice among properties, and the lower level represented the landowner's choice among bidders. Under equilibrium assumptions, Martinez showed the consistency of these approaches.

At the core of the model developed by Martinez is a formulation based on consumer surplus, defined as the willingness to pay for an alternative less the market price of that alternative. It has a simple and intuitive interpretation: a consumer is happiest with an alternative that maximizes the difference between what they are willing to pay and what they must pay based on the market price.

Martinez (1992) derives a multinomial logit model predicting the probability that a consumer h will choose lot i:

$$P_{i|h} = \frac{e^{\mu(\Theta_{hi} - p_i)}}{\sum_j e^{\mu(\Theta_{hj} - p_j)}}$$

where:

Θ_{hi} is the willingness of consumer h to pay for lot i
p_i is the market price of lot I

The probability of choosing alternative i then is a function of the relative consumer surplus of the alternatives:

$$CS_{hi} = \Theta_{hi} - p_i$$

Martinez (1992) adopts an equilibrium formulation in which the market price is endogenous and determined by the highest bid for each site among all consumers. This interpretation is founded on the view of land as a quasi-unique commodity in fixed supply, so that demand dictates price. It does not, apparently, represent buildings as part of supply, with either short or long-term adjustment in supply interacting with demand to influence prices.

A third relevant line of research in residential location, originating in geography and sociology, is on residential mobility. These models include work that focuses on the household characteristics and on dissatisfaction, or push factors, inducing mobility. Research in this vein includes that of Wolpert (1965), work by Brown and Moore (1970) on separating the decision to move and the decision to search, and Speare *et al* (1975). Economists formalized these models as disequilibrium models of housing expenditure, for example by Hanushek and Quigley (1978). Onaka (1983) has formulated a variation of the housing disequilibrium model using hedonic theory. More recent work has linked the mobility and location choice approaches. DePalma and Ben-Akiva developed a dynamic model of residential location based on household choice and transactions costs. Van Lierop and Rima (1982), Onaka and Clark (1983), Clark and Onaka (1985), and Kain and Apgar (1985) also developed two stage models of the decision to move and the choice of location.

The UrbanSim model structure and theory integrate and extend elements of the consumer surplus approach taken by Martinez with the dynamic mobility and location choice modeling approach. This is embedded within a larger simulation model that deals with land market clearing, land development, and aggregate metropolitan changes in the distribution of households and businesses by type.

4.1 Mobility and Location Choice

The location model we propose relates in key respects to the bid component of the model developed by Martinez (1992), based on consumer surplus (equation 1). It diverges from that model in significant ways, but most notably by dropping the equilibrium assumption. We assume that market prices are exogenous to the location choice faced by the individual consumer, and instead resolve price adjustments through an aggregate market clearing process external to the choices made by individual consumers. We structure time in annual steps, within each of which we account for mobility and location choices, as well as space construction decisions. Between years we account for price adjustment and new construction and redevelopment. Rather than imposing the equilibrium assumption that households make costless and instantaneous adjustments in residential location, we follow in the tradition of research that identifies a two-stage process of residential location, consisting of the decision to move, and the choice of location and dwelling type.

4.2 Aggregation of Alternatives

Since we are not dealing with elemental housing units or lots as the level of choice, but are instead aggregating alternatives into zones (traffic analysis zones) and land use types, we need to adjust the choice equation to account for the aggregate nature of the choice set. We do this by including the size of the choice set represented by each of the aggregate choices. We rewrite equation 1 to include the size term, and substitute equation 2 into 1:

$$P_{i|h} = \frac{e^{(\mu CS_{hi} + \alpha \ln S_i)}}{\sum_j e^{(\mu CS_{hj} + \alpha \ln S_j)}}$$

This is the form of the location choice model we estimate.

Note that the model has a simple specification and direct interpretation. The consumer surplus is the difference, in dollars, between what a consumer is willing to bid for an alternative and the market price of the alternative. The log of the size term accounts for the aggregation of the elemental alternatives into zones of arbitrary size.

4.2.1 The Bid Function

While the urban economic literature generally refers to a willingness to pay function that defines a hypothetical maximum a consumer would be willing to pay for an alternative, we suggest that the use of empirical data to estimate this function will reveal a something more aptly described as a bid function. What we actually observe when examining market outcomes of consumer choices is the prices they paid for the alternatives they chose. They might have been willing to pay more than they were required to by the market price for the alternative, but they would undoubtedly be reluctant to reveal their true maximum willingness to pay for it. What we observe, then, in examining actual market outcomes are the successful bids made by particular consumers, that match the market price for the alternative. This is consistent with the interpretation of consumers as price takers in the market.

This interpretation is summarized for the chosen alternative as the bid matching the market price and bounded by the maximum willingness to pay.

$$B_{hi} = p_i \le \Theta_{hi}$$

In order to compare alternatives for predicting the probability that a consumer will select a particular one, however, we need to estimate a bid function that encapsulates consumer preferences for the attributes of the alternatives. The bid function must predict what consumers would have been willing to bid for each of the alternatives in the choice set based on their attributes.

The bid function we propose differs from the typical hedonic regression in that we stratify consumers into market segments, estimating a separate bid function for each. This allows the identification of bid price functions specific to subgroups of consumers, whose tastes vary significantly across incomes and stages of life cycle. A hedonic regression cannot be interpreted as a demand function, since it represents the envelope of demand and supply curves of all consumers and suppliers in the market.

We estimate bid functions for households stratified by income level and by the presence of children, a key life cycle characteristic. For businesses, we estimate separate bid functions for each sector. Once the bid functions have been estimated, the bid equation is used to generate bids for each of the alternatives in the choice set, to estimate the consumer surplus for each alternative, and ultimately to predict the location choice probability.

4.3 Relationship to Other Operational Land Use Models

UrbanSim differs significantly from several existing operational modeling approaches, including the spatial-interaction DRAM/EMPAL models developed by Putman (1983); the spatially-disaggregated input-output TRANUS and MEPLAN models, developed respectively by de la Barra (1989) and Echenique et al (1990); the GIS-based California Urban Futures Model developed by Landis (1995), and the CATLAS (and later METROSIM) model developed by Anas (1982). All of these models are discussed in detail in the reviews cited at the beginning of this section, and are not elaborated on here. Compared with these models, UrbanSim is unique in the following ways:

Dynamic structure of year to year evolution of urban development (as opposed to long-run equilibrium assumptions);
Explicit representation of move and location choices;
Explicit representation and accounting of land, structures and occupants, and market prices;
Parcel-level modeling of land development and redevelopment;
Disaggregation of the location choice to the level of traffic analysis zones;
Substantial disaggregation of household and business types;
Integration with existing travel models;
Explicit input of public sector choices as policy scenarios.

5 Model specification

5.1 Economic Transition

Businesses are classified according to two characteristics: industry and size. Users may aggregate or disaggregate the grouping of industries or size categories as appropriate. Just as households may age and change status of children, income, number of workers, move out of the region, or be created, business establishments may increase or decrease in employment, go into or out of business, or move into or out of the region. There is evidence of very high levels of turnover (birth and death of businesses) in some industries, and especially among smaller establishments. If the ‘churning’ associated with business closure and startup are not accounted for, one is likely to significantly underestimate the responsiveness of employment location in response to changing accessibility patterns and market forces such as land prices or the construction of new space.

$$B_{nst} = \sum_{s'} B_{nst-t} p_{nsi} - B_{nst-t} p_{nso}$$

where

B_{nst} is the regional total of businesses of industry n and size s in time t
P_{nsi} is the inmigration and startup rate for businesses of industry n and size s
p_{nso} is the outmigration and closure rate for businesses of industry n and size s.

The birth and death rates are estimated for each business type (industry and size category) from comparison of two different year inventories of business establishments, preferably 4-5 years apart.

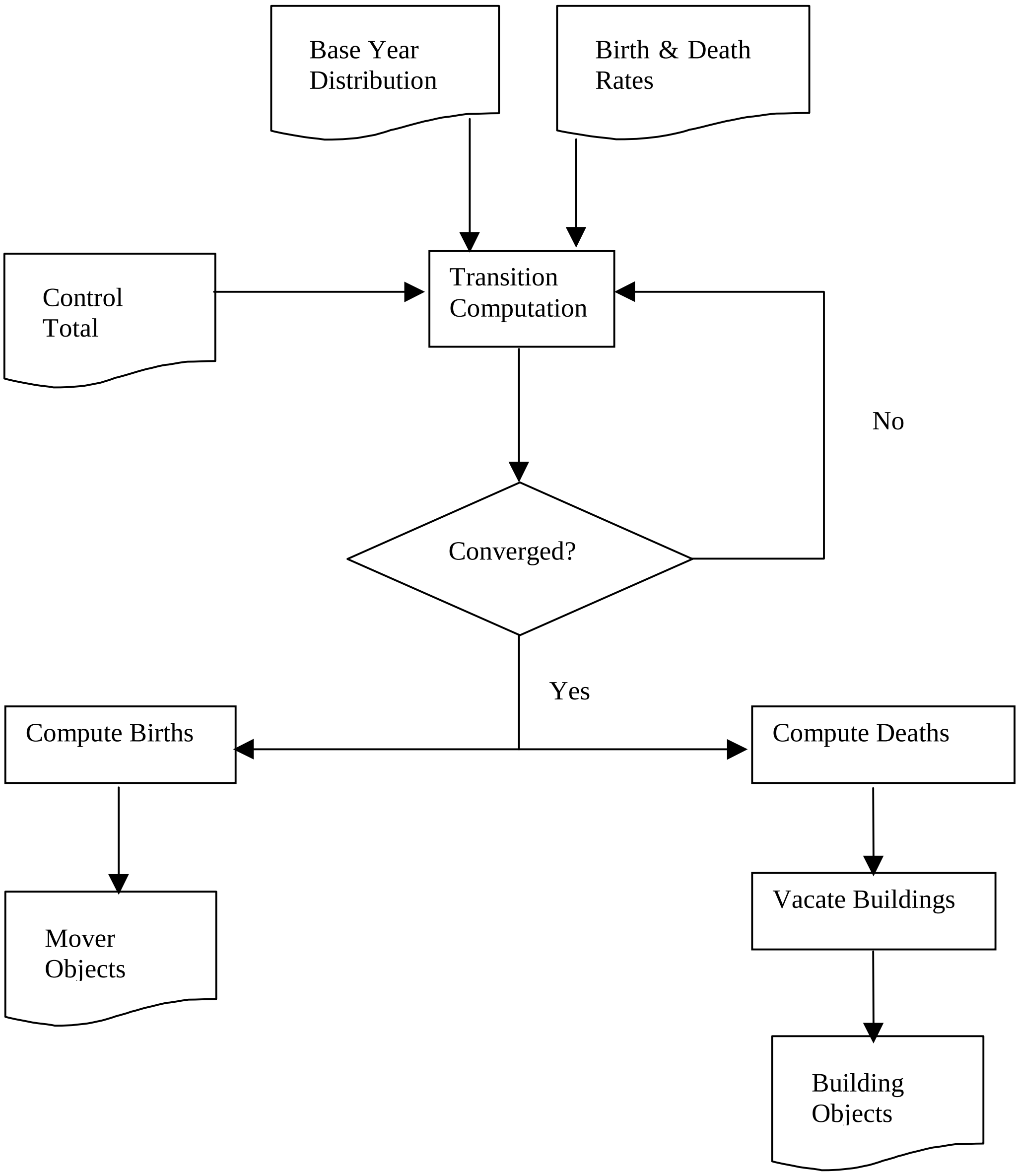
The transition calculation, which applies to both the economic transition and demographic transition components of the model, applies the birth and death rates in an iterative fashion to the start year distribution. In each iteration it scales the birth and death rates proportionately until the aggregate total (employment or population) falls within an allowable tolerance of the target control total for the next year (the tolerance is set as a default to one percent). Control totals are interpolated linearly for years in between those years for which the user has input control totals. The user may specify annual control totals if desired, or totals for selected benchmark years, or a minimum of a single end year control total for the forecasting horizon.

Once the final scaled probabilities of business death are calculated from the convergence of the transition calculation, the aggregate death probabilities by type are applied to businesses at each location and building type by removing a proportion of the businesses of the appropriate type. We assume that the probability that a business will be removed is proportional to the spatial distribution of businesses – there is an equal probability regardless of location. The businesses that are removed vacate the space they were occupying, and this space becomes available to the pool of vacant space for other businesses to occupy, in the location component of the model. This procedure keeps the accounting of land, structures, and occupants up to date.

Birth calculations produce new businesses based on the birth probabilities computed in the converged transition component, but these businesses are not immediately assigned a location. New businesses are assigned a null location, and added to the pool of businesses that will be located in the location component of the model, along with movers, which are calculated in the move component.

A diagram of the procedure is shown below.

FIGURE 4.1
Transition Component Flowchart



5.2 Demographic Transition

The transition component described in the preceding section applies a similar calculation to households, to account for changes in the distribution of households by type over time. These changes result, in reality, from a complex set of social and demographic changes that include aging, household formation, divorce and household dissolution, mortality, birth of children, migration into and from the region, changes in household size, changes in income, among others. The data, and theory, required to adequately represent all of these components and their interaction, are not readily available. What the demographic transition component does, like the economic transition described above, is use birth and death rates by household type to provide a mechanism for the user to approximate the net results of these changes. The birth and death rates may be adjusted by the user, as supported by available data, to cause the transition component to produce a realistic shifting of the population characteristics over time. This may involve a general aging of the population, declining household size, or other observed demographic and social trends that are reflected in the joint distribution of household characteristics in the region.

The core equation in the transition component is identical to the economic component, but applies to households as opposed to businesses.

$$H_{ht} = \sum_{h'} H_{ht-t} p_{hi} + H_{ht-t} p_{ho}$$

where

H_{ht} is the regional total of households of type h in time t
P_{hi} is the birth (inmigration, new household formation) rate for households of type h
p_{ho} is the death (outmigration, household dissolution) rate for households of type h.

As in the economic transition case, household births are added to a list of movers that will be located in the location component of the model. Household deaths, on the other hand, are accounted for at this time by their removal from the housing stock, and the proper accounting of the vacancies created by their departure.

5.3 Business Mobility and location

5.3.1 Business Mobility Model

The business mobility model predicts the probability that establishments of each type will move from their current location or stay during a particular year. Data for estimating these move probabilities come from matching business establishment files from two different years, preferably 4 to 5 years apart. Otherwise, estimates of these rates will need to be developed from other sources. In general, we expect that smaller businesses, and some industries, will have higher tendencies to relocate. In particular, we would expect that large businesses, or firms that have large capital assets tied to their current location, will have very low probabilities of moving over any reasonable forecasting horizon. For this reason, the implementation of the model allows for the identification of major employers that are to be considered ‘non-movers’, and these are exempted from the mobility and location choice modeling. Accounting of their employment, however, is maintained.

The probability of moving in a given year may be estimated using a binary logit model, or simply estimated as a rate of mobility for each business type. Logit models predicting probability of business establishment mobility over a given span can be calibrated with independent variables based on the establishment characteristics of industry and size group, interacted with the alternative-specific dummy representing the choice to move.

$$p(m) = \frac{1}{1 + e^{V_m}}$$

where p(m) is the probability of a business of industry n and size s moving
V_m is the systematic component of the utility of moving.

A simple specification of this utility would be:

$$V_m = \beta_1 + \beta_2 i + \beta_3 s$$

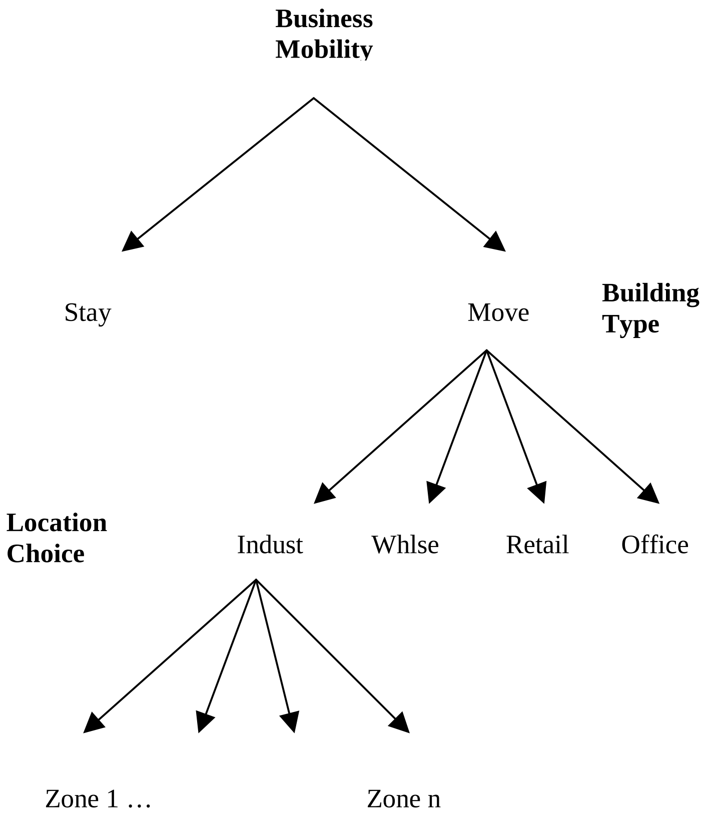
where i is the industry
s is the establishment size

Estimation as a binary logit model would be appropriate if the data supports calibration in a nested logit specification, with the choices of building type and location. Since it is possible that the relative attractiveness of commercial space in other locations compared to an establishment's current location may influence their decision to move, we could structure the mobility model as the higher level in a nested logit model with the lower level being building type and location choice. In this way, we use information about the relative utility of alternative locations compared to the utility of the current location in predicting whether establishments will move. This represents a hierarchical choice of current location vs. all others, and within the all other branch we further disaggregate the alternatives to zones and space types in the employment location model.

Note that in many cases, specification of the mobility model as a nested logit is not warranted, or supported by the data available for calibration. In such cases, the mobility decision is treated as an independent choice, and the probabilities can be estimated either as a binary logit or estimated by simple mobility rates directly observed over a recent period for each business type are used as the predicted probabilities.

As in the case of business deaths predicted in the economic transition component, the application of this model requires subtracting establishments by type from the buildings they currently occupy, and the updating of the accounting to make this space available as vacant space. These counts will be added to the unallocated new establishments by type calculated in the economic transition model. The combination of new and moving establishments serve as a pool to be located in the employment location choice model. Vacancy of nonresidential space will be updated, making space available for allocation in the employment location choice model. Average space per employee will be stored in a lookup table, and is an exogenous input in the initial model specification.

FIGURE 4.2
Nested Logit of Business Mobility, Building Type, Location Choice



5.3.2 Business Building Type and Location Choice

In this component of the model, we predict the probability that a business that is either new (from the transition component), or has decided to move within the region (from the mobility component), will choose a particular combination of location and building type (landuse). The form of the model could be specified as either nested logit or as joint multinomial logit. In order to test for violation of the Independence if Irrelevant Alternatives (IIA) property of multinomial logit, nested specifications would typically be tested during calibration, and if not supported by the data, the model would be estimated using the joint multinomial form.

In the nested formulation, the upper-level nest is the choice of building type, and the lower-level nest is the choice of zone (see Figure 4.2).

The marginal probability of choosing a building type b is given by:

$$P(b) = \frac{e^{V_b + \mu V_b'}}{\sum_{b'} e^{V_{b'} + \mu V_{b'}'}}$$

where

$$V_b' = \ln \sum_{l} e^{V_l}$$

is the logsum of the conditional choice of location l, and

μ is an inclusive value parameter, or logsum coefficient, with a value between 0 and 1.

The conditional probability of choosing a particular location, or zone, is given by the multinomial logit equation:

$$P(l|b) = \frac{e^{V_l}}{\sum_{l'} e^{V_{l'}}}$$

where P(l|b) is the probability of choosing zone l conditional on the choice of building type b,
V_l is the systematic component of the utility of zone l

The logsum is the log of the sum of the utilities of the alternatives at the lower level of the model, and is used as an additional term in the estimation of the higher level nest of the model. In Full Information Maximum Likelihood estimation, these two levels of the model, including the inclusive value coefficient on the logsum term, are estimated simultaneously. The theoretically acceptable range of values for the inclusive value coefficient is between 0 and 1, with values of 1 indicating that the nested model is equivalent to a joint multinomial logit model.

The joint multinomial logit specification combines the two levels of the model, and predicts the joint probability of building type and location. In the event that the data are not consistent with a nested logit form, this is the form of the business location and building type model that is estimated.

$$P_{bl} = \frac{e^{V_{bl}}}{\sum_{b'l'} e^{V_{b'l'}}}$$

where P_{bl} is the joint probability of choosing location l and building type b

The systematic component of the utility is specified as the consumer surplus of each alternative, and a size term to account for the aggregation of alternatives. The consumer surplus is further defined as the bid for an alternative less its market price, which is taken as exogenous to the individual firm.

5.3.3 Business Bid Function

The bid function is specified for each business type based on zone characteristics and building types.

$$B_{bl} = f(Z, S)$$

where Z is an array of zone characteristics
S is an array of dummy variables for space types

The variables included in the business bid price function are drawn from the literature in urban economics. We would expect that accessibility to population, particularly high-income population, increases bids for retail and service businesses. We also expect that two forms of agglomeration economies influence bids: localization economies and inter-industry linkages.

Localization economies represent positive externalities associated with locations that have other firms in the same industry nearby. The basis for the attraction may be some combination of a shared skilled labor pool, comparison shopping in the case of retail, co-location at a site with highly desirable characteristics, or other factors that cause the costs of production to decline as greater concentration of businesses in the industry occurs. The classic example of localization economies is Silicon Valley. Inter-industry linkages refer to agglomeration economies associated with location at a site that has greater access to businesses in strategically related, but different, industries. Examples would include manufacturers locating near concentrations of suppliers in different industries, or distribution companies locating where they can readily service retail outlets.

One complication in measuring localization economies and inter-industry linkages is determining the relevant distance for agglomeration economies to influence location choices. At one level, agglomeration economies are likely to affect business location choices between states, or between metropolitan areas within a state. Within a single metropolitan area, we are concerned more with agglomeration economies at a scale relevant to the formation of employment centers. This scale of effect is likely to be larger than a single traffic analysis zone, the unit of analysis in this application. We therefore include variables representing the activity within an industry both within a zone, and separately for access to the activity weighted by the composite utility of travel between zones (logsum). By including the quantity of employment within a zone, we would introduce an artifact of zone size that would lead to arbitrary results were we to split zones, so we use a gross density of employment in the industry to correct for this.

Age of buildings is included in the model to estimate the influence of age depreciation of commercial buildings, with the expectation that businesses prefer newer buildings and discount their bids for older ones. This reflects the deterioration of older buildings, changing architecture, and preferences, as was the case in residential housing. There is the possibility that significant renovation will make the actual year built less relevant, and we would expect that this would dampen the coefficient for age depreciation. We do not at this point attempt to model maintenance and renovation investments and the quality of buildings.

Density, the inverse of lot size, is included in the business bid price model. We expect businesses, like households, to reveal different preferences for land based on their production functions and the role of amenities such as green space and parking area. As manufacturing production continues to shift to more horizontal, land-intensive technology, we expect the discounting for density to be relatively high. Retail, with its concentration in shopping strips and malls, still requires substantial surface land for parking, and is likely to discount bids less for density. Service firms, which in the traditional urban economics models of bid-rent generally outbid other firms for sites with higher accessibility, land cost, and density, we expect to discount density the least.

We might expect that certain sectors, particularly retail, show some preference for locations near a major highway, and are willing to bid higher for those locations. Note that we measure the presence of a highway as a boolean variable based on its presence within or at the boundary of a zone. There may be some measurement error associated with both the zonal level of aggregation, as well as the functional classification of roadway segments as highways. We also test for the residual influence of classic monocentric model, measured by travel time to the CBD, after controlling for population access and agglomeration economies. We expect that the CBD accessibility influence will be insignificant or reverse of the traditional monocentric model, after accounting for these other effects.

Finally, we test for market supply effects on bids by including the size of the available nonresidential stock of the appropriate type of building space in the zone. If we were truly observing the maximum willingness to pay, then a supply effect should not be present. Since we expect that we are observing a bid that matches the market price, and is below the willingness to pay, then higher market supply might well be expected to add competition and thus lower the bids offered, and therefore the exchange price. This market supply effect is different from the other effects included in the model, since it does not represent an attribute that influences demand. We therefore use the variable in the estimation step to remove the potential bias on other variables that might be encountered by excluding it. In the subsequent step in which we use the fitted bid price function to predict bids, however, we drop this term. This will generate bids that respond more closely to underlying consumer preferences, and leaves the market price adjustment external to the formation of bids. We include a market supply effect measured as the log of the square footage of built space in the zone, of the type chosen by the business. Note that this measure adds an artifact of zone size that is arbitrary. Removal of the size term influenced other coefficients in the model to some degree in the residential case, and to a larger degree in the nonresidential case.

Calibration of the model is based on a geocoded establishment file (matched to the parcel file to link employment by type to land use by type). Movers identified in the file are used as the sample for estimating location choice, since their choices have been expressed under relatively current conditions. As in the residential location choice model, the application of the model produces demand by each employment type for space of each nonresidential type, by zone. The total demand for space by zone by type is computed by summing demand across employment types and space types.

5.4 Household Mobility and Location

5.4.1 Household Mobility

The mobility component described previously for business movement is identical in form to its application to households. The same software component is used, but with rates or coefficients applicable to each household type.

For households, mobility probabilities can be estimated for each type of household using a household survey, or if necessary, from the Public Use Microdata Sample file from 1990. This will reflect differential mobility rates for renters and owners, and households with and without children, etc. Logit models predicting probability of household mobility over a given span can be calibrated with independent variables based on the household characteristics such as age group, children present, number of workers, each interacted with a dummy variable representing the choice to stay.

$$p(m) = \frac{1}{1+e^{V_m}}$$

where p(m) is the probability of a household of type h moving
V_m is the systematic component of the utility of moving.

A potential specification for the mobility equation is:

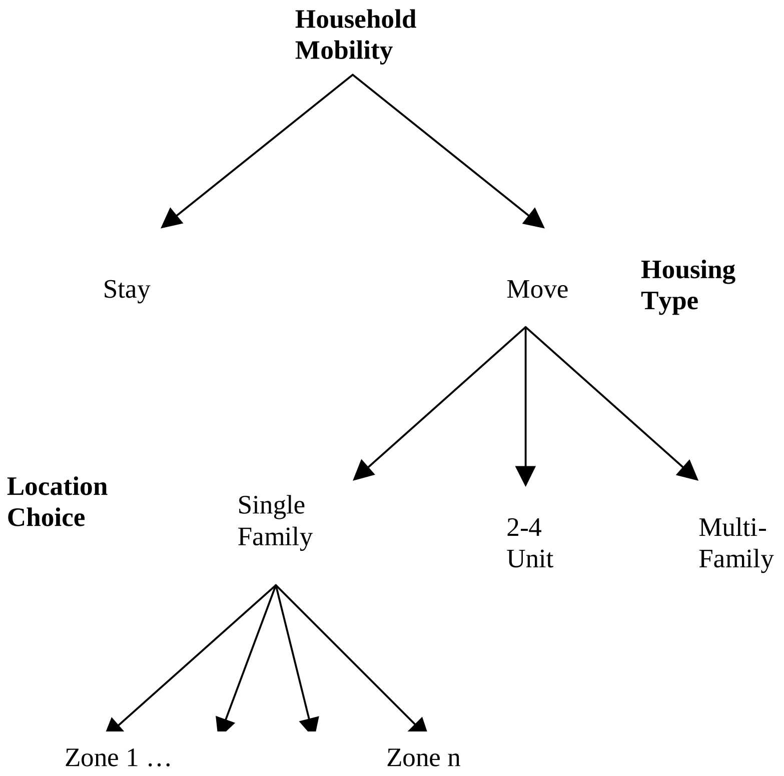
$$V_m = \beta_1 + \beta_2 a + \beta_3 c + \beta_4 i + \beta_5 s$$

where a is the age group of the head of the household
c is a dummy variable for whether children are present in the household
i is the household income level
s is the household size

As with businesses, the mobility choice could be estimated either as a higher level nested logit model than uses building type and location choice as lower levels (see Figure 4.3). Alternatively, it may be estimated using an independent binary logit, or simply computing the mobility rates for each type of household from recently observed mobility.

Application of the residential mobility model requires subtracting mover households by type from the housing stock by zone, and adding them to the pool of new households by type estimated in the Demographic Transition Model. The combination of new and moving households serve as a population of households to be located in the residential location choice model. Housing vacancy is updated as movers are subtracted, making the housing available for occupation in the household location and housing type choice model.

FIGURE 4.3
Nested Logit of Household Mobility, Housing Type, Location Choice



5.4.2 Household Location and Housing Type Choice

In this component of the model, in parallel to the business location component, we predict the probability that a household that is either new (from the transition component), or has decided to move within the region (from the mobility component), will choose a particular combination of location and housing type (landuse). As before, the form of the model can be specified as either nested logit or as joint multinomial logit.

In the nested formulation, the upper-level nest is the choice of housing type, and the lower-level nest is the choice of zone (see Figure 4.3).

The marginal probability of choosing a housing type h is given by:

$$P(h) = \frac{e^{V_h + \mu V_h'}}{\sum_{h'} e^{V_h + \mu V_{h'}'}}$$

where

$$V_h' = \ln \sum_{l} e^{V_l}$$

is the logsum of the conditional choice of location l, and μ is an inclusive value parameter, or logsum coefficient.

The conditional probability of choosing a particular location, or zone, is given by the multinomial logit equation:

$$P(l|b) = \frac{e^{V_l}}{\sum_{l'} e^{V_{l'}}}$$

where P(l|h) is the probability of choosing zone l conditional on the choice of housing type h,
V_l is the systematic component of the utility of zone l

As before, the joint multinomial logit specification combines the two levels of the model, and predicts the joint probability of housing type and location. In the event that the data are not consistent with a nested logit form, this is the form of the business location and building type model that is estimated.

$$P_{hl} = \frac{e^{V_{hl}}}{\sum_{h'l'} e^{V_{h'l'}}}$$

where P_{hl} is the joint probability of choosing location l and housing type h.

As with the business location model, the systematic component of the utility is specified as the consumer surplus of each alternative, and a size term to account for the aggregation of alternatives. The consumer surplus is further defined as the bid for an alternative less its market price, which is taken as exogenous to the individual household.

5.4.3 Residential Bid Function

The bid function is specified for each household type based on zone characteristics and housing types.

$$B_{bl} = f(Z,S)$$

where Z is an array of zone characteristics
S is an array of dummy variables for housing types

We estimate bid functions for households stratified by income level and by the presence of children, a key life cycle characteristic. Once the bid price functions have been estimated, the bid price equation is used to generate bids for each of the alternatives in the choice set, to estimate the consumer surplus for each alternative, and ultimately to predict the location choice probability.

The variables included in the household bid function, and their theoretical justification, are discussed below. The variables are drawn from the literature in urban economics, urban geography, and urban sociology. An initial feature of the model specification is the incorporation of the classical urban economic trade-off between transportation and land cost. This has been generalized to account not only for travel time to the classical monocentric center, the CBD, but also to more generalized access to employment opportunities and to shopping. These accessibilities to work and shopping are measured by weighting the opportunities at each destination zone with a composite utility of travel across all modes to the destination, based on the logsum from the mode choice travel model.

These measures of accessibility should negate the traditional pull of the CBD, and for some population segments, potentially reverse it. In addition to these accessibility variables, we include in the model a net building density, to measure the input-substitution effect of land and capital. To the extent that land near high accessibility locations is bid up in price, we should expect that builders will substitute capital for land and build at higher densities. Consumers for whom land is a more important amenity will choose larger lot housing with less accessibility, and the converse should hold for households that value accessibility more than land, such as higher income childless households.

The age of housing is considered for two reasons. First, we should expect that housing depreciates with age, since the expected life of a building is finite, and a consistent stream of maintenance investments are required to slow the deterioration of the structure once it is built. Second, due to changing architectural styles, amenities, and tastes, we should expect that the wealthiest households prefer newer housing, all else being equal. The exception to this pattern is likely to be older, architecturally interesting and high quality housing in historically wealthy neighborhoods. The preference for these alternatives could be accommodated through a combination of nonlinear or dummy variable treatment for this type of housing and neighborhood.

A related hypothesis from urban economics is that since housing is considered a normal good, and therefore has a positive income elasticity of demand. This implies that as incomes rise, households will spend a portion of the gains in income to purchase housing that is more expensive, and which provides more amenities (structural and neighborhood) than their prior dwelling. A similar hypothesis is articulated in urban sociology (see for example, Massey, 1992), in which upward social mobility is associated with spatial proximity to higher status households. Both of these hypotheses would predict that households of any given income level would prefer, all else being equal, to locate in neighborhoods that have higher average incomes.

The age hypothesis and the two income-related hypotheses are consistent with the housing filtering model, which explains the dynamic of new housing construction for wealthy households that sets in motion a chain of vacancies. The vacancy chain causes households to move into higher status neighborhoods than the ones they leave, and housing units to be successively occupied by lower and lower status occupants. At the end of the vacancy chain, in the least desirable housing stock and the least desirable neighborhoods, there is insufficient demand to sustain the housing stock and vacancies go unsatisfied, leading ultimately to housing abandonment. We include in the model an age depreciation variable, along with a neighborhood income composition set of variables, to collectively test the housing filtering and related hypotheses.

Housing type is included in the model as a set of dummy variables for alternative housing types, with single family housing excluded as a base of comparison. Residential housing with two to four units (duplex, triplex, and quadplex), and multi-family housing, are expected to be significantly discounted in bid prices, since they are likely to have smaller living space and fewer amenities than single family housing.

Given the stratification of households into consumer market segments based on income and the presence of children, we test for compositional effects not only of income, but also of the proportion of households with children in a neighborhood. We expect that households with children would be willing to pay more for a house in a neighborhood with more children, all else being equal, than a similar income household without children.

Among the amenities that households prefer are attributes of the land use mix within the neighborhood. It is likely that residential land use, as a proxy for land uses that are compatible with residential use, positively influences housing bids. On the other hand, industrial land use, as a proxy for less desirable land use characteristics, would lower bids.

The size variable is measured by the log of the number of available housing units of a particular type in the zone. As in the nonresidential case, this market supply effect is included to more purely measure the preference components of the bid price function, and is excluded from the formation of bids used in the computation of consumer surplus.

The model is calibrated using a random sample of alternative locations, which has been shown to provide consistent estimates of the coefficients. In application for forecasting, the predictive equation will be applied to all alternatives for each household type being allocated, producing the demand for housing of each type and tenure in each zone. All of the independent variables will be updated in each forecast year increment, based on results of the prior period iteration of the model set. Total housing demand in each zone is computed by summing demand across household types.

5.5 Market Clearing and Land Price Adjustment

The land market clearing is a component of the model system that reconciles demand for land from households and establishments with each other, and with the available land supply in every forecast interval. It handles the assignment of moving businesses and households to their highest utility alternative that is available, and adjusts land prices according to the ratio of demand to supply in each zone. Since prices enter the location choice utility functions for businesses and households, an adjustment in prices will alter their location preferences, causing higher price alternatives to become more likely to be chosen by occupants that have lower price elasticity of demand, all else being equal. Similarly, any adjustment in land prices alters the preferences of developers to build new construction by type of space, and the density of the construction.

Once households and businesses have evaluated all the available alternatives, and expressed their preferences (through a probability prediction from the location choice models), the simulation attempts to place households and businesses into buildings in proportion to their predicted probabilities. Building objects that become full during this operation are removed from the remainder of the allocation process, and households and businesses that are unable to locate into their highest utility building are forced to accept their next highest utility alternative. This process iterates until all businesses and households are located in buildings and houses.

The market clearing mechanism, then, is not strictly through a full equilibrium price adjustment, in which perfect information exists, and transaction costs are zero, so that prices on all buildings at each location adjust to the equilibrium solution that clears the market. Rather, the solution is based on an expectation of incomplete information and nontrivial transactions and search costs, so that movers obtain the highest satisfactory location that is available, and prices respond at the end of the year to the balance of demand and supply at each location.

Once the market assignment is completed, the information generated by the market simulation about the relative demand and supply of each building type at each location is used to update prices. The magnitude of the price adjustment is based on the ratio of the total demand (existing occupants plus the demand vector from the location choice model) for each building object to the existing supply of space in the building object. The adjustment factor is capped at an annual change of no more than 25% in either direction.

We make the following assumptions:

1. Households and businesses respond to prices of housing and nonresidential space at the start of the current year, if they are moving in this year.
2. Developers respond to current market prices, after they have been adjusted to account for the current year demand and supply
3. Households, businesses, and developers are all price-takers, and market adjustments are made by the market in response to aggregate demand and supply relationships.
4. Location preferences, expressed as the ratio of demand to supply, are capitalized into land values. Building value reflects building replacement costs only, and can include variations in development costs due to terrain, environmental constraints or development policy. The market price per housing unit or per square foot of nonresidential space is the sum of land and building value, based on the density of the construction.
5. There is a normal vacancy rate, above which the market triggers an upward adjustment in land prices, and below which it triggers a decline. Such price adjustments will occur in proportion to the ratio of demand to supply for each building type at each location.

Based on these assumptions, which are consistent with urban economic theory, the price adjustment mechanism causes an adjustment in the location preferences of businesses and households in the following year. Developers respond to current prices by maximizing the profitability of construction, subject to the constraints of land supply and development policy. The supply of housing and commercial space consumed in any iteration comes from existing vacant structures plus any new construction and redevelopment of structures that occurred in the most recent period. New construction in a forecast interval can include committed, proposed, and potential development projects identified by the user as exogenous policy input.

The form of the price adjustment, then, is:

$$P_{lbt} = P_{lbt-1} \; \frac{D_{lbt}}{(1-\alpha)S_{lbt}} \Big|^{\beta}$$

where

P_{lbt} is the land price of building type b in location l in year t
P_{lbt-1} is the previous year closing land price for the same building and location
D_{lbt} is the total demand in the current year for space in the building type and location
S_{lbt} is the current year total supply of space of building type b in location l
α is the normal vacancy rate
$\beta$is a scaling parameter for the price adjustment, initially set to 1

Total demand is estimated from three components, total latent demand, current occupied space, and total vacant space (including potential vacancy to be created by out-movers):

$$D_{lbt} = \sum_{i} P(lb)_{it} M_{it} R_{lb} + \sum_{i} O_{ilbt} - (AV_{lbt} + TV_{lbt})$$

where:

$P(lb)_{t}$ is the prob. that a mover of type i will choose building type b, location l, year t
M_{it} is the total number of movers of type i in year t
R_{lb} is the utilization rate for building type b (for residential=1, for nonres.=sqft/emp)
O_{ilbt} is the total occupied quantity of space in building type b, location l in year t
AV_{lbt} is the total actual vacancy in building type b, location l, and year t
TV_{lbt} is the tentative vacancy (if movers subtracted) in building type b, location l, year t

5.6 Vacant Land Price Adjustment

Since vacant land price is a key determinant of the profitability of alternative development outcomes on each vacant parcel (entering the cost side of the profit equation) the model must update vacant land prices as urban development proceeds and the prices of developed land change around each vacant parcel. We expect that vacant land prices will adjust in relationship to developed land prices in a local area as a result of land speculation. Speculators purchase vacant land and hold the land until the land price increases as the opportunities for developing the land increase with the encroachment of urban land development.

Vacant land prices are adjusted by the weighted average of the price adjustments (in the current year) of each of the building types in a location. After the location of businesses and households triggers a market adjustment in land prices for each building type, these price adjustments are applied to the vacant parcels in a zone in proportion to the acreage of land in each building type.

5.7 Accessibility Indices

Since this model is not of the monocentric or spatial interaction genre, in which the choice of workplace is exogenous and residential locations are chosen on the basis principally of commute to the city center or to a predetermined workplace, we deal with accessibility in a more general framework. Accessibility is considered a normal good, like other positive attributes of housing, which consumers place a positive economic value on. We therefore expect that consumers' value access to workplaces and shopping opportunities, among the many other attributes they consider in their housing preferences. Nor would all households respond to accessibility in the same way. Retired persons would be less influenced by accessibility to job opportunities than would working age households, for instance.

We operationalize the concept of accessibility for a given location as the distribution of opportunities weighted by the travel impedance or alternatively the utility of travel to those destinations. The utility of travel is operationalized as the composite utility across all modes of travel for each zone pair, obtained as the logsum of the mode choice for each origin-destination pair. The resulting access measure for each location, then is:

$$Access_i = \sum_{j}^{J} A_j e^{\beta L_{ij}}$$

where

A_j is the quantity of activity in location j

L_{ij} is composite utility, or logsum (for one car households), from location i to j.

β is the utility scaling parameter, initially set to 1

An accessibility procedure reads the logsum matrix (from the travel model in Emme/2) and the land use distribution for a given year, and creates accessibility indices for use in the household and business location choice models. The general framework is to summarize the accessibility from each zone to various activities for which accessibility is considered important in household or business location choice.

If the user chooses the more traditional travel impedance such as travel time or cost for one or more modes, then the accessibility index is modified appropriately into an entropy formulation, with β taking a negative value.

Recall that the urban simulation model operates on one year time increments, but that travel model updates are likely to be executed for two to three of the years within the forecasting horizon. The travel times remain constant from one travel model run until they are replaced by the next travel model result. Although travel times remain constant, the numerator in these accessibility indices is continuously updated, so that the accessibility indices change from one year to the next to reflect the evolving spatial distribution of activities.

5.8 Land development and Redevelopment

5.8.1 Profitability of Development

The developer component of UrbanSim simulates the process of land development and redevelopment into the urban land uses being modeled. The core of the model is a profit maximization calculation based on the costs and expected revenues from development of alternative parcels into allowable developed uses. The developer component of the model is the most directly influenced by local policies such as the comprehensive plan, density constraints, the Urban Growth Boundary, environmental constraints, and development impact fees or other development costs dictated by local governments. Due to the complexities of this module, the current implementation can only be partly calibrated statistically. The model applies the logic of profit maximization to user inputs regarding development constraints and costs and the available parcel data for both vacant and already developed parcels to microsimulate the behavior of developers development and redevelopment behavior.

Developers are assumed to be myopic in their expectations, making predictions about expected profits from development based on current market conditions. This assumption of imperfect information is entirely consistent with the familiar cycle of real estate speculation, overbuilding, and bust. Over longer forecasting horizons, however, we expect the model to predict development behavior without the short-run volatility present in actual real estate markets.

A key assumption of the model is the standard economic assumption that the value of location is capitalized fully into land value. Land values absorb the value of location, meaning that as demand increases for a certain location, since land is in fixed supply, the price of the land at that location increases. Conversely, as demand for a location declines, land prices at that location decline as well. The improvement values on existing development are assumed not to be affected by these land price fluctuations, though land values would influence developers decisions of what and where to build new structures or redevelop existing ones. Improvement values, then, are based strictly on replacement value, and do not vary spatially.

For new development, developers are assumed to make profitability calculations on converting every vacant parcel to each of the building types (land uses) for the parcel that is allowed within local policy constraints. These combinations of parcels and alternative developments on them, or development ‘projects’, are compared in terms of their profitability to the developer. The profit calculation involves revenue expectations based on current market demand and prices, and on the costs of developing each specific parcel into the development project being evaluated. In short, the profit expectations are influenced both by changing market demand, and by factors influencing development costs. Developers are assumed to build development projects in order of profitability, and to continue building profitable projects until the demand for additional space in the land use is satisfied. The vacancy rate is used as the threshold to trigger new development, since development profits are assumed to go to zero as the vacancy rate reaches the ‘normal’ vacancy rate, and developers are assumed to continue to build until the zero profit threshold is reached[2].

For redevelopment, we assume that developer will examine the potential redevelopment of parcels that are under-utilized, in the sense that the ratio of the value of the improvements on a parcel to its land value is very low. This would typically occur where there may have been low cost construction on certain parcels in an area that is now experiencing upward development pressure, driving land prices up. The combination of depreciated improvements that were perhaps of low value to begin with, and rising land costs, would trigger the assessment of these parcels by developers for potential redevelopment. We assume that redevelopment competes directly with new development on vacant land (which includes infill). This means that a

---

[2] A further refinement of the model would incorporate a cost of capital component in the profitability calculation, which would allow profit to be influenced by interest rates and access to capital. As widely observed in the 1980’s real estate boom, the cost of capital dropped due to a combination of factors, making real estate development profitable to developers at levels well above normal, sustainable, market vacancy rates. This refinement lies beyond the current model scope, however.

developer makes a profit-maximizing choice among the development options, including redevelopment, and will only redevelop a parcel if its total development profitability, including the costs of the improvements and their demolition, fall above the profitability of other available vacant parcels. This is most likely to occur under fairly tight market conditions, such as the imposition of fairly strict growth management policies. A tightly drawn and enforced Urban Growth Boundary, for example, in a metropolitan area with high rates of economic growth, would likely cause land prices to rise rapidly, as the supply of vacant land shrinks, and demand for new development increases. In such a context, it is substantially more likely that a sizable fraction of the currently developed parcels are sufficiently under-utilized to compete favorably for development with some fraction of the remaining vacant parcels.

We can specify the developer decision as one of converting land from existing status to one of a finite set of alternative land uses at a particular density, based on the expected profit of the conversion.

$$\widehat{\Pi}_i(lb) = \widehat{R}_{lb}Q_{ib} - L_iA_i - H_bQ_{ib} - S_{lb}Q_{ib} - I_{ib'}Q_{ib'} - D_{ib'}Q_{ib'}$$

where:

$\widehat{\Pi}_i(lb)$ is the expected profit from developing parcel i in location l into building type b
$\widehat{R}_{lb}Q_{ib}$ is the expected revenue from selling the project to household or business consumers
L_iA_i is the land cost of parcel i (land cost per acre times acres)
H_bQ_{ib} is the 'hard' construction cost of the development project, equal to its replacement cost
$S_{lb}Q_{ib}$ is the 'soft' construction cost of developing the project, inclusive of all development fees
$I_{ib'}Q_{ib'}$ is the cost of existing improvements on parcel i if it is being redeveloped
$D_{ib'}Q_{ib'}$ is the demolition cost for any improvements on parcel i if it is being redeveloped

The expected revenue is based on the current market price for space of building type b in location l:

$$\widehat{R}_{lb} = P_{lb}$$

If no development of type b currently exists in location l, and therefore the current market price is undefined, then the average current market value of buildings type b from locations within 5 minutes is used as the estimate of expected revenue instead. In the event that no buildings of type b are encountered in zones within 5 minutes, then the average current market value from the region is used.

5.8.2 Density

The quantity of construction, Q_{ib}, is a function of the size of the parcel being evaluated and the density of construction. The density at which new construction occurs is predicted to be responsive to land prices, with higher land prices prompting capital/land substitution by developers. As land prices increase, we would expect developers to build at higher densities. In markets with a supply of vacant land that is low relative to the demand generated by economic growth, vacant land prices should increase, sending an economic signal to developers to increase density.

The density on which the expected profit of each development project is computed, then, is:

$$\Phi_{lb} = \alpha_b + \beta_b \ln(P_{lb})$$

where

Φ_{ib} is the density for parcels in location l and building type b

P_{lb} is the land price per acre in location l for building type b

5.8.3 Hard Construction Costs

Hard construction costs are typically the largest component of the development costs of a project. These are the labor and material costs of actually building the structure, not including costs of urban service extensions, and are commonly referred to as replacement costs for a building structure. There is considerable variance in construction costs across different building types, and even within the same building type. We assume, in the initial version of the model, that improvement costs do not vary within a building type. Hard construction costs may be estimated by building type from assessed improvement values, from local construction industry sources, or other possible sources.

5.8.4 Soft Construction Costs

Soft construction costs include a variety of fees determined by local governments, which are assumed by the developer, and, depending on the site, could play a significant role in determining the profitability of developing. While the detailed manner in which such costs are levied vary greatly across municipalities, such fees can be classified into three common categories: development and impact fees, service extension costs, and building permit fees. Because of the tremendous variability in the way such fees are implemented, the model adopts a simplification that collapses all such costs into an average 'soft cost' applicable to each building type, and a soft cost adjustment factor that allows this cost to be adjusted up or down by location (zone) based on such factors as the level of urban service extension that would be required for development at each location.

5.8.4.1 Development and Impact Fees

Impact fees (also commonly referred to as development impact fees, system development charges, and the capital expansion component of connection charges) are assessments levied on new development to help pay for the construction of off-site capital improvements that benefit the contributing development. By far the most common fees charged are water and sewer facilities. After these utilities, roadways are the next most common charge, and after highways, the frequency of use of other fees drops markedly (Nichols et. al 1991) but may include improvements such as parks, libraries, police and fire facilities, hospitals, schools, solid waste.

Impact fee methodologies that reflect the actual cost of providing services based on location provide an incentive for development locate in areas with already facilities or where it is less costly to serve (Nelson et al. 1995). Jurisdictions can use impact fees as a positive growth management tool by encouraging growth (through the use of lower fees) in areas already served by the public facilities and discouraging growth (through the use of higher fees) in areas without infrastructure. Currently, 18 states have adopted impact fee enabling acts and, because they are a derivative police power of the state given to municipalities, the nature, reason, and magnitude of the impact fees differ considerably between communities. Typically, fees are assessed using a schedule that sets forth the charge per dwelling unit or per 1,000 square feet of non-residential floor space. For example, a "typical" impact fee (to cover transportation, stormwater, parks, wastewater) for a single family dwelling unit may be on the order of $3,000 to $4,000 (Nichols et. al 1991, City of Eugene 1997).

5.8.4.2 Service Extension Costs

Local governments may also charge service extension costs for the development to be served by the public water, wastewater, stormwater, electrical and/or other already existing systems. While service extension costs may be commonly grouped with, or referred to as, impact fees, service costs are different in two respects. First, they are usually restricted to utilities such as plumbing, electrical, or city light, where as impact fees may include schools, file, police, etc. More importantly, service extension costs are charged for hooking into *existing* utility systems as opposed to impact fees which are assessed for new services.

Service extension costs, however, vary greatly both *between* and *within* municipalities based on specific site conditions of the parcel or the municipality's fiscal structure, current impact fees, or development objectives. The magnitude of extension costs may depend not only on the size and type of construction, but also on the ease by which a particular service can be accessed from the development site. In Eugene, a 20,000 square foot retail building accrued less than $3,000 in electrical, plumbing and mechanical type charges (excluding impact fees).

5.8.4.3 Building/Permit/Plan Review Fees

Building, permit, or plan review fees are charged by municipalities to cover the application, review and inspection process associated with new construction. The development fee may consist of a permit fee and, where plans are routed for review, a separate plan review fee (e.g. conditional use permit, variance). Often, a significant portion of these fees are derived from a local schedule of rates based on total valuation of the development (using the same data and method for calculating hard construction costs). For example, 80 or 90 percent of the total fees charged for permit and/or plan review are based on the valuation of the structure, and other fees for such things as drainage, grading, or noise reduction may be charged separately.

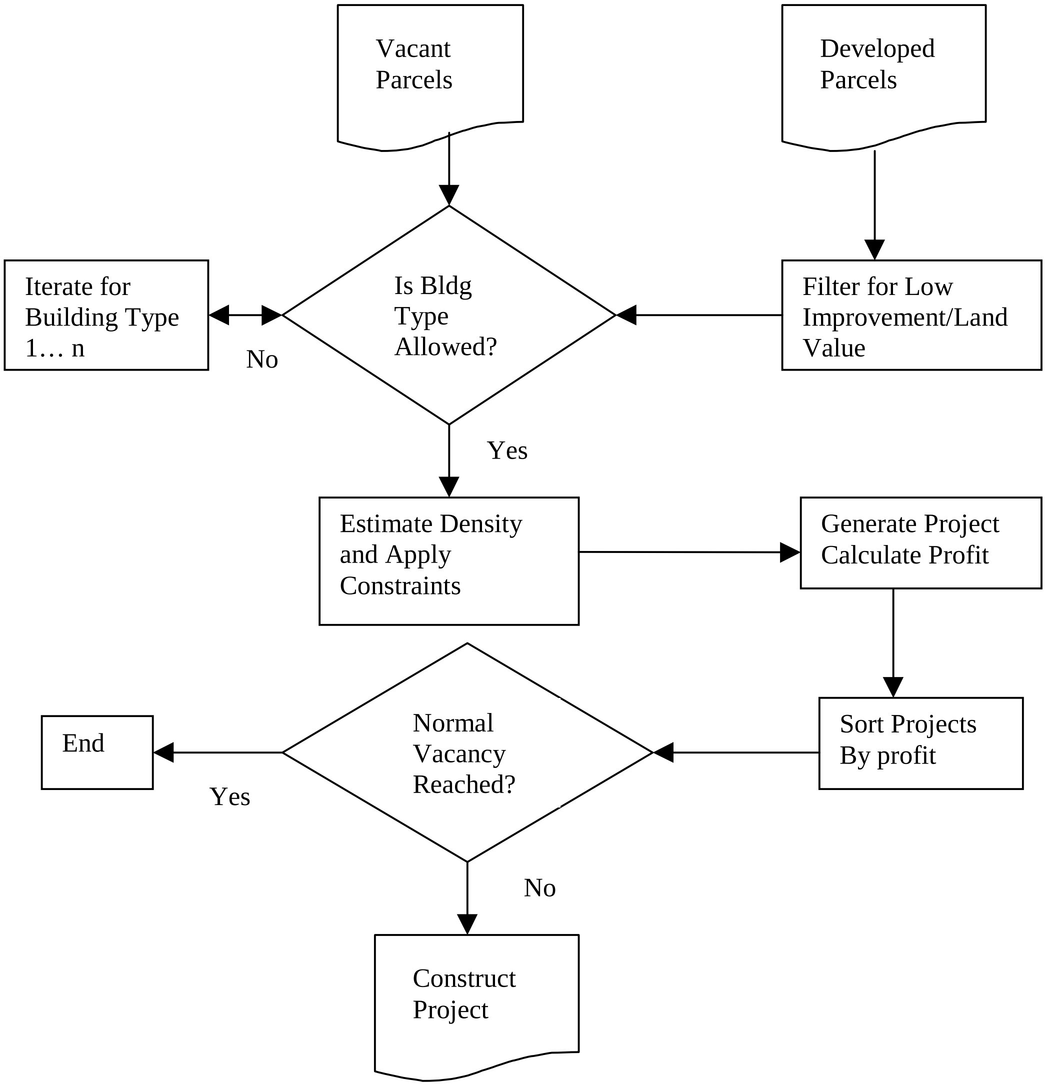
5.8.5 Demolition Costs

To adequately account for the costs associated with infill development, where developers are not assumed to inherit virgin land, it is necessary to account for costs associated the demolition of existing development. Such costs, sometimes referred to as "site improvement costs," widely vary according to the following factors: the type and size of the previous use, the proximity of the nearest land-fill, the portion of the prior building that is going to be preserved, the percent of prior building materials that will be recycled on-site. Parcels that are slated for infill development are assumed to bear an additional expense of $4.00 per square foot to cover such costs.

5.8.6 Developer Model Structure

Figure 4.4 illustrates the structure of the developer component of the model.

FIGURE 4.4
Model Structure for Land Development and Redevelopment



5.9 Model Output

The simulation input data and results are maintained in an internal binary data structure for efficiency, but when the simulation reaches a year that has been identified by the user as a 'Reporting Year' in the user interface, the model translates key results from this internal structure into external files in dBase format. The files written out are stored in a scenario directory, with one set of results files for each reporting year. The files written are:

Table 4.1
Output dBase Files

Business.dbf	Hholds.dbf	Landuse.dbf	Building.dbf	Access.dbf
ZONE	ZONE	ZONE	ZONE	ZONE
TOTEMP	TOTPOP	SFACRES	SFUNITS	TOTALPOP
BASICEST	HHINC1	R24ACRES	R24UNITS	ACCESSPOP
RETAILEST	HHINC2	MFACRES	MFUNITS	HHINC1
SERVEST	HHINC3	INDACRES	INDSQFT	ACCESSHH1
GOVEDEST	HHINC4	WHSACRES	WHSSQFT	HHINC2
BASICEMP	HHAGE1	RETACRES	RETSQFT	ACCESSHH2
RETAILEMP	HHAGE2	OFFACRES	OFFSQFT	HHINC3
SERVEMP	HHAGE3	OTHACRES	OTHSQFT	ACCESSHH3
GOVEDEMP	HHAGE4	VACACRES	SFIMPV	HHINC4
	HHCHILD	UNDACRES	R24IMPV	ACCESSHH4
	HHNOCHILD	SFLANDV	MFIMPV	TOTALEMP
	HHSIZE1	R24LANDV	INDIMPV	ACCTOTEMP
	HHSIZE2	MFLANDV	WHSIMPV	EMPIND1
	HHSIZE3	INDLANDV	RETIMPV	ACCEMP1
	HHSIZE4	WHSLANDV	OFFIMPV	EMPIND2
	HHSIZE5	RETLANDV	OTHIMPV	ACCEMP2
		OFFLANDV	SFTOTV	EMPIND3
		OTHLANDV	R24TOTV	ACCEMP3
		VACLANDV	MFTOTV	EMPIND4
			INDTOTV	ACCEMP4
			WHSTOTV	
			RETTOTV	
			OFFTOTV	
			OTHTOTV	

6 Model Application to Eugene-Springfield

6.1 Overview

This section presents the results of the initial application of the prototype model to the Eugene-Springfield metropolitan area. This section provides background on the planning area for this case study.

The area for this study encompasses the transportation planning area of the Lane Council of Governments[3] (LCOG). The planning area lies towards the southern end of the Willamette Valley, on the I5 corridor. Many of the policy issues discussed in Section 2 apply to Eugene-Springfield, and some additional considerations are described in Appendix 2. Like other metropolitan areas in Oregon, Eugene-Springfield is experiencing rapid growth, and attempting to manage this growth effectively within the constraints of state and local policy initiatives such as the Urban Growth Boundary.

6.2 Zonal System

The zones used for the application of the land use model are the same as are used by LCOG for transportation planning. There are 271 zones, numbered from 25 to 295 (the first 24 are reserved for external stations).

6.3 Data Classification

The classification of land use, households, and businesses is briefly summarized here.

6.3.1 Households

Households are classified using four characteristics: household income, household size, income, and age of the head of the household. The categories are as follows:

Income	Age of Head	Household Size	Children
Under $10,000	Under 29	1	0
$10,000-24,999	20-49	2	1 or more
$25,000-49,999	50-64	3	
$50,000 or more	65 or Over	4 or more	

Note that the household type categories result from the joint distribution of these characteristics. The Eugene-Springfield data produce 111 unique non-zero household types in this classification.

6.3.2 Businesses

Businesses are classified into industry and size. Due to the limitations of a fairly small planning area, the small numbers of businesses required substantial sectoral aggregation to support adequate calibration.

---

[3] The staff of the Lane Council of Governments provided immeasurable assistance to the project in terms of data and assistance in data cleanup and preparation.

The industry sectors are:

Basic	SIC Codes inclusive of Construction-Wholesale Trade
Retail	Retail Trade
Service	All non-educational services
Goved	Government and Educational Services

Note that the Goved sector is not currently modeled. The location of public facilities is treated as exogenous to the model.

The business size categories are:

1-4 employees
5-9
10-19
20-49
50-99
100-249
250-499
500-999
1000 or more

As noted earlier, major businesses are identified as those with 250 or more employees, and are treated as non-movers.

6.3.3 Land Use

Land use is classified using the statistical class of the parcel, which is one of several land use codes in the parcel file. Where missing, alternative codes were used. The classification of existing land uses is as follows:

Residential	Non-Residential
Single-Family	Industrial
Residential 2-4 unit	Warehouse
Multi-Family	Retail
	Office
	Special Purpose

6.4 Database Development

6.4.1 Land Use

The land use data used in this application originate from the 1994 parcel database from LCOG, titled METRO94. This file was obtained as an Arc/Info GIS database, and contained for each land ownership parcel land values, improvement values, land use codes, comprehensive plan designations, and area, among many other attributes. Two particularly important attributes were missing from the database as it was obtained: square footage of nonresidential buildings, and the year built of structures.

Square footage for nonresidential structures proved to be a critical element that required substantial effort to obtain and link to these parcel records. The process of obtaining these supplementary data was aided by a project completed in 1994 by LCOG, to obtain square footage for nonresidential buildings in the City of Eugene, for a transportation planning project related to trip generation. LCOG staff as part of this project collected square footage data for the balance of the metropolitan area, including the City of Springfield and the remainder of Lane County. These square footage data, and some year built values, were linked to the parcel file.

The availability of a business establishment database that was geocoded to a master address file allowed the linkage of the businesses to specific parcels. This linkage, as discussed earlier, is needed to analyze the space utilization of businesses. Not only do we need to observe what kind of space different kinds of businesses occupy, if we are to make reasonable predictions about space demands of future business locations, but we also need to know something about the quantity of space used per employee. Unlike households, which occupy one housing unit each (with rare exceptions), businesses occupy space in a much more fluid manner: adding or reducing employment levels, and adding or subtracting space leased, as needed. The amounts of space vary significantly by land uses, as shown in Figure 5.1, from an average of 355 square feet per employee, to an average of 1125 square feet per employee for industrial space.

In developing these data, and in particular by analyzing the linkage between land parcels and businesses, numerous inconsistencies emerged in the linked database. The sources of these inconsistencies could be attributable to any number of individual variables that might be in error, or some combination of variables. In particular, parcels with one or more businesses assigned to them sometimes had no building square footage, and many significant-sized buildings had no business assigned. Sometimes the square footage to employee ratio was extreme. The analysis and cleanup of these data inconsistencies became a major focus of a supplemental effort to prepare the data for this model. A memo describing the data cleanup and reconciliation process is included as Appendix 4.

Note that price data used in the calibration of the bid functions is taken from appraised values in the tax assessor file for each parcel, and averaged for the parcels of the same land use within a zone. The bid functions estimated for households and businesses therefore use these values rather than sales prices, since inadequate sample size would be available from sales to populate a database for all zones and building types. Nor is it clear that the properties which sold would be representative of the universe of unsold properties. While there is undoubtedly significant error in the assessed values, there are offsetting errors of unknown magnitude in the use of sparse sales data with unknown representativeness.

Table 6.1 summarize the characteristics of the parcel data, and its relationship to employment, as of 1994.

Table 6.1
Parcel Characteristics for Eugene-Springfield Planning Area - 1994

	Model	Acres	Employ	Land Value ($ Million)	Improv. Value ($ Million)	Square Feet (Million)	Housing Units	Improv/ Land Val Ratio	Land Val per Acre
Residential									
Single Family	Y	25117	4267	1247.9	4226.3	73.7	57008	3.4	49683
Residential 2-4	Y	872	309	89.7	354	7.9	8789	3.9	102867
Multi Family	Y	917	581	70.2	411.3	10.1	17343	5.9	76554
Residential Total		26906	5157	1407.8	4991.6	91.7	83140	3.5	52323
Commercial									
Industrial	Y	2744	7118	50.4	494.3	8.9	29	9.8	18367
Warehouse	Y	1049	9486	53.6	209.6	10.6	98	3.9	51096
Retail	Y	1666	23369	244.6	446.7	16.5	514	1.8	146819
Office	Y	814	22533	95.7	364.6	8.9	368	3.8	117568
Special Purpose	N	7764	24870	267	1023.2	22.3	499	3.8	34389
Commercial Total		14037	87376	711.3	2538.4	67.2	1508	3.6	50673
Undeveloped									
Vacant	Y	15173	1290	212.7	18.8	3.7	104	0.1	14018
Nondevelopable	Y	22858	622	94.1	31.8	1	1929	0.3	4117
Undeveloped Total		38031	1912	306.8	50.6	4.7	2033	0.2	8067
Planning Area Total		78974	94445	2425.9	7580.6	163.6	86681		30718

	Impr. Val per Sqft	Units per Acre	Tot Value per Unit	Impr. Val per Unit
Residential				
Single Family	57.3	2.3	96025	74135
Residential 2-4	44.8	10.1	50484	40278
Multi Family	40.7	18.9	27763	23716
Residential Total	54.4	3.1	76971	60038

Commercial		**FAR**	**Total Value per sqft**	**Sqft/Emp** (10% Vac.)
Industrial	55.5	0.074	61.2	1125
Warehouse	19.8	0.232	24.8	1006
Retail	27.1	0.227	41.9	635
Office	41.0	0.251	51.7	355
Special Purpose	45.9	0.066	57.9	807
Commercial Total	37.8	0.110	48.4	692

6.4.2 Businesses

The Lane Council of Governments has been maintaining a database of business establishments and their locations and employment levels since 1978. This level of database maintenance is quite extraordinary and provided exceptionally useful data for this project. In particular, the level of geocoding of the business establishments was well suited to this analysis, since LCOG staff used a Master Address File to geocode the business locations, which linked them directly to a land use parcel. The value of this linkage is that it allowed direct observation of the building type choices made by individual businesses, providing a missing link in the connection between businesses classified by industry and buildings classified by land use. This linkage made possible the estimation of a model of business location and building type choice. This, in turn, solved one of the chronic problems in predicting the location of businesses by land use: the translation of employment by industry – which is the normal classification of businesses at a regional or county level, to employment by land use classification – which is generally preferred for transportation planning purposes.

The following table presents the distribution of businesses by industry and employment size in 1990 and 1994, two years used to compute rates used in the economic transition component.

TABLE 6.2
Industry and Size Distribution of Businesses

1990				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	599	335	255	193	73	41	13	1	0	1510
Retail	407	335	246	193	60	21	1	0	0	1263
Service	1159	462	243	137	39	21	6	3	1	2071
Govt/Ed	49	24	25	58	30	13	4	2	1	206

1994				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	788	338	279	223	67	39	10	1	0	1745
Retail	434	386	301	204	58	19	2	0	0	1404
Service	1285	544	312	183	40	23	4	3	2	2396
Govt/Ed	64	26	40	73	27	11	4	1	2	248

6.4.3 Households

The development of the 1994 base year household data at the zone level was developed using a ‘synthetic baseline population’ method developed by Beckman (1995) as part of the TRANSIMS project. This approach uses Iterative Proportional Fitting to generate a joint distribution of household characteristics with the required geographic detail, by linking the U.S. Census Public Use Microdata Sample (5%) with marginal distributions of household characteristics at the census block group level from Summary Tape File 3A. Iterative Proportional Fitting is applied to the household weights in the PUMS sample to estimate the joint distributions at a census block group level that are consistent with the geographically-detailed marginal distributions and with the aggregate joint distribution from the 5% PUMS household sample.

These joint distributions are converted from census block group to the zones used in the model using parcel data. Since the census block group and traffic zone can both be identified for every ownership parcel, the parcels with housing were used to develop an allocation from block group to traffic zone. The allocation procedure assumes that the households in a sample within a block group have a probability of location within a traffic zone that is proportional to the quantity of housing of the type occupied by the household. This process is implemented using a sampling procedure that also scales the household weights from 1990 to the model base year of 1994, assuming that the distribution of household types remained consistent over that time.

The housing inventory and prices originate from the Lane County parcel database. Assessed values are used as surrogates for market prices in the base year, since sales data would be insufficient to populate values for each zone and housing type. In Oregon, properties are assessed at full market value, though errors in the assessed values clearly add noise to the estimation of the bid functions. The advantage of this procedure is that it uses available data sources so it can be readily replicated. It also provides a large sample size for estimation of the residential mobility rates and location and housing type choice components of the model. The alternative of using household travel surveys to estimate the location choice model would be preferred in metropolitan areas having surveys with sufficient sample size. Similarly, an alternative to assessed values would be preferred for the market price estimates, but the results discussed in the following section suggest that in spite of the inevitable data measurement errors from the data described here, the results of estimation appear reasonable and robust.

6.5 Model Calibration

The following sections summarize the results of the calibration of the UrbanSim model for the Eugene-Springfield area.

6.5.1 Business Birth and Death Rates

We computed the rates at which businesses of each type (industry and size) either closed or moved out of the region between 1990 and 1990, and label these as ‘death’ rates. Similarly, we computed the rates of new business formations and immigration to the region, and label these as ‘birth’ rates. These rates signify the rate of ‘churn’ in the local economy, and as businesses go out of business or move out of the region, they make the building space they occupy available for other businesses. Not accounting for this activity could significantly underestimate the degree of turnover, and the rapidity with which businesses respond to locational influences in the local economy. These rates are shown in Table 6.3 below.

In preparing this analysis, it was discovered that the unique identification numbers that serve as the mechanism to link business establishment listings from different years had occasional failures to match businesses that should have been matched. The reason appears to be that ID numbers on some occasions are either changed or reused. The problem appeared to be concentrated among multiple-establishment firms, so the following analysis was based on single-establishment firms. Nonetheless, it is plausible that the death and birth rates are both biased upwards due to this failure to correctly match all businesses that remained in business and in the region. The implication of this bias is not severe, however, in that these effects should balance each other. On the other hand, slightly higher turnover will be predicted to occur than is actually observed.

The following are the specific calculations used to compute annual birth, death, and mobility rates for businesses from the four year incidence of these respective events occurring between 1990 and 1994.

Annual Rate

$$r = \frac{B+E}{B}\Big|^{\frac{1}{n}} - 1$$

where:

r is the annual birth, death or mobility rate
B is the number of businesses in the base year
E is the number of business events (births, deaths, or moves)
n is the number of years over which the events occurred

Note that the death and move events produce negative rates, reflective of the loss of businesses from time t to t+1.

TABLE 6.3
Business Death Rates by Type

1990-1994 Business Deaths

				Business Size			Not Modeled ----------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	253	106	58	40	10	6	0	1	0	474
Retail	162	108	70	48	10	1	0	0	0	399
Service	422	93	55	43	7	5	1	1	0	627
Govt/Ed	17	1	2	3	0	1	0	0	0	24

Death Rates 1990-94

				Business Size			Not Modeled ----------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	0.434	0.331	0.249	0.231	0.172	0.207	NA	NA	NA	0.314
Retail	0.463	0.427	0.409	0.421	0.323	0.143	NA	NA	NA	0.316
Service	0.378	0.219	0.268	0.364	0.219	0.278	NA	NA	NA	0.303
Govt/Ed	0.405	0.143	0.154	0.167	0.000	0.000	NA	NA	NA	0.117

(* Note: Govt/Ed 100-249 was converted to 0 from 100, since it was based on only 1 establishment)

Annualized Death Rates

				Business Size			Not Modeled ----------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	-0.128	-0.091	-0.062	-0.056	-0.036	-0.039	NA	NA	NA	0.078
Retail	-0.119	-0.093	-0.080	-0.069	-0.045	-0.012	NA	NA	NA	0.079
Service	-0.107	-0.055	-0.062	-0.090	-0.048	-0.066	NA	NA	NA	0.076
Govt/Ed	-0.101	-0.011	-0.021	-0.013	0.000	-0.020	NA	NA	NA	0.029

TABLE 6.4
Business Birth Rates by Type

1990-1994 Business Births

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	431	117	87	41	12	5	1	1	0	695
Retail	177	127	108	50	9	0	0	0	0	471
Service	561	153	66	55	9	4	1	1	0	850
Govt/Ed	26	8	4	3	0	0	0	0	0	41

Birth Rates 1990-94

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	0.720	0.349	0.341	0.212	0.164	0.122	NA	NA	NA	0.460
Retail	0.435	0.379	0.439	0.259	0.150	0.000	NA	NA	NA	0.373
Service	0.484	0.331	0.272	0.401	0.231	0.190	NA	NA	NA	0.410
Govt/Ed	0.531	0.333	0.160	0.052	0.000	0.000	NA	NA	NA	0.199

Annualized Birth Rates

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	0.145	0.078	0.076	0.049	0.039	0.029	NA	NA	NA	0.115
Retail	0.094	0.084	0.095	0.059	0.036	0.000	NA	NA	NA	0.093
Service	0.104	0.074	0.062	0.088	0.053	0.045	NA	NA	NA	0.103
Govt/Ed	0.112	0.075	0.038	0.013	0.000	0.000	NA	NA	NA	0.050

6.5.2 Business Mobility Rates

The rate of intra-regional mobility, not including businesses that closed or moved out of the region, but including only those that moved to a different zone from 1990-94, form the basis for the mobility computations in the model. The move decision is applied based on these observed mobility rates by type, as shown below.

The following table summarizes the four-year and annualized intra-regional mobility rates for businesses by type.

TABLE 6.5
Business Intra-Regional Mobility Rates by Type

1990-1994 Business Moves (Intra-Region)

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	68	36	28	8	2	1	0	0	0	143
Retail	36	23	12	7	0	0	0	0	0	78
Service	138	64	23	13	1	0	3	0	0	242
Govt/Ed	15	0	2	2	1	0	1	0	0	21

Move Rates 1990-94

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	0.114	0.107	0.110	0.041	0.027	0.024	NA	NA	NA	0.095
Retail	0.088	0.069	0.049	0.036	0.000	0.000	NA	NA	NA	0.062
Service	0.119	0.139	0.095	0.095	0.026	0.000	NA	NA	NA	0.117
Govt/Ed	0.306	0.000	0.080	0.034	0.033	0.000	NA	NA	NA	0.102

Annualized Move Rates

				Business Size			Not Modeled ---------------------------			
	1-4	5-9	10-19	20-49	50-99	100-249	250-500	500-999	1000+	Total
Basic	-0.030	-0.028	-0.029	-0.011	-0.007	-0.006	NA	NA	NA	0.024
Retail	-0.023	-0.018	-0.012	-0.009	0.000	0.000	NA	NA	NA	0.015
Service	-0.031	-0.037	-0.025	-0.025	-0.006	0.000	NA	NA	NA	0.029
Govt/Ed	-0.087	0.000	-0.021	-0.009	-0.008	0.000	NA	NA	NA	0.025

6.5.3 Business Location and Building Type

6.5.3.1 Business Bid Function

The estimation of the bid functions for the basic, retail, and service sectors proved to be more difficult than for the residential counterpart. This observation is based on relatively lower goodness of fit measures, and more sensitivity of the results to the specification of the equations. Several variations of similar variables were constructed before relatively consistent and robust results were obtained. The variable definitions used in the bid price function are given in Table 6.6, and results of the business bid price estimation are shown in Table 6.7.

The models, as specified, explain approximately one-half of the variance in the observed bid prices. Localization effects were found to be significant for all three sectors based on the gross density of employment within the same industry in the zone. Using broader access measures of access to employment in the same industrial sector, however, a consistent finding emerged from the estimations for the service sector: while the within zone employment density of services bid prices up, more generalized access to larger concentrations of services caused a discounting of bids. This finding appeared to persist under several alternative specifications, and does not appear to be an artifact of the final specification. It is consistent with a pattern of overall decentralization of service businesses away from the traditional center, the CBD, and into smaller and more suburban centers. These findings conform well to Central Place Theory, as developed by Christaller. Proximity to retail employment appeared to consistently increase the bids of service firms, revealing either an inter-industry linkage or a co-location phenomenon.

Retail businesses appear to have very strong localization effects, with both the within zone retail gross employment density, and the more generalized access to retail employment across zones showing significant positive effects on bids. Retail was also the only sector for which the age effects remained significant in the final specification. The presence of a highway in the zone appeared to raise bids for retail businesses, though the significance of this effect is relatively low in the final specification.

The density effects were consistent with expectations. Service firms discounted the least for higher density, retail businesses discounted more, and businesses in the basic sector discounted the most. Both service and basic firms discounted access to the CBD, all else being equal, though the effect for basic firms is less statistically significant. This finding confirms that the model explains in a more general framework the determinants of location that once were embodied principally in access to the CBD, as predicted in the monocentric model.

The influence of land use composition was analyzed to account for land use externalities associate with industrial land, and found to be significant and negative for all three sectors. In addition, more retail land in a zone raised bids of service firms, as did access to retail employment.

Businesses discounted for other types of building space compared to office space, as appropriate to their preferences. Industrial space was generally discounted less than warehouse space, and retail was discounted less than industrial. The market supply effects were much stronger for businesses than in the residential models described earlier. The effects were highly significant, and the effect appeared to be strongest for service firms, less strong for retail, with basic firms showing the weakest effect. This may be the result of greater speculation in office and retail space, but this is difficult to determine with any certainty.

Table 6.6: Business Bid Price Variables

	Definitions
IndustrialDummy	Dummy variable for industrial building type
WarehouseDummy	Dummy variable for warehouse building type
RetailDummy	Dummy variable for retail building type
LnAccessIncome4	Log of access to households in the highest income group
PctAccessIncome4	High income households as a percentage of access to all households
EmpPopAccessRatio	Ratio of employment access to population access
lnAccessEmployment	Log of access to total employment
lnAccPop+Emp	Log of access to total employment and population
BasicGrossDensity	Basic employment in a zone per square mile
RetailGrossDensity	Retail employment in a zone per square mile
ServiceGrossDensity	Service employment in a zone per square mile
PctAccRetail	Retail employment as a percentage of access to total employment
PctAccService	Service employment as a percentage of access to total employment
lnSQFT	Log of the total square feet of commercial space of a particular type
lnAge	Log of building age
Density (Floor/Area)	Net density of the building type in a zone
PctIndustrialLand	Percent of developed land in a zone in industrial use
PctRetailLand	Percent of developed land in a zone in retail use
CBDTime	Travel time to the CBD, in minutes
HWY	Dummy variable for presence of a highway in a zone

Table 6.7: Business Bid Price Estimation Results

	SERVICE	RETAIL	BASIC
INTERCEPT	0.5826	-0.7054	-2.6015
	(0.317)	-(0.437)	-(0.681)
IndustrialDummy	-0.5763	0.1113	-0.0099
	-(3.518)	(0.584)	-(0.114)
WarehouseDummy	-0.8486	-0.6661	-0.5980
	-(8.701)	-(5.299)	-(8.117)
RetailDummy	-0.5156	-0.1912	-0.4726
	-(12.757)	-(4.013)	-(6.879)
LnAccessIncome4	0.4026		
	(2.139)		
EmpPopAccessRatio	2.0151		
	(6.116)		
PctAccessIncome4		0.3458	
		(3.964)	
lnAccessEmployment			0.4188
			(1.370)
lnAccPop+Emp		0.1414	
		(1.126)	
BasicGrossDensity			1.02E-04
			(6.782)
RetailGrossDensity		4.75E-05	6.48E-05
		(4.850)	(3.486)
ServiceGrossDensity	3.694E-06		
	(2.950)		
PctAccRetail	0.0526	0.0464	0.0723
	(4.788)	(3.933)	(3.638)
PctAccService	-0.0451		
	-(4.628)		
lnSQFT	-0.2930	-0.1563	-0.1906
	-(18.855)	-(9.245)	-(8.019)
lnAge		-0.1203	
		-(3.469)	
Density (Floor/Area)	-0.1558	-0.3690	-0.6631
	(4.225)	-(6.485)	-(5.448)
PctIndustrialLand	-0.0035	-0.0025	-0.0062
	-(2.504)	-(2.607)	-(5.386)
PctRetailLand	0.0084		
	(8.305)		
CBDTime	0.0883		0.0466
	(4.913)		(1.593)
HWY		0.0571	
		(1.268)	
N	1056	603	458
Adj. R^2	0.50	0.42	0.50

6.5.3.2 Logit Estimation of Business Location Choice and Building Type

As in the residential models described earlier, the fitted bid price functions were used to generate estimates of the consumer surplus of each alternative, and were included in a logit specification that included only the consumer surplus estimate and the log of the size variable. We pool all businesses for the logit estimation of location choice. The results are shown below.

Table 6.8: Logit Estimation Results for Business Consumer Surplus

Variable	Coefficient	Z (b/s.e)
Consumer Surplus	3.18E-02	1.768
LnSize	1.60E-02	1.479

Log-Likelihood estimated:	-6693
Log-likelihood with no coefficients:	-6824

These results, like the bid price estimation, show somewhat lower significance than the counterpart residential results, but are generally consistent. This may result from a combination of substantially smaller degrees of freedom, higher uncertainty about the prices of commercial space (based on assessed values), variability in the size of the businesses, and the aggregation of businesses into less homogeneous sectors. In spite of these limitations, the business bid price models explain half of the variation in bid prices, and the consumer surplus logit estimates provide consistent results to use in predicting location choices. Further historical validation will be necessary to learn more about the ability of the model to capture key influences on location choices and prices.

6.5.4 Residential Mobility Rates

The mobility rates of households by type were computed using the household database constructed through the synthetic baseline population method. The identification of movers originates from the census question asking whether residents lived at their current address five years earlier. Negative answers to this question indicate that the household moved into the residence some time during the past five years. Although we would prefer to have a population universe at the beginning of the five-year period as the base for the calculation, this approach uses an end-of-period population universe to estimate mobility rates, which is a reasonable approximation. In other words, some of the movers identified in this way were located outside the region five years prior, and some that were in the region five years earlier are no longer in the region. So, unlike our business database, which allowed the identification of specific businesses that were present in each of two years, from which we could identify the subset that remained in the region but moved, comparable data do not exist for households.

The movers identified in the household database were compared to the total households of each type to compute a five-year mobility rate. It is likely that this approach underestimates the mobility of very mobile household categories, that may have moved more than once during the five year period, but this bias is not anticipated to cause significant problems.

The mobility rates for each household type are presented in Table 6.9. Note that the mobility rates decline from close to 100 percent over five years for households in the first age category (18-29), to close to zero percent for households with an age of head age 65 or older. This is consistent with common expectation, and highlights the importance of accounting for these differences. The rates are computed using the same compound growth rate used to compute business events (births, deaths, and moves).

Table 6.9
Mobility Rates by Household Type

Age	Income	Hhsize	Child	Hholds	Move5	Move5Tot	AnnualMove
1	1	1	0	2263	0.98	2218	-0.541
1	1	2	0	1610	1.00	1610	-1.000
1	1	2	1	125	1.00	125	-1.000
1	1	3	0	320	1.00	320	-1.000
1	1	3	1	247	0.99	245	-0.601
1	1	4	0	42	0.98	41	-0.541
1	1	4	1	116	1.00	116	-1.000
1	1	5	0	60	1.00	60	-1.000
1	1	5	1	80	1.00	80	-1.000
1	2	1	0	358	0.99	354	-0.601
1	2	2	0	940	0.98	921	-0.541
1	2	3	0	203	1.00	203	-1.000
1	2	3	1	240	0.96	230	-0.470
1	2	4	0	158	1.00	158	-1.000
1	2	4	1	106	1.00	106	-1.000
1	2	5	0	6	1.00	6	-1.000
1	2	5	1	18	1.00	18	-1.000
1	3	2	0	83	0.96	80	-0.470
1	3	3	0	81	1.00	81	-1.000
1	3	3	1	16	1.00	16	-1.000
1	3	4	0	20	0.95	19	-0.445
1	3	4	1	6	1.00	6	-1.000
1	3	5	0	28	1.00	28	-1.000
1	4	4	1	16	1.00	16	-1.000
2	1	1	0	3481	0.87	3028	-0.316
2	1	2	0	1738	0.91	1582	-0.370
2	1	2	1	580	0.81	470	-0.252
2	1	3	0	169	0.98	166	-0.541
2	1	3	1	1142	0.84	959	-0.282
2	1	4	0	93	1.00	93	-1.000
2	1	4	1	499	0.62	309	-0.093
2	1	5	1	456	0.82	374	-0.262
2	2	1	0	3013	0.75	2260	-0.197
2	2	2	0	3094	0.79	2444	-0.233
2	2	2	1	564	0.76	429	-0.206
2	2	3	0	546	0.73	399	-0.180
2	2	3	1	1888	0.67	1265	-0.132
2	2	4	0	85	0.75	64	-0.197
2	2	4	1	3087	0.65	2007	-0.116
2	2	5	0	8	0.38	3	0.103
2	2	5	1	1741	0.61	1062	-0.086
2	3	1	0	592	0.71	420	-0.164
2	3	2	0	2902	0.73	2118	-0.180
2	3	2	1	55	0.35	19	0.132
2	3	3	0	942	0.74	697	-0.189
2	3	3	1	1842	0.60	1105	-0.078
2	3	4	0	211	0.56	118	-0.047
2	3	4	1	3446	0.55	1895	-0.039
2	3	5	0	124	0.74	92	-0.189

Age	Income	Hhsize	Child	Hholds	Move5	Move5Tot	AnnualMove
2	3	5	1	1590	0.61	970	-0.086
2	4	1	0	128	0.59	76	-0.070
2	4	2	0	497	0.77	383	-0.215
2	4	3	0	6	0.00	0	0.000
2	4	3	1	310	0.87	270	-0.316
2	4	4	1	483	0.55	266	-0.039
2	4	5	0	43	1.00	43	-1.000
2	4	5	1	254	0.54	137	-0.032
3	1	1	0	1740	0.62	1079	-0.093
3	1	2	0	809	0.62	502	-0.093
3	1	2	1	110	0.78	86	-0.224
3	1	3	0	87	0.67	58	-0.132
3	1	3	1	171	0.66	113	-0.124
3	1	4	1	118	0.69	81	-0.148
3	1	5	1	83	0.95	79	-0.445
3	2	1	0	1794	0.55	987	-0.039
3	2	2	0	2675	0.36	963	0.122
3	2	2	1	103	0.80	82	-0.242
3	2	3	0	317	0.30	95	0.185
3	2	3	1	469	0.47	220	0.024
3	2	4	0	28	0.00	0	0.000
3	2	4	1	374	0.20	75	0.320
3	2	5	0	6	0.00	0	0.000
3	2	5	1	427	0.64	273	-0.109
3	3	1	0	465	0.51	237	-0.008
3	3	2	0	3827	0.42	1607	0.067
3	3	2	1	39	0.97	38	-0.501
3	3	3	0	1128	0.33	372	0.152
3	3	3	1	733	0.50	367	0.000
3	3	4	0	302	0.00	0	0.000
3	3	4	1	978	0.56	548	-0.047
3	3	5	0	188	0.64	120	-0.109
3	3	5	1	504	0.22	111	0.288
3	4	1	0	180	0.86	155	-0.304
3	4	2	0	837	0.31	259	0.174
3	4	3	0	179	0.00	0	0.000
3	4	3	1	118	0.14	17	0.438
3	4	4	0	149	0.64	95	-0.109
3	4	4	1	198	0.44	87	0.049
3	4	5	0	25	0.00	0	0.000
3	4	5	1	186	0.59	110	-0.070
4	1	1	0	4532	0.35	1586	0.132
4	1	2	0	1702	0.42	715	0.067
4	1	3	0	42	0.00	0	0.000
4	1	4	1	1	0.00	0	0.000
4	1	5	1	1	0.00	0	0.000
4	2	1	0	1997	0.43	859	0.058
4	2	2	0	4212	0.33	1390	0.152
4	2	3	0	385	0.17	65	0.373
4	2	3	1	5	0.00	0	0.000
4	2	4	0	143	0.89	127	-0.342
4	3	1	0	460	0.42	193	0.067
4	3	2	0	1369	0.22	301	0.288

Age	Income	Hhsize	Child	Hholds	Move5	Move5Tot	AnnualMove
4	3	3	0	370	0.55	204	-0.039
4	3	3	1	256	0.89	228	-0.342
4	3	4	0	17	0.00	0	0.000
4	3	4	1	12	0.00	0	0.000
4	3	5	1	126	0.72	91	-0.172
4	4	1	0	41	0.00	0	0.000
4	4	2	0	448	0.49	220	0.008
4	4	3	0	62	0.00	0	0.000
4	4	4	0	32	0.00	0	0.000

6.5.5 Household Birth and Death Rates

As noted above, unlike the business database with complete inventories of business establishments in two years that can be compared, no comparable data exists for households. Although it would be possible to assume that the household type distribution remains constant over time, proportionally expanding or contracting in response to changes in the aggregate population of the region, this is not likely to adequately reflect changing demographics of the region. In particular, the rapid inmigration of new, and often younger, households is not likely to be well captured.

The mobility rates presented in the preceding section, given the method of estimation, actually represent a composite of inmigration and new household formation within the region. Unfortunately, these two rates cannot be separately identified from these data (or any other available data). We approximate birth rates by household type, then, with these mobility rates, acknowledging that they are likely to be somewhat skewed towards younger households, that have not only higher rates of new household formation and rates of inmigration to the region, but also higher rates of intra-region mobility.

Data with which to estimate the combined rate of household dissolution and outmigration from the region, which we label the household ‘death rate,’ are also unavailable. We would expect that households with a head of household aged 65 or older would have a higher attrition rate than other households, through mortality or loss from the modeled housing market to group quarters housing (nursing homes). By assuming constant ‘death’ rates across household types, however, we may offset the skewing of birth rates towards younger households.

The demographic transition module applies the birth and death rates in an iterative fashion, scaling the household distribution until the aggregate population control total is reached. We do not have adequate data to estimate these component rates adequately, nor to compare the predicted shifts in the distributions to observed shifts. We expect to assess this component further in Phase 3 of this project.

6.5.6 Household Location and Housing Type

6.5.6.1 Household Bid Functions

The variable definitions are presented in Table 6.10, and results of estimation of the bid price functions of households stratified by market segments by income level and age of children in Table 6.11.

These results provide strong support for the core hypotheses described in this section. Taken together, the model explains approximately three-fourths of the variation in the bid prices of these household market segments. In addition, the segmentation of the market by income and presence of children is borne out by informal comparison of coefficients across market segments, and is substantiated by more rigorous Chow tests.

In almost all cases, the results had the expected signs and were significant at the five- percent level. Compared to single-family housing, we find consistent discounting of bids for duplex/quadplex and multifamily housing. Density, the inverse of lot size, is consistently negative and significant in all but two cases. Access to employment is consistently significant and positive, as is access to shopping[4]. Age depreciation was reflected in lower bids, with a trend that higher income households discounted for age more heavily than lower income households. A consistent pattern also emerged from the income composition of the neighborhood, with all household types discounting for higher percentages of the two lowest income levels, and increasing bids for neighborhoods with greater concentration in the highest income level. This pattern of coefficients supports the housing filtering hypothesis, and the underlying conversion of upward social mobility into residential location choices in more affluent neighborhoods. The wealthiest households will tend to outbid for the newest housing with the highest concentration of wealth, and lower income households will move up through the vacancy chain as affluent households move into new housing.

After accounting for the access to employment and shopping, proximity to the central business district is discounted in bids for most household types. This discounting perhaps reflects negative externalities associated with proximity to the center, such as localized congestion, noise, school quality, or crime, or other factors not included in the model.

The relative preference of households with children for neighborhoods with higher proportions of households that have children appears to be generally supported, but with an interesting trend across income levels. Lower income households tend to bid higher for neighborhoods with higher proportions of children, while the highest income households tend to discount their bids somewhat at higher concentration of households with children.

---

[4] Access to shopping was measured with a value of four on the exponent of the logsum composite utility of travel, compared to an exponent of one for employment access. This reflects more localized accessibility to shopping opportunities. Note that this exponent value is inconsistent with the theoretical range of values for the composite utility of travel to shopping, given a nested logit formulation of a combined housing and travel simulation. The model is not presently structured as a nested logit, however, and this term merely indicates a more localized weighting of travel utility than the exponent of one used for access to employment.

Table 6.10: Household Bid Price Variables

	Definitions
Residential 2-4	Dummy variable for housing type residential with 2-4 units (duplex, triplex or quadplex)
Multi-family	Dummy variable for housing type multi-family, with 5 or more units
lnAccEmployment	Log of accessibility to total employment, with an exponent on the logsum of 1
lnAcc4Retail	Log of accessibility to retail employment, with an exponent on the logsum of 4
Density (units/acre)	The net density in units per acre of a particular housing type in a zone
lnUnits	Log of the number of housing units of a particular type in the zone
lnAge	Log of the average age of the buildings of a type in a zone
PctIncome1	Percent of households in a zone in the lowest income group
PctIncome2	Percent of households in a zone in the second lowest income group
PctIncome4	Percent of households in a zone in the highest income group
PctChild	Percent of the households in a zone that have one or more children
PctLandIndustrial	Percent of the developed land in the zone that is in industrial use
PctLandResidential	Percent of the developed land in a zone that is in residential use
TimeToCBD	Travel time to the Central Business District, in minutes

Table 6.11: Household Bid Price Functions

	INCOME GROUP 1		INCOME GROUP 2		INCOME GROUP 3		INCOME GROUP 4	
	Child	No Child	Child	No Child	Child	No Child	Child	No Child
Intercept	0.8661	5.0712	0.8730	3.3327	4.9405	5.5321	7.2061	4.1270
	(0.759)	(5.170)	(0.680)	(3.227)	(7.243)	(8.915)	(3.197)	(1.163)
Residential 2-4	-0.4297	-0.4815	-0.4507	-0.5162	-0.4179	-0.5848		-0.7776
	-(15.306)	-(19.994)	-(15.398)	-(22.857)	-(9.869)	-(30.252)		-(6.979)
Multi-family	-1.0447	-1.0189	-1.1022	-1.0711	-1.1099	-1.3607	-0.9856	-1.8252
	-(27.161)	-(41.734)	-(20.692)	-(33.888)	-(9.894)	-(35.988)	-(4.170)	-(20.402)
lnAccEmployment	0.8089	0.4326	0.7912	0.6155	0.4593	0.4198	0.3329	0.6557
	(8.081)	(5.045)	(6.845)	(6.694)	(7.167)	(7.059)	(1.619)	(2.020)
lnAcc4Retail		0.0307	0.0077	0.0075	0.0347	0.0087	0.0955	0.0403
		(3.427)	(0.931)	(0.954)	(3.983)	(0.999)	(5.799)	(1.537)
Density (units/acre)	-0.0063	-0.0053	-0.0091	-0.0061	-0.0310	-0.0018	-0.0128	-0.0020
	-(5.488)	-(9.786)	-(4.530)	-(6.963)	-(7.605)	-(1.557)	-(2.700)	-(0.592)
lnUnits	-0.0016	-0.0270	-0.0056	-0.0271	-0.0011		-0.1389	-0.0351
	-(0.131)	-(2.850)	-(0.532)	-(3.104)	-(0.094)		-(6.510)	-(1.202)
lnAge	-0.0929	-0.0789	-0.0791	-0.1416	-0.1789	-0.1770	-0.3714	-0.5391
	-(3.775)	-(4.484)	-(3.229)	-(7.672)	-(7.008)	-(8.486)	-(9.261)	-(9.385)
PctIncome1	-0.0131	-0.0096	-0.0142	-0.0102	-0.0123	-0.0107	-0.0103	-0.0064
	-(12.603)	-(10.906)	-(15.290)	-(11.828)	-(12.604)	-(11.475)	-(4.937)	-(1.893)
PctIncome2	-0.0145	-0.0161	-0.0157	-0.0140	-0.0166	-0.0137	-0.0178	-0.0084
	-(12.006)	-(14.971)	-(14.684)	-(14.921)	-(14.184)	-(13.167)	-(10.116)	-(3.419)
PctIncome4	0.0045	0.0098	0.0075	0.0157	0.0030	0.0080	0.0019	0.0094
	(1.642)	(4.505)	(3.600)	(8.996)	(1.738)	(4.924)	(0.861)	(2.803)
PctChild	0.0032	0.0026	0.0059	0.0027	0.0014	-0.0020	-0.0061	-0.0144
	(3.445)	(3.211)	(7.029)	(3.376)	(1.501)	-2.0500	-(3.863)	-(5.798)
PctLandIndustrial	-0.0057	-0.0108	-0.0051	-0.0097	-0.0029	-0.0057		-0.0188
	-(6.241)	-(15.680)	-(6.077)	-(14.347)	-(2.852)	-(5.292)		-(4.819)
PctLandResidential	0.0011		0.0027		0.0053	0.0031	0.0099	0.0039
	(1.732)		(4.944)		(9.612)	(5.870)	(12.323)	(2.971)
TimeToCBD	0.0204	0.0126	0.0187	0.0129			0.0160	0.0181
	(2.642)	(2.006)	(2.552)	(2.033)			(1.377)	(0.964)
# of Obs	1352	2432	1681	2878	1413	2085	438	508
R-Square =	0.76	0.79	0.73	0.73	0.69	0.74	0.76	0.73

The relative bids for this attribute within each income level suggest consistency in households with children bidding higher than those without children, but the income trend remains. One potential explanation for this trend is that neighborhoods with a high proportion of households with children are a fairly middle-class phenomenon, which represents an attraction for lower income households, and a deterrent for the highest income households.

The land use mix in a neighborhood was found to be significant and reasonably consistent, with a higher percentage of the developed land in a zone in residential use prompting higher bids, and more industrial land associated with discounting. The preference for residential land, and its associated characteristics, increased with income. The distaste for industrial land appeared to be more significant for households with children than those without.

There were some exceptions to the consistency of the results. The market supply effect, measured by the log of housing units, was negative in all but one case, but varied in significance across household groups. This variable was dropped from the one case in which it was positive. Similarly, exceptional signs were found on residential land for childless low and low-middle income households, which might reflect their preference for multi-family housing, but for policy analytical purposes a negative coefficient on residential land is problematic, and was dropped. Travel time to the CBD was dropped for income group three, in which it was insignificant, and for childless households, negative.

6.5.6.2 Logit Estimation of Residential Location Choice and Housing Type

The fitted bid functions described in the preceding section were used to generate estimates of the consumer surplus of each alternative, and were included in a much simpler logit specification that included only the consumer surplus estimate and the log of the size variable.

Since the estimation of consumer surplus for all households makes them directly comparable, and we expect that households of all types compete in the housing market according to their consumer surplus, we pool all households for the logit estimation of location choice. The results are shown below.

Table 6.12: Logit Estimation Results for Residential Consumer Surplus

Variable	Coefficient	Z (b/s.e)
Consumer Surplus	4.73E-05	6.748
LnSize	2.30E-02	4.156

Log-Likelihood estimated:	-70047
Log-likelihood with no coefficients:	-81592

These results provide confirmation of the basic structure of the model, with expected signs and significance on the two terms. The greater the consumer preference, the more likely a consumer is to choose the option. The larger the number of underlying alternatives within an aggregate choice (zone), the more likely a consumer is to choose it, holding constant the consumer surplus of the alternatives.

6.5.7 Land Development and Redevelopment

The implementation of the developer component requires the assembly of all of the relevant inputs to the module:

- Base parcel database with acreage, land value, improvement value, units, sqft, land use
- GIS overlays for environmental constraints and UGB:
    - Slope over 25%
    - Wetlands
    - Stream Buffers
    - Floodplains
    - Utility line easements
    - Urban Growth Boundary
- Hard Construction Costs by building type
- Soft Construction Costs by Building type

In addition to these data, a density equation is estimated for each building type, as a function of land prices. The density function is estimated from parcels that were developed between 1990 and 1994, using multiple regression estimated with Ordinary Least Squares. The results for the density functions are presented in the following table.

TABLE 6.13
Density of New Construction

Buiding Type	Dep. Var.	N	Constant	t-stat	Ln(Lv/Ac)	t-stat	R2
Single-Family	Units/Acre	2925	-11.24	-18.33	1.43	27.34	0.204
Residential 2-4 Unit	Units/Acre	145	-59.69	-8.12	6.23	9.88	0.404
Multi-Family	Units/Acre	8	-22.80	-0.63	3.08	0.98	0.119
Industrial	FAR	7	-0.93	-1.31	0.11	1.64	0.311
Warehouse	FAR	40	-1.16	-2.40	0.14	3.15	0.202
Retail	FAR	79	-0.54	-0.69	0.08	1.15	0.016
Office	FAR	28	-3.47	-3.15	0.35	3.60	0.324

Ln(lv/Ac) is the natural log of the land price of the developed parcel.

We document each of the remaining data inputs in the following sections.

6.5.7.1 Base Parcel Database

The parcel data used in this analysis, as noted earlier, comes from the LCOG 1994 metropolitan parcel database, in Arc/Info format. Although it initially lacked some of the needed attributes, these were acquired and linked to the database during the project, as documented in the section on database development, and the appendix documenting data cleaning procedures. This data cleaning remains less than complete, as will be evident from some of the following data. It is likely that it would not be cost-effective to attempt to reach 100% cleanup of such a database. Nonetheless, the results of the analysis of these data suggest that they are sufficiently clean to be usable for the purposes of this model application.

The following tables document the characteristics of parcels classified into each of the modeled building types, and compares the full inventory of buildings to those constructed during 1990-94. The sample of buildings constructed during the 1990-94 time frame is used to estimate the hard construction costs for new development of each building type, as well as providing valuable insight into the pattern of densities of new and older construction, by building type.

TABLE 6.14
Development Characteristics: Single Family Residential

All Parcels

Single-Family	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	50985	0.49	0.01	0.04	0.11	0.16	0.20	0.26	0.78	5.55	178.70
Land Value	50985	24476	250	8070	10950	15690	20620	26210	46020	74380	24118512
Improvement Value	50805	83187	200	18390	32580	55670	72450	99540	161390	241820	4751540
Total Value	50805	106934	1100	35170	49090	74000	93370	124680	199280	304030	5311310
Impval/Landval	50805	3.93	0.00	0.64	1.60	2.80	3.66	4.67	6.58	9.29	527.31
Impval/Sqft	49470	55.09	0.40	19.16	32.07	47.00	55.26	62.73	76.69	89.37	6243.45
Impval/Unit	50695	81371	28	15520	30810	54680	71640	98510	159280	234370	1304380
Landval/Acre	50783	50783	10	7162	35517	71137	98279	130256	231957	449391	2588637
Units/Acre	50985	5.69	0.00	0.15	1.33	3.91	5.04	6.17	9.43	30.30	190.48
FAR	49470	0.17	0.00	0.01	0.05	0.12	0.15	0.20	0.32	0.72	5.76

1990-1994

Single-Family	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	2884	0.43	0.02	0.08	0.12	0.15	0.18	0.23	0.45	5.07	116.29
Land Value	2884	28252	700	7560	12260	16800	23600	32635	61670	75960	170190
Improvement Value	2884	136050	11340	28080	61750	94240	121570	165075	253380	348560	750650
Total Value	2884	164302	21390	45940	79740	112360	144470	197090	312760	427750	831560
Impval/Landval	2884	5.53	0.42	1.22	2.60	4.00	5.17	6.30	8.68	13.60	157.03
Impval/Sqft	2884	69.87	5.12	15.50	37.67	63.09	71.08	79.33	91.30	110.60	177.69
Impval/Unit	2881	135744	11340	28080	61630	94040	121200	164660	253240	348560	750650
Landval/Acre	2881	143771	84	5463	50480	99050	126231	166597	283641	449514	1835565
Units/Acre	2884	5.56	0.00	0.20	2.22	4.32	5.55	6.63	8.35	13.55	41.84
FAR	2884	0.23	0.00	0.01	0.10	0.18	0.22	0.27	0.40	0.61	1.62

TABLE 6.15
Development Characteristics: Residential 2-4 Unit

All Parcels

Residential 2-4	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	4053	0.22	0.04	0.07	0.10	0.15	0.19	0.23	0.33	0.85	8.10
Land Value	4053	22137	590	8940	10650	14710	19120	24840	43440	62790	776510
Improvement Value	4039	87645	110	27080	43800	68380	82070	102360	144340	184190	1460490
Total Value	4039	109818	12810	48900	63100	86480	101800	125350	175330	223440	1912580
Impval/Landval	4039	4.64	0.01	0.71	1.54	3.28	4.31	5.72	8.39	11.14	54.90
Impval/Sqft	3963	44.05	0.34	16.30	25.48	37.40	43.52	49.50	61.64	79.45	377.78
Impval/Unit	4002	42927	55	10420	18797	32770	40145	50045	74200	112220	311890
Landval/Acre	4051	120367	239	31377	54123	77611	98407	132737	278938	462643	705052
Units/Acre	4053	12.15	0.00	0.00	5.27	8.54	10.79	13.99	24.13	38.97	82.58
FAR	3963	0.26	0.01	0.06	0.13	0.19	0.24	0.30	0.47	0.68	1.20

1990-1994

Residential 2-4	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	143	0.18	0.08	0.09	0.10	0.13	0.15	0.21	0.27	0.36	1.06
Land Value	143	19573	8020	8590	11820	14920	17710	26420	27750	42370	43380
Improvement Value	143	116053	30490	46200	79620	93960	108970	134420	177310	261930	272000
Total Value	143	135626	45410	67950	97590	114710	124730	150500	205820	292980	305120
Impval/Landval	143	6.56	1.07	1.09	3.13	4.42	6.43	7.83	10.67	14.08	26.58
Impval/Sqft	143	57.44	15.71	26.83	33.04	43.79	54.49	60.96	102.96	141.33	377.78
Impval/Unit	140	60459	11550	15245	39810	46965	54410	67223	114190	157070	175570
Landval/Acre	143	129294	17363	22960	61002	86348	101506	145878	268882	309131	336561
Units/Acre	143	12.84	0.00	0.00	4.19	9.01	13.40	15.30	20.14	25.48	26.77
FAR	143	0.33	0.04	0.07	0.10	0.23	0.29	0.42	0.63	0.70	0.77

TABLE 6.16
Development Characteristics: Multi-Family Residential

All parcels

Multi-family	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	976	0.94	0.00	0.01	0.02	0.16	0.25	0.59	4.80	10.10	27.60
Land Value	964	72866	22.6	22.6	4510	18735	45485	70330	248920	704797	1765250
Improvement Value	897	458537	750	3540	25080	80750	170350	395900	1869060	5132100	11614330
Total Value	897	531753	2390	3562	32300	118370	215470	466620	2175210	5440300	12689910
Impval/Landval	897	11.02	0.01	0.14	0.99	2.99	5.52	8.30	21.80	156.50	156.55
Impval/Sqft	160	94.83	1.28	10.00	12.94	30.81	32.09	46.86	302.79	1189.00	4447.00
Impval/Unit	841	25117	125	1846	7960	16010	21228	26827	46610	95199	965051
Landval/Acre	886	173315	134	12017	34812	76385	149418	235085	421495	530035	1288468
Units/Acre	976	36.80	0.00	0.00	0.00	15.29	29.96	42.53	91.74	198.20	1245.00
FAR	190	0.49	0.00	0.00	0.01	0.10	0.36	0.78	1.34	1.74	1.92

1990-1994

Multi-family	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	12	0.57	0.12	0.12	0.12	0.15	0.19	0.71	2.28	2.28	2.28
Land Value	10	39301	11190	11190	11190	17250	19885	50730	123792	123792	123792
Improvement Value	9	315399	70670	70670	70670	138650	158570	638549	725040	725040	725040
Total Value	9	353730	85670	85670	85670	149840	200360	747560	762341	762341	762341
Impval/Landval	9	10.21	3.13	3.13	3.13	5.16	8.63	10.61	32.20	32.20	32.20
Impval/Sqft	9	135.32	30.95	30.95	30.95	33.24	40.87	293.87	389.60	389.60	389.60
Impval/Unit	7	40862	31714	31714	31714	35335	37974	45778	53212	53212	53212
Landval/Acre	9	106805	12480	12480	12480	65554	109593	137450	230629	230629	230629
Units/Acre	12	11.15	0.00	0.00	0.00	3.95	12.56	16.39	22.94	22.94	22.94
FAR	12	0.30	0.02	0.02	0.02	0.10	0.23	0.51	0.65	0.65	0.65

TABLE 6.17
Development Characteristics: Industrial

All parcels

Industrial	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	331	8.28	0.03	0.07	0.18	0.52	1.37	4.93	33.43	93.91	321.72
Land Value	331	152232	810	2350	5190	24240	57180	148480	497340	1299740	6336500
Improvement Value	216	2288510	610	1210	6090	82805	241480	797375	6513000	27191360	2.02E+08
Total Value	216	2489690	7560	8940	33390	137400	318880	984060	6938560	27899280	2.08E+08
Impval/Landval	216	11.82	0.01	0.02	0.12	1.26	3.43	7.24	21.05	54.98	1237.34
Impval/Sqft	165	25.83	0.01	1.52	3.47	11.83	18.79	29.74	73.68	165.76	166.11
Landval/Acre	326	48541	729	1389	5714	22128	39669	59907	118673	170729	522537
Units/Acre	331	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.04	2.64	19.35
FAR	177	0.29	0.00	0.00	0.02	0.11	0.24	0.37	0.78	2.14	2.89

1990-1994

Industrial	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	7	1.17	0.38	0.38	0.38	0.58	0.63	1.10	3.92	9.92	3.92
Land Value	7	47089	10880	10880	10880	31130	37970	57750	111710	111710	111710
Improvement Value	7	358800	89190	89190	89190	125230	214780	600850	799940	799940	799940
Total Value	7	405888	100070	100070	100070	156880	272530	638820	911650	911650	911650
Impval/Landval	7	7.85	3.72	3.72	3.72	3.96	7.16	10.39	15.82	15.82	15.82
Impval/Sqft	7	31.25	20.74	20.74	20.74	24.85	26.86	44.81	45.04	45.04	45.04
Landval/Acre	7	48650	28474	28474	28474	28798	50615	54419	92091	92091	92091
Units/Acre	7	0.86	0.00	0.00	0.00	0.00	0.00	1.72	2.65	2.65	2.65
FAR	7	0.26	0.10	0.10	0.10	0.20	0.26	0.32	0.40	0.40	0.40

TABLE 6.18
Development Characteristics: Warehouse

All parcels

Warehouse	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	550	1.91	0.02	0.06	0.14	0.32	0.79	1.55	5.50	14.49	143.27
Land Value	550	97517	580	4760	10930	27900	56355	113450	273790	817430	1875730
Improvement Value	533	393313	520	5550	13810	78480	162130	363800	1664030	3649330	8789380
Total Value	533	491300	1100	19760	45970	114250	222230	457750	1914260	4577150	9047590
Impval/Landval	533	6.49	0.01	0.08	0.35	1.60	3.32	5.67	13.31	27.35	868.10
Impval/Sqft	489	22.52	0.04	1.28	4.25	11.32	16.48	24.39	45.94	143.01	849.53
Landval/Acre	546	92127	162	1125	21746	50351	77731	119988	214414	316751	471544
Units/Acre	550	0.23	0.00	0.00	0.00	0.00	0.00	0.00	61.00	5.10	36.59
FAR	491	0.46	0.01	0.02	0.06	0.20	0.37	0.53	1.20	2.95	4.35

1990-1994

Warehouse	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	28	3.35	0.10	0.10	0.14	0.41	0.87	1.73	11.27	47.83	47.83
Land Value	28	75054	9230	9230	12470	19850	49145	122930	198200	243860	243860
Improvement Value	28	570326	4300	4300	21290	150685	410965	634325	2098180	2330000	2330000
Total Value	28	645381	34480	34480	63380	163525	447285	731810	2294430	2528200	2528200
Impval/Landval	28	7.97	0.06	0.06	1.61	4.29	7.20	10.83	17.66	19.36	19.36
Impval/Sqft	28	29.27	1.14	1.14	7.74	21.82	29.48	34.18	55.66	63.36	63.36
Landval/Acre	28	70913	1124	1124	4144	45412	64340	83577	168741	189979	189979
Units/Acre	28	0.57	0.00	0.00	0.00	0.00	0.00	0.22	4.09	5.04	5.04
FAR	28	0.39	0.05	0.05	0.05	0.15	0.37	0.45	1.14	1.51	1.51

TABLE 6.19
Development Characteristics: Retail

All parcels

Retail	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	1701	0.98	0.01	0.05	0.09	0.20	0.34	0.71	4.16	10.31	75.62
Land Value	1701	143804	500	5470	13940	35880	69090	134080	430110	1374980	10551900
Improvement Value	1605	278323	140	690	8060	45860	101670	209120	916130	3684880	41245684
Total Value	1605	426375	8110	22040	42620	102520	180500	344090	1393730	5059540	51797584
Impval/Landval	1605	3.00	0.00	0.01	0.14	0.73	1.51	2.74	6.22	16.37	925.18
Impval/Sqft	1486	33.75	0.09	0.51	5.37	12.67	22.02	37.47	86.22	193.54	1262.70
Landval/Acre	1692	231686	519	13037	37907	108884	203412	309804	533822	587681	826565
Units/Acre	1701	1.24	0.00	0.00	0.00	0.00	0.00	0.00	4.17	34.54	120.20
FAR	1508	0.49	0.00	0.01	0.04	0.14	0.27	0.52	1.72	3.86	9.84

1990-1994

Retail	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	53	1.08	0.13	0.13	0.18	0.32	0.65	1.14	4.81	5.04	5.04
Land Value	53	182526	9050	9050	21710	46860	122340	229930	585570	1213270	1213270
Improvement Value	53	552507	10890	10890	22500	114900	354960	591500	2056290	2697540	2697540
Total Value	53	735034	45310	45310	64850	272600	462600	815260	2781490	3269560	3269560
Impval/Landval	53	4.41	0.18	0.18	0.32	1.48	2.50	4.83	13.28	37.70	37.70
Impval/Sqft	53	84.17	4.54	4.54	10.56	27.87	53.71	86.22	171.34	1262.70	1262.70
Landval/Acre	53	217872	33322	33322	37678	108500	205039	305907	561439	571326	571326
Units/Acre	53	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.20	12.13	12.13
FAR	53	0.35	0.00	0.00	0.04	0.11	0.21	0.35	1.42	1.84	1.84

TABLE 6.20
Development Characteristics: Office

All parcels

Office	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	818	1.00	0.02	0.05	0.07	0.16	0.28	0.62	2.79	9.28	114.56
Land Value	817	117191	500	3100	10810	28940	55200	115780	361920	978500	8345000
Improvement Value	769	474168	500	1810	15310	56537	123620	300000	1839150	4092670	51331310
Total Value	768	595850	9720	16870	46340	100660	193570	436420	2161340	4856760	59676310
Impval/Landval	768	4.76	0.00	0.05	0.28	1.22	2.40	4.60	12.49	49.63	446.26
Impval/Sqft	699	38.62	0.38	2.45	8.55	17.88	29.85	45.47	89.71	201.96	806.76
Landval/Acre	810	239463	240	14326	31442	94968	208861	360183	533182	569551	901689
Units/Acre	818	2.00	0.00	0.00	0.00	0.00	0.00	0.00	13.30	31.92	200.00
FAR	710	0.63	0.00	0.01	0.07	0.18	0.34	0.63	2.16	5.49	16.92

1990-1994

Office	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	25	1.11	0.09	0.09	0.10	0.23	0.65	1.54	2.78	6.34	6.34
Land Value	25	197620	7810	7810	8000	17155	46290	184220	1031120	1563610	1563610
Improvement Value	25	1194678	11400	11400	28460	66730	304560	1064790	6287270	8722270	8722270
Total Value	25	1392298	21250	21250	36270	96450	420790	1081946	6603450	10285880	10285880
Impval/Landval	25	9.30	0.67	0.67	1.16	3.33	4.83	10.73	20.07	62.07	62.07
Impval/Sqft	25	42.05	8.04	8.04	10.78	13.28	31.17	5028.00	101.51	144.16	144.16
Landval/Acre	24	171851	16488	16488	29343	35949	89171	291254	522738	527765	527765
Units/Acre	25	1.41	0.00	0.00	0.00	0.00	0.00	0.00	12.87	19.96	19.96
FAR	25	0.78	0.08	0.08	0.08	0.14	0.33	0.48	3.03	6.17	6.17

TABLE 6.21
Development Characteristics: Special Purpose

All parcels

Special purpose	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	2629	2.95	0.00	0.00	0.02	0.14	0.33	1.24	9.40	38.49	643.40
Land Value	2629	101568	100	450	500	4070	29990	68540	307200	1164380	29610780
Improvement Value	1292	791977	160	500	1620	6755	77505	401400	2857010	14079853	70353360
Total Value	1292	964826	770	6760	18110	59345	162120	524695	3275480	15144580	70394570
Impval/Landval	1292	6.91	0.00	0.01	0.05	0.12	1.23	5.75	25.09	60.40	1707.19
Impval/Sqft	631	60.11	0.01	0.59	6.01	22.26	41.11	62.49	128.20	310.80	2187.20
Landval/Acre	2551	131701	32	214	1077	13747	58471	203448	517842	584927	1250000
Units/Acre	2629	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.80	80.97
FAR	685	0.52	0.00	0.00	0.02	0.11	0.23	0.52	1.36	4.30	53.67

1990-1994

Special purpose	Obs	Mean	Min	1%	5%	25%	50%	75%	95%	99%	Max
Acres	31	2.13	0.08	0.08	0.12	0.85	1.73	3.31	5.71	6.72	6.72
Land Value	31	258488	8280	8280	18010	50860	126550	348660	1037140	1249310	1249310
Improvement Value	31	1290919	7800	7800	10690	337560	978930	1992710	4416530	4845000	4845000
Total Value	31	1549408	25810	25810	94680	372360	1381420	2291820	5030900	5453670	5453670
Impval/Landval	31	8.53	0.05	0.05	0.10	1.97	5.96	11.68	26.06	37.27	37.27
Impval/Sqft	30	68.41	0.89	0.89	1.46	54.17	65.00	91.06	121.45	234.75	234.75
Landval/Acre	31	175279	8900	8900	10973	35052	117960	310170	464058	530166	530166
Units/Acre	31	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.17	8.38	8.38
FAR	31	0.36	0.01	0.01	0.02	0.08	0.21	0.57	1.04	1.29	1.29

6.5.7.2 GIS overlays for environmental constraint layers

The following GIS layers were obtained from LCOG in Arc/Info format and used as environmental constraints that can be applied by the user through the user interface to the model:

- Slope over 25%
- Wetlands
- Stream Buffers
- Floodplains
- Utility line easements
- Urban Growth Boundary

These layers were combined with the base parcel layer through polygon overlay in Arc/Info, using the union function. This processing split parcels into sub-parcel polygons that had unique combinations of the parcel characteristics and each of the constraint layers. As an example, if a particular parcel had a floodplain boundary bisecting it, and no other environmental boundary crossed it, then it would be split into two records in the database, one representing the portion of the parcel within the floodplain, and the second representing the portion outside the floodplain. Area calculations for the components are computed as well.

6.5.7.3 Hard Construction Costs by building type

Hard construction costs by type are drawn from the analysis of new construction documented in tables 5.9-5.16. The improvement value per residential unit, and the improvement value per commercial square foot, for buildings constructed between 1990 and 1994 serve as the basis for the hard construction cost estimates. Since it is apparent in these tables that there are substantial outliers in each building type, the mean is in some cases substantially above the median improvement value per unit or per sqft. We use the median values to be more representative of the building type, and adopt these as the initial estimates for hard construction costs. These costs are entered in the user interface, and can be modified by the user with more current or accurate information, if available.

6.5.7.4 Soft Construction Costs by Building type

Initial estimates of soft construction costs were based on average values from several sources, but these should be considered provisional estimates. As these soft costs represent policy assumptions that the user may wish to test, the values are again editable in the user interface, for replacement with values that the user wishes to apply to a particular scenario.

Soft cost adjustment factors by zone allow the user to specify policies that apply spatial variation in the soft construction costs, to account for such policies as development impact fees or tax abatements. The default value for each zone is 1, so the user may input specific zones and adjustment factors that should be modified from this default, through the user interface.

References

Alonso, W. (1964) **Location and Land Use**. Harvard University Press: Cambridge, MA.

Anas, A. (1982) **Residential Location Markets and Urban Transportation: Economic Theory, Econometrics, and Policy Analysis with Discrete Choice Models**. Academic Press: New York.

Barrett, G.V. and J.P. Blair (1988). How to conduct and analyze real estate market feasibility. Van Nostrand Rheinhold: New York.

Beckman, R. J., K.A. Baggerly, and M. D. McKay (1995) 'Creating Synthetic Baseline Populations', paper presented to at the Transportation Research Board Annual Meeting, Washington, D.C.

Brown, L. A. and E. G. Moore (1970) 'The intraurban migration process: a perspective,' **Gegrafiska Annaler, Series B**, 1-13.

City of Eugene (1997). Fee Estimating Guide: Building Permits and Systems Development Charges. City of Eugene: Eugene, Oregon.

Clark, W. A. V. and J. Onaka (1985) 'An empirical test of a joint model of residential mobility and housing choice,' **Environment and Planning A, 17**

DePalma, A. and M. Ben-Akiva (1981) Interactive dynamic modeling of residential location choice, Umea, Sweeden, Paper presented at the International Conference on Structural and Economic Analysis and Planning in Time and Space.

Ellickson, B. (1981) 'An alternative test of the hedonic theory of housing markets,' **Journal of Urban Economics 9**, 56-79.

Galster, G. C. (1977) 'A bid-rent analysis of housing market discrimination,' **American Economic Review 67**(2), 144-155.

Garret M. and M. Wachs (1996) **Transportation Planning on Trial: The Clean Air Act and Travel Forecasting**. Sage Publications: Thousand Oaks, CA.

Hanushek, E. and J. Quigley (1978) 'An explicit model of residential mobility,' **Land Economics 54**, 411-429.

Harris, B. 'Urban simulation models in regional science,' **Journal of Regional Science 25**(4), 545-567.

Harvey, G. and E. Deakin

Kain, J. F. (1985) 'Computer simulation models of urban location,' in **Handbook of Regional and Urban Economics, Volume II**, Edited by E. S. Mills, Elsevier Science Publishers B.V.

Kain, J. F. and W. C. Apgar (1987) **Housing and Neighborhood Dynamics: A Simulation Study**, Harvard University Press: Cambridge, MA.

Lancaster, K. J. (1966) 'A new approach to consumer theory,' **Journal of Political Economy 74**, 132-157.

Lee, D. B. (1994) 'Retrospective on large-scale urban models,' **Journal of the American Planning Association 60**(1), 35-40.

Lerman, S. R. (1977) 'Location, housing, automobile ownership and mode to work, a joint choice model,' **Transportation Research Record 610**, Washington, D.C., 6-11.

Massey, D. and B. Mullen. (1984) 'Processes of Hispanic and Black Spatial Assimilation,' **American Journal of Sociology 89**:4 836-873.

Martinez, F. (1992) 'The bid-choice land use model: an integrated economic framework,' **Environment and Planning A 24**, 871-885.

McFadden, D. (1973) ‘Conditional logit analysis of qualitative choice behavior,’ in P. Zarembka, ed., **Frontiers in Econometrics**, Academic Press: New York.

McFadden, D. (1978) ‘Modelling the choice of residential location in spatial interaction theory and planning models,’ in: A. Karlqvist, L. Lundqvist, F. Snickars and J.W. Weibull, eds., **Spatial Interaction Theory and Planning Models**. North Holland: Amsterdam, 75-96.

McFadden, D. (1984) ‘Econometric analysis of qualitative response models,’ in Z. Griliches and M. Intriligator, eds., **Handbook of Econometrics**, Vol II. North Holland: Amsterdam, 1395-1457.

Mills, E. S. (1967) ‘An Aggregative Model of Resource Allocation in a Metropolitan Area,’ **American Economic Review 57**,197-210.

Muth, R. F. (1969) **Cities and Housing**, University of Chicago Press: Chicago.

Onaka, J. (1983) ‘A multi-attribute housing consumption disequilibrium model of residential mobility,’ **Environment and Planning A** 15, 751-765.

Onaka, J. and W. A. V. Clark (1983) ‘A disaggregate model of residential mobility and housing choice,’ **Geographical Analysis, 15**, 287-304.

Paulley, N. J. and F. V. Webster (1991) ‘Overview of and international study to compare models and evaluate land-use and transport policies,’ **Transport Reviews 11**, 197-222.

Quigley, J. M. (1976) ‘Housing demand in the short-run: an analysis of polytomous choice,’ Explorations in Economic Research 3, 76-102.

Rosen, S. (1974) ‘Hedonic prices and implicit markets: product differentiation in pure competition,’ **Journal of Political Economy 82**, 34-55.

Southworth, F. (1995) A Technical Review of Urban Land Use-Transportation Models as Tools for Evaluating Vehicle Reduction Strategies,’ Report to U.S. Department of Energy.

Speare, A., S. Goldstein, and W. Frey (1975) **Residential mobility and migration and metropolitan change**. Ballinger: Cambridge, MA.

Strazheim, M. R. (1974) **An Econometric Analysis of the Urban Housing Market, National Bureau of Economic Research**: New York.

Van Lierop, W. F. J. and A. Rima (1982) ‘Towards an operational disaggregate model of choice for the housing market,’ Second Interim Report. The Free University: Amsterdam.

von Thünen, J. H. (1826) **Der Isolierte Staat in Beziehung auf Landwirtshaft und Nationalökonomie**. Hamburg.

Waddell, P. A. (1998a) Development and Calibration of the Prototype Metropolitan Land Use Model, Final Report to the Oregon Department of Transportation.

Waddell, P. A. (1998b) ‘UrbanSim: The Oregon prototype metropolitan land use model,’ forthcoming in the Proceedings of the 1998 ASCE Conference on Land Use, Transportation and Air Quality: Making the Connection, Portland, Oregon.

Waddell, P.A. (1998c) ‘Exploiting parcel level GIS in land use models,’ forthcoming in the Proceedings of the 1998 ASCE Conference on Land Use, Transportation and Air Quality: Making the Connection, Portland, Oregon.

Waddell, P.A. and M. Alberti (1998) ‘Integration of an Urban Simulation Model and an Urban Ecosystems Model,’ forthcoming in the Proceedings of the International Conference on Modeling Geographical and Environmental Systems with Geographical Information Systems, Hong Kong.

Wegener, M. (1995) ‘Current and Future Land Use Models,’ Paper presented at the Travel Model Improvement Program Land Use Model Conference, Dallas.

Wheaton. W. C. (1977) ‘A bid rent approach to housing demand,’ **Journal of Urban Economics 4**(2), 200-217.

Weiner, E. (1997) **Urban Transportation Planning in the United States: An Historical Overview**. U.S. Department of Transportation, DOT-T-97-24.

Williams, R. C. (1979) 'A logit model of demand for neighborhood,' in D. Segal, ed., **The Economics of Neighborhood**. Academic Press: New York, 17-42.

Wolpert, J. (1965) 'Behavioral aspects of the decision to migrate,' **Papers and Proceedings of the Regional Science Association**, 15, 159-169.

Appendix 1: State Policy Requirements

Consistency Between Transportation and Land Use Planning

Clearly the foremost requirement of new land use model design is that it provide a capacity to assess land use and transportation interactions, in order to develop consistent land use and transportation plans and policies. OTP Policy 2A, Land Use, requires that transportation systems serve the land uses identified in local comprehensive plans. TPR 660-12-045 (2)(g) requires that local governments adopt land use regulations that are consistent with identified functions, capacities, and levels of service on facilities as identified in transportation system plans. TPR 660-12-060 specifies that amendments to comprehensive plans and zoning and other ordinances be consistent with identified functions, capacities, and levels of service on facilities in transportation system plans. Consistency can be achieved by changing either land use or transportation plans or both. These policies go beyond the general requirements laid out in federal policies for land use and transportation planning.

The design of the land use models is based on the priority of this requirement, but within the constraint that new land use models be integrated with existing transportation models. The implication of the latter constraint is that completely integrated land use and transportation models lie beyond the scope of this project. The level of integration that will be attempted in this project is the implementation of feedback from the transportation models to the land use models. A series of accessibility measures will be developed to capture the influence of changes in multimodal accessibility on residential and employment location as well as on land use, density, and prices. In addition, the geographic level of detail in the land use models will be synchronized with that of the transportation models so that the two share the same zonal structure.

Consistency with Comprehensive Plans and Urban Growth Boundaries

A series of policies address aspects of consistency of transportation plans with local comprehensive land use plans and statewide planning goals. OTP Policy 2A, Land Use, requires that transportation plans and policies implement Oregon’s Statewide Planning Goals. OTP Policy 2G, Regional Differences, requires that the state transportation system plan recognize differences in regional and local land use and economic development plans throughout the state. TPR 660-12-030 requires that within urban growth boundaries, the determination of local and regional transportation needs shall be based upon population and employment forecasts and distributions which are consistent with the acknowledged comprehensive plan. It also addresses Goal 14, on urbanization, which requires that urban growth boundaries be based in part on the orderly and economic provision of public facilities and services. Community Design Benchmark #130 addresses the proportion of development that occurs inside urban growth boundaries.

Of particular relevance to the design of the land use models is the requirement that population and employment forecasts be consistent with the acknowledged comprehensive plan within urban growth boundaries. This requires that the land use models explicitly account for the constraints imposed by such plans in the form of allowable land uses and densities in particular. These constraints are addressed within the proposed model and data specifications in later sections. Policies to promote targeted development or redevelopment through particular incentives such as tax abatements or reduction in applicable development fees would need to be incorporated into the proposed developer activity land use model component. To the extent that adequate data on the costs of development and on applicable taxes and development fees can be collected, the feasibility of evaluating these impacts can be addressed.

The impact of changes in urban growth boundaries is one element of these policies that warrants further attention. There appears to be considerable interest in assessing the potential impacts of the urban growth boundaries on locational choices of businesses and households, and on land and housing prices. Within the prototype area of Eugene-Springfield, this issue manifests itself in the form of potential spillover to nearby satellite cities that fall outside the Eugene and Springfield UGBs, but within easy commuting distance. The proposed model design should be able to provide information on the potential impacts of UGB changes on these outcomes. In the Eugene-Springfield application, it will require extension of the data and transportation models to encompass these satellite cities.

It could be argued that facility and service plans, which influence the design of urban growth boundaries, should be explicitly incorporated into the land use models. Although this is likely to be the case, we propose that this be considered beyond the scope of the current project, since the impact of these plans should be reflected at least indirectly in the comprehensive plans and urban growth boundaries.

Minimize Development Pressures on the Urban Fringe

Related to the urban growth boundary and comprehensive plan policies are a set of policies that attempt to minimize the pressure on urban development outside the urban growth boundary. OTP Policy 2A, Land Use, directs the state to restrict assess from state facilities to rural or resource lands if access would encourage the development of activities incompatible with rural or resource uses. OTP Policy 2C, Relationship of Interurban and Urban Mobility, calls for interurban mobility through and near urban areas in a manner which minimizes adverse effects on land use.

TPR 660-12-035 (9) requires that transportation facilities proposed for the urban fringe show that the facility does not significantly reduce peak period travel time for the route or that the purposes of the project cannot be reasonably met by:

- improvements to transportation facilities and services within the urban growth boundary;
- transportation system management measures that do not significantly increase capacity; or
- transportation demand management.

TPR 660-12-045 (2)(a) on implementation of transportation system plans requires that local governments adopt access controls that limit development on rural lands to rural uses and densities.

Land Benchmarks #114 and #117 set goals for preserving agriculture and forestry lands. These are core benchmarks, central to Oregon’s strategy for the future. For agriculture the goal is that 95 percent of the land preserved for agriculture in 1970 have the same status in 1995 and 94 percent in future years. For forestry, the goal is 91 percent in 1995 and 90 percent in 2010.

The TPR defines the urban fringe as a five mile band outside the urban growth boundary of MPOs and a two mile band outside the urban growth boundary of urban areas with at least

25,000 residents. These policies are designed to keep the urban fringe rural in character and to preserve resource lands from urbanization. Transportation projects that reduce travel times to the urban fringe would have the opposite effect of encouraging urban development and are, therefore, restricted. Nonetheless, access between cities and from rural areas to cities is required and these access routes must pass through the urban fringe. Thus, the TPR outlines a strict set of conditions for projects that increase transportation capacity within the urban fringe. In 1992, 98 percent of the 1970 farmland base and 92 percent of the forestry land base was still preserved in that status. Thus, the benchmarks for resource lands are currently being met, but expansion of urban areas could change this.

These policies and standards require monitoring of type and intensity of development in the urban fringe and the measurement of the amount of land in agriculture and forestry. They require that alternatives to transportation facilities in urban fringe be considered. Thus, models must be able to compare the impacts of alternative routes, transportation management systems, and demand management programs in order to judge whether any of these alternatives are "reasonable." In order to accomplish this, the current land uses in agriculture, forests, and other "rural" uses would need to be available, and reflected in the accounting of absorption of land for future development. The feasibility of adding such land use categories to the land use models will be assessed on the basis of data availability.

Support Compact, Mixed Use Development Including Infill and Redevelopment

Goals of compact, mixed use development through infill and redevelopment are supported by various policies. OTP Policy 2B, Urban Accessibility, specifies that multimodal accessibility in urban areas support the development of compact, livable urban areas. Preference should be given to projects that support compact, infill development and mixed uses. TPR 660-12-030 (3)(a) requires that transportation needs analysis in metropolitan areas take into consideration planned infill and redevelopment which minimizes the need to expand urban growth boundaries.

The probability of infill or redevelopment can be influenced by land use and transportation policies, but the effects are likely to be subtle and complex. Infill or redevelopment occurs through the operation of the land market as developers evaluate the profitability of development, including development costs, demolition costs, anticipated demand for alternative improvement types and densities at the available locations, and the expected market price of such development. A developer module is specified for the proposed land use models, and will be structured to allow the estimation of these effects. The robustness of this component will depend on the availability and quality of data to support this component, as well as the relative priority of this policy issue. It is a very complex area and likely to be one that will require extended research to appropriately specify and measure the relevant developer behavior.

Evaluate Land Use Alternatives for Meeting Transportation Needs

TPR 660-12-035 (2) requires the evaluation of alternative land use designations, densities, and design standards to meet transportation needs in the Portland metropolitan area. Other areas may evaluate land use alternatives but are not required to do so. The Western Bypass Major Investment Study (MIS) in Washington County was one of the first MISs to include a land use alternative. The LUTRAQ alternative rearranged new development within the study area to put most employment growth and planned moderate and higher density residential development near transit. This section of the TPR requires that land use alternatives also be considered when developing the Transportation System Plan for the Portland metropolitan area.

Although this policy is directed at Portland specifically, it may be applied to other metropolitan areas at a later date. The implication for the land use model design is that it provide the user a capacity to specify alternative land use scenarios to interact with a particular transportation system plan. This will be incorporated into the user interface within the policy analysis module.

Limit Parking Supply in Metropolitan Areas

TPR 660-12-035 (2)(e) requires that the Portland metropolitan area’s land use alternative include maximum parking limits for office and institutional developments in order to reduce the amount of parking available. TPR 660-12-045 (5)(c) requires that metropolitan areas have a plan to reduce the number of parking spaces by 10 percent per capita over the next 20 years. This includes setting minimum and maximum parking requirements for new development and may include redevelopment of existing parking spaces. TPR 660-12-035 (7) specifies that the Land Conservation and Development Commission evaluate the progress toward reducing parking spaces every five years.

Parking is a major consumer of land as well as a place to store motor vehicles between trips. The TPR requires that all metropolitan areas reduce the supply of parking by setting maximum, as well as minimum, parking requirements. In order to reflect the progress towards these requirements, and to assess their impact, measures of parking supply and costs will be required, and the availability and cost of parking would need to be incorporated into the business location component and possibly into the developer component. A recently completed TCRP study by Ken Duecker assessed the impact of parking costs on travel mode and business location, and may provide some insights into ways to incorporate this influence into the land use models. We propose this assessment as a research area for involvement of Portland State University.

Access Management

OTP Policy 2C, Relationship of Interurban and Urban Mobility, sets state policy to provide mobility through and near urban areas in ways the minimize the effects on land uses and urban travel. OTP Policy 4G, Management Practices, makes it state policy to maximize the use of existing facilities before building new ones. Access management is one method for maintaining the primary function of a facility. TPR 660-12-045 (2)(a) on implementation of transportation system plans requires that local governments adopt access controls consistent with the function of the highway.

Access management assures that state highways whose main function is to carry long distance freight and passengers between cities can effectively maintain the function even in urban areas. Access management regulates the number, spacing, type, and location of access points. Alternate routes and modes for local trips should be considered. Land use and transportation plans should avoid dependence upon the state system for direct access to development.

Access points to state highways and other major facilities may influence certain types of business and residential location, or developer activity. In order to measure such influences, the design of accessibility measures would need to reflect proximity to these access points. An assessment of the influence of this effect could be incorporated into the calibration process by experimentation with alternative measurements and for different types of businesses and developer types. This is proposed as a second or third priority policy, to be evaluated only after higher priority policy requirements are addressed satisfactorily.

Statewide Economic Development

OTP Policy 2F, Rural Mobility, establishes state policy to provide access and mobility in rural areas. OTP Policy 3B, Linkages to Markets, emphasizes transportation linkages for goods and passengers as a means of attracting a larger share of international and interstate trade. TPR 660-12-030 (1)(c) specifies that transportation needs includes the movement of goods and services to support planned industrial and commercial development consistent with Statewide Planning Goal 9, Economic Development. Economy Benchmark #195 sets a goal of 50 percent of all jobs in the state outside the Portland tri-county area in 1995. This percentage should increase to 52 percent by 2010. This is a core benchmark. Economy Benchmark #196 sets a goal of 26 percent of all jobs in the state outside the Portland tri-county area and the Willamette Valley in 1995 and thereafter. This is an urgent benchmark requiring immediate attention in order to meet long-term goals.

These policies emphasize that transportation investments must serve all parts of the state, not just congested urban areas. The Benchmarks emphasize the need to retain and expand economy activity outside the most populous areas in the Portland metropolitan area and the Willamette Valley. The transportation system moves goods and services as well as people, and the models developed need to incorporate these flows. These policies require models that includes flow of goods and services between regions of the state and to markets in other states and other counties.

OTP Policy 3E, Tourism, calls for a transportation system that supports intrastate, interstate, and international tourism and improves access to recreational destinations. Economic Benchmark #200 sets goals for the tourism industry. Several factors are listed such as total payroll and proportion of visitors from other counties, but the only established targets are for total visitor industry expenditures by non-Oregonians. The goal is $1.91 billion by 1995 rising to $2.63 billion in 2010.

OTP Policy 3D encourages the development of intermodal freight and passenger hubs to enhance competitiveness, improve rural access, and promote efficient transportation. Intermodal hubs encourage the use of the most efficient mode for each leg of the trip. Marine ports, airports, and truck to rail intermodal facilities all facilitate these transfers. Passenger hubs such as airports facilitate the transfer of travelers from one mode to another.

These policy requirements, broadly linked to statewide economic development, should be addressed in the design of the statewide models. It is not proposed that they be explicitly incorporated into the design of the metropolitan land use models, other that through the use of outputs from the statewide model as potential input to the metropolitan land use models in the form of regional control totals.

Transportation System Efficiency

This policy requires an efficient transportation system, by maximizing the net full benefits of the transportation system. It requires that full economic, social, energy, and environmental costs and benefits be identified, quantified, and priced when possible so they can be included in the evaluation of alternatives. There are likely to be several outcomes related to land use that are relevant to this policy. Impacts of transportation on land use, density, and prices could be accounted for in the land use models, but requires that a land market component be designed into the models, and that alternative transportation scenarios can be compared on the basis of these land use impact measures. The proposed specifications will address this.

The efficiency policy also states that users (should) face prices that reflect the full costs of their transportation choices. This includes automobile emissions charges based on vehicle miles traveled (VMT) and relative emissions, congestion charges based on time of day and type of vehicle, parking charges in urban areas, and user charges such as tolls, gas taxes, and weight-mile charges. To the extent that transportation costs influence land use, prices, and the location choices of households and businesses, there is a potential for capturing the impact in the land use models. In order to do so, travel costs as well as times would need to be incorporated into land market, residential location, and business location components. These could be incorporated into the land use models either through generalized cost functions or as separate travel cost measures in the accessibility measures used in the household and business location modules. Such measures will be evaluated during the calibration of the models.

Multi-Modal Accessibility

OTP Policy 2B, Urban Accessibility, requires the state to define minimum levels of service and assure balanced, multimodal accessibility to existing and new development within urban areas...OTP Policy 2E, Minimum Levels of Service, specifies that the state will define minimum levels of service for all modes and all users.

Transportation Benchmark #138 has set targets of 1.3 transit hours of service per capita per year in Oregon metropolitan areas by 1995, 1.5 by 2000 and 1.7 by 2010. In addition, this benchmark addresses the proportion of arterial and collector streets in urban areas that have adequate pedestrian and bicycle facilities, but the Progress Board has not yet set targets or measured performance.

Since these are principally benchmarks of transportation targets their relevance to the land use models is limited. The impact of multi-modal accessibility on residential and business location, would be reflected in accessibility measures as described above, but are not likely to accommodate non-motorized travel modes such as bicycle and pedestrian accessibility within the current project since the current travel models do not address these modes. The benchmark target that deals with pedestrian and bicycle facilities could be incorporated into residential location models to reflect the influence of urban design considerations such as these on residential location choices. This would require the development of data in the base year on pedestrian and bicycle facilities, and their update in each forecast year. It is not likely that this would be feasible within the current project, but could be considered for later extension.

A related question is how level of service, e.g. levels of congestion, influence residential or business location. Although little research has been done on the congestion influence on location choices, level of service measures could be incorporated as zonal attributes in the residential and business location models to assess their significance. This will be identified as an optional component of the land use model development that will be explored as time and resources permit. By the same token, an evaluation component should be designed into the models to generate measures of as many of the benchmarks as possible.

Demand and Congestion Management

OTP Policy 1B, Efficiency, includes an action item to use demand management to reduce single occupant vehicle use during peak periods to increase the efficiency of the highway system. OTP Policy 4G, Management Practices, makes it state policy to maximize the use of existing facilities before building new ones. Methods for maximizing use include demand management and congestion management.

Transportation Benchmark #139 calls for an increase in the percentage of people who commute to work during peak periods by modes other than single occupant vehicles (SOV). The goals are 29 percent non-SOV by 1995, 33 percent by 2000, and 38 percent by 2010. Transportation Benchmark #137 sets a standard for the proportion of all limited-access highways in metropolitan areas that are not heavily congested at peak periods. The target is for 60 percent of limited-access highways to have a volume service flow ratio less than 0.17 during peak periods.

Demand and congestion management programs such as employer carpooling incentives, transit subsidies, and related measures will influence the relative costs of alternative modes, including shared ride modes. To the extent that accessibility measures are multi-modal, there is the potential for measuring the impact of such measures on residential location choices, though the magnitude of any such effects on long-term location choices are likely to be small and perhaps insignificant. Other programs such as telecommuting or staggered work hours have the potential to influence residential or conceivably even business location, though the state of research suggests that such influences lie beyond the current work scope.

Reduction in Automobile Reliance and State VMT Per Capita

Several policies are targeted towards reducing automobile reliance and VMT. TPR 660-12-035 (3)(e) requires that the transportation system avoid reliance on any one mode of travel and reduce reliance on the automobile. TRP 660-12-035 (4) specifies that metropolitan areas reduce per capita vehicle miles of travel (VMT) by 20 percent within 30 years and sets intermediate milestones. TPR 660-12-035 (5) requires that regional and local transportation plans set measurable benchmarks for achieving reduced VMT. Section (6) requires that MPOs and local governments evaluate progress every five years, and section (7) requires that the Oregon Land Conservation and Development Commission review progress every five years as well. TPR 660-12-045 (5) requires local governments in metropolitan areas to amend their land use plans to reduce reliance on the automobile. Land use plans must allow transit oriented development along transit routes, support demand management programs, and reduce the supply of parking. Transportation Benchmark #140 sets goals for yearly per capita VMT in metropolitan areas. The goal for 1995 is 7,864 miles and declines to 7,443 by 2010.

The principal linkage to the land use model specification of these policies is in the incorporation of land use plan components that are intended to address transit oriented development, demand management programs, and parking supply. Transit oriented development within land use plans will typically address allowable land uses and densities in the vicinity of transit stations or corridors. The land use models should be designed to reflect the constraints imposed by land use plans with regard to land uses and densities. These constraints should be easily modified in alternative scenarios to be of maximum usefulness to planners. One mechanism to facilitate this is by designing a policy module that has a GIS component to allow land use plan information to me edited and reviewed graphically. As noted earlier, a land market component will need to be incorporated into the land use models in order to address these constraints and their consequences not only for locational choices but also for land and housing prices.

Appendix 2: Local Policy Requirements

Many of the policy requirements for metropolitan land use models are provided through the state policies outlined above. In this section we review briefly some of the local policy considerations that apply to MPOs in Oregon, focusing in particular on the metropolitan area selected as the prototype application site for testing the initial land use models: the Eugene-Springfield metropolitan area, for which Lane COG is the designated MPO.

The current direction for the transportation plan for Eugene-Springfield is outlined in *Eugene-Springfield Transportation System Plan (TransPlan) Update: Policy Makers' Decision Package for Draft Plan Direction* (November, 1996). The current comprehensive plan is documented in *Eugene/Springfield Metro Area General Plan: 1987 Update.* Through these documents and interviews with Lane COG staff, several policy issues were raised as priority issues:

Development of Behavioral Land Use Procedures

The current land use forecasting procedures used by LCOG are based on the allocation of growth according to the availability of vacant land. There is currently no component to reflect demands for development from businesses of households, or the supply behavior of developers. There is also no feedback from the transportation models to the land use procedures. A behaviorally-based land use model is desired that would more realistically forecast land uses.

Relationship Between Highway Improvements and Business Location

The impact of planned highway improvements on business location choices is a local policy interest, and consistent with the basic state and federal policy mandates to examine such land use impacts and incorporate them into the transportation planning process. The proposed specifications should be able to address these kinds of basic planning requirements.

The Assessment of Nodal Development Plans

One of the dominant aspects of the comprehensive plan is its orientation towards the concept of a nodal development pattern intended to promote transportation efficiency, compact urban form, and increased transit use. It also promotes urban infill and redevelopment in areas deemed suitable. There is a desire to use the proposed land use models to assess the market potential for alternative configurations of these development nodes, based on interacting the land supply constraints and regulations imposed by the comprehensive plan (or alternative land use plan scenarios) with the developer activity, household location and business location modules that represent the private participants in the land market.

Infill and Redevelopment

A key component of the nodal development plan is the promotion of infill and redevelopment. This will require information on existing land and building values, and historical records of land conversion and development. These data appear to be available, with some limitations (most notably the absence of square footage of non-residential buildings). The initial design of the model is likely to be fairly simple with respect to infill and redevelopment behavior, accounting through decision rules within the developer activity module for the availability of land for redevelopment, such as a threshold ratio of building to land value below which a parcel is considered a candidate for redevelopment. These decision rules should be validated with local historical data.

The Role of Satellite Cities

Another issue that was raised is the concern about the spillover of residential population and possibly of businesses outside of the Eugene-Springfield metropolitan area and into nearby satellite cities such as Junction City, Coburg, Veneta, Pleasant Hill, Creswell, and possible Cottage Grove. The tentative decision was made to attempt to expand the study area within Lane County to cover these nearby satellite cities. It may be possible to evaluate a nested logit formulation for the household and business location modules that represents at the higher level a choice between the Eugene-Springfield urban growth boundary and all areas outside of that, with the selection of zones within the satellite cities of alternatively within the Eugene-Springfield UGB within the two respective branches. This will be proposed as a second priority assessment that could be evaluated during calibration if time and resources permit.

The Influence of Demographic Change

The increase in dual worker households, declines in household size, aging of the population, and changes in the income distribution are but a few of the demographic changes underway in Lane County and elsewhere. The implications of these changes for land use are potentially significant, and should be explored in the model specifications to the extent possible. We propose to stratify households using most of these household characteristics, and will be able to assess their significance during model calibration.

The Impact of Large Corporate Relocations

The upcoming relocation of Hyundai to Eugene, with potentially 3,500 employees at a computer chip manufacturing plant, may stimulate substantial secondary development of related and support businesses as well as residential development for the plant employees. The land use models should be able to incorporate information on such corporate locations and assess the secondary influence on other business and household locations. This can be done by providing a mechanism to insert user-specified employment into particular zones as part of the user interface within the policy module, and reflecting the influence of the business location in the residential and business location modules.

The Effect of CBD Parking Prices on Business Relocation Decisions

The use of parking policies in the CBD as a traffic management policy instrument could impact business location choices. The sensitivity of business location choices to this cost is an issue of local interest. As noted earlier, this is a potential research area but is not identified as a committed policy analytical capability in the prototype model.

Employment Location in Residential Areas

A trend towards increasingly dispersed employment location has been noted, with potentially significant quantities of employment locating in residential areas. The magnitude and nature of this employment is of potential concern for travel demands forecasting. The proposed specification of the business location models could include residential zones and land uses as allowable choices for small (e.g. less than 5 employee) business establishments, but the ability to estimate these propensities may be limited by the availability of adequate data. This issue will be explored as time permits once the basic business location models are estimated.