

## **Between Politics and Planning: UrbanSim as a Support System for Metropolitan Planning**

### **Overview**

There has often been an uneasy relationship between politics and planning in the selection of the policies and investments that shape urban areas. Competing interests vie to shape these decisions through the political process, while planning attempts to rationalize the process through analytical methods. Experience has shown that politics all too often trumps analysis, leaving both sides frustrated and the outcome poorly informed. The quest to elevate the political process through informed and objective analysis is a central objective of the development of planning support systems. This paper describes the recent development of UrbanSim, an urban simulation system, and its application as a planning support system for metropolitan land use and transportation planning.

The need to promote consistency between land use, transportation, and air quality planning has motivated a substantially different approach to planning than characterized these efforts in previous decades. Transportation planning, perhaps through the 1970s, was preoccupied with reducing congestion through capacity increases. The secondary effects of transportation on land use, and the resulting induced congestion and consequent increase in emissions from the new expansion of capacity, had been well and widely documented (e.g., Downs, 1992). But these ideas did not impact the planning practice in most metropolitan areas until the passage of federal legislation mandating that these interactions be considered in transportation planning. In the early 1990s, The Sierra Club and Environmental Defense Fund lawsuit in the San Francisco Bay Area took on the

metropolitan transportation planning process and sent a wake-up call to Metropolitan Planning Organizations across the nation (Garrett and Wachs, 1996).

The years after the Bay Area lawsuit have witnessed a frenzy of activity by MPOs, consultants, researchers and activists focusing on the weaknesses of the current transportation and land use models, and beginning to improve them to respond to a new generation of requirements. The Federal Highway Administration, through its Travel Model Improvement Program (TMIP), has invested millions of dollars in developing TRANSIMS, a long-term project to improve travel models using extremely disaggregate microsimulation techniques. On the other hand, there has been only token federal support for research on land use model improvement. In the face of federal legislation requiring more sophisticated treatment of land use and transportation interactions, on the one hand, and a dearth of support for the development of new tools to do so, MPOs have been scrambling to develop their own approaches or to stretch their existing tools as far as possible, all under the shadow of potential legal challenges.

This paper describes the UrbanSim land use model that has been developed in an effort by several states and the federal government to begin more systematically addressing the shortcomings of existing tools to address these issues. The model is a work in progress, now being implemented for the first time in four states, and with further federal funding to extend the model and software implementation in an ongoing research program. It is being developed entirely within the public domain, to minimize the impediments to improving these new tools through collaborative research and development efforts.

The organization of this paper begins with an overview of the design of the model and its software implementation; a more complete treatment is available elsewhere (Waddell, 1998a, 1998b, 1998c). The model's user interface model is then discussed to illustrate the use of the model as a planning support system for metropolitan land use and transportation planning. The third section reviews the status of the model and its application in several states. The final section concludes with an agenda for further development.

### **DESIGN OF URBANSIM**

UrbanSim was developed to deal with the increasingly complex questions facing metropolitan planning agencies attempting to make mutually-consistent long-term plans for transportation, land use, and air quality. The Oahu Metropolitan Planning Organization supported the initial design of UrbanSim and the development of a tour-based travel model system. The Oregon Department of Transportation subsequently funded the full implementation of the UrbanSim model, and its application to Eugene-Springfield as a prototype to be linked to existing MPO travel models in Oregon. The State of Utah has also begun adapting the UrbanSim model to the Greater Wasatch Front area, in combination with a public visioning process organized by a public-private collaboration known as Envision Utah. These applications will be discussed in some detail in a subsequent section, after a more complete description in this section of the model and its use for strategic metropolitan planning.

The basic features of the UrbanSim model are highlighted in Table 1. The model is unique in that virtually all existing operational land use models are cross-sectional, equilibrium seeking, and fairly aggregate in nature (see Miller and Hunt 1998 for a review of operational models including UrbanSim). While simpler, these approaches require very strong assumptions about human behavior and the nature of metropolitan regions. The UrbanSim model is based on a behavioral approach that focuses on the key actions taken by the principal urban actors, namely, households, businesses, developers, and governments. Moreover, the model is the first one to simulate the land development process at the level at which it actually occurs, the individual land parcel. The model also treats explicitly the decision to move or not in modeling the location of households and businesses. Location choices are expressed in terms of both the building type and the traffic analysis zone. This degree of spatial detail is consistent with the travel models used at the metropolitan scale, which makes this model uniquely more useful for interactive land use and transportation modeling.

The software was developed using object-oriented software tools to make the system as portable and modular as possible, with a long-term intent of implementing the model over the Internet. We expect that there will be substantial gains in the reusability and flexibility of a completely object-oriented approach to model development. As will be noted in the final section of the paper, we are now of developing a completely new software implementation to support substantially greater flexibility in the definition of model components and will be refining each of the model components in this effort.

[TABLE 1 ABOUT HERE]

The eight components of the model can be described with reference to the object diagram in Figure 1. The model represents the processes by which developers construct new buildings or redevelop existing ones. Buildings are located on land parcels that have particular characteristics such as value, land use, slope, and other environmental characteristics. Governments set policies that regulate the use of land, through the imposition of land use plans, urban growth boundaries, environmental regulations, or through pricing policies such as development impact fees. Governments also build infrastructure, including transportation infrastructure, which interacts with the distribution of activities to generate patterns of accessibility at different locations that in turn influence the attractiveness of these sites for different consumers. Households have particular characteristics that may influence their preferences and demands for housing of different types at different locations. Businesses also have preferences that vary by industry and size of business (number of employees) for alternative building types and locations.

[FIGURE 1 ABOUT HERE]

These urban actors and processes are implemented in model components that are connected through the software implementation shown in Figure 2. The diagram reflects the interaction between the land use and travel model systems, and between the land use model and the GIS used for data preparation and visualization.

[FIGURE 2 ABOUT HERE]

The model predicts the evolution of these objects and their characteristics over time, using annual steps to predict the movement and location choices of businesses and households, the development activities of developers, and the impacts of governmental

policies and infrastructure choices. The land use model is interfaced with a metropolitan travel model system to deal with the interactions of land use and transportation. Access to opportunities such as employment or shopping are treated as a composite utility of accessing these opportunities via all available modes of travel, given their time and other costs of access.

The key factors considered in the household and business location demand functions are shown in Table 2. The influence of these factors on household and business location and building type choices are estimated through a calibration process, with different parameters estimated for significantly different subgroups of households or businesses. Common elements considered in both include accessibility to population or employment at each location, density of development, and the age of the development. Prices that each subgroup would be willing to pay for each alternative are estimated, and form the basis for predicting which consumer type will outbid others for a particular site. The probability of choosing a particular site and of being the highest bidder on it, are resolved using consumer surplus theory. That is, the consumer having the highest consumer surplus for a particular alternative is assumed to be the most likely to be the highest bidder on it. Consumer surplus is defined as the willingness to pay for a good less the actual cost incurred.

[TABLE 2 ABOUT HERE]

The factors considered in determining development and redevelopment of land parcels are shown in Table 3. These factors are combined to estimate the profitability of land development on each parcel of land, for all of the permitted development types. The assumption that drives the development component of the model is that the most

profitable sites and uses will have the highest probabilities of development. The model operates at the level of the individual land parcel, to provide behavioral realism and the ability to incorporate and test spatially explicit policies. However, this does not reflect an expectation that one could anticipate the precise timing and nature of development on specific parcels two decades into the future.

This is why the results are aggregated to the level of the Traffic Analysis Zone, to provide a reasonable level of aggregation for use of the model results. Nonetheless, the model provides useful information about the type of development patterns that are likely to occur as a result of policy interventions. Thus, for example, the quantity of green field development, infill, and redevelopment that occur in different scenarios can be compared, as well as the distribution of densities and property values in new development.

The revenue component of the profit calculation is straightforward. The current estimated market price for each development type within a zone, is multiplied it by the anticipated size of the new development. The costs are more complex, and involve the land cost, construction (hard) cost, site preparation, and policy-based costs such as impact fees (soft costs). Redevelopment is considered by comparing the developed parcels with relatively low improvement to land value ratios and comparing them to new “green field” developments. The costs of acquiring and demolishing any existing buildings are included in the costs of redevelopment.

[TABLE 3 ABOUT HERE]

In order to reconcile the demand and supply components of the local real estate markets, the model implements a market clearing and price adjustment mechanism. This is similar to the stock-adjustment model (DiPasquale and Wheaton, 1996), and is based

on the use of structural or normal vacancy rates as market signals that trigger new construction and price adjustments. Movers and new migrants are assigned to the available vacant space in each year on the basis of their consumer surplus for each alternative. New construction decisions then instigate developments for additions to the building stock in the following year. Vacancy rates at the end of the year are used to make price adjustments that influence location choices in the beginning of the following year. This model sequencing, over the period of one year, provides a dynamic process that reflects the tendency of real estate development to respond to market signals, and strive to achieve an equilibrium.

## **URBANSIM AS A SUPPORT SYSTEM FOR METROPOLITAN PLANNING**

We now turn to a more in-depth description of the use of the UrbanSim model for analyzing transportation and land use alternatives. The discussion is organized around the description of the current “beta” version of the UrbanSim user interface, to illustrate the use of the model for strategic metropolitan planning. The core of this user interface is designed to create and test policy scenarios. Since the term ‘scenario’ has been appropriated by many to mean different things, we will elaborate on the intended meaning and use of the term within the UrbanSim application.

The public and community leaders are occasionally invited to participate in a community visioning process as a way to begin a community planning process. This visioning process may evoke its participants’ general values, community goals and objectives, or benchmarks they would like to achieve. Often this kind of an exercise

requires having participants to articulate a vision of the community as they would like to see it at some time in the future, in an attempt to develop consensus about the direction that participants wish to head. These visions are sometimes labeled ‘scenarios’ for the future. This process and the use of the term scenario is distinct from, though perhaps complementary, to our intended use.

While a community visioning process is an excellent means of eliciting community residents’ and stakeholders’ values and general goals, it generally does not provide concrete and specific guidance on how to achieve these goals and objectives. Before any vision of the future can be realized local governments, metropolitan planning agencies, and other stakeholders must choose courses of action and anticipate the eventual consequences of these actions. The tools they possess to influence the outcomes of interest include at least three broad categories: regulatory, infrastructure, and pricing. As a result, in order to move beyond a community visioning process, a community needs to be able to assess the costs and benefits of different combinations of these policy instruments, and estimate their potential for achieving the desired outcomes. In short, imagining a particular future is only a small step in a long-term process to achieve it.

The UrbanSim model attempts to provide a systematic vehicle for developing and testing the potential effectiveness of combinations of these policy instruments in achieving desired outcomes. We use the term ‘scenario’ then, to indicate a package of infrastructure, regulations, and pricing where the impacts on a variety of outcomes one intends to test. The simulation model incorporates these scenarios as external interventions that influence the operation of real estate markets through both the demand and supply of land of each type, at each location within the metropolitan area. The model

predicts outcomes that can be used to assess the degree to which different objectives are achieved for a given scenario, and the tradeoffs between objectives that may result.

The data inputs and outputs for operating the UrbanSim model are shown in Table 4. Developing the input database is a difficult challenge, owing to its detailed data requirements. A GIS is required to manage and combine these data into a form usable by the model, and can also be used to visualize the model results. Once the database is compiled, the model equations must be calibrated and entered into the model. A final step before actual use of the model is a validation process that tests the operation of the model over time and makes adjustments to the dynamic components of the model. Ideally, this will be done with historical data over a fairly long period of time, such as is now being done in the Eugene-Springfield area for 1980 to 1994.

[TABLE 4 ABOUT HERE]

The policy instruments that can be incorporated into an UrbanSim scenario are summarized in Table 5. Several land use policy instruments are available in addition to the transportation system assumptions regarding route capacity, level of service, and pricing. These policy instruments include a comprehensive land use plan, the number of land use conversions to be allowed in new development or redevelopment, minimum and maximum density constraints, and pricing instruments such as development impact fees and infrastructure costs. Other available instruments include regulatory overlays such as the rules regulating development outside an urban growth or urban service boundary, an of environmentally sensitive lands, or within any special planning overlays designated by the user. Several of these rules, including the allowed land use conversions, soft development costs, and density constraints, can be varied between counties, cities, and

specific overlays. That is, different regulatory and pricing policies can be applied to each county, city and overlay area if needed. This affords an extremely high degree of flexibility in articulating the character of local government land policies, determined by municipalities and counties.

[TABLE 5 ABOUT HERE]

The process of entering these land use policies is straightforward. The user interface of UrbanSim facilitates the creation and editing of policy scenarios, and the operation of the model using these scenarios. Several components of the user interface of the beta version of UrbanSim are presented below to describe how scenarios may be created and modified.

The process of interacting with the model, once the database and calibration steps are completed, is as follows:

- Create a new scenario or open an existing one
- Set the metropolitan control totals and the reporting years for the outputs
- Set the land use conversion rules based on the land use plan designations in the parcel database
- Set density constraints
- Set development costs
- Set normal vacancy rates
- Save the scenario
- Run the model on the scenario
- Visualize and interpret the model results
- Repeat the process for other scenarios and compare results

### ***Editing Scenarios***

To edit a scenario, a user clicks on the “edit scenario” button to reveal the screen shown in Figure 3. This screen has five tabs corresponding to the major variable types that the user specifies for a particular scenario: regional control totals, land use conversion, density constraints, development costs, and vacancy rates.

[Insert Figure 3 About Here]

***Control Totals.*** The first tab, used to enter the control totals, is shown in Figure 4. It allows the user to specify the years and data for which population and employment forecasts are available. The user first enters the base year and the ending year. While UrbanSim will interpolate projections for years in which there are no forecasts, the model requires, at a minimum, both population and employment forecasts for the ending year. Since the model operates on a yearly timetable, the data produced by the forecasts can be written out as ASCII files for any years of the model run for use in future analysis. The selection of reporting years is made by checking the Report Year box for years for which the user wishes outputs to be reported.

[Insert Figure 4 About Here]

When the model reaches a year that the user has selected as a travel model year, it writes the model results for that year into external data files in ASCII format. The modeling process is suspended until the travel model sequence is executed using the current land use data. Once new travel time matrices have been 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 point this process is repeated. The years for which a user plans to run a travel model may be checked in the boxes labeled “Travel.”

***Land Use Conversion.*** The Land Use Conversion screen allows a user to specify those actual land uses (ALU) permitted in each planned land use (PLU), and whether or not conversion to such use is permitted within each county, city, or overlay. If an overlay constraint is specified, it overrides the conversions allowed for the given city or county. While the model is not currently designed to handle multiple uses on a parcel of land, it can reflect mixed use policies by allowing different parcels within a cluster to be developed into each of the allowed uses in a plan designation.

***Density Constraints.*** The Density Constraints sheet can be used to set density constraints. The user may specify the minimum and maximum density permitted by land use policy in any county, city, or overlay area. This screen also allows the user to specify land use policies that may pertain to critical environmental areas. UrbanSim allows the allowable development densities in a protected area as a percentage of the normal permitted densities.

For example, if a user wishes to totally exclude an environmentally sensitive type of land use, such as wetlands, a density adjustment would be set to zero. If the constraint were to reduce densities by 50% in selected areas such as those with high slope, then the applicable density adjustment would be 0.5. Densities for residential uses are entered in units per acre whereas all others are entered as a floor area ratio. If an overlay density/constraint is specified, it overrides the general density constraints for the city or unincorporated county.

The density constraints provide upper and lower bounds on the feasible densities for developing specific land parcels affected by a combination of land use plan designations, environmental regulations, and policy overlays such as urban growth

boundaries or enterprise communities. The land development component of the model estimates the density of development for any feasible development types, and predicts the profit-maximizing density for developing a parcel. This estimate is compared to the specified density constraints and if they differ the density is adjusted to conform to the applicable regulations.

***Development Costs.*** The Development Costs tab allows the user to set the development costs. Hard development costs represent the labor and material costs of construction, not including costs of urban service extensions. Commonly referred to as a building's replacement costs, hard development costs are assumed to be the same across the metropolitan area, but to vary across different building types. They may be estimated for each building type from assessed improvement values, local construction industry information, or other sources.

Soft construction costs include a variety of fees set by local governments which are assumed by the developer. Depending on the site, these costs could play a significant role in determining the profitability of a development. While specific fees vary greatly across municipalities, they can be classified into three common categories: development and impact fees, service extension charges, and building permit fees. However, because of the tremendous variability in the way such fees are implemented, the model collapses them 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 on the basis of factors such as project-specific service extension levels and costs. Again, if an overlay value is provided for this factor, it overrides the soft development costs for the given city, county, and actual land use.

***Normal Vacancy Rates.*** The final tab allows a user to enter estimates for normal vacancy rates for each actual land use. These should be interpreted as structural vacancy rates that signal price adjustments and demand for new construction when actual vacancy rates fall below them.

***Visualizing Simulation Results.*** Because the model produces voluminous results, a GIS is used to visualize these outputs in map form, in addition to any other data visualization and reporting that the user may wish to use. Figure 5 portrays the cumulative single family housing production generated by a particular diagnostic scenario for the Eugene-Springfield metropolitan area. The results of the model are summarized by Traffic Analysis Zone, and may be linked to boundary files in a GIS for display. This particular display used ArcView 3.1, though other systems could be used as well.

[Insert Figure 5 About Here]

***Testing Scenarios.*** As is evident from the foregoing discussion, substantial flexibility is provided for defining scenarios for the different policy instruments that affect transportation and land use, through infrastructure, regulation, and pricing. This allows for the creation of multiple scenarios and running the model for each scenario. The model results for each reporting year specified by the user are stored in a scenario directory. Typically, a series of benchmarks or measures of particular interest to the model users could be derived from these results and compared across scenarios. These measures might include, for example, the quantity of agricultural land consumed, the average density of new residential development, average housing values, total infrastructure costs, and total vehicle miles traveled per capita.

It is to be expected that the analysis of these results will expose underlying tradeoffs between different policy objectives. An example might be housing affordability and preserving open space. The real utility of the model as a decision support system for metropolitan planning is in the assistance it can provide in exploring the nature of these tradeoffs. Use of analytical tools such as UrbanSim to explore the effects of alternative policies on the outcomes of interest and the nature of the tradeoffs involved in achieving the desired objectives, may help achieve greater mutual understanding and compromise among the many constituencies affected by metropolitan plans and policies. While it is unlikely that analysis will ever trump politics, perhaps there is some ground on which the two could be more constructively engaged. This hope provides the basis for the research agenda described in this paper.

### **APPLICATIONS OF UrbanSim**

UrbanSim is presently being applied in four states: Hawaii, Oregon, Utah, and Washington. It will be further distributed as an open, non-proprietary software application via the Internet. It remains, however, a new analytical tool and is undergoing rapid evolution and further development. This section reviews briefly the development and application of the model to date. The closing section describes its further development as a planning support system that is planned under currently funded research grants.

## *Hawaii*

The initial design of the UrbanSim model was funded by the Oahu Metropolitan Land Use Model as part of a larger effort to undertake the development of new travel models. Oahu presents a highly unusual location for development of land use and transportation models, for several reasons. First, it more closely approximates a closed system than any metropolitan area in the mainland U.S., eliminating some of the boundary conditions that plague analysis of many mainland metropolitan areas. Second, the use of land is highly constrained by water, mountains, and policy. Approximately four percent of the land area is designated for urban uses, with the vast majority of land on the island assigned to agricultural and watershed preservation areas. Development is highly regulated and the City and County are consolidated, eliminating the jurisdictional fragmentation that characterizes most mainland metropolitan regions. These factors, coupled with high density, extremely high housing prices, and high transit ridership make Honolulu an interesting application of these modeling tools.

Several policy concerns have guided the land use and transportation model development effort in Honolulu. Recent votes on light rail systems have been turned down by voters, though variations on bus-alternative transit continue to be brought up for discussion. Linkages between transportation investments and land development are key to these analyses. Of particular concern in Honolulu are issues regarding housing affordability and the degree that which policies to steer development towards certain areas such as Ewa can be realized. The high degree of state and local regulation of land development also motivate questions regarding how to make development decisions that are responsive to market conditions. The use of UrbanSim to assist in these analyses will

incorporate anticipated development events directly into the model. The ability to incorporate anticipated development projects in the pipeline such as major business relocations or major policy changes are some of the extensions of the model that are planned for near-term implementation.

The project also involves the development by Parsons Brinckerhoff of a travel model system based on modeling activities such as tours rather than trips *per se*. The linkage of the land use modeling with this new generation of travel models will open new venues for more accurately representing the nature of land use and transportation interactions. For example, the choice of households to locate in a dense, transit-oriented neighborhood is likely to be dependent on their choice of auto-ownership and travel modes. These kinds of linkages are not easily explored within a traditional four-step travel modeling system, but are open research avenues with activity-based travel models.

### ***Oregon***

In 1996, the Oregon Department of Transportation (ODOT) launched an ambitious project to support growth management policies within the state. The Transportation and Land Use Model Integration Project (TLUMIP) sought to develop analytical tools to support both state-wide and metropolitan-scale land use and transportation planning. The prototype metropolitan land use model was based on the UrbanSim design developed in Honolulu, which was extended and fully implemented as an operational prototype software system within the TLUMIP project. The model was calibrated for a case study in Eugene-Springfield, using principally cross-sectional data. A second TLUMIP project being a longitudinal calibration and validation process to

examine the dynamic behavior of the model over the period from 1980 to 1994 is now underway and should assist in refining the model's dynamic properties. A broader agenda of the second TLUMIP project is to better integrate the analytical tools for statewide land use and transportation planning with those for the Willamette Valley substate area and the metropolitan scale models. Given the diversity of the state, and the variation in the issues, theoretical concerns, and data availability at these three scales the design of the second-generation models will break substantially new ground.

The key policy concerns motivating the Oregon project relate to the effects of different growth management policies on a series of outcomes of interest and the interaction between land use and transportation initiatives. For example, what effect would an overly restrictive urban growth boundary in Portland have on the potential relocation of businesses and households into other metropolitan areas in the Willamette Valley, such as Salem? If this effect were substantial, it might seriously undermine the original objectives of growth management, promoting long-distance commuting on an already congested Interstate 5. Other questions concern the effects of the urban growth boundary on housing densities and housing costs. Critics of the urban growth boundary complain about its effects on housing prices, but there is little compelling evidence in either direction on these questions.

Oregon is a mature growth management state, perhaps even the national leader in this arena. Yet the ongoing evaluation and refinement of growth management strategies remains problematic, owing to the lack of systematic monitoring and evaluation tools. UrbanSim was developed to assist in this process by providing a way to test in a simulation model various changes in these elaborate growth management strategies and

their potential effects. If coupled with a consistent monitoring program, this approach may offer a valuable prototype for not only developing and testing growth management strategies, but for maintaining and refining them over time.

### ***Utah***

In Utah, the Governor's Office of Planning and Budget has been coordinating a technical process in close cooperation with a community visioning process titled Envision Utah. The Envision Utah process has engaged community leaders from the public and private sector to assess alternative visions of how the community might wish to evolve over the next several decades in the face of unrelenting population growth that threatens the region's environmental amenities and quality of life. Peter Calthorpe and John Fregonese have been engaged to lead this public visioning process and have raised community awareness of more transit-oriented, dense and walkable urban neighborhoods as an alternative to continued sprawl.

Utah provides a fascinating political testing ground for the growth management debate. Environmental groups are very active, and concerned about the potential environmental damage from not only continued sprawl, but also from large-scale infrastructure such as the proposed Legacy Highway that may be built through some of the region's prime wetlands. Yet Utah is a state in which private property rights are held in high regard and intervention by state and local government on the rights of landowners to develop their property is viewed with skepticism. In many ways, Utah provides a microcosm of the political debate likely to be played out across much of this country, as citizens grapple with congestion and environmental concerns on the one hand and

strongly held sentiments about individual property rights and limited governmental intervention on the other.

The Utah Governor's Office has chosen to use UrbanSim as a way to facilitate the public visioning process of Envision Utah. The product of many public workshops conducted by the Envision Utah process will be a preferred scenario for the future of the Greater Wasatch Front area. This will be a broad vision of the desired future of the region, along with some broad policies to be endorsed as the means to achieve this vision. UrbanSim will be used to facilitate the testing of packages of policy instruments, and assessing their ability to achieve the desired vision of the future. This will involve examining the costs of alternative scenarios, the mediating role of real estate markets, and the tradeoffs between objectives that result from alternative policy packages. The final selection of a preferred scenario will be based on an iterative process of community workshops and technical analysis. This process provides an outstanding opportunity to seek to constructively engage public participation and technical analysis. The coming year will provide substantial insights into issues of in making such a linkage productive.

### ***Washington***

The State of Washington is also a growth management state, though with perhaps less stringent application than in Oregon. Much of the control for implementing the Growth Management Act remains in the control of local governments, and there has been relatively little evaluation of compliance to date. Recent concerns over the imminent listing of the Chinook Salmon as an endangered species in several watersheds in the greater Puget Sound region have generated substantial interest in better understanding the

linkages between urban development, agricultural and forestry practices, and the quality of the Salmon habitat in these watersheds. A University of Washington research project, dubbed PRISM (Puget Sound Regional Synthesis Model) has taken on the ambitious challenge of engaging researchers from many scientific disciplines ranging from hydrology to atmospheric science, landscape ecology, and urban planning, to begin linking models of urban development and natural ecosystems.

UrbanSim was selected as the basis for the modeling of urbanization and will be extended by the development of complementary model components for predicting land cover, water demand, and nutrient emissions. The target area for this application is the core Puget Sound region, encompassing the four central counties in the Seattle-Tacoma metropolitan area. This effort begins to emphasize the potential for more integrated modeling of land use, transportation, and environmental interdependencies. Not only do land use and transportation choices have environmental consequences; but these consequences may also impact land uses and location choices. For example, air quality and open space may influence the attractiveness of locations for residential location and habitat preservation may restrict areas from further development.

## **FUTURE DIRECTIONS**

This section concludes the paper with a review of the current commitments to extend and distribute the UrbanSim model and software and engage in ongoing research to improve the analytical components of the model system. Two specific projects are described briefly, followed by general conclusions.

## *National Distribution*

The National Cooperative Highway Research Program recently completed a research project entitled 'Integration of Land Use Planning and Multimodal Transportation Planning,' coordinated by Parsons Brinckerhoff. A component of this project was the development of new analytical tools for integrated land use and transportation planning. The UrbanSim model prototype developed in Oregon was used as a foundation for this component. Three products completed from this project are now available. The first is a guidance document for land use and transportation planning which reviews the nature of land use and transportation interactions and the existing tools used by Metropolitan Planning Agencies to undertake such analyses.

The second is a beta version of the UrbanSim software implementation, and supporting reference and user guides, developed at the University of Washington. The software, as mentioned previously, is entirely in the public domain, and is covered by a GNU General Public License, otherwise known as 'Copyleft'. This licensing approach guarantees that the source code, and any extensions of it, will remain non-proprietary in the future. The adoption of this open approach was a reaction to high-priced and proprietary approaches to land use and transportation modeling software that inhibits innovation or even correction of deficiencies, and restricts access limited to large organizations that can afford the license fees.

A web site, <http://urbansim.org>, has been established to provide ongoing access to model and software improvements as well as documentation and news regarding the project. The status of the UrbanSim implementation at the end of 1998 is a Beta version of the software, which contains a level of generalization that should allow users to load

data and model coefficients for a metropolitan region and execute the model for that region. Supporting tools, especially for data preparation, are currently lacking. Moreover, the software implementation is still based on the original prototype software and lacks substantial flexibility. These two deficiencies are being addressed in the two projects described below.

### ***Data Preparation Tools***

The Federal Highway Administration has funded the development of tools to facilitate the preparation of data inputs for the land use and transportation modeling process. KJS Associates is coordinating this project, with tool development being undertaken by Environmental Systems Research Institute based on the ArcView product, and by the University of Washington based on the UrbanSim data preparation component. This effort focuses on developing high-resolution employment and land use data from public and private sources. Employment data has historically been one of the most difficult of the modeling inputs to develop, owing to a lack of public data sources comparable to the census of population. The most common public source of employment data is from the ES-202 unemployment insurance files maintained by states. These data are often difficult to obtain, have confidentiality restrictions, and contain various reporting problems such as the reporting of all employment for a firm at a headquarter or accounting office rather than at individual branch establishments.

The project will involve the creation of GIS-based tools to interface employment records from multiple sources, geocode them, and reconcile them with parcel-based land use data. In addition, the project will develop a set of data preparation tools linked to

UrbanSim that develop the model's internal database for the model and develop and validate the consistency of the database. These tools will also be provided to the public domain.

### ***Reusable Software Architecture***

The National Science Foundation launched an Urban Research Initiative in 1998, signaling new attention to the need for basic research and model development dealing with the interactions between the built environment, the social environment, and the natural environment. The University of Washington was awarded a grant entitled 'Reusable Model Components for Simulating Land Use, Transportation and Land Cover.' This project will seek, over the next two years, to develop a flexible software architecture to support the modular development and evaluation of model components related to land use, transportation, and land cover.

The research will examine the effects of scale and resolution in space, time, and behavior on the utility and realism of urban models. This project will explore implementation of the various model components dealing with demand and supply of land development at a microsimulation level, using a grid locational reference underlying the parcel and zonal features now forming the basis of location in the models. By developing more aggregate models and evaluating the tradeoffs between scale and resolution among these model implementations, we hope to learn more about the compromises involved in selecting different model scales and resolutions. We anticipate that higher resolution in each dimension will achieve greater realism, but at increasing cost. Reasonable compromises may be found in which the marginal data collection costs

match the marginal improvements in the model's ability to represent behavior and policy responsiveness.

### ***In the Long Run***

The long-term objectives of the research described in this paper are improving the ability of planning agencies and the general public to understand the complex interactions between land use, transportation, and the environment and the potential effects of alternative policy choices on these outcomes. Our hope is that there is some middle ground between politics and planning and that well-designed analytical tools can help explore this ground. We also hold out some expectation that there is a way to constructively engage public participation and objective technical analysis. To this end we are developing a strategy to deploy these tools over the Internet, in the form of a distributed decision support system.

The objectives laid out in this paper are ambitious to a fault. The echoes Lee's "Requiem for Large Scale Models" (Lee, 1973; Lee, 1994) still resonate today, provide a still-relevant caution against unguarded optimism for the potential for such models. It is indeed, far too early to tell the extent to which these objectives are achievable, but the options of not trying to attempt them seems a far more daunting prospect.

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**TABLE 1**  
**Key Features of UrbanSim**

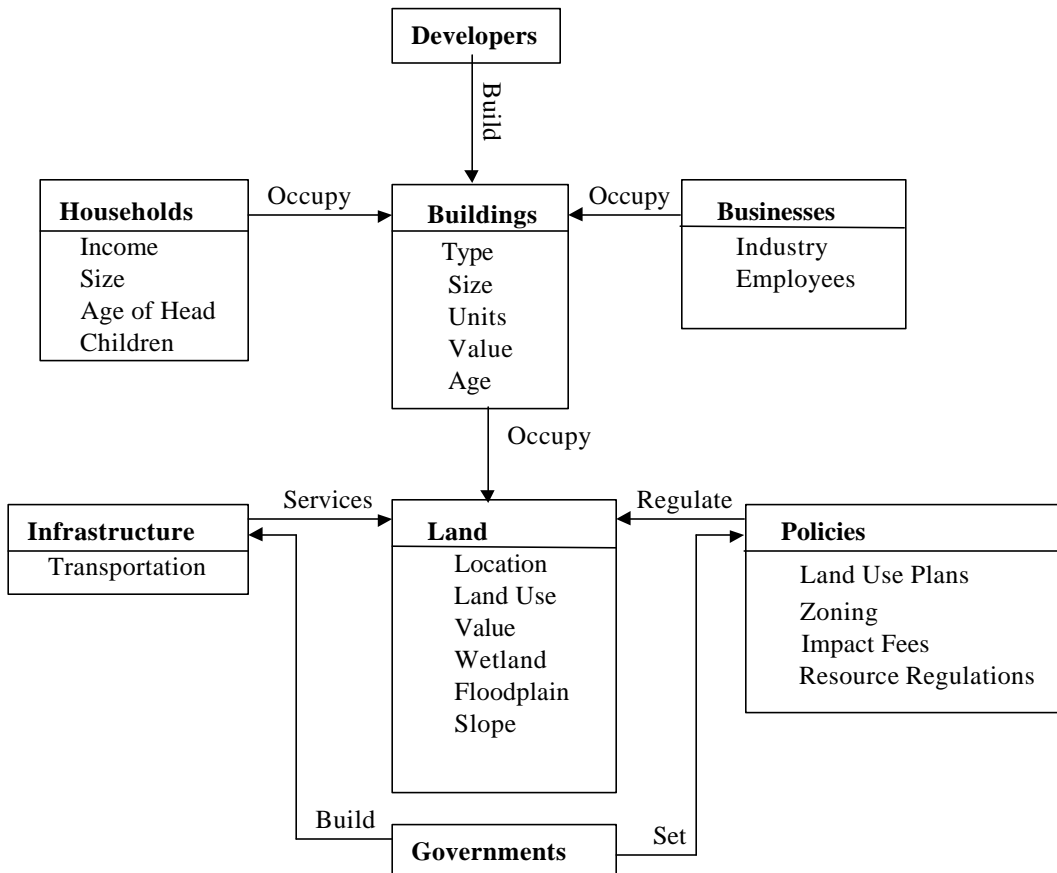
***Key Features of the UrbanSim Model***

- 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 the 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.

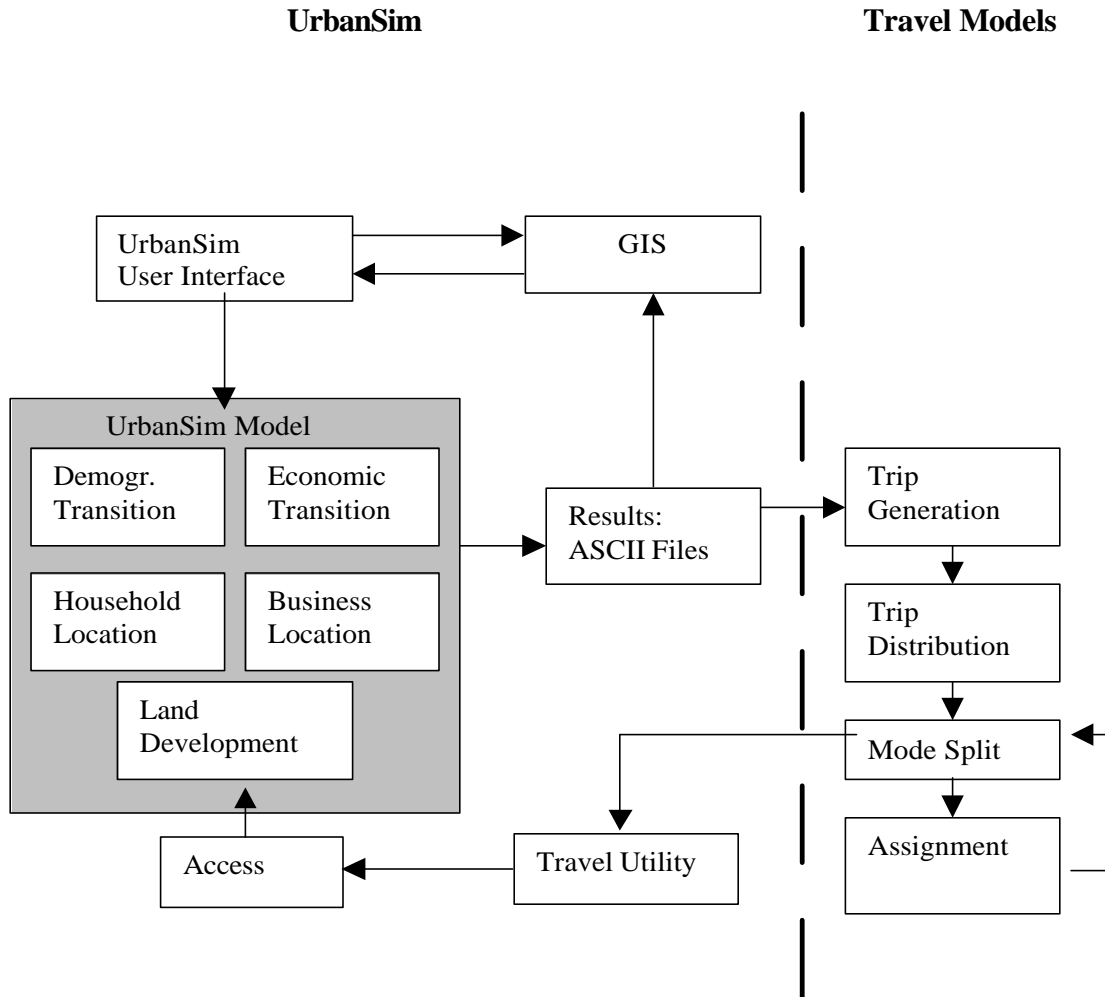
***Key Features of the UrbanSim Software Implementation***

- The model and user interface is currently compatible with Windows95/NT, Unix, Macintosh, and other platforms supporting Java JDK 1.2; reporting tools are currently implemented in Excel;
- 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 inputs and results can be displayed using ArcView, Arc/Info, or other GIS software;
- Model results are written as ASCII, tab-delimited files for external use.

**Figure 1:  
Urban Simulation Model Object Structure**



**FIGURE 2**  
**UrbanSim Software Implementation**



**TABLE 2**  
**Factors Considered in Location Demand Components**

***Household Demand for Housing Types and Locations***

- Housing Type: Single Family, Residential with 2-4 units, or Multi-Family
- Accessibility to total employment
- Accessibility to retail employment
- Net density in units per acre of a particular housing type in a zone
- Number of housing units of a particular type in the zone
- Average age of the buildings of a type in a zone
- Percent of households in a zone in the lowest income group
- Percent of households in a zone in the second lowest income group
- Percent of households in a zone in the highest income group
- Percent of the households in a zone that have one or more children
- Percent of the developed land in the zone that is in industrial use
- Percent of the developed land in a zone that is in residential use
- Travel time to the Central Business District, in minutes

***Business Demand for Building Types and Locations***

- Building Type: Industrial, Warehouse, Retail, Office, or Special Purpose
- Accessibility to total population, total employment, and high income households
- Basic employment in a zone per square mile
- Retail employment in a zone per square mile
- Service employment in a zone per square mile
- Accessibility to Basic, Retail and Service employment
- Total square feet of commercial space of a particular type
- Building age
- Net density of the building type in a zone
- Percent of developed land in a zone in industrial use
- Percent of developed land in a zone in retail use
- Travel time to the CBD, in minutes
- Presence of a highway in a zone

**TABLE 3**

**Factors Considered in Land Development and Redevelopment Component**

***Expected Revenue***

- Current market price for type of development at zonal location
- Quantity and type of development feasible under development rules

***Expected Costs for New Development***

- Land Cost
- Hard Construction Costs (replacement cost of structure)
- Soft Construction Costs (development impact fees, infrastructure costs, taxes or subsidies)

***Density of Development***

- Regulatory Constraints (land use plan, urban growth boundary, environmental constraints)
- Land Value
- Land Use

***Filter for Considering Developed Parcels for Redevelopment***

- Improvement to Land Value Ratio of Parcel

***Additional Costs for Redevelopment***

- Current Building Improvements
- Demolition Costs

**TABLE 4**  
**Data Inputs and Outputs from UrbanSim**

***UrbanSim Inputs***

- Employment data, in the form of geocoded business establishments
- Household data, merged from multiple census sources
- Parcel database, with acreage, land use, housing units, nonresidential square footage, year built, land value, improvement value, city and county
- Land Use Plan
- GIS Overlays for environmental features such as wetlands, floodways, steep slopes, or other sensitive or regulated lands
- Traffic Analysis Zones
- GIS Overlays for any other planning boundaries
- Travel Model outputs
- Development Costs

***UrbanSim Outputs (by Traffic Analysis Zone)***

- Households by income, age, size, and presence of children
- Businesses and employment by industry
- Acreage by land use
- Dwelling units by type
- Square feet of nonresidential space by type
- Land values per acre by land use
- Improvement values per unit or sqft by land use

***Travel Model Outputs (Zone-to-Zone)***

- Travel time by mode
- Composite utility of travel using all modes

**TABLE 5**

**Policy Instruments Incorporated in UrbanSim Scenarios**

***Transportation (From Travel Model)***

- Transportation Capacity: Highway, Arterial, Bus, Rail, and HOV
- Transit Level of Service
- Pricing: tolls, gasoline tax, etc.

***Land Use***

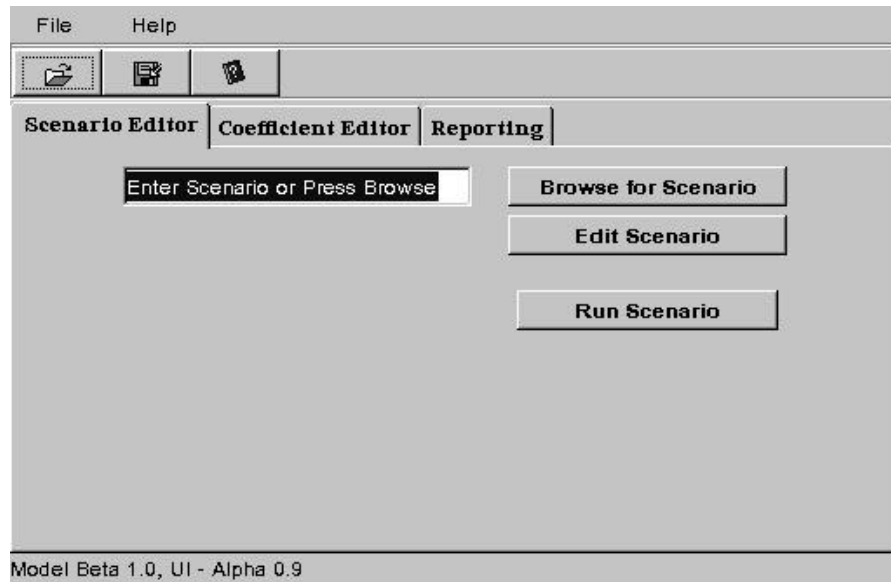
- Land Use Plan: restrictions on conversion of land to alternative urban land uses
- Density Constraints: minimum as well as maximum density by land use
- Soft Construction Costs: development impact fees, infrastructure costs, taxes or subsidies

***Policy Overlays (can affect land uses allowed, density, soft development costs)***

- Urban Growth Boundary
- Environmental Restrictions
- Other Policy Overlays (special planning areas designated for exceptional policies)

**FIGURE 3**

**Initial UrbanSim Menu: Edit Scenarios and Execute the Model**



**FIGURE 4**

**Initial UrbanSim Menu: Edit Scenarios and Execute the Model**

Control Totals	Land Use Conversion	Density Constraints	Development Costs	Vacancy Rates
Project Base Year is: 1995 Ending Year for Scenario: 2010				
Year	Population	Employment	ReportYear	Travel
1995	172559	96217	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1996	175148	97660	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1997	177775	99125	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1998	180441	100612	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1999	183148	102121	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2000	185895	103653	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2001	188684	105208	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2002	191514	106786	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2003	194387	108388	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2004	197302	110013	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2005	200262	111664	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2006	203266	113339	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2007	206315	115039	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2008	209410	116764	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2009	212551	118516	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2010	215739	120293	<input checked="" type="checkbox"/>	<input type="checkbox"/>

**FIGURE 5**  
**Visualizing Simulation Results:**  
**Eugene-Springfield Single Family Housing Construction in a Diagnostic Run**

