Land Use Scenario DevelopeR

Practical Land Use Model Using a Stochastic Microsimulation Framework

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Land use models are generally recognized as useful tools for forecasting land use inputs to transportation models and for analyzing the land use effects of transportation projects. Unfortunately, the complexity of most land use models gets in the way of their widespread use by planning agencies. The Land Use Scenario DevelopeR (LUSDR) incorporates most of the land use behavior and policy sensitivity desired in a land use model, yet it has a simple structure and manageable data requirements. LUSDR operates at the level of individual households and employment establishments and microsimulates location decisions of land developments. The model produces a synthetic population of households with the attributes of size, workers, age of household head, income, dwelling tenure, and dwelling type. Households are packaged into residential developments. Employment is calculated from workers and allocated to economic sectors, employment establishments, and business developments (e.g., shopping centers, office parks). Residential and business developments are allocated to zones by an iterative process that identifies candidate zones on the basis of land availability and plan compatibility, chooses zones by using a location model and reconciles land supply and demand in each zone through a bidding process. The model is being used in a long-range land use visioning study in a small metropolitan planning organization and is planned for use in a number of applications in Oregon.

The Land Use Scenario DevelopeR (LUSDR) is a new entrant into the field of land use models. The impetus for its development was to provide modeling support for a long-range urban growth study of a small metropolitan area. Although the pending model application influenced the design of the model, it did not establish constraints limiting the applicability of the model to urban growth studies. LUSDR may be used to provide land use forecasts for transportation modeling studies and may also be run in a connected manner with a transportation model to support a variety of integrated modeling studies. What sets LUSDR apart from other land use models, though, is its support for strategic planning and the assessment of uncertainty and risk. To understand this distinguishing capability, it is worthwhile to understand the project that initiated development of LUSDR.

DRIVER OF LUSDR DEVELOPMENT

LUSDR was developed for a study on the Rogue Valley metropolitan area, a relatively small, but rapidly growing, metropolitan area in Jackson County, Oregon. Seven cities and one unincorporated urban area are located in the metropolitan area boundary. The metropolitan planning organization (MPO) for the region is the Rogue Valley MPO.

Purpose of Study

The purpose of the growth study is to identify urban reserve lands that will allow the area to accommodate a doubling of the metropolitan area population. The cities within the area, like all cities in Oregon, have designated urban growth boundaries that determine which lands may be urbanized. Urban growth boundaries are one of the mechanisms in Oregon's statewide planning program to combat sprawl and conserve farmland and other important resources. These boundaries, however, are not static creations. Cities are required to expand them periodically to maintain a 20-year supply of urbanizable land. Urban reserves are the long-range supply of lands that urban areas may be expanded into as the need arises.

As might be expected, individual cities' decisions about where to grow have regional consequences. Given that a number of the cities in the metropolitan area have pro-growth attitudes, the sum of every city's desire for expansion is likely to exceed the amount of land needed in the region to accommodate growth and to result in excessive consumption of resource lands. Moreover, excessive sprawl can have adverse consequences for regional services like the state highway system. For these reasons, the region embarked on a multijurisdiction urban growth study called the regional problem-solving (RPS) study.

Role of LUSDR

LUSDR was developed to be used in combination with the regional transportation model to evaluate the potential transportation consequences of alternative land use patterns and transportation system additions. The modeling had the following objectives:

1. To develop a moderately large set of plausible future land use patterns consistent with the study goals,
2. To test the effects of this set of future land use patterns on the transportation system,
3. To identify the features of land use patterns that most affect transportation performance, and
4. To assist in identifying additions to the transportation network needed to serve future development of the urban reserves.

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LUSDR was developed as a stochastic microsimulation to facilitate the automatic generation of multiple scenarios subject to general specifications of potential urban reserve areas. The governments in the metropolitan area identified areas they would like to include within urban reserve areas and the general mix of uses (e.g., residential, commercial, industrial) they would like to achieve. This inventory was treated as a future land supply, and LUSDR was then run several dozen times to produce scenarios that vary in the arrangement of land uses but are consistent with the regional inputs, land use designations, and development location behavior. The scenarios show the variety of ways growth might occur if lands were made available as proposed. The regional transportation model was run for each scenario to compare the transportation effects.

LIMITATIONS OF URBAN LAND USE MODELS AND ADVANTAGES OF LUSDR'S APPROACH

Despite recurring criticisms (*1–3*), the theory and practice of urban modeling has advanced substantially since its beginnings in the 1950s. In addition, it is well recognized in planning and modeling circles that land use models are a desirable complement to transportation models. They can be useful for the following purposes (*4, 5*):

- Producing future land use forecasts needed for running transportation models,
- Analyzing cumulative and indirect effects of proposed transportation projects,
- Evaluating compliance with land use and transportation integration requirements of federal transportation and clean air laws,
- Considering more completely the economic effects of land use and transportation policies, and
- Facilitating integrated land use and transportation planning.

Limitations of Land Use Models

Although the technical capabilities of land use models have increased substantially, as have the computer capabilities for running them, only a small proportion of the urban areas that have transportation models also have land use models. Wegener (*6*) identified 12 integrated models in 1994 that were being used for research or application. More recently, Wegener (*7*) inventoried 20 models, of which fewer than a third have been used in multiple applications. Hunt et al. (*8*) described six operational urban land use transport modeling frameworks in 2005. Oregon was used as an example and, although transportation models and modeling practices in the state are advanced, only the Portland metropolitan area had an operational land use model (*9*) before the use of LUSDR in the Rogue Valley MPO area.

Some reasons why land use models have not been implemented in more areas harken back to the earlier criticisms of large-scale urban models. Land use models are complicated, are data hungry, and do not always produce good results at a scale that is disaggregate enough to be useful for more than broad policy studies.

Complexity

Although computing power and the capabilities of software have increased greatly over the past several decades, and much more data for model building are readily available in electronic form, land use model builders have used those advantages to build even more comprehensive land use models. Land use models are complicated in their designs, their data management requirements, and their programming. The technical challenges to building and implementing a land use model are substantial. Miller et al. (*10*) discuss these challenges with respect to ILUTE, an advanced urban microsimulation modeling system that is under development.

Long Run Times Limit Usability

The complexity of the models also limits their ability to be used for policy analysis. Significant expertise is required and long model run times are common. This limits the number of model runs that can be made for any project and severely limits the usefulness of the models. It is difficult to derive much benefit from an integrated modeling process if only a few model runs are made. Integrated modeling needs to be thought of as an experimental system that allows policies to be tested before they are put into place. However, this requires running the models many times to learn the causal linkages between policies and system performance and to make well-informed policy recommendations.

Unreliability at Disaggregate Level

A larger underlying problem of land use models is that they do not deliver reliable results at a level that is disaggregate enough to be useful for most transportation and land use studies. The Sacramento comparison test of three land use integrated models and the regional transportation model demonstrated this problem well (*11*). Although the models were built and calibrated using the same information and run on the same set of transportation scenarios, they produced different results. There were substantial differences in large-scale land use allocations and some of the transportation results varied in direction as well as magnitude. Although some of the differences in results could be related to differences in model calibration, they were also shown to be related to the different ways the models worked.

Strategic Planning Orientation of LUSDR

The philosophy underpinning LUSDR's design was influential in creating a model that substantially addresses the problems of land use models. This philosophy is simply that planning should be done strategically with explicit consideration of uncertainty. Society and the economy will change and affect urban development in many ways that it is not possible to predict. This was stated well with regard to the Sacramento model comparison.

> Predicting the future of a city is a bit of a fool's game: there is really no hope that a mathematical model can ever accurately predict what will happen 25 years in the future, given all the uncertainty in demographics, national economies, technological shifts, and social changes. If land use modelers could accurately predict the future form of a city, they would all spend their time on real estate speculation, not planning. (*11*)

The rational planning response to an uncertain future is to consider explicitly how robust various policy options are in responding to uncertainty. Plans should be viewed as courses of action that help position an urban area so that the public's goals are more likely to be achieved instead of as blueprints of the future. Analysis to support strategic planning needs to consider the uncertainty explicitly and needs to combine modeling with sensitivity analysis. Urban models need to represent urban areas as dynamic systems that may evolve along many different pathways and not as equilibrium systems moving toward certain outcomes. The important influence of path dependency on land use outcomes is leading some in the land use modeling profession toward microsimulation approaches. UrbanSim is representative of this approach to land use modeling (*12*). LUSDR is following this direction by combining microsimulation, detailed zone geography, and dynamic, instead of equilibrium, processes.

Modeling Completeness Versus Model Comprehensiveness

Modeling Completeness

An important condition for being able to incorporate uncertainty into modeling completely is that the models be run many times. Running a dynamic simulation just a few times is an incomplete modeling process and of little value for several reasons:

- Dynamic microsimulations require many runs to understand the range of behavior and to identify outliers.
- Understanding the strategic context of a decision requires sensitivity testing of the model's exogenous inputs. One advantage of a microsimulation model is to evaluate the gradient (elasticity) of response in a system involving nonlinear processes. However, this requires doing many model runs, altering one parameter at a time (*13*).
- Considering policy options requires that model runs be made with different policy inputs.
- A modeling process that is complete will have enough model runs to allow the modeler to consider the effects of dynamic model behavior, uncertainty of exogenous factors, and the relevant range of policy options. But carrying out a complete modeling process requires models that have reasonably short run times, which brings up the underappreciated trade-off between modeling completeness and model comprehensiveness.

Model Comprehensiveness

The term model comprehensiveness has been applied to models to describe how many elements of the urban system and how much behavior are incorporated in a model (*7*). Researchers working on integrated models have given much attention to model comprehensiveness, because more comprehensive models are better able to address the effects of policies on more parts of the urban system. The following attributes of an ideal comprehensive model have been proposed (*5*):

- Operating in 1-year time steps over time;
- Modeling land supply and usage at the parcel level;
- Explicitly representing building stock by type, price, and so forth;
- Including a full multimodal representation of the transportation system;
- Representing other services important to land development decisions;
- Modeling persons and households and the relationships between them;
- Modeling firms and their employment and location decisions;
- Including the decisions of public authorities;
- Representing most decisions as the result of market interactions;
- Modeling demographic processes endogenously;
- Modeling the most important regional economic processes endogenously;
- Modeling travel demand in an activity-based manner; and
- Modeling automobile ownership.

Trade-Off Between Comprehensiveness and Completeness

Comprehensiveness, however, brings with it complexity and greater model development and run costs. Even with great advances in computer technology, the ideal comprehensive microsimulation model is likely to take days to run on the computers most planning organizations are able to afford. Long run times guarantee that modeling studies using a very comprehensive model will be incomplete.

The trade-off between model comprehensiveness and modeling completeness needs to be addressed during the model design and development process. Every proposed addition to a model should be evaluated with respect to what information gains may come from making the model more comprehensive versus information that may be lost because fewer model runs may be done. This trade-off was considered in the design and implementation of LUSDR. LUSDR's simpler approach is similar to that taken by Venter et al. (*14*) for modeling the City of Johannesburg, South Africa, with respect to being a stochastic simulation, which generates a range of potential outcomes using a flexible low-cost modeling framework. LUSDR differs in several important respects, however. The Johannesburg land use model is predominantly a rule-based model, similar to UPlan (*15*), whereas LUSDR relies more on behaviorally based processes. Also, LUSDR treats residential and business developments as discrete units of development, whereas the Johannesburg model (as do most other land use models) treats individual households and units of floor space as units of development.

OVERVIEW OF LUSDR

LUSDR is a stochastic microsimulation of land development implemented in the R programming language. Households, employment establishments, and developments are simulated as individual agents that are allocated at the level of the transportation analysis zone (TAZ). Almost all the modeling processes are Monte Carlo processes, in which outcomes are derived by sampling from probability distributions. The probability distributions come from the following:

- Joint probabilities derived from cross tabulations of Census Public Use Microsample (PUMS) data,
- Terminal node probabilities from decision trees,
- Probabilities derived from inventory size distributions,
- Logit model probabilities, and
- Expert judgment of land use compatibilities used as probabilities.

The basic processes in LUSDR are presented in Figure 1.

Generating Households and Residential Developments

A synthetic set of households is generated from an exogenous forecast of population by age cohort. Households are created by placing

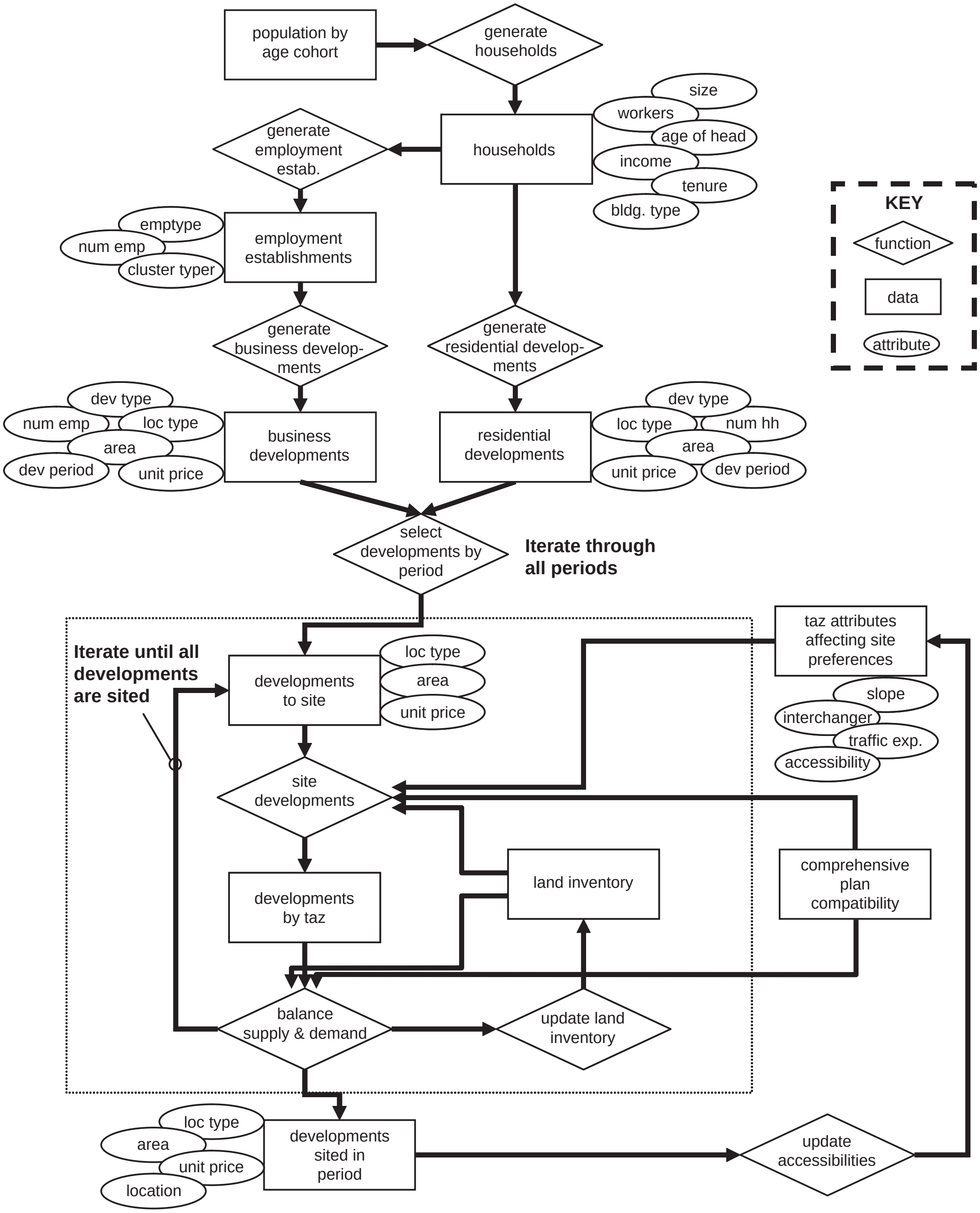

FIGURE 1 Overview of LUSDR structure.

persons by age group into households by size, workers, and age of the head of household. This is done through a straightforward Monte Carlo sampling process in which the number of samples equals the projected population. Each age cohort has its own sampling distribution derived from cross tabulations of PUMS person and household data. The resulting allocations of persons by age cohort to households by type are summed by household type and divided by persons per household by household size category to produce an array of households by household type. This array is then converted into individual household records.

Once individual households have been created with size, worker, and age characteristics, attributes of income, dwelling tenure, and building type are added to the household records. This is also done using a Monte Carlo process, but, in this case, the sampling distributions are the terminal node probabilities of decision trees. These decision trees were estimated from PUMS data using a conditional inference tree method for recursive partitioning (*16*).

Households are synthesized at the model-wide level, not at a TAZ level. The synthesized households are placed in geographic locations by assigning them to residential developments for the proper building type and then locating the residential developments. Developments are created for each building type by successively drawing from development size distributions for the respective type and then randomly assigning households identified as occupying the building type. The development size distributions were derived from local partition and subdivision records, tax assessment data, and census data. Residential developments are randomly assigned to development periods.

Generating Employment Establishments and Business Developments

Total employment is forecast from total household workers and the ratio of employment to workers in the region. The employment is split into employment sectors, at the two-digit North American Industrial Classification System level, and business development types by using joint probabilities derived from employment and property data. Employment establishments are created from employment totals by repeatedly sampling from employment establishment size distributions until all employment is accounted for.

Business developments are generated by aggregating employment establishments into development clusters. Clusters are generated by successively drawing from cluster size distributions and then randomly assigning to them employment establishments with the identified cluster type. Business developments are also identified as one of eight location types. This is done to produce simpler and more robust location models. Business developments are randomly assigned to development periods.

Locating Residential and Business Developments

Developments are allocated to TAZs in each development period. The allocation is based on consideration of land constraints, including environmental and regulatory constraints, location “preferences,” and prices (Figure 1). TAZ choices are made for each development in random order. These choices are the result of two steps. First, a set of candidate TAZs is identified based on the amount of available land in each comprehensive plan category in each TAZ. For a TAZ to be considered a candidate, sufficient land has to be available in comprehensive plan designations that permit the development. Second, a choice is made among the candidate TAZs using a Monte Carlo process in which the choice probabilities are generated from a location choice model for the type of development. Such models were estimated for each of the six residential development types and eight business development location types. The location choice model calculates the probability that development of the type is located in a TAZ based on TAZ characteristics, including slope, distance to the nearest freeway interchange, traffic exposure, local employment accessibility, regional employment accessibility, local household accessibility, and regional household accessibility.

After preliminary locations for all developments have been chosen, the model balances land supply and demand. This is done on the basis of land supply in each comprehensive plan category and the relative price each development is willing to pay. Median land prices for each type of development, derived from tax assessment data, are used for establishing the relative willingness to pay.

A preferred order of plan designations is identified for each development based on ratings of compatibility of each type of development with each type of comprehensive plan designation. Land in each plan designation is allocated iteratively to the largest development that is willing to pay the most until no more developments with that preferred plan category can fit into the remaining land area. For those developments that are priced out of their preferred plan category, an attempt is made to locate them in lower priority categories. As developments are located, the inventory of available land in the TAZ is updated. Developments that are outbid for all suitable plan categories in the TAZ are added to a list of developments that must be reallocated. For these developments, the process is repeated for identifying candidate TAZs, choosing a preferred TAZ and bidding with other developments for location in the TAZ. The process is repeated until all developments are successfully located.

Features That Reduce Model Complexity

To reduce complexity and run times but retain the most important behavioral elements, LUSDR departs from the comprehensive model ideal in a number of ways.

Simplified Household Models

LUSDR does not follow the ideal of simulating person and household transitions. LUSDR creates a population of households periodically during the modeling process by sampling from distributions that respond to changing age demographics. A person and household transition model does not appear to offer sufficient added benefit to justify the added complexity and cost for several reasons:

- There are well established methods for developing demographic forecasts.
- The practice of modeling household transitions is still in a formative state.
- It would be more efficient to do sensitivity testing of alternative demographic forecasts than to build and calibrate an internal demographic model.
- The land use and transportation policies that local governments and metropolitan areas are likely to evaluate have little to do with the internal dynamics of households.

Simplified Employment Establishment Models

LUSDR also does not microsimulate the internal dynamics of employment establishments. The study of such changes, also known as “firmography” is in its infancy (*17*). The firmographic approach simulates the growth, decline, and movement of individual businesses. None of the current operational land use–transport modeling frameworks reviewed by Hunt et al. (*8*) uses a firmographic approach. Either an aggregate equilibrium approach to the allocation of employment is used, or, in the case of UrbanSim, transitions are simulated at an individual employee level. LUSDR uses a partial firmographic approach by modeling employment establishments as whole units. This is an important feature because the path-dependent nature of land development is affected by the “lumpiness” of development. However, going further in a firmographic approach would be very expensive and risky, given the need for stronger foundations in basic research. The time required to develop and run a model of employment establishment dynamics would be better spent on improving sampling distributions and testing model response to altered distributions.

Focus on Development Location

LUSDR simplifies the microsimulation by focusing on locating developments instead of locating individual households and employment establishments. In the ideal microsimulation, individual households and employment establishment agents interact with the owners and developers of built space through markets. Location decisions are affected by relative prices, which reflect demand-and-supply relationships. Development decisions are influenced by prices and vacancy rates. Modeling these agents and their interactions correctly is a complicated, costly, and time-consuming undertaking.

LUSDR avoids this complexity by more closely relating household and business location decisions with development location decisions. The type of spaces that households and businesses occupy is determined at the household and business levels, respectively. This links households and businesses to the correct development types. These development types in turn have corresponding location models that were estimated from existing land use patterns. Because land use patterns are a function of the decisions of developers and the decisions of those who occupy the developments, models derived from existing land use patterns will reflect the combined effect of the household or business and developer decisions. The estimation of location models from existing development patterns simplifies the model development process.

This simplification has more significant trade-offs than the other simplifications. Modeling household and business location behavior can provide valuable information about changes in housing prices and rents that may result from policies. This information can also be used to model the changes in demand by building type as prices change. Finally, modeling household and business location behavior may help with simulating the segregation of households by income, which would have a significant effect on travel demand. The trade-off is worthwhile when LUSDR is planned to be used (smaller metropolitan and urban areas that are growing). Moreover, some of the limitations can be addressed in the LUSDR framework without creating household and business location models. These are addressed at the end of the paper.

Simplified Land Supply Approach

LUSDR also has a simplified approach to modeling land supply that operates at the TAZ level instead of at the parcel level. Parcel level modeling is a difficult undertaking stemming from the fact that parcels are not units of development. Parcels are legal units of land that may be bought or sold without government approval. With approval, they may be partitioned or subdivided into smaller units to be sold. This occurs regularly. Parcel boundaries are rarely dissolved to create larger parcels, but parcels may be combined in other ways to accommodate development. It is common for persons or corporations to own several adjacent parcels and to have a development that occupies several or all of the parcels they own. In addition, developments such as shopping malls often are built across disjoint ownerships through long-term leases or other agreements. Zero-lot-line building and zoning codes also allow development to occur so that multiple buildings act like coordinated developments. The intricacies of how parcels can be split and used in combination make parcel level modeling a substantial undertaking. Unless a parcel level approach accounts for the complexity of how properties may be split apart and used together, it is unlikely to be any more realistic than a zone-based approach that has a reasonably small zone size.

MODEL DEVELOPMENT

Model Development Platform

Model estimation, calibration, and implementation of LUSDR were done in the R programming language (*18*). In addition, a large portion of the data preparation was done using R. It has been used previously for implementing travel demand models for urban areas (*19*) and for tying together transportation and air quality models to produce air quality analysis (*20*). Implementation of the model in R simplified the process of data development, exploratory data analysis, and model estimation. The wide variety of statistical modeling methods available in R provided development flexibility. Because R is a full-featured programming language, model components could be moved directly from estimation to application. R's graphic features made it possible to develop custom plotting and mapping to display model outputs.

Data

The data used for developing and applying LUSDR for the RPS study were fairly modest. They included the following:

- Base-year households and employment by TAZ;
- Geocoded base-year employment data;
- Travel times from the regional travel demand model;
- Travel paths from the regional travel demand model;
- PUMS household and person files;
- Other census files such as household size, number of workers, age of household head, building type, and tenure;
- County tax assessment data [geographic information system (GIS) layer];
- County building polygon GIS layer;
- Inventory of subdivision and partition approvals by size (number of lots) for a 5-year period;
- Metropolitan area general comprehensive plan designations' GIS layer;
- Unbuildable lands' GIS layer;
- Proposed urban reserve areas' GIS layer; and
- Regional transportation plans' GIS layer.

Most of the data development efforts were straightforward and based on well-developed procedures. The most complicated and time-consuming data development process was to develop an inventory of properties used to identify residential and business developments. Developments are composed of one or more buildings that act as a coherent development unit and the property on which they are situated. The tax lot data, building envelope data, and geocoded employment data were used to combine tax lots into properties. GIS processes were used to relate these data to each other and the resulting data tables were imported into R for analysis.

The process for identifying properties proceeded iteratively through the following steps:

- The geographic layers were overlaid and examined along with aerial photography to identify rules for identifying properties.
- The rules were coded in R and applied to the data.
- The resulting properties were exported to GIS and examined.
- New rules were developed and existing rules were modified.

Final adjustments were made by examining aerial photography to adjust the identified properties and to look for developments the rules did not identify.

MODEL RESULTS

The LUSDR model has been run through several tests to evaluate reasonableness and to produce results for the RPS study.

Household Models

The results of 50 runs of the household models using the 2000 Census counts of population by age cohort for Jackson County were compared with the 2000 Census tabulations of households by size, workers, age of head of household, building tenure, and building type. Table 1 compares observed and modeled proportions by household category for each household attribute. The model results are quite close in most respects.

The most significant deviations occur in the income comparison. This is most likely to have resulted from using statewide PUMS data for estimating the income model. The Jackson County data were not sufficient to estimate a model, so the statewide data were used instead. The model may be improved by weighting the statewide PUMS records to reflect Jackson County household attributes. Despite the variation in income, the building tenure and building type models produce values that are quite close to the census values.

Employment Establishment Size Distributions

Several tests were also conducted to check how well the procedures for picking from employment establishment size distributions replicated the observed distributions. Figure 2 compares employment establishment size distributions by employment type for one model run with the observed size distributions.

Full Model Runs

The results of full model runs were validated for reasonableness using an expert review process. Because time-series data for model estimation and calibration were not available, it was not possible to validate the model by comparing a forecast from a previous starting point against current patterns. Instead, model results were reviewed for reasonableness by a committee of local and regional land use planners who are knowledgeable about land use and development in the study area and by a peer review panel of land use and transportation modeling experts. A future application is planned for an urban area for which time-series data are available. This will permit more robust validation.

Figure 3 compares the results of two model runs in box percentile plots (*21*) for portions of the model area. The series of box percentile plots drawn in black show employment distributions that emerge when the model is started from the 2030 MPO consensus TAZ level forecasts. The black horizontal line indicates the 2030 consensus forecast. The gray series of box percentile plots show the employment distributions that emerge when the LUSDR model is started at the 2005 base year. Several observations are worth noting:

TABLE 1 Observed and Modeled Household Characteristics

	Percentage of Households	
Household Characteristic	Census	Model
Household size		
1 person	25.1	24.8
2 persons	37.8	38.4
3 persons	15.2	15.8
4 + persons	21.9	21.0
Household workers		
0 worker	31.3	30.5
1 worker	35.0	35.4
2 workers	28.3	28.6
3 + workers	5.4	5.5
Age of household head		
≤25	5.7	6.6
26–55	53.6	54.3
56–65	14.7	14.1
>65	26.0	25.0
Household income		
$ 0–15K	17.3	19.0
$ 15–30K	23.1	27.2
$ 30–45K	19.8	21.1
$ 45–60K	13.8	12.7
$ 60K +	25.9	20.0
Building tenure		
Owner	66.5	64.9
Renter	33.5	35.1
Building type		
Detached single family	63.9	63.7
Attached single family	3.2	3.1
2–4 unit apartment	8.3	7.8
5+ unit apartment	9.3	8.8
Mobile home	14.9	16.2
Other	0.5	0.4

- The microsimulation modeling approach produces appreciable amounts of variation even at a fairly high level of aggregation.
- Even though there is variation, there are clear central tendencies.
- Variation increases over time.
- Some areas are more sensitive to variation than others.
- For most of the urban areas, the 2030 consensus forecasts are significantly different than the forecasts from the model starting at the base year.
- Even with the 2030 differences, the results for the forecast horizon year for a few of the urban areas are similar for the two sets of runs.
- Growth follows different paths in different areas; it accelerates in some areas and decelerates in others.

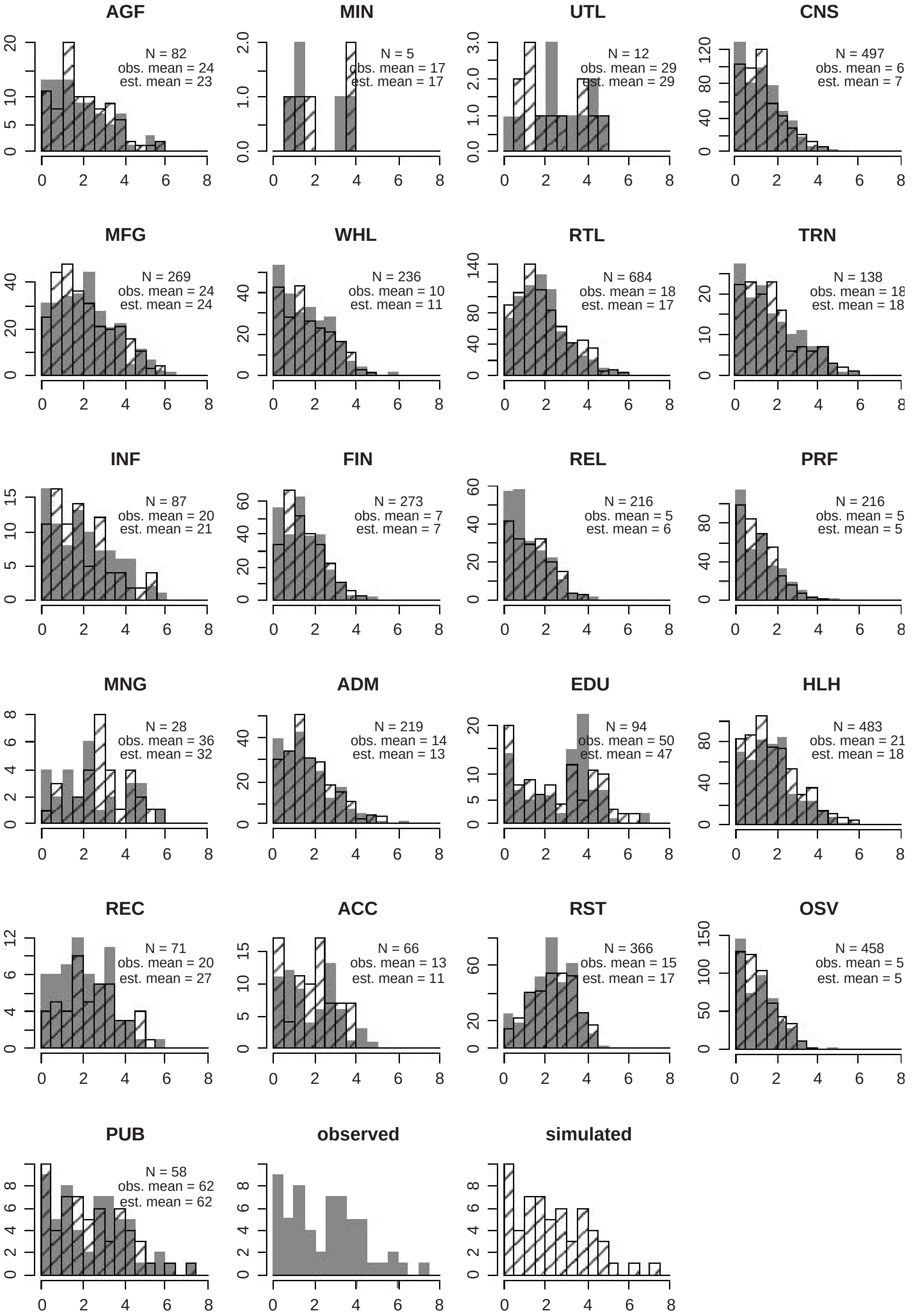

FIGURE 2 Observed and simulated employment establishment size distributions [*x*-axis = log(number of employees); *y*-axis = number of employment establishments; AGF = agriculture, forestry, fishing, and hunting; MIN = mining; UTL = utilities; CNS = construction; MFG = manufacturing; WHL = wholesale trade; RTL = retail trade; TRN = transportation and warehousing; INF = information; FIN = finance and insurance; REL = real estate and rental and leasing; PRF = professional, scientific, and technical services; MNG = management of companies and enterprise; ADM = administrative and support and waste management and remediation services; EDU = educational services; HLH = health care and social assistance; REC = arts, entertainment, and recreation; ACC = accommodations; RST = restaurants; OSV = other services (except public administration); and PUB = public administration].

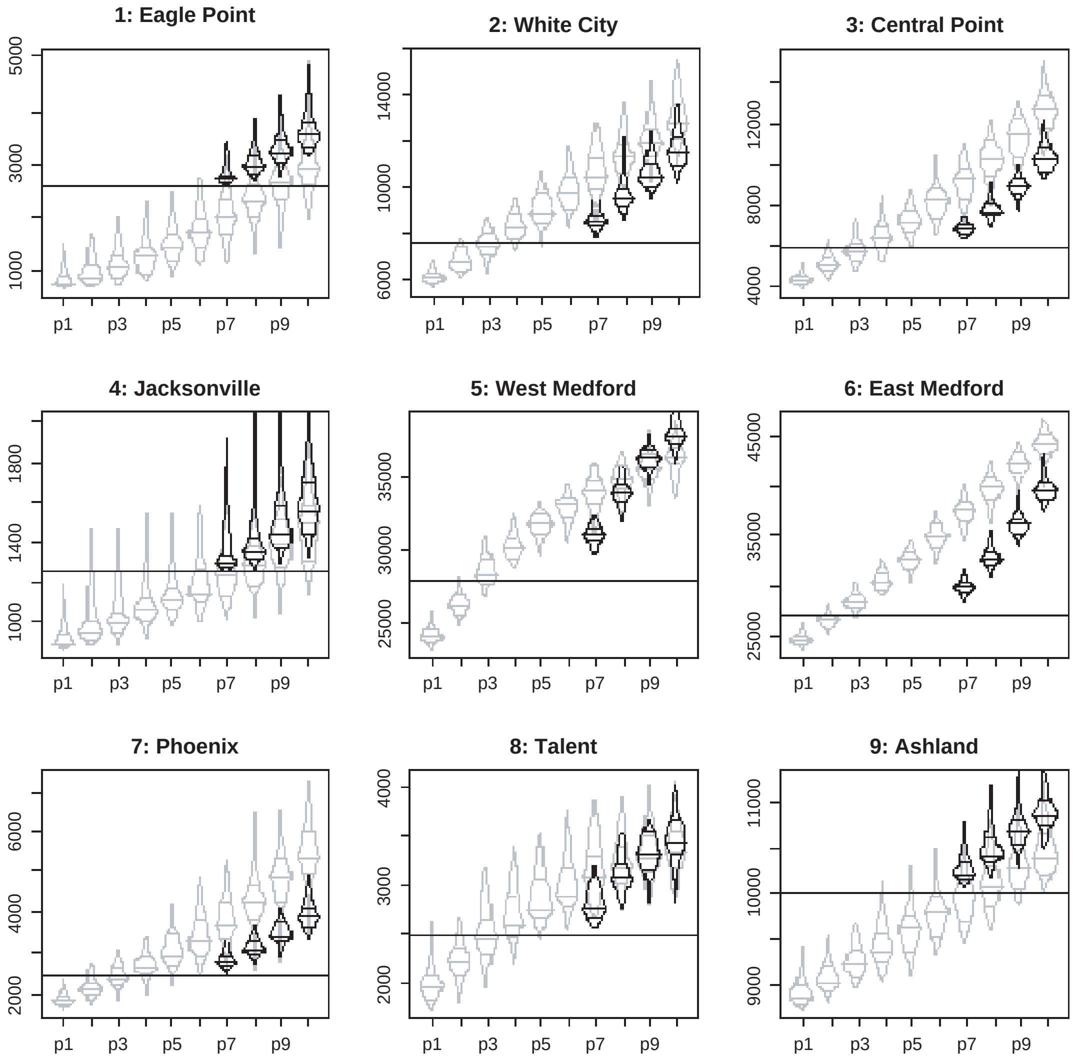

FIGURE 3 Comparison of two sets of LUSDR model runs (*y*-axis = number of employees).

CONCLUSION

LUSDR demonstrates the value and practicality of implementing land use models as stochastic microsimulations. The model explicitly addresses uncertainty and supports a more realistic strategic planning approach. Consideration of the trade-off between modeling completeness and model comprehensiveness resulted in a model that runs quickly and addresses the most important land use behavioral elements. The approach also permits land use models to be built with a modest amount of data.

A number of enhancements are planned for LUSDR. They include the following:

- Developing housing compositions for each interim model year from demographic forecasts;
- Keeping track of an inventory of developed space over time, allocating household and employment establishment demand to existing space, and then creating new developments to accommodate the excess demand;
- Running LUSDR and the regional transportation model in a connected fashion through time;
- Incorporating densification and redevelopment into the model; and
- Modeling the additions to urban growth boundaries incrementally instead of as long-range aggregate amounts.

LUSDR is on the way to becoming a standard model in Oregon's toolbox of models. It will enable modelers to improve land use forecasts for transportation modeling and will provide useful modeling support for land use and transportation planning studies. In the simplest applications, it will assist local planners with developing the long-range forecasts that are used for transportation modeling and other studies. Even if a consensus process is used to obtain agreement on a final forecast, LUSDR can help by producing a set of plausible alternatives that are consistent with comprehensive plan regulations and market behavior as a starting point for discussions.

For more complex integrated land use and transport studies, LUSDR will be coupled with an urban travel model to assess the effects of proposed transportation system changes on urban development patterns. LUSDR produces the TAZ-level population and employment inputs required by transportation models, and it uses transportation model outputs to calculate the accessibility and travel exposure variables used in its location model component. LUSDR and the transportation model can be run iteratively through time, passing this information back and forth to simulate the effects of land use and transport interactions.

Finally, LUSDR will be used to support a risk-assessment approach to transportation and land use planning. The response to this approach by planners and elected officials in the Rogue Valley MPO area has been good. It has been helpful in identifying the magnitude of transportation problems and the relationship between land use patterns and transportation problems. This is likely to become an active area of application and development at the Oregon Department of Transportation.

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