Simulations for Urban Planning: Designing for Human Values

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Sophisticated simulation systems such as UrbanSim model the long-term impacts of transportation and land-use alternatives. Accounting for human values throughout the design process helps in designing interactions that engage both planners and citizens in the decision-making process.

Regional officials, urban planners, and citizens must grapple with issues such as traffic jams, resource consumption, and urban sprawl. Decisions about new freeways, transit service expansion, or land-use regulations are often controversial and expensive, with long-term consequences.

In many cases, neither planners nor citizens have sufficient information about how the various alternatives will play out over the long term. This represents a gap in informed decision making because long-term assessment is essential.

A metropolitan region that is considering a new light rail system or a new freeway—both major investments—must look beyond the immediate effects on traffic congestion. Decision-makers must attempt to understand how different alternatives might affect land use, transportation, and environmental impacts over the next several decades. Without carefully considering long-term effects, the chosen alternative might lead to the exact opposite of the original goal: A new freeway's convenient access, for example, could result in more development of new houses and businesses far away from existing employment and population centers, which in turn could *increase* traffic congestion.

Because these decisions will affect the entire region for many years, it makes sense to inform decision making with long-term analyses that are as accurate as possible. Sophisticated urban simulation models can support such analyses by predicting the long-term effects of alternative policies.

But data is not the only element of effective democratic decision making: In a democratic society, public deliberation by citizens and their elected representatives must precede such major decisions. Thus, in addition to providing accurate information, a design goal for an urban simulation system should also be to facilitate public understanding and citizen engagement.

We present a snapshot of ongoing research into the design of user interactions around the results from one such simulation system. UrbanSim[1] (www.urbansim.org), a large-scale urban simulation system developed at the University of Washington, projects patterns of land and transportation use and the environmental impact of various policies and investments over 20 years or more.

Results from UrbanSim take the form of indicators[2]—variables that represent key aspects of the simulation results, such as population and employment density. To better support the use of urban simulation systems in public deliberation, we are designing tools to support urban planners, citizens, and other stakeholders in their interaction with UrbanSim indicators. The development of these tools is guided by Value Sensitive Design,[3] a theoretically grounded approach to technology design that

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accounts for human values throughout the design process. The "What Is Value Sensitive Design?" sidebar gives more details about this approach.

Our application of this method has led to five interaction design goals:

- Improve the system's functionality by developing new tools for stakeholders to learn about, select, and visualize indicators to use in decision making.
- Support citizens and other stakeholders in evaluating alternatives with respect to their own values.
- Enhance the system's transparency with respect to its design, assumptions, and limitations—so it is not a black box.
- Contribute to the system's legitimacy by providing information that is credible and appropriate to the use context.
- Foster citizen engagement in the decision process by providing tailored information and opportunities for involvement.

To meet these goals, we developed and are refining three tools to help a variety of stakeholders—planners, modelers, citizens—understand UrbanSim's indicators: technical documentation designed to make information about indicators readily accessible; indicator perspectives that provide a platform for organizations to advocate for the use of particular indicators in decision making; and household indicators that let citizens look at simulation results from the viewpoint of their own household within the region.

INDICATORS AND URBAN SIMULATION

UrbanSim is a complex software system that models a region's urban processes over the next several decades. The system takes hours—sometimes days—to run, resulting in a massive database that contains detailed information about the region's households, jobs, travel routes, and real estate in each simulated future year. Our indicator tools aim to help stakeholders extract useful information from this very large database.

What Is Value Sensitive Design?

Value Sensitive Design is a theoretically grounded approach to technology design that accounts for human values, such as privacy, fairness, and democracy, throughout the design process. The method has three key features: an interactional perspective, attention to indirect as well as direct stakeholders, and a tripartite methodology.

An *interactional perspective* views values as stemming from a symbiosis of technology and social forces: People and social systems influence technological development, while technologies shape individual behavior and social systems.

User-centered design methodologies focus their attention on *direct stakeholders*—those who actually use the system. Value Sensitive Design emphasizes consideration of *indirect stakeholders* as well—those who do not use the system but are affected by its use. For UrbanSim, direct stakeholders are urban planners and modelers; indirect stakeholders include the residents of the region being modeled. Part of the UrbanSim vision is to empower indirect stakeholders to become direct stakeholders—to let citizens interact directly with UrbanSim's output, and ultimately to run different simulations themselves.

Finally, the *tripartite methodology* consists of conceptual, empirical, and technical investigations. The application of these investigations is both iterative and integrative; results from new investigations build on and integrate earlier ones.

Conceptual investigations comprise philosophically informed analyses of the values at stake. Empirical investigations focus on the human response to the technical artifact and on the larger social context in which the technology is situated. Technical investigations focus on the design and performance of the technology itself.

For example, in our UrbanSim conceptual investigations, we sharply distinguished *stakeholder values*—those that some stakeholders, but not necessarily all, would view as important—and *explicitly supported values*—those for which we could make principled arguments and that we explicitly support in UrbanSim's design. Explicitly supported values include freedom from bias, representativeness, and support for a democratic society.

As part of supporting a democratic society, we decided that the system should not a priori favor or rule out any given set of stakeholder values, but should allow various stakeholders to articulate the values most important to them and to evaluate alternatives in light of these values. Furthermore, our translation of Jürgen Habermas's four elements of legitimation potential into actionable design goals illustrates how different kinds of investigations build on one another—in this case, a technical investigation builds on a conceptual investigation.

UrbanSim currently supports 55 indicators for extracting information from simulation results, and one of our goals in the indicator tools is to support urban planners in developing new indicators for their particular region. Presenting simulation results with a consistent set of indicators for all the candidate policy alternatives can greatly enhance scenario assessment and comparison.

For example, suppose that stakeholders want to foster compact urban neighborhoods that make it easy and pleasant to walk and at the same time keep outlying areas rural by containing sprawl. In urban planning literature, population density is a key indicator of development character (in this case, walkable neighborhoods versus urban sprawl). Planning agencies can monitor population density throughout the region to understand current trends and use UrbanSim to understand the pos-

Figure 1. UrbanSim's geographic representation. The small white polygons are individual lots, while the blue squares are the 150-meter grid cells that form the core of UrbanSim's geographic representation. The data is for the Green Lake neighborhood in Seattle, Washington.

sible impact of various policies on population density 30 years later.

UrbanSim's interacting component models represent major actors and processes in the urban system.[1] The system takes a highly disaggregated approach, modeling individual households, jobs, and real-estate development and location choices, using relatively small grid cells (typically 150 × 150 meters), such as those in Figure 1.

Most UrbanSim models are discrete-choice models, in which the probability that a given agent will make a particular choice is a function of a set of variables that measure the relative attractiveness of that choice. For example, in the Residential Location Choice model, the probability that a particular household will choose to locate to a residential unit within a particular area depends on household attributes, such as income and number of children, as well as attributes of the potential dwelling, such as cost and location.

An external travel model simulates trips between the locations of various households and jobs. The resulting patterns of transportation use and congestion then give rise to accessibility measures for different locations, which in turn influence the desirability of these locations for housing or jobs.

The most recent version, UrbanSim 4, is built on the Open Platform for Urban Simulation, an object-oriented architecture and platform recently developed at the University of Washington.[4] OPUS and UrbanSim 4 are implemented in Python, using highly optimized array and matrix manipulation packages written in C++ to handle inner loop computations. The system is open source, under the GNU public license.

Currently, regional planning agencies are transitioning UrbanSim into operational use in the Puget Sound region (Seattle and surrounding areas), Honolulu, and Salt Lake City. Urban planners already use UrbanSim to inform decisions in Houston, and there have been research and pilot applications in Detroit, Eugene, and Phoenix, as well as in Amsterdam, Paris, Tel Aviv, and Zurich. UrbanSim also played a significant role in the out-of-court settlement of a lawsuit in Utah regarding a major highway construction project.[5] UrbanSim refinement is ongoing, and it is evolving as we add new models and capabilities.

VALUES IN DEMOCRATIC PLANNING

Commitment to three core values helps UrbanSim achieve the goal of supporting democratic urban planning: democratic engagement, freedom from bias, and political legitimacy.

Democratic engagement

Democratic urban planning requires that citizens be engaged in decision making. While acknowledging that engaged citizenship is not simple to characterize, Michael X. Delli Carpini[6] offers this definition: "A democratically engaged citizen is one who participates in civic and political life, and who has the values, attitudes, opinions, skills, and resources to do so effectively."

To foster engaged attitudes, consistent opinions, and enthusiastic participation, a planning system must provide information about the issues that form the substance of political life. UrbanSim helps fulfill that requirement by providing information about the potential impacts of land-use and transportation alternatives—a major political issue.

But providing information is not enough. Citizens must want to use it. Through UrbanSim, we seek to foster such democratic engagement, not only to help citizens make more informed decisions, but also to encourage an attitude that can lead to participation in public decision making. Information systems, such as online discussion forums or tools for citizens to propose new policy and investment packages, for example, could provide new opportunities for citizen participation in urban planning. Of course, systems such as UrbanSim supplement—not replace—informal discussions, town meetings, and voting.

Freedom from bias

Batya Friedman and Helen Nissenbaum[7] refer to bias in computer systems as

> computer systems that systematically and unfairly discriminate against certain individuals in favor of others. A system discriminates unfairly if it denies an opportunity or a good or if it assigns an undesirable outcome to an individual or a group of individuals on grounds that are unreasonable or inappropriate.

To warrant the term *biased*, then, discrimination must be both systematic and unfair.

Democratic urban planning requires that citizens be engaged in decision making.

We first identified freedom from bias as an explicitly supported value—one that we wanted the simulation to support—because it is a moral good in itself. However, there are other reasons to support this value: Freedom from bias is instrumental in providing an equal opportunity to participate in a democratic society; stakeholders whose concerns are represented in the system could have a privileged place in deliberation relative to those whose concerns are not represented.

Political legitimacy

UrbanSim's legitimacy is crucial for its effective use in urban planning. Unresolved disagreements about its legitimacy might disenchant some stakeholders or cause the agency to stop using the system.

Our conceptual investigation of political legitimacy draws primarily on the work of Jürgen Habermas.[8] The use of modeling software is just one part of the planning process, and even the best-designed system could be used in a process lacking in legitimacy. Because most factors are beyond our control, we focus on the modeling system's "legitimation potential"[8] rather than the legitimacy of the entire decision-making process.

Communicative action plays a key role in legitimation potential. Habermas defines communicative action as speech in which all parties aim for mutual understanding without manipulative or strategic designs. In communicative action, each utterance raises four validity claims, which we have mapped to testable design goals. Achieving these goals helps establish UrbanSim's legitimacy.

- *Comprehensibility*. Can a wide range of stakeholders understand the information provided?
- *Accuracy and transparency*. Are the models and data a reasonable representation of reality? Are the inner workings and design of UrbanSim transparent to stakeholders so they can assess its accuracy?
- *Clarity of intent*. Is the intent behind the information—to advocate for a particular position, or to provide relatively neutral, factual information—clear to the users?
- *Appropriateness with respect to values and norms*. Is the information relevant to the stakeholders' values in the decision-making context?

Although comprehensibility, accuracy, transparency, freedom from bias, and relevance to decision making are not new goals for operational models,[9] tying these goals to the potential for achieving legitimacy helps us understand their significance for models that must support democratic decision making.

INTERACTION DESIGN

The part of our work described in this article is intended primarily to create an interaction design around UrbanSim indicators through technical documentation, indicator perspectives, and household indicators.

Just the facts

We designed the technical documentation to provide comprehensible, useful, factual information about the indicators to urban planners and other stakeholders, with an eye toward minimizing both actual and perceived bias. By putting technical information about indicators in a single place on the Web, we intended to make this information easy to access, or "ready to hand,"[10] during the deliberation that precedes decision making.

Feedback from urban planners, modelers, and policy experts led us to standardize the technical documentation for each indicator to consist of 11 sections, including (among others) its name, an informal definition, a more formal specification, known limitations, and advice for interpreting results. The technical documentation also includes the Structured Query Language (SQL) code used to compute the indicator from databases of simulation results, as well as input and expected output for a unit test to check the code's correctness. The technical documentation is "live" in that the Web server extracts SQL code and tests directly from the code base each time it displays it, guaranteeing that what the user reads in the technical documentation is current. We also provide similar functionality for the new Python-based indicator computations in UrbanSim 4.

We conducted a study[11] of our technical documentation design with eight urban planners interested in UrbanSim, who currently represent its primary user community. Through interviews in which the planners interacted with the system, we learned that they required much less time to complete each of four tasks using the technical documentation as compared with their current work practices. This result is evidence that we have at least partially solved the information fragmentation problem in terms of both consolidating information and making it readily accessible. This in turn would improve task performance by increasing comprehension and making indicator evaluation more meaningful. The results also supported our hypothesis that including live SQL code, unit test information, and limitations increases indicator transparency and comprehensibility.

Room for advocacy

In formative evaluations of our design for technical documentation, much of the strongest feedback was about neutrality. Earlier documentation versions included a section describing the desired direction of change for the indicator, which we had thought useful in decision making. However, information in this section reflected widespread disagreement about the desired direction for many indicators. Some participants indicated that even the name, "Desired Direction," conveyed bias. On the basis of this feedback, we replaced the problematic section with "Interpreting Results," which relates how the indicator might be used in policy evaluation.

> **Including live SQL code, unit test information, and limitations increases indicator transparency and comprehensibility.**

Given the goal of democratic urban planning, having stakeholders advocate values and put forth opinions is an essential and integral part of the overall process, not an inconvenient blemish on an otherwise clean technical exercise. How then could we enable stakeholders to use indicators to represent and express their views, yet maintain the informative role of technical documentation? Our solution was to construct *indicator perspectives,* which stakeholders can use to tell a story and advocate particular values and criteria for evaluating outcomes.

We have partnered with three local organizations to construct prototype perspectives: a government agency, a business association, and an environmental group—King County Budget Office, Washington Association of Realtors, and Northwest Environment Watch, respectively. Each organization provides content for each perspective, and the UrbanSim team provides technical support. In keeping with our emphasis on fair representation, we chose partners that cover a range of views. We plan to provide opportunities for broader involvement, actively soliciting partners as needed to ensure that the perspectives cover a wide range of political views and economic interests.

We are currently analyzing the results of a study to assess our success at simultaneously providing facts and relatively neutral technical information through documentation, while also supporting value advocacy and opinion through the indicator perspectives. We also investigated how these systems approach our ideal of freedom from bias.

In the study, we engaged 20 Seattle citizens in interacting with both the indicator perspectives and technical documentation and in reflecting on their perceptions. Preliminary results confirm that the indicator perspectives framework is indeed useful in advocating for specific views and values and will be a valuable source of information about UrbanSim indicators.

Personal touch

While indicators such as population density and total vehicle miles traveled are familiar to urban planners who monitor or model regional trends, such aggregate measures are probably less compelling to citizens not well versed in urban planning. To reach these citizens, we created *household indicators,*[12] tailored simulation results that show how policy alternatives could affect their own households. Through such indicators, we hope to encourage citizens to become involved in evaluating the impact of transportation and land-use choices.

When users launch the Web application, they supply personal information. On the basis of this information, the application answers questions the users might pose: Where could I afford to live in the region? How long would it take to get to work? How long would I have to travel to get out of the city?

Initial user study results[12] support the hypothesis that citizens can more readily understand household indicators because they can compare such indicators directly to living, working, and getting around. Household indicators also aim to engage citizens by showing them how policy decisions could affect their lives in the long term. In that sense, they answer the broader question, How will this decision affect my future?

Earlier work on the technical documentation aimed to provide comprehensible, accurate, transparent, useful, and relatively neutral technical information to urban planners. Household indicators, in contrast, focus on providing information that is comprehensible to citizens and clearly relevant to their own lives. However, our commitments to accuracy, transparency, and freedom from bias remain.

In meeting our accuracy commitment, we were careful not to oversimplify to enhance comprehensibility. The commitment to transparency presents the challenges of conveying uncertainty in simulation results and having results explanations at hand when questions arise. A focus on personal impacts might bias deliberation toward individual rather than societal or environmental impacts—a focus we hope to balance by linking household indicators to related regional indicators and indicator perspectives.

Because one of our main aims is to engage citizens, users begin by creating a household profile. Seeing your own name and personal information throughout the system fosters a sense of identity that persists while viewing different indicators. The household profile includes the household's name, its approximate location, a set of places important to the household, and descriptions of trips between those places.

As Figure 2 shows, the current trip interface lets the user specify a start location, a destination, a time of day, and a travel mode for a particular trip. On the basis of this information, the user can view indicators such as travel times, employment and population density in their neighborhoods or other important places, land-use mix in their neighborhood, and property values. Each indicator display includes a question or a group of questions the indicator is intended to address—a strategy that encourages users to ponder how the information might apply to their own lives. We designed the indicator displays to let the user compare the same indicator for all the alternatives under consideration.

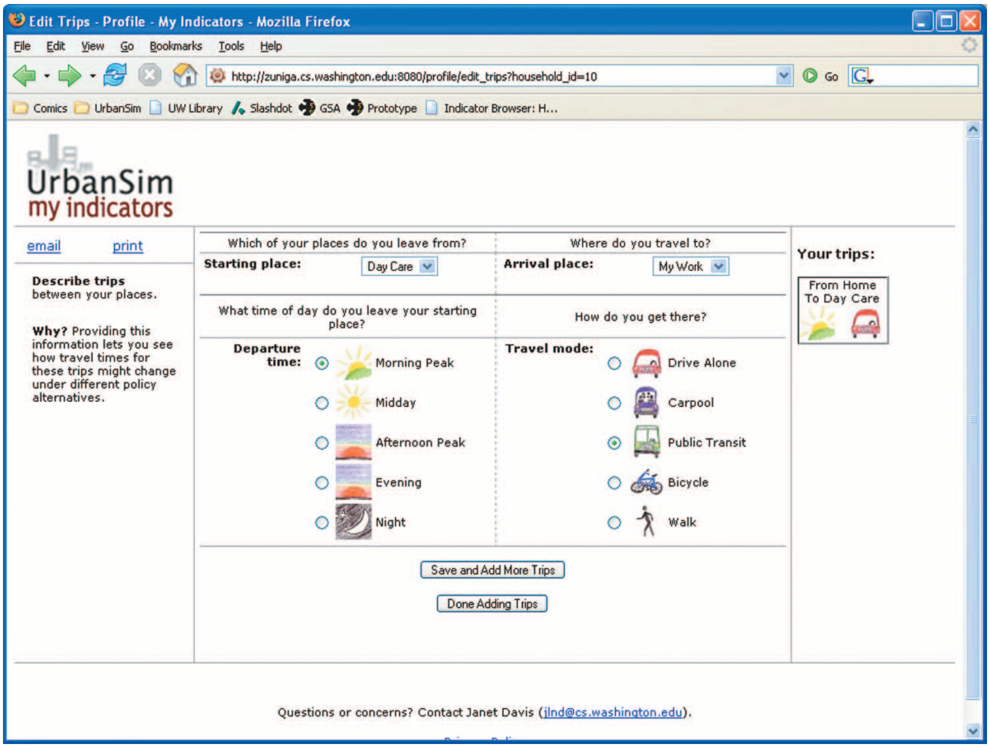

Figure 2. Household indicators prototype, showing the trip configuration page. Household indicators aim to show citizens how transportation and land-use alternatives will affect their everyday lives—for example, how their travel time between places could change under different alternatives.

Our central hypothesis in designing to inform citizens is that simulation results in familiar terms will be easier to understand. Early user studies and informal feedback support this hypothesis; indeed, there has been a push for greater realism and detail in reporting household indicators. In early paper prototypes, the Travel Times indicator showed only the round-trip travel time between home and work at peak travel times. Some participants—those who travel at nonpeak times, from locations other than home, to destinations other than work—found this difficult to relate to. In response, we revised this indicator to use trip profiles that include a starting location, destination, travel mode, and time of day. Colleagues have also noted that a trip might include several stops along the way, for example, to buy coffee or leave a child at day care, a phenomenon that urban planners call *trip chaining*. The current interface, which focuses on one-way trips, better supports queries involving trip chaining.

We have recently completed a prototype implementation of household indicators and conducted focus groups to further inform the design; a summative evaluation of the concept and design is planned for future work.

We have presented but a snapshot of our work to inform public deliberation and decision making about major land-use and transportation issues. Our future work will include further research on applying UrbanSim in real planning contexts and on developing tools to support citizen discussion and comment. All these efforts are part of an overall agenda: to better support informed public deliberation and democratic engagement in the urban planning process.

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