A Case Study in Digital Government: Developing and Applying UrbanSim, a System for Simulating Urban Land Use, Transportation, and Environmental Impacts

Paul Waddell

Director, Center for Urban Simulation and Policy Analysis

Evans School of Public Affairs

University of Washington

Box 353055

Seattle, Washington 98195

pwaddell@u.washington.edu

Alan Borning

Co-Director, Center for Urban Simulation and Policy Analysis

Department of Computer Science & Engineering

University of Washington

Box 352350

Seattle, Washington 98195

borning@cs.washington.edu

Introduction

UrbanSim is a tool for use by urban planners, policymakers, and other community stakeholders to help formulate and evaluate combinations of land use, transportation and environmental policies. It is intended to support deliberation and debate on such issues as building new transit systems or freeways, or adopting alternative growth management regulations and incentives, as well as on broader issues such as sustainable, livable cities, economic vitality, social equity, and environmental preservation. Stakeholders should be able to consider different scenarios – packages of possible policies and investments – and then, based on these alternatives, use UrbanSim to model the resulting patterns of urban growth and redevelopment, of transportation usage, and of resource consumption and other environmental impacts.

The aim of this paper is to describe the UrbanSim project as a case study in Digital Government, and to examine progress to date in developing and applying the system in a range of metropolitan areas. Digital Government is meant here in the context of an innovative, cross-cutting initiative of the National Science Foundation, from which the UrbanSim project has received funding. The project approach integrates academic research on urban simulation modeling and policy evaluation with research on human-computer interaction and software engineering, and uses a value-sensitive design process to ensure that the system addresses the needs of governments and citizens. The following sections argue for the importance of the problem domain and the project objectives, lay out a range of challenges that must be overcome, and then outline the design and application of UrbanSim in response to these objectives and challenges. We discuss one application in detail, in the Salt Lake City metropolitan region. The paper closes with an assessment of the project and directions for future research.

Why the Problem Domain is Challenging

Challenges in the Urban Domain

Urban regions are complex systems, by any definition (Parker, 2000; Wolfram, 1984). They include social, economic, political, and ecological structures and processes and their interactions. Individual households and firms make choices and interact within markets for real estate, labor, and goods and services, within institutional, legal and regulatory frameworks established by a range of independent governmental agencies. Households and organizations use natural resources, produce waste material, and interact with a variety of ecological processes both within and outside the urban region. Technology and external economic and environmental factors shape these metropolitan processes from outside, and structures and processes continually evolve as the result of ongoing internal interactions. At the core of these interactions within urban systems are those between land use, transportation, and environmental quality.

Urban transportation systems and travel patterns heavily influence urban development, shape property values, and affect location choices of households and firms (Alonso, 1964; Mills, 1967; Muth, 1969). By the same token, patterns of development and the location of firms and households strongly influence the demand for travel and the resulting patterns of usage of the transportation system and its congestion (Berman, 1996; Cervero & Landis, 1995; Giuliano, 1989; Hanson, 1995; Kelly, 1994; Moore & Thornes, 1994; Noland & Lem, 2000). Both travel and land use patterns affect environmental outcomes profoundly, at all scales. For example, local and regional effects may include the conversion of agricultural land to urban uses, loss and fragmentation of sensitive habitat, and pollution of the air, soil, and surface and ground water (1000 Friends of Oregon, 1993; Alberti, 1999; Anderson, Kanaroglou, & Miller, 1996; Banister, Watson, & Wood, 1997; Marsh, Porter, & Salvesen, 1996). At the global scale, impacts may include climate change, air and water pollution, and overall resource consumption. And of course, environmental quality, as well as various location-specific amenities, influence the desirability of residential and business locations, and therefore urban development and travel (Diamond, 1980; Gottlieb, 1995; Greenwood & Hunt, 1989; Krumm, 1980; Sivitanidou, 1995).

Due to these intensive interactions among land use, transportation and environment, and their varying spatial and temporal scales, the factors that shape cities and urban regions are inherently complex and dynamic. Problems that arise in the urban system, ranging from traffic congestion, to loss of open space, fragmentation of habitat, and air and water pollution and their harmful effects on the health of humans and other species, to patterns of concentrated poverty and attendant social problems, are fundamentally hard problems to address, since causes are difficult to isolate and interventions have often unanticipated consequences.

Challenges in Metropolitan Governance

The interdependence of these three metropolitan systems of land use, transportation, and environment is readily apparent to even the casual observer, but presents profound challenges for developing appropriate policies. Such policies are generally formulated in a patchwork of agencies that have limited scope within one of these three systems, and that exist at different levels of government. Reconciling the formulation and evaluation of policies on a metropolitan scale in the face of heavy interdependence among land use, transportation and environmental systems, and fragmentary governmental authority and scope remains an elusive goal.

The processes for developing local and metropolitan investments in transportation and other infrastructure and policies governing land use are fraught with difficulties. We outline but a few of these that are particularly germane to the context of land use, transportation and environmental policy. These include fragmentation of land use authority among local jurisdictions, spillover effects of urban problems such as traffic congestion and air pollution, lack of metropolitan authority to forge metropolitan policies, difficulties in achieving meaningful public participation in metropolitan planning processes, and deep conflicts among stakeholders over values to guide priorities in decision-making.

Local governments are given the power to regulate land use by states, and most metropolitan areas are composed of multiple, sometimes hundreds, of local jurisdictions that exercise this control to serve the wishes of their local constituents. In a seminal paper (Tiebout, 1956), this fragmentation of local jurisdictions was characterized as a market for local public goods, since households (and firms) 'shop' for combinations of local public goods such as school quality, parks, libraries, and public safety, weighing the cost of these services in the form of taxes and fees levied by the jurisdiction against the quality of the services. While there is much academic debate about whether such markets for public goods are efficient (Fischel, 1990) and equitable (Orfield & Katz, 2002), there is not much doubt that the local control of land use, coupled with reliance on property and sales taxes to fund local infrastructure and services, often puts jurisdictions in fierce competition for tax base, and makes the achievement of regional coordination of land use policies fundamentally challenging (Bollens, 1993).

In the U.S., each region with a population over 50,000 is required to have a designated Metropolitan Planning Organization to be eligible for federal transportation funding. These Metropolitan Planning Organizations are charged with coordinating long-term regional transportation planning, but generally lack any legal authority over land use decisions, which is instead under the control of cities and counties. Given the inherently parochial nature of local land use policies, the needs to coordinate land use policies more effectively, in ways that are consistent with broader regional goals, have led increasingly led to the adoption of state growth management legislation (Bollens, 1992; Burchell, Listokin, & Galley, 2000; Knaap & Nelson, 1992; Nelson, Duncan, Mullen, & Bishop, 1995). But most states use approaches that leave broad discretion at the local level to implement goals that are often vague, and not infrequently objectives that are inconsistent with each other. Moreover, there has been considerable debate over whether growth management policies such as Urban Growth Boundaries are effective in achieving their aim of containing urban sprawl, and whether they worsen housing affordability problems (Blanco, 1998; Ding, Knaap, & Hopkins, 1999; Longley, Batty, Shepherd, & Sadler, 1992; Mildner, Dueker, & Rufolo, 1996; Nelson & Peterman, 2000; Weitz & Moore, 1998).

Challenges within Academia

In addition to challenges arising from the nature of the domain and the difficulties of metropolitan governance, there are also challenges within academia that make it difficult to focus systematic academic research on these problems. Three specific challenges relate to interdisciplinarity, under-appreciation for applied research, and the differences between academic and governmental priorities, approaches to risk, and schedules.

Challenges of Interdisciplinary and Applied Research

That the problem domain we have outlined is fundamentally interdisciplinary goes without saying. These topics are the subject of active research in ecology, economics, sociology, psychology, political science, public policy, urban design and planning, to name but a few. Add statistics and computer science and engineering to address modeling methods, software systems, and human-computer interaction, and the challenge of interdisciplinarity becomes clearer. These disciplines, while all relevant to the problem domain we have outlined, embrace different methods, theories, and epistemologies. Simply describing a problem in ways that researchers from this range of disciplines can begin to communicate using a common language and conception of the problem requires a very significant effort. Moreover, universities as institutions are organized around disciplinary building blocks, and often the incentives are heavily stacked against doing interdisciplinary research. Our approach to addressing this challenge has combined push and pull factors. On the one hand, researchers motivated by and interested in the challenges of this interdisciplinary research agenda are drawn together by self-selection, and find ways to justify to their respective departments their engagement in the endeavor. On the other hand, there has been a growing appreciation for the importance of doing interdisciplinary research, both within academic institutions and in government, resulting in additional funding opportunities for these efforts. In our case, the project has received funding from four interdisciplinary programs at the National Science Foundation: the Digital Government Program, the Urban Research Initiative, the Information Technology Research Program, and the Biocomplexity Program, in addition to funding from governmental agencies such as the Puget Sound Regional Council that have a decidedly problem-centered perspective.

In addition to problems of interdisciplinary research, applied research that attempts to make basic research relevant to constituencies such as local governments or the general public are often treated with less regard than scholarship that advances basic theory or methods. Outside of academia, these sympathies are generally reversed, and the term ‘ivory tower’ is not widely intended as a compliment. Creating or finding a supportive environment for undertaking large-scale, difficult applied research is a non-trivial challenge. In this particular project, the grounding of the project within professional disciplines such as public affairs and urban planning has made this more feasible. In addition, we have developed a basic research agenda on the analysis of the components of the urban systems we are modeling, such as residential location, employment location, real estate development and prices, and on the design of an integrated urban simulation system (Alberti & Waddell, 2000; Waddell, 2000, 2001, 2002; Waddell et al., 2003; Waddell & Ulfarsson, 2003).

Disciplines such as computer science and engineering have always been concerned with the practical application of research. However, the typical path is first to investigate the concepts in prototype form in a university or research laboratory setting, and then turn the work over to a development group for commercialization or deployment. In contrast, in our project, an integral requirement of the research is that we have a fully implemented, highly reliable, and documented system – if we had only an undocumented and somewhat unreliable research prototype, we would be unable to deploy it at Metropolitan Planning Organizations, or use it in case studies such as the one in Salt Lake City described later in this paper. There are several components to our approach to this problem. Our staff includes two highly experienced software engineers, who ensure the quality of the code and also supervise the work of undergraduate research assistants. Also, we are engaged in several different kinds of information technology research: first, research that in fact does require the use of a fully-operational, deployed system; second, research spinoffs that involve studying our processes and methodologies; and third, research that (because it is not on the critical path for system deployment) can rely on experimental implementations on top of the core UrbanSim system.

One important example of research that requires a fully-operational, deployed system is on extending and validating Value Sensitive Design (Friedman, Kahn, & Borning, 2002). Value Sensitive Design is a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process. The domain of urban development and environmental impacts is clearly value-laden, with different stakeholders bringing a range of strongly-held and sometimes conflicting values to the table. We make substantial use this methodology in our system design work to handle the design questions raised by this range of values and the value conflicts. At the same time, UrbanSim is the most complex domain in which Value Sensitive Design has been deployed to date, and as a result has required us to extend the methodology in significant ways, for example, to deal with the broad range of stakeholder values and value conflicts. Having a system used by actual governments for real decisions is of major importance for the development of Value Sensitive Design as a methodology with the potential for real-world impacts. A closely-related research area is evolving our software development methodology to better meet these value concerns (Freeman-Benson & Borning, 2003).

We have also had success in developing research spinoffs that involve studying our processes and methodologies, for example, in software engineering (Noth, Borning, & Waddell, 2003), ***ALSO INSERT NOTH PHD HERE*** techniques used in our group to facilitate group awareness and coordination (Brush & Borning, 2003), and remote usability testing of sophisticated interfaces, such as the UrbanSim graphical user interface shown in Figure 2. Finally, an example of research that can rely on experimental prototypes, because it is not on the critical path for system deployment, is our graphics research project on generating 3-D street scenes of neighborhoods and business districts, complete with building facades, streets and sidewalks, and moving pedestrians and vehicles, based on simulated results produced by UrbanSim (Fitzner, Grochow, & Popovic, 2003).

Challenges of Aligning Academic and Government Objectives

A third set of issues arises from the need to align the interests of academia and government. Besides the challenges of doing applied and interdisciplinary research challenge outlined above, the core goals and objectives of academia and government are different enough so that partnerships require some conscious alignment of these goals. Academic goals focus on research and teaching, with a broad endorsement of service (although this is often interpreted as service to the department, the university, or the discipline, rather than service to the broader community). Governmental goals focus on the specific mandates of the charter of each agency, and general-purpose local governments are driven by the need to deliver a range of public services, and to be responsive to the demands of their constituents. In the case of Metropolitan Planning Organizations, the constituency is generally not directly the population of the region, but rather the local governments that form the membership of the metropolitan organization. This complicates the goals of Metropolitan Planning Organizations, given the issues outlined previously.

Assessment and management of risk is also fundamentally different between academia and government. Academic research is inherently risky. Many (most) experiments fail, and as much is learned from failures as successes. Governments, on the other hand, as stewards of public funds, and charged with line responsibility for service delivery, are fundamentally risk-averse. The problem this presents is that developing the research and information technology needed to address the problems outlined earlier require development of new theory, data, methods and software systems – all of which involve considerable risks. Our approach to this problem has been to use research funding from sources such as the National Science Foundation – whose charter calls for funding fundament and perhaps high-risk research – to develop and test ideas, methods, and technologies, and then engage in more manageable levels of risk for applying these in an operational setting in local and metropolitan government, with funding from these agencies.

Another aspect of the research-government partnership that has posed challenges is the coordination of schedules. While this might appear to be a trivial issue compared to others, that has not proven to be our experience. First, governmental agencies frequently operate under intense project deadlines that are short-term, and do not lend themselves to engaging in research and development of technology. Even if a combination of multiple projects might warrant making a significant investment in research or technology that could be used for all of them, the management and timing of projects often precludes such coordinated effort – especially when the projects cross the boundaries within and between institutions.

Given the range of challenges outlined above, it became apparent that some institutional structuring would be required to address them. Over the past year, we have formed a Center for Urban Simulation and Policy Analysis (CUSPA), and enlisted the Puget Sound Regional Council and other governmental agencies as partners, with mutually-agreed objectives to develop and apply UrbanSim, and to conduct research relevant to policy formulation and evaluation. A Memorandum of Understanding was developed to articulate common interests and objectives, and to set out the broad ground-rules for the partnership. Specific contracts for specified periods operationalize this partnership. Within the University of Washington, CUSPA has been positioned as an interdisciplinary center, coordinated by a Director affiliated with the Evans School of Public Affairs and the Department of Urban Design and Planning, a Co-Director from the department of Computer Science and Engineering, and Steering Committee members from Civil and Environmental Engineering, the Information School, Urban Design and Planning, and Statistics. The Center is housed in a (politically neutral) off-campus laboratory. Having dedicated lab space for the project also allows the project participants to be physically co-located, which has proven valuable in facilitating interdisciplinary collaboration.

Challenges in Modeling

The idea of developing an operational model of urban dynamics with the capacity to simulate the effects of urban land use, transportation and environmental policies and investment, singly and in combination, is beyond challenging – it is daunting. Urban models have a checkered history, and the early generation of modeling originating in the 1960's was roundly criticized in an influential paper entitled 'Requiem for Large Scale Models' that all but halted serious academic research in this area (at least in the United States) for two decades (Lee, 1973, 1994). Many of the concerns raised by Lee still apply to current work in urban modeling. In particular, concerns that models were not founded on clear behavioral theory, were not responsive to clearly identified problems, and were too much like a 'black-box' that could not be readily explained or evaluated, still resonate.

Other problems identified by Lee, such as limitations in computing, statistical methods, and data, are still large, but dramatic progress has been made on all of these fronts, and these appear considerably more tractable today than they were at the time of Lee's initial critique. The advent of Geographic Information Systems, advances in database technology, in computing hardware, in object-oriented software engineering, and agile software development methods all contribute significant capacity to new model designs. Groundbreaking work on modeling choice processes using discrete choice methods (McFadden, 1973, 1981, 1984) and on microsimulating individual agents (Clarke, 1996; Mackett, 1992; Orcutt, Greenberg, Korbel, & Rivlin, 1961; Salomon, Waddell, & Wegener, 2002; Waddell et al., 2003; Wegener, 1985) have opened an avenue to make the models more behaviorally sound and transparent.

Our approach to the design of the model system has been to identify policy questions of interest, then identify the key agents and processes that these policies impact, and then to model the choices and interactions of these agents explicitly, incorporating sufficient detail and characteristics to be able to use the model system to evaluate relevant policies. The process of investigating the policy and functional requirements for the system has been documented in the context of the Puget Sound Regional Council, a partner in the development and application of the model system in the Seattle-Tacoma metropolitan area (Waddell, Schroer, & Outwater, 2001).

The process of developing and applying a model system within an operational context in a government agency requires a situated design that recognizes the institutional and political milieu in which it will be used. Our vision for this process is encapsulated in Figure 1, which represents an iterative process beginning with the articulation of goals and specific objectives consistent with these goals. These may follow from legislative requirements or guidelines, such as the Growth Management Act in Washington and its influence on the articulation of goals and objectives in the PSRC Vision 2020 plan. Or they may result from a regional visioning exercise led by community leaders and non-profit organizations, as in the Envision Utah visioning process. In either case, the articulation of goals and objectives needs to be translated into a set of tangible actions that are within the mandates of the organizations participating in the process. In the case of Metropolitan Planning Organizations and local jurisdictions, these pertain to transportation plans, land use plans and other forms of land regulation, and policies influencing the use of land in environmentally sensitive areas. Although such policies may actually be made, in practice, by a range of different organizations operating within limited mandates and scopes, the intent of this project is to facilitate coordinated assessment of the cumulative effects of these policies, and to encourage the coordination of the policies to achieve collective goals and objectives. It is therefore important to allow the combination of multiple policies and infrastructure investments, into what we refer to as policy scenarios. Note that these are not scenarios in the sense of predictions of the future, but rather as packages of policies that are intended to be implemented in a coordinated fashion. The use of models, then, in this vision, is to simulate the effects of these policy scenarios on the outcomes they affect. From these outcomes, indicators can be derived that ideally form direct measures of accomplishment of the articulated objectives. Once such performance measures are generated, they facilitate an assessment phase, which requires examining the effects of the chosen combination of policies on the benchmarks of progress towards the intended objectives, and making decisions about how to proceed in improving on the outcomes. Alternatives include generating permutations of policy scenarios to seek more effective strategies, and to learn through this exploration about the trade-offs among the selected objectives, or to revise the objectives once more is known about the tradeoffs.

[Insert Figure 1 About Here]

This approach has resulted in a model design that features households and their decisions to move and locate within a metropolitan housing market, firms and their movement and location of individual jobs, real estate developers and their choices to develop or redevelop different kinds of projects across locations, and the representation of governments and their policy and investment choices as external acts that the model system responds to in order to predict outcomes in terms of the spatial patterns of households, jobs, real estate inventory and prices. By interacting the model system with an external travel demand model system, we capture the feedback between the spatial configuration of the urban form, the transportation network, and the patterns of travel generated.

A limitation of this approach is that the model system is still constrained by design limitations of the external travel demand model (Beimborn, Kennedy, & Schafer, 1996), as well as by difficulties of interfacing the travel demand model with UrbanSim and of extracting all of the desired information from the travel model. This raises the need in the longer-term to integrate travel demand modeling more closely, drawing on recent advances in activity-based travel modeling (Ben-Akiva & Bowman, 1998; Bowman, Bradley, Shiftan, Lawton, & Ben-Akiva, 1998; Kitamura, 1988; Pendyala, Kitamura, & Reddy, 1998). The design has been regarded as intuitive and straightforward, as well as behaviorally sound (Miller, Kriger, & Hunt, 1998), and therefore more accessible to non-technical audiences.

Particularly in light of the spotty track record of urban modeling, the credibility of the model system we have been developing is a priority, and there is a considerable burden of proof. Standard methods of testing the accuracy of models are unfortunately sparse, and for integrated models of this scale, forms of model validation include sensitivity testing and longitudinal validation. The use of a historical period to validate the accuracy of the model over time is an attractive method, but almost no published exercises of this type exist in the literature. We have conducted such an assessment, using 15 years of simulated change and comparing it to observed changes within the Eugene-Springfield, Oregon area, and found the results to be robust (Waddell, 2002).

We are currently engaged in a year-long project to assess the application of the model system in the Salt Lake City, Utah area, discussed in detail in the case study section of the paper.

Development and Application of UrbanSim

The UrbanSim model system has been in development since 1996 in response to many of the considerations outlined above. An initial design was developed for the Honolulu, Hawaii metropolitan area as part of a larger transportation modeling effort, and was subsequently developed into a working prototype for the Eugene-Springfield, Oregon metropolitan area with support from the Oregon Department of Transportation (Waddell, 1998, 2000). The design and algorithms have been extended significantly since the initial prototype, and continue to evolve (Waddell, 2002; Waddell et al., 2003).

After a collaboration between the authors began in 1998, the software architecture and implementation was re-engineered and made more modular, facilitating the maintenance and evolution of the system (Noth et al., 2003). Version 1 of the software was released in 2000, and subsequently applied to Salt Lake City, Utah. Application to Houston, Texas began in 2001. Starting in summer 2002, we rewrote the software from the ground up using an Agile development methodology, with the release of Version 2.0 later that year. Also in 2002, we set up a partnership with the Puget Sound Regional Council (the Metropolitan Planning Organization for the region that includes Seattle) to further develop UrbanSim and apply it locally, with the intent of making it the operational land use model for the region. Finally, in 2003, the University of Washington approved the formation of a new Center, the Center for Urban Simulation and Policy Analysis, to provide a formal organizational home for the interdisciplinary effort.

Current effort on the model system is focused on developing a user interface for technical modelers, as shown in Figure 2. Following completion of this interface, a user-interface will be designed for non-technical stakeholders, from policy-makers to community residents, to use in evaluating simulation results over the web.

[Insert Figure 2 About Here]

We focus on the Salt Lake City application as a case study, since in many respects it represents the range of complexities and conflicts that are endemic to this domain, and may be generalizable in some measure to other metropolitan areas in the Unites States.

The Greater Wasatch Front region of Utah, centered on Salt Lake City, is a fast-growing western metropolis, bounded by Great Salt Lake and Utah Lake on the west, and by the Greater Wasatch Front range of mountains on the East. Its growth has been rapid and relatively low-density, exacerbating concerns about the long-term development of the region, and about loss of open space, limited water resources, and managing transportation problems. Envision Utah, a nationally-recognized regional visioning process has evolved since 1996, bringing together a wide cross-section of community and business leaders, to generate, compare and adopt a preferred long-term vision for the region. In spite of a prevailing low-density development pattern, the preferred vision selected by the stakeholders focused on more compact development, more mixed-use, and pedestrian and transit orientation. Work has been ongoing since that time to promote this vision and to develop tools to achieve it.

Utah Governor Mike Leavitt and other leaders within the region have championed a major new highway project by the name of Legacy Highway, planned to run west of the I-15 corridor, and adjacent in parts of the region to Great Salt Lake, through sensitive wetland areas. The Sierra Club and Utahns for Better Transportation challenged the legality of the highway project in two separate lawsuits, one related to conformity and one on the environmental impact assessment. In June, 2002 an appeal to the 9th District Court of Appeals succeeded in obtaining an injunction stopping the highway construction, and setting terms of a settlement. These terms included evaluating use of UrbanSim by the Wasatch Front Regional Council in an integrated way with the regional transportation models. A Peer Review Process has been established to monitor and assess the testing of the model system integration, and to make recommendations on its potential for operational use by the WFRC. If deemed suitable, the terms of the settlement require that it be used in a coordinated way in operational use by the WFRC in preparing its Regional Transportation Plan and in major Corridor Studies.

The legal challenges to a highway project posed in this case study are by no means unique to this region. Based on the legal foundations of the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991, which require coordinated assessment of transportation, land use, and air quality, environmental groups have mounted legal challenges to regional transportation planning processes in the Bay Area, Chicago, and Salt Lake City, with other regions threatened by similar lawsuits (Garrett & Wachs, 1996). Opposition to major highway projects has been growing for some time, arising from a variety of sources, but particularly from criticism that construction of highways induces more demand for travel, and therefore overstates the anticipated benefits of congestion relief and improvement in air quality (Bonsall, 1996; Coombe, 1996; DeCorla-Souza & Cohen, 1999; Goodwin, 1996; Heanue, 1997; Levinson & Kanchi, 2001; Noland & Cowart, 2000; Noland & Lem, 2000).

What this case study highlights is both the potential for collaborative visioning and consensus building, and for irreconcilable conflict leading to legal action. Our intention for the use of UrbanSim in contexts such as these is to provide stakeholders with a credible means to evaluate the potential effects of alternative policies and infrastructure choices, both to assist in resolving (or preferably preventing) conflicts over specific projects, and in exploring the efficacy of alternative policy strategies for achieving a vision that has been developed through a consensus-building visioning process. The assessment of UrbanSim in the Salt Lake City case will be completed and documented by the end of 2003.

Assessment and Future Directions

In assessing the status of the UrbanSim project, we should first note that the project has been successful so far in setting up partnerships with local and regional government agencies, in producing an operational urban model that is considerably more advanced than others in routine use, and in setting up a highly interdisciplinary collaboration in the university. However, the long-term success of the project should be judged on whether we produce a software system that is in routine, day-to-day planning use by Metropolitan Planning Organizations and others, and that – ultimately – changes for the better the way urban planning is done. Here the jury is still out. In outline form, here are some reasons that we believe the project has been successful so far:

- Most importantly, we identified real, unmet needs of local and regional governments and are developing a system to meet those needs. (In particular, the land use models that most agencies currently use are quite inadequate to meet the demands and expectations placed on them.)

- We used a process for developing model specifications that identifies public policies of interest, and develop models to examine the potential effects of these policies. We used a behavioral framework that accounts for the interactions of policies and markets. This approach has led to models that are more detailed than prior models, which has added computational and data requirements, but has yielded a more understandable and relevant system.
- We set up an interdisciplinary collaboration among a variety of University of Washington schools and departments, including the Evans School of Public Affairs, Computer Science and Engineering, Urban Design and Planning, Civil Engineering, the Information School, Psychology, Statistics, and others. Both the Evans School and Urban Design and Planning have many years of experience in setting up successful collaborations with local and state government. The project itself has requirements for expertise that any single one of the participating departments would be unable to meet on its own. To foster collaboration, it has been important to find space that allows project faculty, staff, and students from the different departments to be co-located, and to have frequent meetings and informal discussions among project members from multiple disciplines. We have also had a series of interdisciplinary seminars, as well as a graduate course in urban simulation that included students from a wide range of departments.
- We have found ways of balancing the research agendas of the respective academic partners with the more applied research needs of governmental partners, by framing the research agenda in problem-centered terms, and tackling problems

that are difficult enough to provide motivating research challenges within each of the contributing disciplines.

- We use an agile software development methodology (Freeman-Benson & Borning, 2003), which allows us to adapt rapidly to changing requirements. An extensive testing methodology increases confidence in the reliability of the system.
- We use an open source license, the GNU Public License, for our software. Anyone can download the system from our website and use it. For example, groups in El Paso, Texas, Paris, France and Taipei, Taiwan are actively working on applying UrbanSim in those regions. By placing the software under the GPL, rather than simply putting it in the public domain, we have set up a structure that allows the different users to build on each other's work. There is also still ample opportunity for consultancies to use the software in a service-oriented business model. (In contrast, in other cases, land use or transportation modeling software was initially funded by federal or other government agencies and placed in the public domain. It was then modified by a consultancy and made proprietary.)
- We were able to hire two professional software engineers, with extensive industrial experience, to manage and form the backbone of our programming effort. These engineers also coordinate the work of undergraduate and graduate students who write parts of the software system. The graduate students work on programming projects that form part of their own research efforts as well as contributing to the overall project objectives. A set of undergraduate research assistants, majoring in computer science or computer engineering, both make

important contributions to the project as well as gaining valuable experience working on a complex software system with skilled professional engineers. This structure has proven valuable in achieving the software quality, reliability, and maintainability that we require.

- Our research questions are driven first by the requirements of the domain and of delivering a useful, reliable system. In addition, we have had success doing research on theory and methods for the Value Sensitive Design methodology, research that involves studying the methodologies and processes that we use, and research that can build on having such an operational model to produce novel and useful interfaces.

Acknowledgements

We would like to thank all of the members of the UrbanSim research team for making this project possible. This research has been funded in part by National Science Foundation Grants EIA-0090832 and EIA-0121326, by a matching grant from the Federal Highway Administration, by the Puget Sound Regional Council, and by the University of Washington PRISM project under the University Initiatives Fund.

References

All the UrbanSim papers in this bibliography are available from www.urbansim.org/papers. This reference list is intended to support the discussion in this case study, rather than to provide a comprehensive set of references to the field of land use and transportation modeling.

1000 Friends of Oregon. (1993). *Making the Land Use Transportation Air Quality Connection, Vol. 4A: The Pedestrian Environment*. Portland, OR: LUTRAQ, with Cambridge Systematics, Inc., Calthorpe Associates, and Parsons Brinkerhoff Quade and Douglas.

Alberti, M. (1999). Modeling the urban ecosystem: a conceptual framework. *Environment and Planning B: Planning and Design, 26*, 605 - 630.

Alberti, M., & Waddell, P. (2000). An Integrated Urban Development and ecological Simulation Model. *Integrated Assessment, 1*(3), 215-227.

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

Anderson, W. P., Kanaroglou, P. S., & Miller, E. J. (1996). Urban Form, Energy and the Environment; A Review of Issues, Evidence and Policy. *Urban Studies, 33*(1), 7-35.

Banister, D., Watson, S., & Wood, C. (1997). Sustainable cities: transport, energy, and urban form. *Environment and Planning B: Planning and Design, 24*, 125 - 143.

Beimborn, E., Kennedy, R., & Schafer, W. (1996). *Inside the Black Box: Making Transportation Models Work for Livable Communities*: Citizens for a Better Environment and The Environmental Defense Fund.

Ben-Akiva, M., & Bowman, J. L. (1998). Integration of an Activity-based Model System and a Residential Location Model. *Urban Studies, 35*(7), 1131-1153.

Berman, M. A. (1996). The Transportation Effects of Neo-Traditional Development. *Journal of Planning Literature, 10*(4), 347-363.

Blanco, H. (1998). *The Effectiveness of Policies to Contain Urban Sprawl and their Evolution in Florida, Oregon, and Vermont* (Working Paper).

Bollens, S. A. (1992). State Growth Management: Intergovernmental Frameworks and Policy Objectives. *Journal of the American Planning Association, 58*(4), 454 - 466.

Bollens, S. A. (1993). Restructuring Land Use Governance. *Journal of Planning Literature, 7*(3), 211 - 226.

Bonsall, P. (1996). Can induced traffic be measured by surveys? *Transportation, 23*(1), 17 - 34.

Bowman, J. L., Bradley, M., Shiftan, Y., Lawton, T. K., & Ben-Akiva, M. (1998). *Demonstration of an Activity-Based Model System for Portland.* Paper presented at the 8th World Conference onTransport Research, Antwerp, Belgium.

Brush, A. J. B., & Borning, A. (2003). Today Messages: Lightweight Group Awareness via Email. *ACM CHI 2003 (short paper)*.

Burchell, R. W., Listokin, D., & Galley, C. C. (2000). Smart Growth: More Than a Ghost of Urban Policy Past, Less Than a Bold New Horizon. *Housing Policy Debate, 11*(4), 821 - 877.

Cervero, R., & Landis, J. (1995). The Transportation-Land Use Connection Still Matters. *Access, Fall*(7), 2-10.

Clarke, G. P. (Ed.). (1996). *Microsimulation for Urban and Regional Policy Analysis* (Vol. 6). London: Pion Limited.

Coombe, D. (1996). Induced traffic: what do transportation models tell us? *Transportation, 23*(1), 83 - 101.

DeCorla-Souza, P., & Cohen, H. (1999). Estimating induced travel for evaluation of metropolitan highway expansion. *Transportation, 26*, 249 - 262.

Diamond, D. B. (1980). The Relationship Between Amenities and Urban Land Prices. *Land Economics, 56*(1), 21 - 32.

Ding, C., Knaap, G. J., & Hopkins, L. D. (1999). Managing Urban Growth with Urban Growth Boundaries: A Theoretical Analysis. *Journal of Urban Economics, 46*, 53 - 68.

Fischel, W. (1990). *Do Growth Controls Matter? A Review of Empirical Evidence on the Effectiveness and Efficiency of Local Government Land Use Regulation*. Cambridge, MA: Lincoln Institute of Land Policy.

Fitzner, C., Grochow, K., & Popovic, Z. (2003). *StreetScapes:Visualizing Results of Urban Simulation.* Paper presented at the IEEE Conference on Visualization, Interactive Presentation, Seattle, WA.

Freeman-Benson, B., & Borning, A. (2003). *YP and Urban Simulation: Applying an Agile Programming Methodology in a Politically Tempestuous Domain.* Paper presented at the 2003 Agile Development Conference, Salt Lake City, UT.

Friedman, B., Kahn, P., & Borning, A. (2002). *Value Sensitive Design: Theory and Methods* (No. UW CSE Technical Report 02-12-01). Seattle: University of Washington.

Garrett, M., & Wachs, M. (1996). Transportation Planning on Trial: The Clean Air Act and Travel Forecasting -- Introduction & Conclusions. In *Transportation Planning on Trial: The Clean Air Act and Travel Forecasting* (pp. 1 - 27; 195 - 223). Thousand Oaks, CA: SAGE Publications.

Giuliano, G. (1989). New Directions for Understanding Transportation and Land Use. *Environment and Planning A, 21*, 145-159.

Goodwin, P. B. (1996). Empirical evidence on induced traffic: A review and synthesis. *Transportation*, *23*(1), 35 - 54.

Gottlieb, P. (1995). Residential Amenities, Firm Locations and Economic Development. *Urban Studies, 32*(9), 1413-1436.

Greenwood, M. J., & Hunt, G. L. (1989). Jobs Versus Amenities in the Analysis of Metropolitan Migration. *Journal of Urban Economics, 25*, 1-16.

Hanson, S. (1995). Getting There: Urban Transportation in Context. In S. Hanson (Ed.), *The Geography of Urban Transportation* (Second ed., pp. 3-25). New York: The Guilford Press.

Heanue, K. (1997). *Highway Capacity and Induced Travel: Issues, Evidence and Implications.* Paper presented at the 76th Annual Meeting of the Transportation Research Board.

Kelly, E. D. (1994). The Transportation Land-Use Link. *Journal of Planning Literature, 9*(2), 128-145.

Kitamura, R. (1988). An Evaluation of Activity-based Travel Analysis. *Transportation, 15*, 9-34.

Knaap, G., & Nelson, A. (1992). The Regulated Landscape: Lessons on State Land Use Planning from Oregon (ch. 1 - 3). In (pp. 15 - 97). Cambridge, Mass.: Lincoln Institute of Land Policy.

Krumm, R. J. (1980). Neighborhood Amenities: An Economic Analysis. *Journal of Urban Economics, 7*, 208-224.

Lee, D. (1973). Requiem for Large Scale Models. *Journal of the American Institute of Planners, 39*(3).

Lee, D. (1994). Retrospective on Large-scale Urban Models. *Journal of the American Planning Association, 60*(1), 35-40.

Levinson, D. M., & Kanchi, S. (2001). *Whence Induced Demand?* Paper presented at the Western Regional Science Association Conference.

Longley, P., Batty, M., Shepherd, J., & Sadler, G. (1992). Do Green Belts Change the Shape of Urban Areas? A Preliminary Analysis of the Settlement Geography of South East England. *Regional Studies, 26*(5), 437 - 452.

Mackett, R. L. (1992). *Micro Simulation Modelling of Travel and Locational Processes: Testing and Further Development*. London: Transport Studies Group, University College London.

Marsh, L., Porter, D., & Salvesen, D. (1996). The Impact of Environmental Mandates on Urban Growth. *Cityscape: A Journal of Policy Development and Research, 2*(3), 127 - 154.

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

McFadden, D. (1981). Structural Discrete Probability Models Derived from Theories of Choice. In C. Manski & D. McFadden (Eds.), *Structural Analysis of Discrete Data and Econometric Applications* (pp. 198-272). Cambridge: The MIT Press.

McFadden, D. (1984). Econometric analysis of qualitative response models. In Z. Griliches & M. Inrilligator (Eds.), *Handbook of Econometrics* (Vol. II, pp. 1395-1457). Amsterdam: North Holland.

Mildner, G. C. S., Dueker, K. J., & Rufolo, A. M. (1996). *Impact of the Urban Growth Boundary on Metropolitan Housing Markets*. Portland, OR: Portland State University Center for Urban Studies.

Miller, E. J., Kriger, D. S., & Hunt, J. D. (1998). *Transportation - Land Use Modeling: Review of Operational Models* (Technical Memoranda: documenting findings of TCRP Project H-12, Integrated Urban Models for Simulation of Transit and Land-Use Policies No. 4): University of Toronto Joint Program in Transportation; DELCAN Corporation.

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

Moore, T., & Thornes, P. (1994). *The Transportation/Land Use Connection*. Chicago: American Planning Association, Planning Advisory Service Report Nos. 448/449.

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

Nelson, A. C., Duncan, J. B., Mullen, C. J., & Bishop, K. R. (1995). *Growth Management Principles and Practices*. Chicago: American Planning Association.

Nelson, A. C., & Peterman, D. R. (2000). Does Growth Management Matter? The Effect of Growth Management on Economic Performance. *Journal of Planning Education and Research, 19,* 277 - 285.

Noland, R. B., & Cowart, W. A. (2000). Analysis of Metropolitan Highway Capacity and the growth in vehicle miles of travel. *Transportation, 27*, 363 - 390.

Noland, R. B., & Lem, L. L. (2000). *Induced Travel: A Review of Recent Literature and the Implications for Transportation and Environmental Policy.* Paper presented at the European Transport Conference; Conference of the Association of Collegiate Schools of Planning.

Noth, M., Borning, A., & Waddell, P. (2003). An Extensible, Modular Architecture for Simulating Urban Development, Transportation, and Environmental Impacts. *Computers, Environment and Urban Systems, 27*(2), 181-203.

Orcutt, G., Greenberg, M., Korbel, J., & Rivlin, A. (1961). *Microanalyis of Socioeconomic Systems: A Simulation Study*. New York: Harper and Row.

Orfield, M., & Katz, B. (2002). *American Metropolitics: The New Suburban Reality*. Washington, D.C.: The Brookings Institution.

Parker, M. T. (2000). *Ascape: Abstracting Complexity* (Working Paper): Center on Social and Economic Dynamics, The Brookings Institution.

Pendyala, R. M., Kitamura, R., & Reddy, D. V. G. P. (1998). Application of an activity-based travel-demand model incorporating a rule-based algorithm. *Environment and Planning B: Planning and Design, 25*, 753 - 772.

Salomon, I., Waddell, P., & Wegener, M. (2002). Sustainable Life Styles? Microsimulation of Household Formation, Housing Choice and Travel Behaviour. In W. Black & P. Nijkamp (Eds.), *Social Change and Sustainable Transport* (pp. 125-131). Bloomington, IN: Indiana University Press.

Sivitanidou, R. (1995). Urban Spatial Variations in Office-Commercial Rents: The Role of Spatial Amenities and Commercial Zoning. *Journal of Urban Economics, 38,* 23-49.

Tiebout, C. (1956). Pure Theory of Local Public Expenditures. *Journal of Political Economy*, *64*, 416-424.

Waddell, P. (1998, May 1998). *UrbanSim: the Oregon prototype metropolitan land use model*. Paper presented at the ASCE Conference on Land Use, Transportation and Air Quality: Making the Connection, Portland, OR.

Waddell, P. (2000). A behavioral simulation model for metropolitan policy analysis and planning: residential location and housing market components of UrbanSim. *Environment and Planning B: Planning and Design*, *27*, 247 - 263.

Waddell, P. (2001). Towards a Behavioural Integration of Land Use and Transportation Modeling. In *Travel Behavior Research: The Leading Edge* (pp. 65-95). New York: Pergamon.

Waddell, P. (2002). UrbanSim: Modeling Urban Development for Land Use, Transportation and Environmental Planning. *Journal of the American Planning Association*, *68*(3), 297-314.

Waddell, P., Borning, A., Noth, M., Freier, N., Becke, M., & Ulfarsson, G. F. (2003). UrbanSim: A Simulation System for Land Use and Transportation. *Networks and Spatial Economics, 3*, 43-67.

Waddell, P., Schroer, E., & Outwater, M. (2001). *Assessment of Model Requirements: Final Report to the Puget Sound Regional Council on Land Use and Travel Demand Forecasting Models*. Seattle: Puget Sound Regional Council.

Waddell, P., & Ulfarsson, G. F. (2003). Introduction to Urban Simulation: Design and Development of Operational Models. In P. Stopher, K. Button, K. Haynes & D. Hensher (Eds.), *Handbook in Transport, Volume 5: Transport Geography and Spatial Systems*: Pergammon Press.

Wegener, M. (1985). *The Dortmund Housing Market Model: A Monte Carlo Simulation of a Regional Housing Market* (Paper in Lecture Notes in Economics and Mathematical Systems: Microeconomic Models of Housing Markets No. 239). Berlin.

Weitz, J., & Moore, T. (1998). Development inside Urban Growth Boundaries: Oregon's Empirical Evidence of Contiguous Urban Form. *Journal of the American Planning Association, 64*(4), 424 - 440.

Wolfram, S. (1984). Cellular automata as models of complexity. *Nature*(311), 419-424.

Figure 1: A Proposed Role for Modeling in the Policy Process

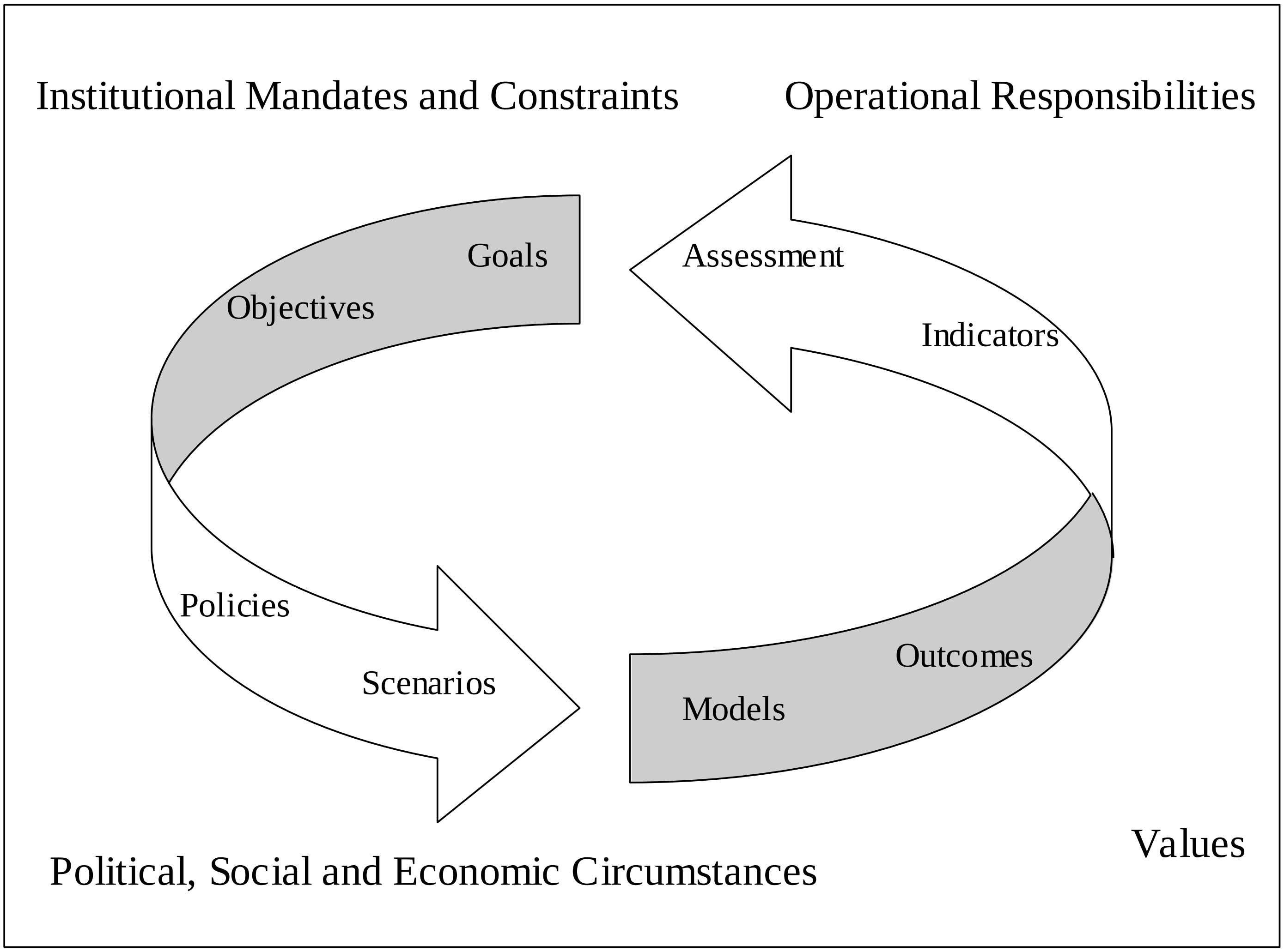
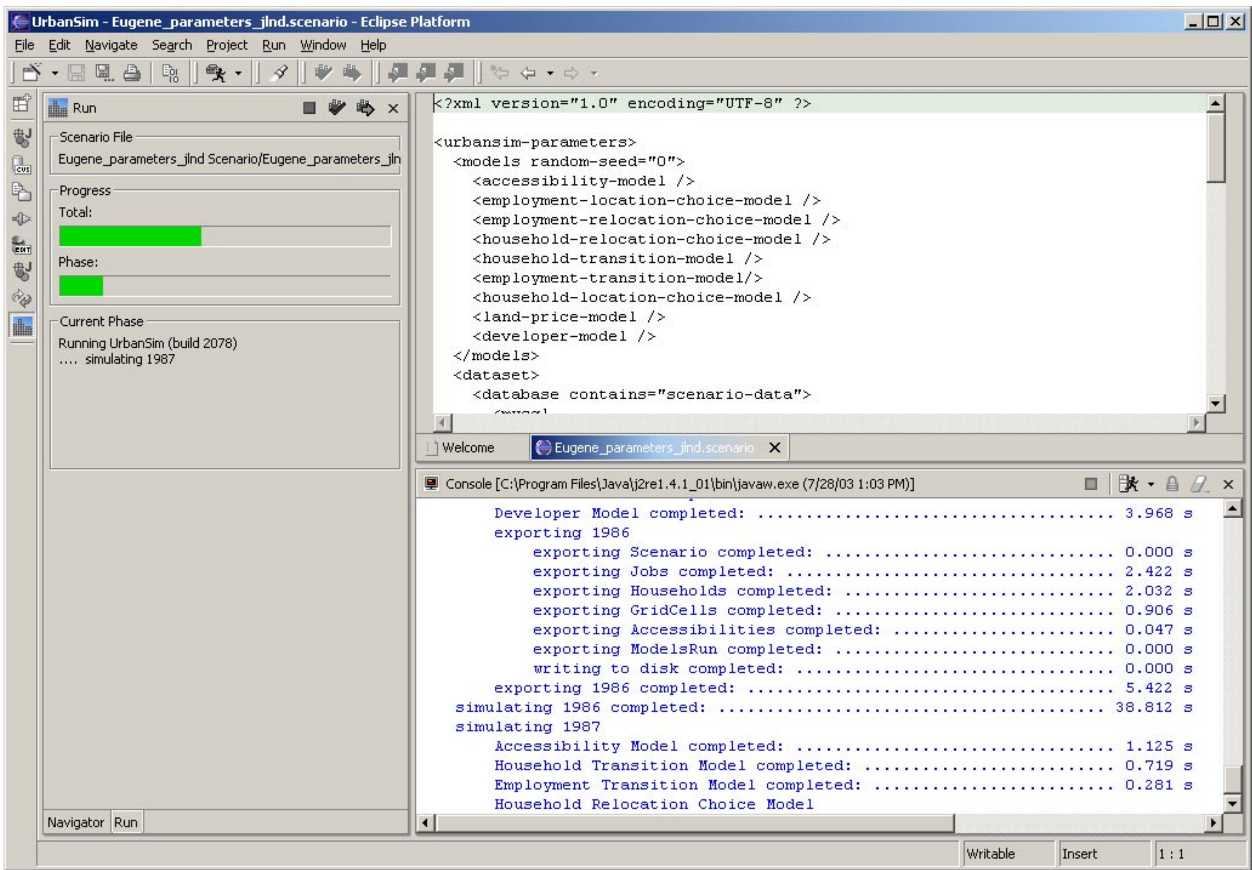


Figure 2: Screenshots of Technical Modeler Interface

2a: Running a Simulation



2b: Visualizing Indicator Output