Value Sensitive Design of Interactions with UrbanSim Indicators

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A dissertation submitted in partial fulfillment
of the requirements for the degree of

Doctor of Philosophy

University of Washington

2006

Program Authorized to Offer Degree: Computer Science & Engineering

University of Washington
Graduate School

This is to certify that I have examined this copy of a doctoral dissertation by

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Abstract

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Around the United States and around the world, people grapple with issues such as traffic jams, affordable housing, and urban sprawl. Decisions such as whether to build a new freeway, expand transit service, or change land use regulations interact in complex ways and have long-term consequences. At the same time, stakeholders have strongly held, often conflicting views about what will make the city a better place. I present my contributions to work on developing interfaces for UrbanSim, a large-scale simulation system that projects patterns of urban development for periods of twenty years or more under different scenarios, to inform deliberation about the consequences of these decisions. My specific focus is on the design of interactions with indicators, which portray key results from UrbanSim.

I and my colleagues draw on the Value Sensitive Design theory and methodology to proactively account for human values in the design of interactions with indicators. In designing with an eye towards the explicitly supported values of representativeness, fairness, and support for a democratic society, we face several challenges, including responding to the values and interests of diverse stakeholders, providing ready-to-hand documentation that supports the system's legitimation, balancing this relatively neutral information with a range of advocacy positions, and engaging and informing citizens who may have different interests and less expertise than urban planners who use UrbanSim in their work.

We address these challenges in the development of three new tools for interacting with UrbanSim indicators: (1) ready-to-hand Technical Documentation providing factual information about indicators for urban planners and other stakeholders; (2) Indicator Perspectives intended to provide a platform for political advocacy and civic discourse; and (3) Household Indicators intended to help citizens explore the question, "How could this decision affect me?" Our work contributes to Value Sensitive Design as an example of designing a system for effective use in a highly political environment with multiple stakeholders having conflicting interests and differing expertise.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

I thank my advisors, Alan Borning and Batya Friedman for the opportunity to work with them on the enterprise of applying Value Sensitive Design to UrbanSim. This work would not have been possible without their contributions, and I have benefited greatly from their guidance and support.

I also thank Paul Waddell for his helpful feedback and his contributions to the ideas underlying the work, as well as his help in learning the ins and outs of UrbanSim and the urban planning context.

I thank the remaining members of my committee, Tom Anderson and Judy Ramey, for their insightful questions at my defense.

I thank Peyina Lin, who was a student in the Value Sensitive Design Research Lab while this work was being done, for her substantive contributions to the work presented here and for her help in learning about the discipline of Information Science.

Also in the Value Sensitive Design Research Lab, I thank Brian Gill for his assistance with statistics and for many conversations about careers. I also thank Peter Kahn for his encouragement and for his contributions to the underlying ideas. I further thank the members of the VSD Research Lab and of the LIS558 reading seminar for their stimulating discussions, questions, and feedback.

On the UrbanSim project, I thank A.J. Bernheim Brush for her mentorship; I learned a lot about HCI and graduate school by working with her. I thank Michael Noth for introducing me to the project; Yael Schwartzman and Travis Kriplean for for their friendship and for the opportunity to be a mentor myself; and David Socha for his expert advice in software engineering and for many interesting conversations.

Larry Blain, Mark Simonson, Mark Charnews, and Peter Caballero at the Puget Sound Regional Council helped me learn about the application of UrbanSim in the Puget Sound region.

I also thank Lance Bennett for discussions about Habermas.

Ann Hendrickson, Bjorn Freeman-Benson, Jon Fuchs, Casey Huggins, Charles Naumer, and David Socha all helped with the design and implementation of different versions of the Indicator Browser and Technical Documentation. Stephanie Collett, Shireen Deboo, Nicole Gustine, and Jessica Miller provided assistance with the evaluation of the Technical Documentation.

Jeff Hepinstall and Liming Wang provided valuable technical assistance for the development of the Household Indicators prototype.

For their collaboration in a course project on credibility and bias in UrbanSim, I thank Peyina Lin, Jessica Miller, and Kevin Ramsey. That collaboration was a significant step down this path, and I learned a lot by working with them.

I thank all our user study participants and pilot study participants, citizens and urban planners alike.

I thank Robert Grimm for his mentorship in the earliest years of my academic career; Tom Anderson and David Wetherall for their advising and their graciousness as I moved on to pursue other research interests; and Rachel Pottinger for her care and mentorship as I made this difficult transition.

I also thank those wonderful teachers who turned me on to computer science and encouraged me in my pursuit of higher education: Ran Libeskind-Hadas, Mike Erlinger, Margaret Fleck and the other computer science faculty at Harvey Mudd College during my time there; as well as Eugene Thoms, who gave me my first introduction to computer science at Hesperia High School.

I thank Kate Deibel, Zasha Weinberg, Eric Lemar, and Tammy VanDeGrift for their friendship, which I hope will continue long beyond graduate school ends. I particularly want to thank Kate for her help in submitting this dissertation from afar.

I thank my mom and dad, Paulette and Bernard Newman, for always being proud of me and for the sacrifices they made for my education. I thank my in-laws, Rick and Judy Davis, for their encouragement and understanding as I made my way through graduate school.

Above all, I thank my husband, Brooks Davis, for his love, devotion, and patience, and for nourishing me in body and spirit. I look forward to growing together for many years to come.

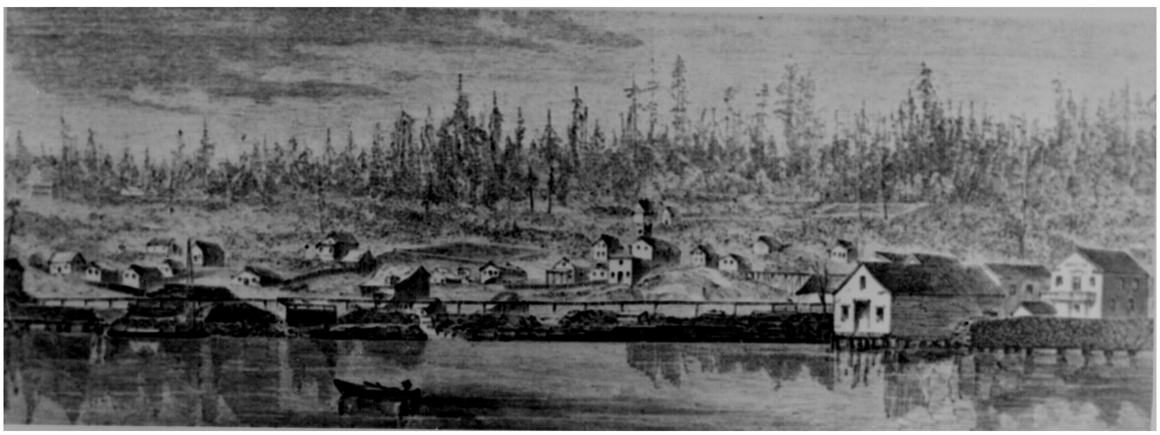
Finally, I thank Isaac Asimov for being the unwitting (and unlikely) hero of my teenage years. His many essays showed me the romance and beauty of science. I can only aspire to someday explain computer science with such life and clarity.

This material is based upon work supported by the National Science Foundation under Grants No. EIA-0121326, IIS-0325035, and IIS-0534094. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

This work was also supported in part by gifts from IBM and from Google.

DEDICATION

To Seattle



"Seattle, Washington Territory." Engraving from *Harper's New Monthly Magazine* (Sept. 1870). Courtesy of the National Archives and Records Administration.

Chapter 1
INTRODUCTION

In many regions, elected officials, planners, and citizens grapple with issues such as traffic jams, resource consumption, and urban sprawl. Decisions such as whether to build a new freeway, expand transit service, or change land use regulations are often controversial and expensive, and have long-term consequences. UrbanSim [127, 131] is a large-scale simulation system intended to inform decision-making by projecting patterns of land use, transportation use, and environmental impacts that might result from different packages of policies and investments over periods of twenty years or more.

For example, a metropolitan region might be considering major investments such as a new light rail system or a new freeway as alternate approaches to adding transportation capacity. To help compare these alternatives and their long-term impacts, the regional planning agency might use UrbanSim to simulate the development of the region for the next thirty years under the alternative plans, in order to determine which alternative might better meet policy objectives. In assessing the impacts of building the freeway, it is important to consider not only immediate effects on traffic, but also longer-term effects on land use and development. For instance, construction of homes and businesses that rely on the new freeway for convenient access might induce additional travel demand, increasing traffic congestion in the long term.

Predicting the future is of course a risky business. In this example, unknown factors that could significantly affect the long-term outcome include the price of oil, possible breakthroughs in technology, or unexpected major shifts in population. Yet we do have to make decisions now, with the information we have. As E.F. Schumacher [108, p.240] observed, “The future cannot be forecast, but it can be explored.”

These are important decisions that will affect all of the citizens of the region for many years to come. Thus, one major theme of our work is informing decision-making with results from computer simulations, to help planners and decision makers understand the long-term consequences of different choices. Facilitating informed decisions is one side of the coin, but another is the legitimacy of the process by which the decisions are made. In a democratic society, major decisions such as these should ultimately be made by direct popular vote, or by representative government bodies, accountable to the people. Further, the decision should be preceded by informed public deliberation and debate by an engaged citizenry. Although unfortunately the norm in practice is that few citizens are aware of the decision-making process and fewer still have access to participate in decision-making, this remains an important goal. Thus, a second theme is to design interfaces and interaction techniques for such urban simulation systems that facilitate public understanding and citizen engagement.

Both urban planning decisions and the process by which they are made touch important human values, such as fairness, democratic participation, and human welfare. By applying the Value Sensitive Design theory and methodology [42, 37, 35, 34], we aim to account for such values in a principled and comprehensive manner throughout the development of interfaces for interacting with UrbanSim's results. One important characteristic of this particular problem domain is that it centers on public deliberation and decision-making involving many stakeholders. Another is that there are often long-standing disagreements, both on particular projects or legislation, and on overall approaches to land use and transportation. Such disagreements may be rooted in fundamental conflicts among stakeholders about values such as environmental sustainability, economic growth, or social equity. A third is that the decision-making process can be informed by using modeling and simulation to help reveal the long-term consequences of alternative choices, and that such models can also raise concerns themselves, for instance regarding input assumptions or black box simulations. A fourth is that there is a large gap in expertise between most stakeholders and the professional planners who currently develop, operate, and interpret the models. From the beginning, our designs have been shaped by these characteristics, which are shared by other domains such as long-range budget forecasts and global warming policy.

1.1 Overview

In this dissertation, I present my contributions to ongoing research into the Value Sensitive Design of interactions with UrbanSim's results. Results from UrbanSim take the form of indicators [60, 49]—variables that represent key aspects of the simulation results, such as population and employment density. To support use of UrbanSim as part of a democratic planning process, we are designing tools to support urban planners, citizens, and other stakeholders in their interactions with UrbanSim indicators.

As part of our application of Value Sensitive Design to this problem, we pay particular attention to the values of democracy and freedom from bias in UrbanSim's design. This attention has led to several 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.

- Contribute to the system's legitimacy by presenting information that is comprehensible, accurate, clear in its intent, and relevant to the decision making context.

- Enhance the system's transparency with respect to its design, assumptions and limitations—so it is not a black box.

- Foster citizen engagement in the decision process by providing tailored information and opportunities for involvement.

To meet these goals, we have developed and are refining three tools to help a variety of stakeholders—planners, modelers, and citizens—understand UrbanSim indicators: Technical Documentation intended to make information about indicators ready-to-hand in interactions with indicators; 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. A fourth tool, not discussed in depth here, is the Indicator Browser [109], intended to aid urban planners and other stakeholders in selecting, understanding, and visualizing indicators. The development of these tools is founded in conceptual investigations of UrbanSim's stakeholders and the explicitly supported values of freedom from bias and support for a democratic society.

We have grounded the design and evaluation of these systems in the context of using UrbanSim to model the interactions between land use and transportation in the central Puget Sound region. UrbanSim is not yet being used as an operational model to inform decisions; rather, its application is in a preparatory phase. The Indicator Browser and Technical Documentation are currently being deployed for use by urban planners and modelers at the Puget Sound Regional Council as they prepare UrbanSim for operational use. However, from the perspective of interactions with citizens and other stakeholders, the design and evaluation of the Technical Documentation, Indicator Perspectives, and Household Indicators tools is exploratory work; we are not studying a deployed system. I address operational use in decision making as a new context for use and evaluation of these three tools in section 7.3.4.

1.2 Contributions

This work contributes to general knowledge as an example of designing a system to inform decision making in an environment with many stakeholders having deep-rooted conflicts. Specifically, I will show how applying Value Sensitive Design has helped to make progress on this problem. The conclusion of this dissertation includes lessons learned that can inform the design of sophisticated simulations to inform public deliberation around other conflicted domains, such as global warming policy, water rights, or long-range budget forecasts.

Work on the conceptual investigations, Technical Documentation, and Indicator Perspectives was conducted jointly with Alan Borning, Batya Friedman, and Peyina Lin. The development of Household Indicators was primarily my own work. I also contributed substantially to the identification of testable design goals in support of UrbanSim's legitimacy, drawing on the theory of Jürgen Habermas. I point out my individual contributions in the introduction to each chapter, and summarize these in the conclusion.

1.3 Outline

The dissertation proceeds as follows. In the next chapter, I provide background and discuss related work. I explain the Value Sensitive Design theory and methodology and discuss how the work presented here relates to previous applications of the methodology and contributes to future applications. I also give further background on the application, UrbanSim, and discuss how this work fits in with previous work on that project. I also discuss related work in computer support for urban planning, ethics in modeling, and access to information. Finally, I situate the work with respect to two other approaches to design: computer-supported cooperative work and participatory design.

In Chapter 3, I present the conceptual investigations that have served as the foundation of the work. These include analyses of UrbanSim's stakeholders and their values, and the key move to a principled choice of specific values to explicitly support in the design work. I discuss two of these values, freedom from bias and support for a democratic society, in more detail, drawing on political philosophy and on a previous application of Value Sensitive Design to characterize each of these values and identify design goals to support them. Of particular interest are the values of legitimacy, transparency, and democratic engagement, all instrumental to the value of support for a democratic society.

Chapter 4 begins my presentation of the design of three tools to support stakeholders in their interactions with UrbanSim. This chapter focuses on the Technical Documentation, intended to make technical information about UrbanSim indicators ready-to-hand in the deliberation about the indicators, in support of UrbanSim's transparency and legitimacy. I present our design process and the results of a summative evaluation of the Technical Documentation with urban planners, illustrating Value Sensitive Design's iterative and integrative methodology and providing some evidence that we are succeeding in providing ready-to-hand information in support of UrbanSim's legitimacy.

While the Technical Documentation presents relatively neutral information about UrbanSim Indicators, there is also value in having a range of clearly stated, well argued viewpoints about which indicators are most important to consider in decision making. Indicator Perspectives, presented in Chapter 5, are intended to provide a platform for organizations to present their own strongly held views. I discuss the process of engaging organizations in designing the initial set of three Indicator Perspectives. I include a discussion of the problem of prioritizing the implementation of additional indicators, arising in part from this work. Finally, I present preliminary findings from an evaluation study that engaged citizens in interacting with both Indicator Perspectives and the Technical Documentation. These findings 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.

Chapter 6 shifts the focus to a new means for interacting with and comparing simulation results: Household Indicators, intended to support citizens in asking the question, "How could this decision affect me?" The development of Household Indicators is aimed at improving comprehensibility and transparency for citizen users and enhancing democratic engagement. After giving an overview of the system, I discuss the design problem and present an overview of my iterative and integrative design process. I follow with a discussion of recurring design themes, notably the problem of selecting indicators (echoing the problem of prioritizing the implementation of new indicators for the Indicator Perspectives), potential biases in Household Indicators, comprehensibility and transparency for users who are not urban planners, the choice of geographic and temporal abstractions, and supporting democratic engagement. I briefly discuss the software architecture and sketch a summative evaluation with respect to the initial design goals.

Finally, in the concluding chapter, I summarize my contributions to this joint design work. I discuss lessons learned that can be generalized to future work in related domains, as well as future directions for the application of Value Sensitive Design to UrbanSim.

Chapter 2
BACKGROUND

In this chapter, I discuss background and related work. I first explain the methodological and theoretical framework for this work—Value Sensitive Design—and discuss how the work presented in this dissertation draws on and contributes to the evolution of this framework. I present the application, UrbanSim, in greater detail than in the previous chapter, and situate this work with respect to other publications arising from the project. I further discuss the context of computer support for urban planning, ethics in computer modeling, and access to information. Finally, I consider the relationship of this work to two other approaches to design: Computer-Supported Cooperative Work (CSCW) and Participatory Design.

2.1 Framework: Value Sensitive Design

Research on the design of tools for interacting with UrbanSim indicators is guided by the Value Sensitive Design theory and methodology [34, 35, 37, 41, 42], a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process. Value Sensitive Design is concerned primarily not with personal preferences, but with values of moral import such as privacy, trust, and informed consent. Key features of the methodology are its interactional perspective, tripartite methodology, and emphasis on direct and indirect stakeholders.

Value Sensitive Design is an interactional theory: values are viewed neither as inscribed into technology nor as simply transmitted by social forces. Rather, people and social systems affect technological development, and technologies shape (but do not rigidly determine) individual behavior and social systems.

Value Sensitive Design employs a tripartite methodology, consisting of conceptual, empirical, and technical investigations. These investigations are applied iteratively and integratively, with results from new investigations building on and integrating earlier ones. Conceptual investigations comprise philosophically informed analyses of the central constructs and issues under investigation. For example, how does the philosophical literature conceptualize certain values and provide criteria for their assessment and implementation? How should we engage in trade-offs among competing values in the design, implementation, and use of information systems? Empirical investigations focus on the human response to the technical artifact, and on the larger social context in which the technology is situated. The entire range of quantitative and qualitative methods used in social science research may be applicable. Technical investigations focus on the design and performance of the technology itself. Technical investigations can involve either retrospective analyses of existing technologies or the design of new technical mechanisms and systems.

A third key aspect of Value Sensitive Design is its focus on both direct and indirect stakeholders. Direct stakeholders are those who designers would usually think of as the users: those who interact directly with the system or its outputs. Indirect stakeholders are those who do not interact directly with the system, but who are affected by how the system is used. For example, in studies of projecting digital imagery of outdoor settings in windowless offices as a kind of "augmented window" [38, 44], the direct stakeholders are those who view the digital imagery in their offices. But those whose images are captured by the outdoor video cameras are an important class of indirect stakeholders, whose privacy, physical safety, and psychological wellbeing are impacted by the presence of the cameras and how their images are used [44].

Previous applications of Value Sensitive Design have started with conceptual investigations of values such as trust [45], freedom from bias [46], and informed consent [83]; with retrospective investigations of technologies currently in widespread use such as web browsers [39, 40, 45, 47] and video cameras in public places [44]; and with prospective investigations of emerging technologies such as robotic companions [45, 68, 69, 82] and augmented windows for windowless interior offices [38, 44]. UrbanSim is one of the first systems for which the primary developers have adopted Value Sensitive Design as a design methodology, so that it can indeed proactively account for human values throughout the design process. Applying Value Sensitive Design has influenced not only the design of the system itself, but the design of the software development *process*, in that the adoption of agile programming methodology supports the UrbanSim team in developing reliable and transparent code and in responding more quickly to stakeholder values and concerns [33].

As in previous work on users' conceptions on web security [40] and risks and harms on the web [47], stakeholders come to the table with vast differences with respect to technological expertise and education. In this earlier work, Friedman et al. found that stakeholders had different concerns with respect to the use of web technology, but these could be attributed to differing experiences and understandings rather than fundamentally different values [47]. While this study is not the first to address value conflicts, the application of Value Sensitive Design to UrbanSim is unique thus far in that the context of use, urban planning, involves a multiplicity of stakeholders who bring to the table not only differing expertise but also a range of deeply held, sometimes conflicting values. Our response has been to make a clear, principled distinction between explicitly supported values—those which we specifically want to embed in our designs—and stakeholder values—those that are important to some but not necessarily all stakeholders [12, 42]. This distinction is a novel contribution of work on the UrbanSim project to Value Sensitive Design; we expect the approach will also be useful to other designers working in contexts where stakeholders have diverse or conflicting values.

UrbanSim's explicitly supported values include freedom from bias and support for a democratic society. We draw on previous work on the value of freedom from bias [46], but have contributed a new investigation of the value of democracy drawing on the political philosophy literature. In particular, we have identified democratic engagement and legitimacy as instrumental values in support of the use of UrbanSim as part of a democratic process and developed testable design goals in support of legitimation. In support of legitimation, we have explored providing ready-to-hand information and reducing information fragmentation as approaches to increasing the transparency and comprehensibility of information about UrbanSim. This work provides further guidance to designers working in politically contested contexts.

These commitments to explicitly supported values in turn led to the decision not to support or exclude particular stakeholder values *a priori*, but rather to aim to allow all stakeholders to assess alternatives with respect to their own values. Thus, the research team cannot focus on a few key values, as occurred in studies of informed consent in web browsers [39] or the effects of augmented windows on privacy and well-being [38, 44]. Though not as problematic as the problem of redesigning the HTTP protocol to account for the value of informed consent [39], responding to particular stakeholder values is not easy, as it may require significant research and development efforts. We cannot immediately do everything we want to do. Where Value Sensitive Design has long considered the problem of designing for tradeoffs among values, here we must prioritize among the many competing stakeholder values we want the system to address.

Finally, while Value Sensitive Design directs us always to weigh impacts on indirect stakeholders against those on direct stakeholders, it is clear that some of UrbanSim's indirect stakeholders—those who are most affected by urban planning decisions informed by UrbanSim—have at least as much at stake as the urban planners and modelers who operate the system. Concerns such as environmental justice are weighty indeed. This is also the case in the assignment of medical residents to hospitals, as discussed by Friedman and Nissenbaum [46]. A more extreme case is reported in Cumming's work on designing weapons systems [17], where the very lives of indirect stakeholders are at risk. This earlier work aims primarily to protect indirect stakeholders through attention to potential harms and benefits in system design. We do the same in UrbanSim by explicitly supporting the value of freedom from bias and aiming for representation of the range of stakeholder values in the system. But unlike these earlier cases, we have the opportunity to go beyond protecting indirect stakeholders—we can involve them directly in the use of the system so that they can influence how it is used, thus letting indirect stakeholders become direct stakeholders. The context of a democratic society ideally involves all citizens in decision making, whether in direct deliberation on the matter, through voting, or through elected representatives. Most, though not necessarily all, strongly impacted indirect stakeholders are citizens of the region where the decision is made. Thus, a novel goal in applying Value Sensitive Design to UrbanSim is to enable indirect stakeholders to become direct stakeholders, so that they can interact with UrbanSim in the context of democratic decision making. We address this goal in the design of Indicator Perspectives and Household Indicators. Designers of other systems for use in democratic decision making should consider adopting a similar goal. Designs that expand the category of direct stakeholders may also serve other values, for example, in allowing patients to defend their privacy by learning who has accessed their electronic medical records, rather than leaving system access to only the medical staff who are direct stakeholders now.

2.2 Application: UrbanSim

I turn now to the technology at hand. UrbanSim [127, 131] is a large-scale urban simulation system that projects patterns of land and transportation use and the environmental impact of various policies and investments over periods of 20 years or more. UrbanSim's primary purpose is to provide urban planners and others with tools to aid in more informed decision making; a secondary goal is to support further democratization of the planning process.

UrbanSim is implemented as a set of interacting component models that represent major actors and processes in the urban system [131]. For example, the Residential Location Choice model simulates the process of a household choosing a new place to live, while the Developer model simulates the actions of a real estate developer deciding whether to develop, where to do so, and what to build. UrbanSim takes a highly disaggregated approach, modeling individual households, jobs, and real estate development and location choices, using small areas such as grid cells of 150x150 meters in size. The system microsimulates annual changes in locations of individual households and jobs, and the evolution of real estate within each individual grid cell as the result of actions by real estate developers. Most of the component 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 are correlated with that choice. For example, in the Residential Location Choice model, the probability that a particular household will choose to locate in a residential unit in a particular grid cell depends on attributes of the household (e.g., income and number of children), as well as attributes of the potential dwelling (e.g., cost and location). UrbanSim is also coupled to an external travel model. The locations of households and jobs give rise to simulated trips in the travel model, and the resulting patterns of transportation usage and congestion give rise in turn to accessibility measures for different locations, which then influence the desirability of these locations for housing or jobs.

The most recent version of the system, UrbanSim 4, is built on the Open Platform for Urban Simulation (OPUS), a new object-oriented architecture and platform developed by our group and others [132]. OPUS and UrbanSim 4 are implemented in Python, making use of 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.

As of this writing, UrbanSim is being transitioned into operational use in the central Puget Sound region (Seattle and surrounding areas), Honolulu, and Salt Lake City; it has already been used operationally in Houston. There have been research and pilot applications in Amsterdam, Detroit, Eugene, Paris, Phoenix, Tel Aviv, and Zurich. UrbanSim also played a significant role in the out-of-court settlement of a lawsuit in Utah regarding a major freeway construction project [129]. The system continues to evolve, with the development of improved and new models. Because UrbanSim is not yet in use to inform decision making in the central Puget Sound region, the design work presented in this dissertation should be considered exploratory with respect to citizens and other stakeholders beyond the urban planners and modelers involved in preparing and deploying UrbanSim applications.

Previous publications on UrbanSim have spanned a range of topics, including the architecture of the modeling system [127, 130, 132], specific problems in urban modeling [128, 133, for example], software engineering [33, 90, 112] and usability testing [13] methods, and a case study of UrbanSim's application in the Salt Lake City area [129]. Most directly related is Denise Pinnel Salisbury's dissertation [106] and work by Pinnel et al. [97], on the design of visualizations for urban modeling. Like this earlier work, my focus here is on how people interact with the results of running simulations. However, Pinnel et al. took a user-centered design approach to selecting visualizations of UrbanSim data, aiming to provide the most efficient and usable visualizations for accomplishing specific data interpretation tasks. In employing Value Sensitive Design, this work takes a broader view of the values at stake, going beyond efficiency and usability to look at freedom from bias and the system's use in the context of a democratic society.

In the remainder of this section, I discuss the use of indicators to summarize UrbanSim output and consider somewhat more deeply the design and development methodologies used on the UrbanSim project.

2.2.1 Indicators

A critical aspect of using a system such as UrbanSim is extracting useful information from it. UrbanSim is a complex software system that models a region's urban processes of the next several decades. The system takes hours or even 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.

In urban planning, indicators [49, 60] are used to monitor changes in a region with respect to specific attributes of concern. The term "indicator" has been defined in a number of ways, from summarized aggregate forms of data [62, 81], to proxies or phenomena that cannot be directly measured [15, 14]. In its most general sense, an indicator is information that points to [60, 94] or directs attention to [94] particular information of interest, usually to inform a decision. For our purposes we define indicator as a variable selected and constructed to convey information on the condition and/or trend of an attribute of the system considered. The indicator will have a specific value at a given time. We take Gallopin's stance that "[t]he most important feature of indicators compared to other forms of information is relevance to policy and decision-making" [49].

In UrbanSim, ideally, simulation results can be presented using the same set of indicators for all the policy alternatives being considered, thus aiding the assessment and comparison of different scenarios. For example, suppose that stakeholders are interested in fostering compact, walkable neighborhoods within the urban area, and curbing low-density, auto-oriented development (sprawl). In the urban planning literature, population density is regarded as one of the key indicators of the character of development. Planning agencies can monitor population density to understand current trends, and also use UrbanSim to assess and compare the impacts of different policies on population density 30 years in the future.

In addition, modelers use UrbanSim indicators diagnostically, to learn about the system's internal operation, to help assess whether it is operating correctly, and to debug problems. In the work reported here, we are concerned with both evaluative and diagnostic uses.

2.2.2 Design and Development Methodologies

As mentioned earlier, UrbanSim's software development process embodies an agile programming methodology [33]. Automated regression testing, in which system tests are automatically run whenever new code is committed to the UrbanSim code base, helps ensure that the code base always contains a working, releasable system. Applying Test First methodology also helps in writing more reliable code. A traffic light makes system status visible to the developers, whether all is well (in which case the traffic light is green) or test failures need to be fixed (red). Visibility of system status supports UrbanSim's transparency and legitimacy. The testing methodology not only fosters greater system reliability, but enables more rapid responses to concerns about the correctness and accuracy of the software models and to emerging stakeholder values.

Previous design work for UrbanSim user interfaces applied user-centered development methodologies. Norman defines user-centered design as "a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable" [89, p. 188]. The use of the term has grown to include a variety of methods such as contextual inquiry [6], usability testing [115], and personas [16, 54] that involve users or realistic representations of users in the design process. Like Value Sensitive Design, user-centered design is an iterative process. Yet, it differs significantly from Value Sensitive Design in that it focuses exclusively on the users of the system rather than the range of direct and indirect stakeholders. Furthermore, where user-centered design is concerned primarily with efficiency, efficacy, and usability, Value Sensitive Design engages human values of moral import such as privacy, freedom from bias, and democracy. Developing a system with the goal of usability does not imply that system will support ethical values; for example, a highly usable credit application system might nonetheless violate users' privacy [42, 87].

Pinnel et al.'s earlier work on helping users to accomplish specific tasks using UrbanSim indicators [97] took a user-centered design perspective. I was involved in another design effort, to create a graphical user interface for configuring and running UrbanSim, that took a user-centered design stance [13]. Our focus was solely on helping urban planners and modelers accomplish their tasks. Some design was guided by appeals to personas [16, 54], which are fictionalized representation of the urban planning users, and by task analyses. User testing involved primarily urban planners and modelers. Applying Value Sensitive Design has redirected our attention to supporting values such as political legitimacy and freedom from bias, and to the many indirect stakeholders who are affected by UrbanSim's use in decision making. System design and user testing quickly expanded to include policy experts, members of interest groups, and engaged citizens.

2.3 Computer Support for Urban Planning

UrbanSim reflects a tradition of research in computer support for urban planning extending back to at least the 1960s. While characterizing this history is beyond the scope of this work, I will highlight some key points from one such characterization to show to the reader who is less familiar with urban planning that our view of UrbanSim's role in urban planning is not without precedent. I will also distinguish UrbanSim's role as an operational urban model from the roles of other computer technologies.

According to Klosterman [72], the 1960s marked a paradigm shift from planning as design to planning as an applied science. In the "applied science" view, planning is the search for an optimal action or policy to achieve specified goals. "Computers were assumed to play an important role in this task by collecting and storing the required data, providing systems models that could describe the present and project the future, and helping unambiguously to identify the best plan from the range of available alternatives" [72, p. 6–7]. Planning was assumed to be value neutral and politically neutral.

In the 1970s [72], planners discovered that public policy making is fundamentally different from decision making in the private sector. Collective goals and objectives are not so clearly defined, but rather must account for stakeholders' conflicting interests and values. Planners further recognized that planning is not value-neutral, but rather an inherently political activity. Providing more information does not necessarily make the right course of action obvious, but may increase conflicts by revealing issues previously hidden from view. Informed by ethnographic studies of planning practice, this view further evolved into that of "planning as communication," in which the role of planners is not to identify an alternative that optimizes overall system goals, but to help communities engage in collective design.

While sophisticated technologies may provide planners with more accurate information, if planners cannot effectively communicate this information to the public, the tools may only serve to put greater barriers between planners and the public.

The application of Value Sensitive Design to UrbanSim is congruent with the recognition that planning, like technology, is not value-neutral. We are not unique in recognizing that the urban planning domain includes a range of stakeholders with conflicting values and interests. We deliberately do not identify a single best alternative as in the "applied science" view, but rather aim to help stakeholders make more informed judgments based on their own values. The identification of support for democratic society as one of UrbanSim's explicitly supported values reflects growing pressure for urban planning to become more open and participatory, in contrast to planners running models in a context that is separate from decision making [134]. One of our instrumental goals is to make UrbanSim transparent and comprehensible to the public, so the technology can inform communication among stakeholders rather than being a barrier.

In the remainder of this section I make a few distinctions among types of technologies used in urban planning, to clarify UrbanSim's role as an operational urban model. First, models in urban planning may be either theoretical or operational [134, 136]. Where theoretical models are intended to test theories or illustrate concepts in urban planning in a general context, operational models are applied in specific contexts to inform policy and decision making in that context. UrbanSim is intended primarily as an operational model, though it may also have uses in education and theory-building.

Second, I wish to distinguish operational urban models from tools for sketch planning. Sketch planning, like an artist's sketchbook, is intended to support the rapid exploration of many different alternatives; a key feature is the suppression of detail [58]. Because of its complexity and long running time, UrbanSim is not well suited to sketch planning. Better suited are tools such as the INDEX software for community indicators [1], which lets users represent a region, city, or neighborhood and compute a number of indicators based on this data at a single point in time. INDEX can be used to compare many alternative visions of future development, but cannot predict the effectiveness of enacting particular policies today for achieving those visions in the future. UrbanSim's use is complementary to sketch planning in that it can inform more accurate and thorough assessments once a relatively small number of alternatives have been selected for more careful consideration.

Finally, although visualization and simulation are distinct domains, visualization is important to understanding the results of simulations. Visualizations of UrbanSim data in use today take the form of maps, tables, charts, and statistical graphics. Our primary aim with UrbanSim is not to provide detailed, realistic visual representations of urban environments through three-dimensional modeling or illustration. Rather, we provide more abstract representations similar to those of geographic information systems [75]. The focus of the work presented in this dissertation is not the development of sophisticated new visualizations of simulation results, but rather accounting for the value implications of how people interact with simulation results.

2.4 Ethics in Modeling

In the field of modeling there is widespread awareness of ethical considerations [5]; philosophers too have turned their attention to the ethical dilemmas of computer modeling [79, 66]. Recently, a code of ethics for simulationists has been published [93] and adopted by several professional societies [92]. Indeed, ethics in modeling has typically been framed as an issue of professional responsibility between modelers and their clients [66, 79]. Johnson and Mulvey wrote in 1995, “At present, there is no formal relationship between the system designer and the third parties affected by the use of the decision system. Any accountability to third parties is through the client” [66, p. 61]. Although modelers are aware that many indirect stakeholders—even all of society [77]—can be affect by how models are used to inform decision making, our application of Value Sensitive Design to the problem of urban modeling adds to this by giving indirect stakeholders equal consideration to the client planning agencies and designing new interfaces to engage them in the use of the model.

Mason [79] and Johnson and Malvey [66] recommend a fiduciary relationship between modelers and their clients. The emphasis in this type of relationship is on shared decision making. This relationship depends on trust and on clients’ willingness to learn enough about the system to participate in decision making and use the results of models well. In considering citizens and other non-expert stakeholders as users of the model, we face the problem of educating those who have little time to spend learning about the model and with whom we may not have any continuing personal relationship. While increasing the transparency of a model certainly reduces the burden on users to educate themselves about that particular model [30], there is also a need for more general education about the nature of computer models as decision aids [77].

Furthermore, many modelers recognize that modeling, like urban planning and technology, is not value neutral. Leet and Wallace wrote, “Values are inherent in any model, whether they are incorporated intentionally or unintentionally” [77, p. 242]. Mason [79] advocates for a “covenant with values”: modelers must accurately capture clients’ values and reflect them in the model. We also start from the stance that models (like all technology) are not value neutral, but we take an interactional perspective in which, rather than seeing values as embedded in models, models are better suited to addressing some values than others. UrbanSim must be designed to account for stakeholders’ values, but we have deliberately chosen to avoid the perils of UrbanSim making decisions or ranking alternatives based on an objective function that formalizes stakeholders’ values. The domain is too complex. And again, it is not only the client’s values we take into account, but those of indirect stakeholders.

Some of the instrumental values we identify as goals in support of UrbanSim’s legitimation are widely recognized as goals for the design and use of models. I have just discussed the importance of relevance to stakeholders’ values; important too is relevance to the decision context, or addressing the right problem [3]. Comprehensibility of the model results is clearly of importance to model users [79], though not often explicitly mentioned. Because of the impacts of poor information on decision making, one fundamental ethical concern is with the accuracy, reliability, or validity of simulation results [2, 5, 92, 100]. Mason frames this as the “covenant with reality”: “The model builder asserts that the model he or she has designed adequately represents reality” [79, p. 188]. Transparency about models’ design, assumptions, and limitations is also widely cited as a goal [2, 92, 30]. Fleischmann and Wallace [30] argue cogently for a “covenant with transparency” in support of users’ autonomy in making decisions, assessing the validity of the model, and learning how their values are represented in the model. Finally, where the Code of Ethics for Simulationists requires "unbiased interpretations and evaluations of the results of modeling and simulation studies" [93], we instead aim for clarity of intent: a clear distinction between information intended to advocate for particular values and alternatives, and information of a more neutral flavor. We recognize that advocacy has a role in the interpretation and evaluation of simulation results, though it may not be appropriate for the model designers to take this role. Where we go beyond this previous identification of guidelines for ethical modeling is to link design goals to philosophical theory (specifically, Habermas's theory of communicative action [56, 57]) in support of UrbanSim's legitimate use in democratic decision making. Value Sensitive Design provides us with not only guidelines, but also a method for design that proactively accounts for human values.

2.5 Access to Information

The development of publicly accessible web-based tools for interacting with UrbanSim indicators reflects a widespread trend towards using the web as a platform for disseminating government information and supporting civic engagement. The problem in the context of a democratic society is ensuring equitable access to that information.

Shneiderman [116] characterizes universal usability as a threefold problem: building tools that accommodate users with differing technologies; accounting for the diversity of users with respect to a variety of factors such as gender, age, disability, and culture; and "bridging the gap between what users know and what they need to know." Wilhelm [137] also recognizes that access to information is not simply a matter of access to computers and networks. He argues that the digital divide is not so much about economic barriers to owning a computer so much it is about education, skills, and resources: literacy, numeracy, reasoning and argumentation skills, and facility with using computers for communication and information seeking. Kling [71] (cited by Tedesco [121]) draws a similar distinction between technological access (the physical equipment) and social access (the skills to make use of it). It's not enough to provide access to computing facilities; programs to increase access to the Internet must also provide the "human infrastructure" [137, p. 120] to help people become literate computer users. Technologies must account for the diversity of users and educate users when needed.

With respect to "bridging the gap between what users know and what they need to know" [116], the GovStat project [78] is particularly relevant to the work presented here. The GovStat project is a research effort to help people find and understand statistical information provided by the United States federal government. Much of the work has focused on the use of dynamic queries to find specific data in a vast ocean of data, ensuring that data is presented with appropriate context about how it is collected, and helping to bridge the gap between complex statistical information and users' limited statistical literacy.

Providing citizens with access to UrbanSim results poses similar challenges in addressing limited expertise. The problem of providing metadata about statistics is similar to that of providing metadata about UrbanSim indicators. Both statistics and simulations involve models—abstract representations of real world phenomena—and model abstractions that will be unfamiliar to many users. Indeed, the two projects have taken similar approaches, in providing information that is ready-to-hand (or "just-in-time" [78]) while interacting with data. Previous work on informed consent and web browser illustrated the importance of making technical information ready-to-hand if it is to be used [39]. The GovStat Statistical Interactive Glossary [78], which provides pop-up definitions for statistical terms, was one source of inspiration for "ready-to-hand FAQs" included in the Household Indicators prototype. As UrbanSim moves towards more online displays of indicator data, we should continue to draw on the GovStat work.

Beyond "bridging the gap" is the problem of engaging those who are not active technology users. Wilhelm observes that "given the demographic makeup of the Internet, it is not surprising that those who engage in political activity [on the Internet] are those who are already most likely to participate in nonvirtual civic and political life" [137, p.102]. A concern is that, in providing UrbanSim information and opportunities for political activity on the web, we only serve to enhance the divide between the politically engaged and the disengaged.

2.6 Computer-Supported Cooperative Work

Computer-Supported Cooperative Work (CSCW) is concerned with understanding the needs of people who do cooperative work and designing application systems to support them [4, 107]. As such, the field of CSCW continues to evolve as new questions are investigated when technologies are used in different contexts and reshape social and communication aspects of cooperative work. Our work contributes to CSCW as an example of designing a system for effective use in an environment with deep-rooted conflicts.

That conflict is inherent in cooperative work is well recognized, for even though the core of cooperative work is interdependence in work, this is "by no means necessarily harmonious" [107, p. 8], and "successful cooperation depends on how conflict is handled" [23, p. 3]. Yet, the urban planning context requires a different view of conflict. Conflict between stakeholder groups is often what Pace [95] calls "competitive conflict" among "entrenched" participants: "[t]his may occur where participants have opposing basic beliefs, values or principles which they believe must be mutually exclusive" [23, p. 25]. Competitive conflict may also be seen in groups' formative stages or within functional teams around power relationships.

Much of the work on group decision-making and deliberation seeks to structure interactions between participants. For example, Decision Support Systems focus on the provision of a decision model [74]. Collaboration tool-based Group Support Systems are intended to support and structure group deliberation [19], as are argumentative or discursive information systems such as Issue-Based Information Systems [65]. In contrast, here we seek to inform rather than to structure deliberation.

2.7 Participatory Design

Participatory Design is a philosophy and design methodology that brings the users of technology into the design process as design partners [8, 9, 24, 31, 105]. In its classic form, as developed in Scandinavia in the 1970s and 1980s, it is focused on the workplace. The researchers work with an organization or set of organizations (for example, publishers and graphics unions, in the case of the seminal Utopia project [9]). Participatory Design substantively embeds democratic values into its practice, specifically the value of workplace democracy—in our terminology, then, this would be an explicitly supported value.

Since its early development, Participatory Design has been used in or adapted to a variety of other contexts, including work with children [21], with participants with disabilities [139], and many others. In addition, of course, many of the techniques originally developed in Participatory Design work, such as paper prototyping, are by now standard practice in HCI design—but typically stripped of the original political commitments.

Chapter 3
CONCEPTUAL INVESTIGATIONS

In the Value Sensitive Design methodology, design often begins with conceptual investigations regarding who is impacted by the use of the system, how they might be impacted, and what values are at stake. However, the designer returns to conceptual investigations throughout the design process: for instance, as empirical investigations lead to the discovery of additional stakeholders, or as technical investigations reveal additional values to be considered.

In this chapter, I present results from conceptual investigations that have implications throughout the design work presented in this dissertation. I discuss UrbanSim's direct and indirect stakeholders, values held by those stakeholders, and two explicitly supported values: freedom from bias and support for a democratic society. Although these conceptual investigations started early in our application of Value Sensitive Design to UrbanSim, they have continued to be informed by empirical investigations and by new design directions taken in technical investigations.

While I was not involved in identifying UrbanSim's explicitly supported values, I have contributed to our understanding of support for a democratic society and specifically to the identification of testable design goals in support of legitimation. I also conducted investigations of transparency, civic engagement, and the distinction between perceptions of bias and actual biases.

3.1 Stakeholder Analysis

A key feature of the Value Sensitive Design methodology is the identification of direct and indirect stakeholders. Direct stakeholders are those who interact directly with the system—the conventional notion of "the user"—while indirect stakeholders do not use the system themselves, but are impacted by its use. A summary of UrbanSim's direct and

Table 3.1: UrbanSim's direct stakeholders and selected indirect stakeholders.

Direct Stakeholders
Modeling staff at the Center for Urban Simulation and Policy Analysis (CUSPA)
Planning staff at local and regional agencies

Indirect Stakeholders	
Elected representatives	Homeowners
Government officials	Renters
Citizens	Real estate developers
Voters	Businesses
The media	Farmers
Taxpayers	Commuters
Civic activists	Mass transit users
Environmentalists	Bicyclists
Native American tribes	Pedestrians
Disadvantaged minorities	Children and youth
Low-income households	Residents of the region
People with disabilities	Residents of nearby regions
The elderly	Future generations

indirect stakeholders is presented in Table 3.1. Although this list is not comprehensive, it is representative; it is informed by empirical investigations in which citizens were asked to name people who would be impacted by urban planning decisions, as well as by conceptual investigations.

For UrbanSim, the group of direct stakeholders that came into contact with the system the earliest includes the urban planners and modelers who operate the system by manipulating input data, configuring simulation runs, running the software, and interpreting and reporting on simulation results.

Because decisions about land use and transportation strongly affect the future development of urban areas and their surroundings, UrbanSim's indirect stakeholders are many and diverse. Elected representatives and government officials have a strong role in making and implementing decisions informed by data from UrbanSim, and are held accountable for these decisions. Citizens, too, may inform their opinions with UrbanSim data, as well as their votes on ballot initiatives and referenda. Members of the news media have a role in explaining news, as well as reporting facts and acting as investigative watchdogs [118], and so have a stake in how UrbanSim is used and what information about it is available. Finally, everyone who lives, works, or travels in the region or nearby regions is affected by the decision that is made. But particular groups, such as low-income households, renters, mass transit users, or people with disabilities may be subject to particularly strong impacts. And although future generations are impacted by these long-term decisions, they cannot have a voice themselves.

Note that each individual may have several different stakeholder roles. For example, a member of planning staff may also be a resident, a citizen, a mass transit user, a homeowner, and a person with a disability.

Not all indirect stakeholders will be impacted to the same degree; for example, residents of nearby regions or visitors to the region will generally be less affected than residents of the region itself. And engaged citizens who participate in the decision making process have a particularly strong interest in better-informed decisions. In their application of Value Sensitive Design to the augmented office window [44], Friedman, et al., also noted that potentially everyone could be counted as indirect stakeholders, but they identified one particularly strongly impacted group of stakeholders ("the Watched") on which to focus their empirical investigations. Similarly, our empirical investigations with indirect stakeholders have focused on engaged citizens. Future investigations may focus on other groups of indirect stakeholders who have strong moral claims to representation and may suffer particularly great harms from decisions that fail to adequately take their claims into account, such as renters, mass transit users, or wheelchair users.

Thus, one of our goals in developing UrbanSim is to provide strongly impacted indirect stakeholders—notably citizens of the region—with opportunities to become direct stakeholders. We acknowledge that this work is Western-centric in that it assumes government through representative democracy. To support a democratic society, UrbanSim should enable stakeholders to inform themselves about urban planning decisions so they engage in informed deliberation about the decisions. As an example, Indicator Perspectives and Household Indicators, and to a lesser extent the Technical Documentation, are intended to provide opportunities to interact directly with UrbanSim results to engaged citizens with no particular expertise in urban planning or modeling. This work is unique among applications of Value Sensitive Design thus far in having the explicit design goal to provide direct access to a greater number of indirect stakeholders over time.

3.2 Stakeholder Values

With so many different stakeholders, their values are diverse as well: health, economic growth, housing affordability, property rights, low taxes, open space, social equity, walkability, access for people with disabilities, biodiversity, sustainability, and many others. In the context of a particular decision, stakeholder values may conflict. For instance, a measure intended to preserve open space and biodiversity may encroach on individual property rights.

Furthermore, we as designers of the system may hold some of these values, but not others. Given limited resources, how do we prioritize these values? Should our role as designers let us privilege our values over those of stakeholders who may have a far greater stake in the decision that is made? In response to this concern, we made a sharp distinction between explicitly supported values (i.e., ones that we explicitly want to support in the simulation) and stakeholder values (i.e., ones that are important to some but not necessarily all of the stakeholders).

3.3 Explicitly Supported Values

We committed to several key moral values to support explicitly: fairness and more specifically freedom from bias [46], accountability, and support for a democratic society. Here we focus primarily on support for a democratic society and freedom from bias; accountability is further considered by Freeman-Benson and Borning [33]. In turn, 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 instead should allow different stakeholders to articulate the values that are most important to them, and evaluate the alternatives in light of these values.

Note that explicitly supported values are not the same as the designers' values—they are subjected to a principled analysis of arguments for their inclusion rather than simply being a matter of personal preference. This provides a strong response to the concern that the system simply reflects the personal values of the designers.

The remaining sections of this chapter elaborate on two of the explicitly supported values: support for a democratic society and freedom from bias.

3.3.1 Support for a Democratic Society

In this section, I consider the value of support for a democratic society. First, I sketch the concept of deliberative democracy and contrast it with classic liberal theories of democracy. I argue for the importance of UrbanSim's legitimacy in the context of a democratic society, drawing on Jürgen Habermas's work in political philosophy to identify design goals in support of legitimacy. I further discuss the instrumental goal of transparency and present a characterization of what it means for a citizen to be democratically engaged.

Deliberative Democracy

While there are many conceptions of democracy, deliberative democracy has gained prominence over the last few decades. Gutman and Thompson succinctly characterize deliberative democracy as

> a form of government in which free and equal citizens (and their representatives) justify decision in a process in which they give one another reasons that are mutually acceptable and generally accessible, with the aim of reaching conclusions that are binding in the present on all citizens but open to challenge in the future [55, p. 7].

A key feature of deliberative democracy is the giving of reasons to justify decisions. Such reasons must be given publicly (not merely weighed in the privacy of one's own mind) and rest on information that is accessible to all.

By contrast, in classic liberal theories of democracy, people's interests are taken as given; each individual is best able to judge his or her own interests [59, p. 9]. The role of democracy is to aggregate the preferences of individuals into a decision. Gutman and Thompsom [55] argue that this conception of democracy is fatally flawed. Voters are not required to give reasons for their preferences. There is no provision for a process by which citizens' views about the needs of society can be changed, nor for citizens to challenge the means by which preferences are aggregated. Deliberative democracy better serves to promote the legitimacy of collective decisions by making reasons public and considering everyone's claims; to encourage the taking of public rather than purely self-interested perspectives; and to promote mutual respect in decision making in the face of conflicting moral values [55, p. 10-11]. One flaw of deliberative democracy is that in the absence of consensus it does not provide a method for making a decision; yet its strength is that it can accommodate other means of decision making—including voting—as long as these means are deliberatively justified [55, p. 19].

We adopt the stance that deliberation is a key feature of democracy. In this view, the role of UrbanSim is to provide information that can support (or refute) reasons given in the course of public deliberation about urban planning decisions. A secondary role is to promote deliberation in decision making, in a society which does not take deliberation as given [29]. Furthermore, the use of UrbanSim itself is open to challenge and must be publicly justifiable. Next, we draw on the work of Jürgen Habermas to consider how the use of UrbanSim might be justified in the face of such challenges.

Legitimation: A Habermasian View

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

We distinguish legitimation from credibility on the one hand, and technical accuracy on the other. As we learned in our conceptual investigations, both credibility and technical accuracy are important, but not sufficient. Credibility is open to psychological manipulation, and thus problematic as a primary design goal. We would like to have stakeholders place some credence in the results of the simulation, but for the right reasons. Similarly, technical accuracy is important, but it is also essential, for example, that decisions regarding which alternatives to model and how to assess the results be made in an open and democratic manner.

Our conceptualization of legitimation—its central role in the political process, and what allows a political process to be legitimate—draws primarily on the work of Jürgen Habermas [56, 57]. The legitimation of an urban planning process depends on a huge number of factors. The modeling software forms only one small part, and even the best-designed system could be used in a process lacking in legitimacy. Since most of these factors are out of our control, in this work we concern ourselves with the *legitimation potential* of the modeling system, rather than the legitimation of the entire process in which it plays a part.

Communicative action plays a key role in legitimation potential. According to Habermas [56], legitimation in the modern state has achieved a reflective or procedural level of justification, in which legitimacy is contingent on free and equal agreement among all parties. For participants to agree freely, the process of coming to an agreement must be free of coercion or manipulation. Habermas defines communicative action as speech in which all participants aim towards mutual understanding, without manipulative or strategic actions. In communicative action, each utterance implicitly raises four validity claims: to the comprehensibility of the utterance, to the truth of its propositional content, to the truthfulness of the expression of the speakers intent, and to the rightness and appropriateness of the utterance with respect to existing norms and values.

UrbanSim is just one voice in public discourse about urban planning. It does not dictate the truth; rather, it informs a process of coming to an understanding. As it is used in the course of deliberation, information from and about UrbanSim will raise the four validity claims of communicative action. To provide legitimation potential for the use of UrbanSim, we as designers should do our best to ensure these claims are well grounded. First, the information UrbanSim provides should be comprehensible to the range of stakeholders. Second, UrbanSim's models and results should be a reasonable representation of reality. Third, UrbanSim should be transparent with respect to its inner workings and design, so that stakeholders can see that the model and its results are truthfully represented in the deliberation. Fourth, UrbanSim is cast in the role of a source of relatively neutral, technical information in a highly political process. To rightly fulfill this role, and in the interest of fairness to all stakeholders, UrbanSim should provide information that is as unbiased as possible. The information provided should be appropriate and relevant to the policy context.

Those who have access to information such as that provided by UrbanSim have a power advantage in discourse. In the interest of permitting an equal agreement, as many stakeholders as possible should have access to UrbanSim. Many different presentations may be required so that results can be comprehended by stakeholders with differing expertise and accepted by stakeholders with differing norms and values. While the Technical Documentation is intended primarily for modelers and planners, our Indicator Perspectives mechanism, which lets different organizations present perspectives on how UrbanSim output should be used in making policy decisions, is intended for a wide range of interested stakeholders. Household Indicators are intended primarily for citizens, but may also be used by decision makers in taking the perspectives of their constituents.

Though Habermas has been criticized (sometimes strongly), for our purposes there is much of value here. Indeed, we embrace critiques such as that of Nancy Fraser [32], who argues that the ideal of the public sphere must be reconstructed to permit the participation of all. According to Fraser, even after everyone is formally licensed to participate in the public sphere, informal barriers such as that of differing communication styles remain. These barriers can be reduced through a multiplicity of publics that give members of subordinated groups safer venues in which to find their voice, so that they can better articulate and defend their interests in the larger public sphere. The Indicator Perspectives mechanism could support multiple publics in that it allows members of particular groups to formulate positions in discourse amongst themselves and then articulate those positions to the larger public.

Transparency

The term "transparency" appears in contexts of human-computer interaction, modeling, and public policy, all of which have relevance to UrbanSim. In both human-computer interaction [25, 61] and modeling [76, 30], transparency is used to designate the opposite of a "black box" system, which hides all information beyond its inputs and outputs. In contrast to a black box, du Boulay, et al. describe a transparent system as a "glass box" that functions rather like the cut-away models of machines to be found in technical museums, and indicates the more important events going on inside [22]. Some go beyond a literal application of the glass box metaphor to include the availability and comprehensibility of information about the purpose and design of the system, and in particular its assumptions [102, 120]. In the public policy literature, the term transparency is widely used to designate mechanisms for public disclosure of information [27, 64]. Finel and Lord [28] capture the notion of transparency as a "glass box" in emphasizing the visibility of the internal characteristics of a government.

For simulation models, transparency supports several of the goals for legitimation: it helps stakeholders to comprehend the simulation results, it allows them to assess whether the simulation is sufficiently accurate for the decision making context, and it allows stakeholders to verify the intent of the model developers to provide relatively unbiased information. However, a simple "glass box" notion of transparency is insufficient. Seeing inside the box is not the same as understanding what is there. It is important to make the purpose and assumptions of the system apparent so that stakeholders can assess when its assumptions do not hold or its purpose is incompatible with the goal of the deliberation.

Furthermore, Value Sensitive Design leads us to consider transparency for both direct and indirect stakeholders, who will have differing expertise with respect to urban planning, simulation, computer systems, and the region in which UrbanSim is applied. Therefore, transparency is needed at a number of levels—in the reports read by elected officials and the public, in documentation about simulation outputs, in model specifications, and in the availability and comprehensibility of the simulation code itself.

Democratic Engagement

One of our goals in supporting more democratic urban planning is to foster citizen engagement in the decision making process.

According to Delli Carpini [20], who has written extensively on the topic, there is no simple answer to what defines the engaged citizen. Yet,

> most theory and research would include (1) adherence to democratic norms and values; (2) having a set of empirically grounded attitudes and beliefs about the nature of the political and social world; (3) holding stable, consistent, and informed opinions on major public issues of the day; and (4) engaging in behaviors designed to influence, directly or indirectly, the quality of public life for oneself and others. Underlying all of these elements is the assumption that citizens also have the skills and resources necessary to develop informed values, attitudes, and opinions, connect them together, and translate them into effective action. [20]

To further elaborate Delli Carpini's characterization of democratic engagement [20], democratic norms and values include a sense that one's participation in public affairs can make a difference, trust in government and one's community, interest in politics, tolerance for others' political views, and a sense of civic duty. Attitudes and beliefs refer to one's overarching views about the political world, such as a commitment to a political party. There is no presumption that any particular attitudes are more or less beneficial to a democratic society, but the hope is that these are based on accurate information about the world. Opinions pertain to specific issues, policies, and officeholders, and while they reflect one's attitudes, the hope is that they are also well informed. The participatory behaviors of engaged citizens can take many forms, including following politics and public affairs in the news, discussing public affairs in formal and informal settings, voting, contacting government representatives, volunteering, and active involvement in collective public problem solving. Finally, citizens need basic skills such as reasoning, argumentation, and communication, as well as resources such as information about the substance of political life, in order to translate values, attitudes, and opinions into effective political behaviors. According to Delli Carpini, more informed citizens are not only more likely to have the attitudes described above and to participate in civic life, but to do so more effectively [20]. Thus, information is key to civic engagement.

We seek to foster civic engagement in urban planning primarily by informing citizens, both indirectly—through citizen's interactions with urban planners, elected officials, political organizations, and the media—and directly, through citizen interactions with UrbanSim. By informing citizens, we intend to not only help foster more informed opinions, but also to support values and attitudes that are conducive to democratic engagement.

3.3.2 Freedom from Bias

Simulation is necessarily an abstraction and simplification of the real world. We want to make these abstractions and present information in a way that minimizes bias, while being as transparent as possible about the biases the system does introduce.

In its most general sense, bias simply means "slant" or "skew." In evaluating computer systems such as UrbanSim, we are primarily concerned with bias in a moral sense. In this sense, *bias* is not the same as *lack of accuracy.* Following Friedman and Nissenbaum, we identify moral bias in computer systems that "systematically and unfairly discriminate against certain individuals or groups in favor of others" in some context of use [46, p. 332]. Discrimination is "to make a distinction as in favor of or against a person or thing" [48]. To be of moral import, such distinctions must be both unfair and systematic. Unfair discrimination denies a good, or assigns an undesirable outcome, based on grounds that are "unreasonable or inappropriate" to the decision at hand [46]. This unfair assignment of outcomes is considered to be a moral bias if it occurs systematically rather than randomly, making some individuals or groups more likely than others to suffer the undesirable outcome.

In determining whether a bias is unfair, we should ask two questions. First, against whom is the system biased? Who suffers the undesirable outcome? If we cannot identify the groups or individuals discriminated against, we should question whether anyone is harmed, and therefore, whether the bias is of moral import. A concern with UrbanSim is to what extent biases against policies (rather than directly against people) can be considered moral biases. For example, consider a simulation system that models travel by automobile but not by mass transit or non-motorized transit. If simulation results contribute to policies that neglect travel options for those who cannot afford a car, or whose cognitive and physical limitations prevent them from driving a car, surely this is of moral significance. However, we can also consider this outcome to be biased against those who have other reasons to support travel by means other than automobile, because their values were not given equal weight with those of car supporters in the decision making process.

Second, is there a reasonable justification for the slanted outcome? In some cases, the slant is unintentional, with no attempt to justify the outcome. For example, the designers of an airline reservation system may not intend to favor American Airlines when they choose to list airlines in alphabetical order. Such an unjustified bias is clearly unfair. In other cases, stakeholders may disagree as to whether the justification for the slanted outcome is reasonable. Indeed, moral and legal systems differ dramatically in what constitutes a reasonable justification for discrimination. Even within itself, the United States legal system is not always consistent in its judgments, and laws such as Title VII of the Civil Rights Act of 1964 that were once believed to be straightforward have proved ambiguous and difficult to apply in practice [48]. Rather than attempting to distill and synthesize the philosophical literature to develop a compete theory of justice here, we will draw on these sources as needed to develop a more sophisticated understanding of fairness in particular contexts as our investigations require. Empirical work helps in understanding how stakeholders perceive fairness and justification for discrimination in the context of urban planning.

The interactional perspective taken in Value Sensitive Design becomes particularly salient when considering software bias in a complex context of use such as that of UrbanSim. Bias is easier to identify in systems that directly assign outcomes to individuals, or in systems where the human process for making a decision based on the system's output is well understood. For instance, take the example of the airline ticket purchasing system described by Friedman and Nissenbaum [46]. Knowing that users rarely read past the first few screens of search results makes it far easier to argue that a fixed ordering of flights results in an unfair outcome and therefore is biased. Since UrbanSim is only one source of information taken into account by decision makers, bias in UrbanSim's results does not guarantee a biased outcome, nor do fair simulation results guarantee a fair outcome. However, quantitative information such as that provided by UrbanSim may be privileged over more qualitative assessments—and may even contribute to framing stakeholders' understanding of the decision itself [63]. Therefore, we cannot neglect the potential for biases in UrbanSim to contribute to biased outcomes. But because UrbanSim does not determine the outcome of decision making, I will sometimes write about a “potential bias”—a slant in the system which has the potential to lead to biased outcomes.

In UrbanSim, potential biases take a number of forms. In its most blatant form, models or input data could be slanted to favor particular policies without any theoretical basis. UrbanSim indicators might permit the assessment of scenarios with regards to analogous concerns of one stakeholder group but not another, for example, providing information about housing costs that is useful to homeowners without providing similar information to renters. The system might leave out some morally significant concern altogether, such as greenhouse gas emissions, due to limited resources for modeling and software development or due to the fundamental limits of modeling. Information might be accessible to one group but not another, where groups have differing expertise, literacy, physical abilities, or economic resources. As discussed earlier, the digital divide is a significant concern here. Finally, the interaction design itself could be biased, for example, by the order in which indicators or other options to be selected from are listed [46].

Sources of Bias

Friedman and Nissenbaum [46] identify three sources of bias: pre-existing bias, technical bias, and emergent bias. *Pre-existing bias* occurs when design is influenced by the existing biases of society or of an individual against particular individuals or groups, for example, as in a real estate listing service that supported the practice of red-lining. *Technical bias* arises from technical constraints or considerations. There is no intent to discriminate unfairly, but in practice, some groups have less desirable outcomes than others. For example, the inappropriate use of a sorting algorithm to alphabetize flights by airline name would give a significant unfair advantage to American Airlines. Technical sources of bias include tradeoffs made in addressing the limitations of computer tools, imperfect random number generation, choosing algorithms without consideration of the context of use, and inadequate formalizations of human concepts, which is of particular concern for UrbanSim as a model of real cities. *Emergent bias* may result when new contexts of use differs significantly from the context the system was designed for. For example, societal knowledge changes over time, and new users (e.g., in a different culture) may have different values or expertise than the users the system has design form.

The lines between these categories are not always clear. Any technology is a product of society, and as such reflects the values and biases of society. This blurs the line between pre-existing and technical bias, as the limitations of existing tools may reflect biases in society. Similarly, the line between technical and emergent bias is blurry, and technical bias may results from failing to take the *immediate* context of use into account, while emergent bias results from failing to take *future* contexts of use into account. Whether a bias is considered technical or emergent depends on how we draw the line around the user population.

Nevertheless, we can draw meaningful boundaries by limiting the scope of each category as follows. Pre-existing biases reflect existing biases of societies or individuals. These existing biases, if left unchecked, would tend to lead to unfair outcomes regardless of whether technology is used. Technical biases result from technical limitations; although these limitations may reflect preferences or tendencies of society, the limitations themselves do not discriminate against any particular group. The moral aspect of the bias arises when the technical limitations clash with a context of use, particularly when system designers make poor choices in trading off technical and value concerns, or when designers are unaware they are making a choice. Emergent bias occurs when the system was explicitly designed for one context of use and is used in substantially different contexts.

Bias and democracy

Freedom from bias is a moral good in itself, and we first identified freedom from bias as an explicitly supported value for this reason. However, freedom from bias is also instrumental to equal opportunity to participate in democratic society; stakeholders whose concerns are represented in the system may have a privileged place in deliberation relative to those whose concerns are not represented.

Furthermore, the use of a biased information system could undermine the legitimacy of the decision making process it informs. Even the perception of bias could raise doubts

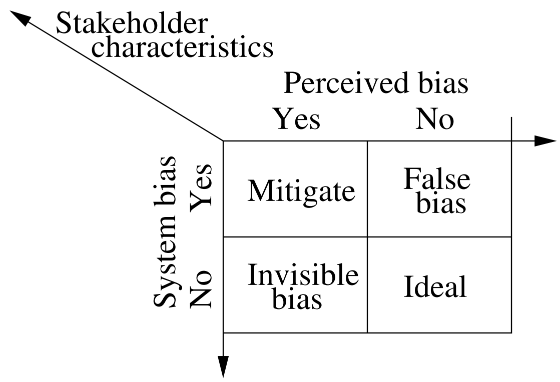


Figure 3.1: Matrix illustrating the relationship between system bias, stakeholder perceptions of bias, and stakeholder characteristics.

about the accuracy of the information provided and the intent of the system designers.

Perceptions of bias in the system may differ from whether that system actually contributes to biased outcomes, as shown in Figure 3.1. Stakeholders may not be aware of potential biases in the system—an *invisible bias error*. Similarly, stakeholders may attribute false discriminations to the system, or fail to comprehend reasonable justifications for some discrimination, resulting in a *false bias error*. Of course, the stakeholder may understand the justification for discrimination but disagree that it is valid or sufficient; this is not an error, but a legitimate point of contention. Perceptions of bias are likely to depend on stakeholder characteristics such as the stakeholder's own position on the issue, domain expertise, computer skills, interest in the outcome, and so forth.

The ideal case is that the system is free from bias and stakeholders agree that it is free from bias, but when bias is unavoidable it should be made transparent so as to mitigate its effects.

Invisible bias errors may be categorized by the source of the bias: pre-existing, technical, or emergent. Pre-existing bias may be invisible because stakeholders are not aware of their own or society's biases, as well as biases of the system builders, and so do not recognize it in system output. Technical bias is especially likely to be invisible in a simulation system, as the details of model operation are often not transparent. In particular, low-level implementation details are not easily understood by stakeholders with limited technical expertise, and would be overwhelming if exposed indiscriminately. Those who have little domain expertise, and cannot judge whether the system's outputs are reasonable, may be especially prone to invisible technical bias errors. Invisible emergent bias may arise when stakeholders are unaware of important differences between the present context of use and the contexts that were taken into account in the design.

False bias errors arise when a stakeholder believes that the system would contribute to systematically unfair outcomes, when in fact the outcomes are not systematically skewed or have justifications that the stakeholder would agree are adequate if he or she understood them. For example, advocates for building a new freeway might believe that an urban simulation system is biased against car travel if it shows that traffic congestion increases despite the new freeway. This is a false bias error if these advocates are unaware of or misunderstand the theories of induced congestion that are implemented in the simulation models. If stakeholders disagree with the theories underlying the model, this is not necessarily an error, but may be a legitimate point of contention. Errors of understanding and disagreements about the theoretical framework must both be addressed to establish the legitimacy of using the model.

3.4 Conclusion

In this chapter, I have presented the results of conceptual investigations into UrbanSim: its stakeholders, stakeholder values, and the explicitly supported values of freedom from bias and support for a democratic society.

These conceptual investigations have not occurred in isolation, as might be implied by their presentation in a separate chapter, but rather reflect Value Sensitive Design's iterative and integrative process. The mapping of Habermas's theory of communicative action onto testable design goals represents a move from the conceptual into the technical which has affected all of the work to follow. Investigation of democratic engagement was sparked by a new technical direction for the work, the development of Household Indicators. Discussion of further conceptual work is embedded as needed in each of the following chapters.

Chapter 4

INFORMING DELIBERATION THROUGH THE TECHNICAL DOCUMENTATION

I turn now to one aspect of the design problem that is the focus of this dissertation: creating an interaction design around UrbanSim indicators that will provide improved functionality, support stakeholder values, enhance the transparency of the system, contribute to the system's legitimation, and foster political engagement. With the design and development of the Indicator Browser—a suite of tools to help urban planners and other stakeholders select, visualize, and learn about UrbanSim's indicators—I and my colleagues set out to help support the process of legitimation through increased access to and transparency of the indicators.

This chapter presents initial explorations into the Indicator Browser, and the development and evaluation of the Technical Documentation, intended to provide ready-to-hand information about indicators to urban planners and other stakeholders. This work was conducted jointly with Alan Borning, Batya Friedman, and Peyina Lin. I contributed to the identification of design goals in support of legitimation (see Section 3), to the iterative design of the Technical Documentation based on these goals, and to the design and execution of a summative evaluation of the Technical Documentation. The text of this chapter is largely adapted from an earlier publication by Borning, Friedman, Davis, and Lin [12].

After discussing the design challenges with UrbanSim indicators, I describe our iterative Value Sensitive Design process around the Indicator Browser and Technical Documentation. I briefly discuss considerations for the implementation of the Technical Documentation. Then, I present the results of a more formal evaluation of the Technical Documentation with urban planners. Finally, I conclude with lessons learned.

4.1 The Design Problem: Challenges with Indicators

When we began our work, the code to produce indicator output from UrbanSim was intertwined with the simulation code itself, and adding a new indicator was not straightforward. No single list of the implemented indicators existed, and no single place contained the definitions of the indicators or other details that would be needed by modelers and planners working with UrbanSim. There was no easy mechanism for ensuring that indicator documentation was current, including documentation for how indicators were computed. And none of the above information was ready-to-hand [39, 138], that is, easy to access in the course of interacting with UrbanSim. With the design and development of the Indicator Browser, we set out to remedy this situation in a way that would help to support the process of legitimation through increased access to and transparency of the indicators. Specifically, we set out to address the following design challenges:

1. Fragmentation of indicator information, in many different sources.
2. Lack of ready-to-hand indicator information.
3. Diverse sources and competing definitions for indicators.
4. Difficulty of comprehending indicator information.
5. Difficulty of inspecting and understanding how indicators are computed.
6. Sometimes outdated or inaccurate information.
7. Difficulty of adding and modifying indicators (and corresponding documentation), due in part to the system architecture.
8. Concerns regarding perception of bias in the indicator information, including what information is provided about the indicators and how they are organized and presented to the user.

9. Potentially inadequate representation of stakeholder values, including a cogent argument for why a given indicator is important and relevant for assessing a particular policy.

We hypothesized that the transparency of the system would be directly enhanced by addressing the first six design challenges. Moreover, we believed that stakeholder representation could be better supported with mechanisms to easily add new indicators. While at the start it was unclear how much progress we could make on any of the first seven design challenges, from our perspective there was little controversy that making progress on any of these would be beneficial.

The last two design goals—that of addressing perceptions of bias and of supporting specific stakeholder value representation—provided a greater challenge, in that they represented a tension between the competing goals of neutrality and value advocacy. In this case, what we sought to make transparent was the purpose of information: when information was of a more neutral flavor and when it clearly represented a specific stakeholder perspective.

4.2 The Design Process

In this section we describe our iterative Value Sensitive Design process around the development and informal formative evaluation of the Technical Documentation. Our purpose is to convey how we thought through the value implications of our work and how those analyses impacted our design work. We highlight the integrative nature of our design work, moving among conceptual analyses of transparency, legitimation, representation, and freedom from bias, technical development, and empirical investigations in the form of informal (and eventually more formal) formative evaluations.

4.2.1 Prototype 1: Envisioning the Indicator Browser

Prototype 1 was developed before I joined the project. The first problems to be addressed concerned information fragmentation, the lack of ready-to-hand information, and balancing tensions between neutrality and value commitments. The first prototype (Prototype 1) was sketched on a whiteboard (Figure 4.1 and shortly thereafter developed in Microsoft Ac-

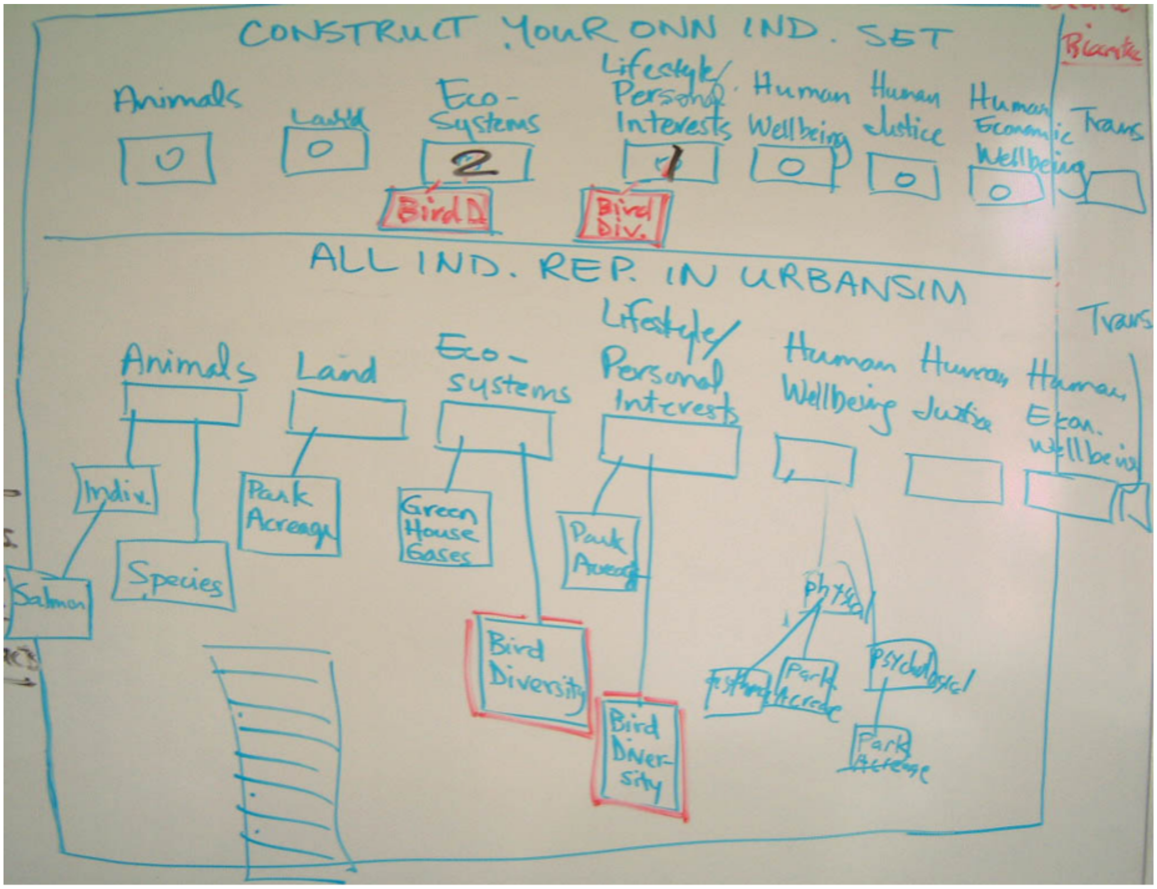


Figure 4.1: Whiteboard sketch of Prototype 1, showing "Construct Your Own Indicator Set" (top) and "All Indicators Represented in UrbanSim" (bottom), grouped by category.

cess (Figure 4.2). This version divided the screen into two parts: the top part showing the specific indicators a user had selected and the bottom part showing the available indicators to select from. In addition, it grouped the indicators into eight overarching categories and showed the number of indicators selected from each category. The idea was to make visibly salient to users which categories were well represented by any given indicator selection, and which categories less so. The research group also envisioned a system that would allow users to click on the name of an indicator to bring up ready-to-hand information about that indicator, as well as sample output, though these features were not implemented until Prototypes 2 and 3.

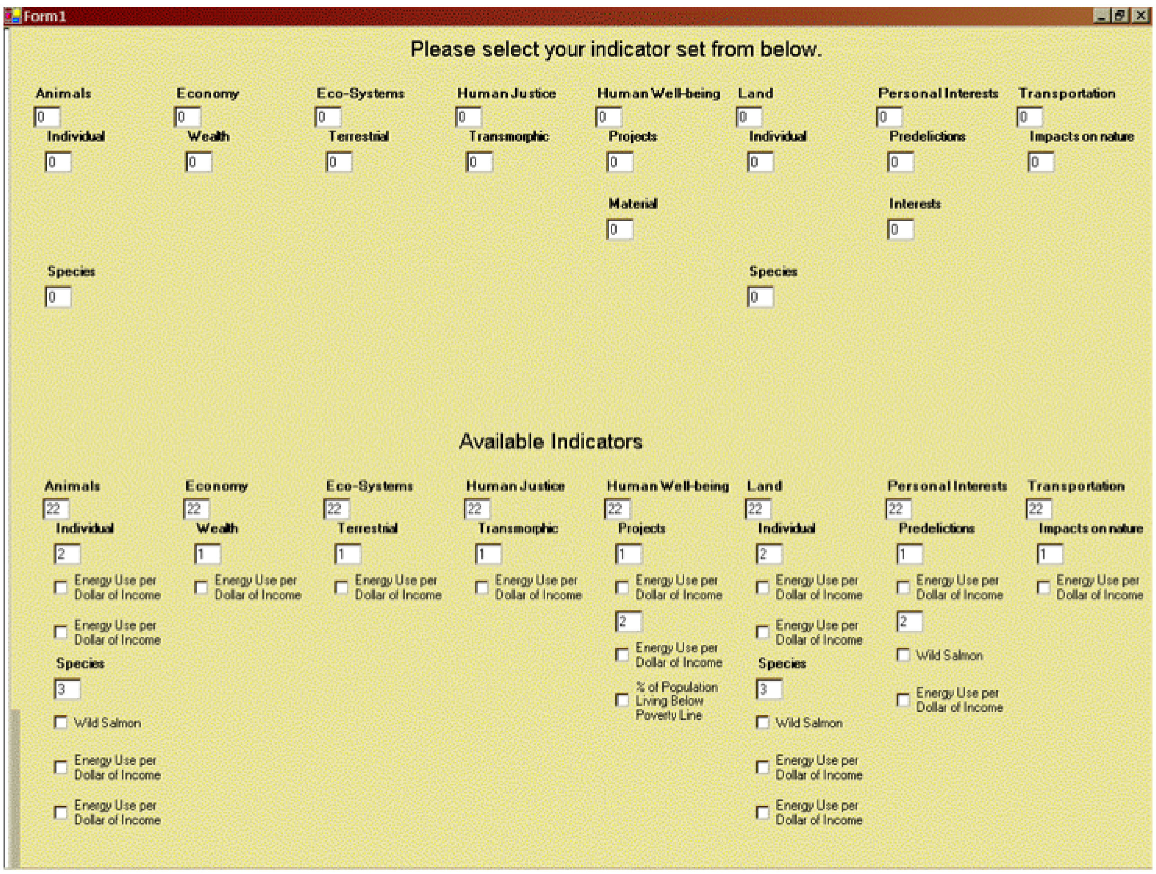


Figure 4.2: Screen shot of Prototype 1, showing the users' selected indicator set with the number of selected indicators per category (top) and all available indicators (bottom), grouped by category.

4.2.2 Prototype 2: Refining the Indicator Browser and Developing the Technical Documentation

The initial sketch of the Indicator Browser realized in Prototype 1 led naturally to the need for two key developments: (a) a change of platform to a web-based implementation that could be readily connected to the working UrbanSim simulation and (b) ready-to-hand Technical Documentation for each of the individual indicators. The former development would allow for a close coupling of the Indicator Browser with the running models and position us to develop live documentation for the indicators; the latter development would increase transparency and comprehensibility of the indicators by providing easy access at the time of use to accurate, useful information about each indicator. With Prototype 2, we set out to design and implement these changes.

At this stage key disagreements arose within the design team regarding categorization schemes that might be perceived as biased and as a result undermine the system's legitimation. Our discussions here were extensive, lasting many months, and nearly bogged down the development of the Indicator Browser. To help move past this log-jam, in this prototype we implemented more than one categorization scheme and put the selection of the categorization scheme into the users' hands. Figure 4.3 shows one scheme; clicking on the tabs at the top provide a display of the indicators in alternative schemes.

As shown in Figures 4.3 and 4.4, Prototype 2 is implemented as a series of web pages. Figure 4.3 shows the main Indicator Browser page (similar to Prototype 1) with the list of all available indicators now on the left (categorized as Economics, Environment, and Social) and the indicators selected by the user on the right. In addition, Technical Documentation was created for each indicator. Figure 4.3 shows sample documentation for a "Salmon" indicator for the Pacific Northwest. Once reasonable Technical Documentation had been developed for the 40 indicators implemented for UrbanSim, we began to engage in formative evaluation to refine the content, organization, and presentation of this information.

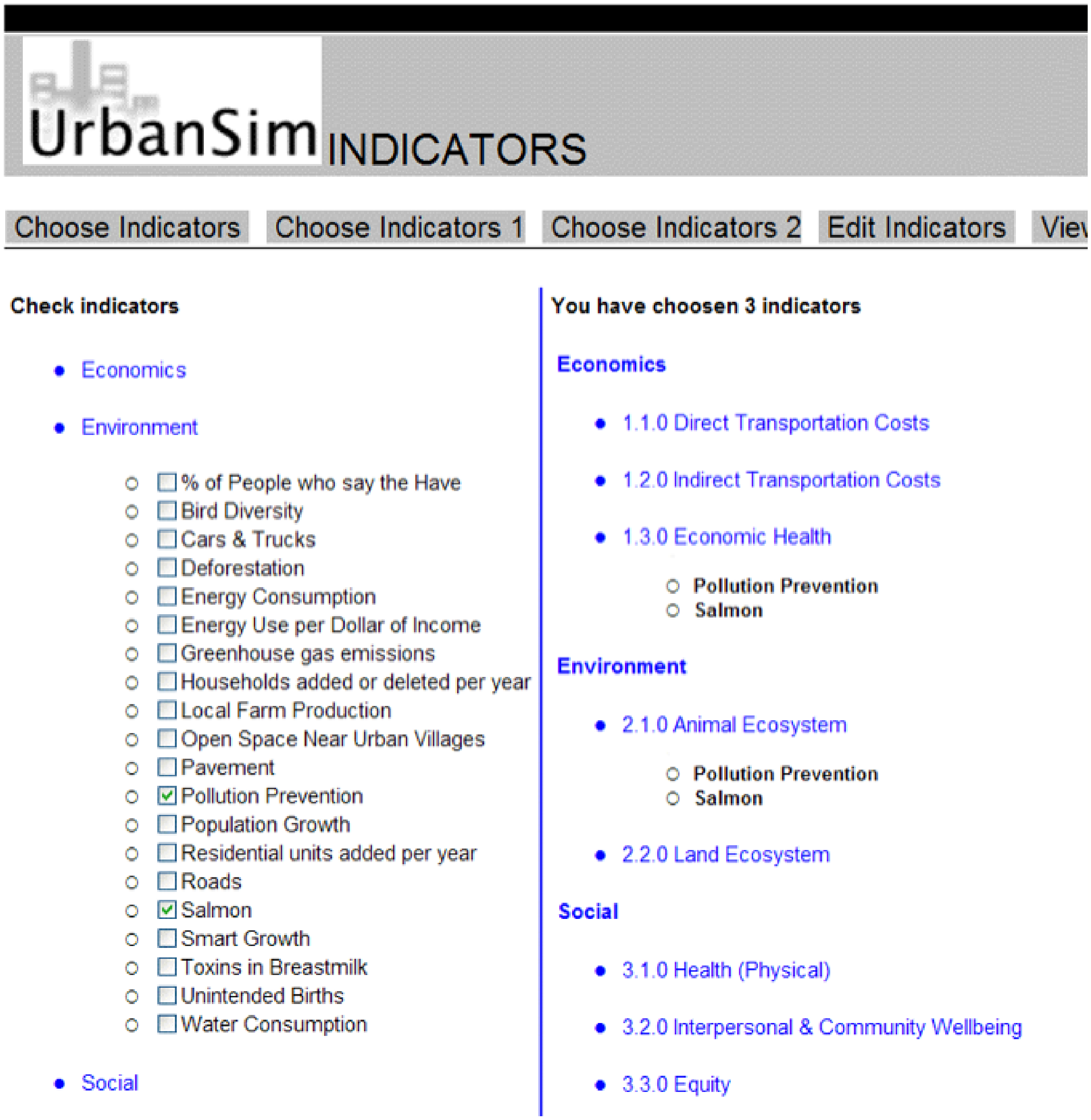


Figure 4.3: Screen shot of the Indicator Browser Prototype 2, showing all indicators (left) and user selected indicators (right), categorized as Economics, Environment, or Social. The Choose Indicators tabs at the top allow the user to choose among different categorization schemes for the indicators.

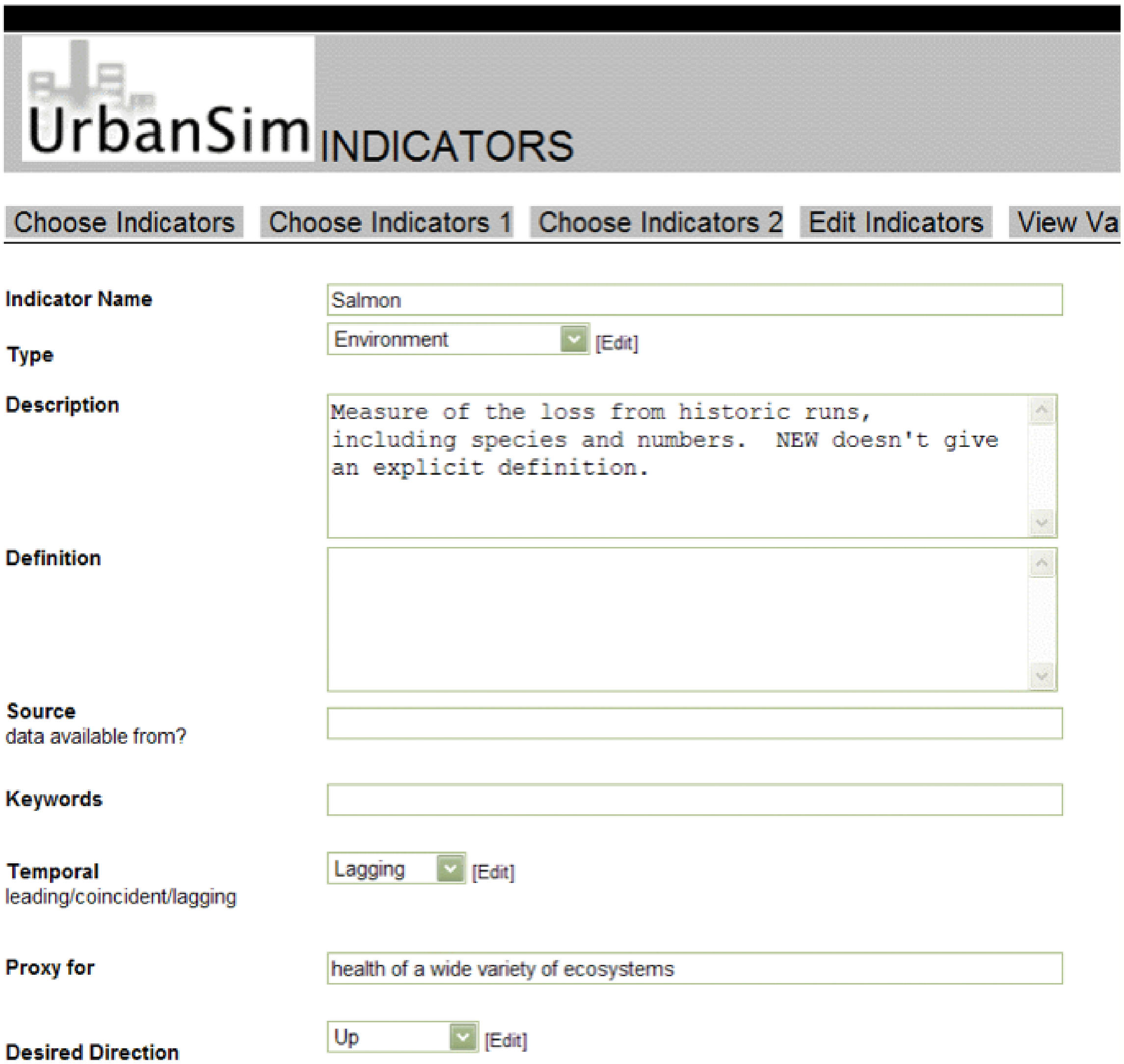


Figure 4.4: Screen shot of initial Technical Documentation about the "Salmon" indicator. Sections shown include indicator name, type, description, definition, source, keywords, temporal relationship, proxy for other indicators, and desired direction of change.

4.2.3 Informal Formative Evaluation and Iterative Design of Prototype 2

To test our design intuitions, we conducted a series of informal-formative-evaluation/redesign cycles of the Technical Documentation with nine participants, five with a modeling background and four with a policy background. Within each evaluation/redesign cycle, the participant was asked to think aloud while browsing the Technical Documentation in the presence of a facilitator, who made note of the participant's comments and suggestions. We also asked the participant questions about particular documentation elements. Following each evaluation session, changes were made in quick iteration so that each subsequent participant engaged with a slightly improved version of the Technical Documentation.

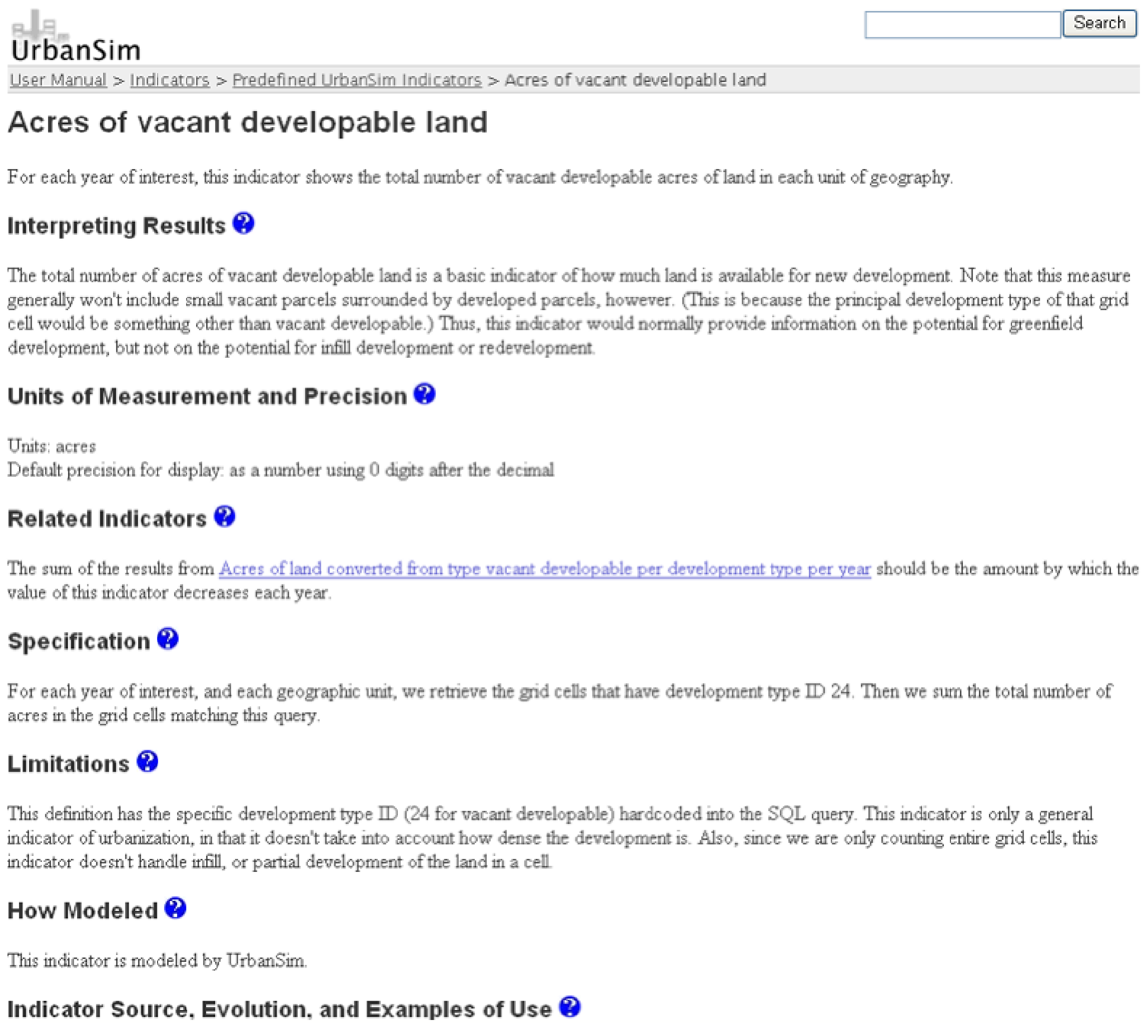
Taken as a whole, the formative evaluation guided our redesign to better achieve our design goals. For transparency, we learned that we needed to make assumptions more prominent within the technical documentation, and received some confirmation of our decision to include a section particularly for reporting limitations. For relevance to policy, several participants requested examples for how specific indicators might be used, and we iterated several times on the organization of indicators into categories without clear resolution.

Much of the strongest feedback we received was with respect to neutrality. Early versions of the Technical Documentation included a section for the desired direction of the indicator, which we thought would be useful in the context of decision making. However, the information in this section reflected widespread disagreement about the desired direction for many indicators, and some participants indicated that even the sections name conveyed bias. We also experimented with designating indicators as primarily diagnostic or primarily evaluative. Several participants pointed out to us that some indicators we had designated as diagnostic (e.g., "Acres of Developable Land") would in fact be of policy interest to some stakeholders (in this case, real estate developers). Based on this feedback, we eliminated this distinction; instead we included a prominent comment in a new "Interpreting Results" section for the few indicators that report on simulation artifacts and thus are not at all appropriate for evaluating policies.

4.2.4 Prototype 3: The Indicator Browser with Live Technical Documentation

With the current version of the Indicator Browser (Prototype 3), we completed the work of connecting the web-based Indicator Browser to the live UrbanSim simulation and refined the Technical Documentation in response to the informal formative evaluation reported above. With an eye toward providing useful, ready-to-hand, comprehensible information about each indicator as well as minimizing perceptions of bias, we refined the Technical Documentation to include the following sections, as shown in Figure 4.5:

1. indicator name;
2. definition of the indicator;
3. advice for interpreting indicator results;
4. units of measurement and precision of the results;
5. related indicators;
6. a specification of how the indicator can be computed;
7. any known limitations of the indicator;
8. how the indicator relates to the simulation models;
9. the indicators source and evolution, as well as examples of its use;
10. the SQL code that is used to compute the indicator from databases of simulation results; and
11. input and expected output for a test to verify that the SQL code computes the indicator results correctly.



Search

UrbanSim

User Manual > Indicators > Predefined UrbanSim Indicators > Acres of vacant developable land

Acres of vacant developable land

For each year of interest, this indicator shows the total number of vacant developable acres of land in each unit of geography.

Interpreting Results

The total number of acres of vacant developable land is a basic indicator of how much land is available for new development. Note that this measure generally won't include small vacant parcels surrounded by developed parcels, however. (This is because the principal development type of that grid cell would be something other than vacant developable.) Thus, this indicator would normally provide information on the potential for greenfield development, but not on the potential for infill development or redevelopment.

Units of Measurement and Precision

Units: acres
Default precision for display: as a number using 0 digits after the decimal

Related Indicators

The sum of the results from Acres of land converted from type vacant developable per development type per year should be the amount by which the value of this indicator decreases each year.

Specification

For each year of interest, and each geographic unit, we retrieve the grid cells that have development type ID 24. Then we sum the total number of acres in the grid cells matching this query.

Limitations

This definition has the specific development type ID (24 for vacant developable) hardcoded into the SQL query. This indicator is only a general indicator of urbanization, in that it doesn't take into account how dense the development is. Also, since we are only counting entire grid cells, this indicator doesn't handle infill, or partial development of the land in a cell.

How Modeled

This indicator is modeled by UrbanSim.

Indicator Source, Evolution, and Examples of Use

Figure 4.5: Screen shot of live Technical Documentation for a particular indicator, in this case “Acres of vacant developable land.”

This Technical Documentation is live in that the SQL code and tests are extracted directly from the code-base each time they are displayed. This guarantees that what the user reads in the Technical Documentation is current.

Moreover, the Technical Documentation is easily updated and extended. In keeping with our design goal to create an underlying architecture that can incorporate new indicators readily [33], Technical Documentation can be easily added to the system as new indicators are implemented. Thus we are able to support the extensibility of indicators in UrbanSim, not only technically, but from the user perspective as well.

4.3 Implementation Notes

In this section, I briefly discuss the implementation of the "live" Technical Documentation.

For each indicator, there is an XML file containing the indicator definition and documentation. To display the Technical Documentation, the user's web browser fetches the XML document and renders it using an XSL stylesheet. To compute an SQL-based indicator on the results of a simulation run, UrbanSim software extracts the relevant SQL code from the XML file and executes it. Thus, the Technical Documentation is "live" in that it contains exactly the code that is run by UrbanSim. The categorized list of indicators is kept in an XML file separate from the documentation for individual indicators, so that the system could include several different categorizations of indicators. The technical decision to support multiple categorization schemes in the system architecture arose from conceptual and empirical investigations suggesting that multiple categorization schemes may be needed to address concerns about potential biases and about providing relevant, comprehensible information.

At the time of the evaluation study presented in the next section, all indicators were computed using SQL; currently they can be computed either using SQL or as Opus variables. Because the new Python-based indicators are implemented as Python classes, their code is in separate files. The XML file contains a hyperlink so that the live code can be read online as part of the Technical Documentation.

As per UrbanSim's agile programming methodology, the Technical Documentation for each indicator includes a unit test. This test is run to verify that the indicator is computed correctly for some simple test data set. When we began developing SQL indicators, there was no framework for automated unit testing of SQL code. Once we had written several indicators, we developed this framework: Technical Documentation for each indicator includes a simple but carefully chosen input data set, and the results that are expected from computing the indicator on that data set. A test harness runs the tests for every indicator defined in UrbanSim's code base as part of UrbanSim's automated unit testing. Indicators that are Opus variables also include tests that are run every time the code is checked in; these are part of the variable definitions.

4.4 Evaluation

In January 2005, at this formative stage of our design process, we sought to systematically evaluate the Technical Documentation. While we hypothesized that we had solved key aspects of the information fragmentation problem (both in terms of consolidating information and making it ready-to-hand) and would positively impact task performance (e.g., comprehension and evaluation of indicators), we had not tested our redesign work. We also hypothesized that design features such as providing live SQL code, limitations of the indicators, and test case information would increase comprehensibility and transparency of the indicators. There were also unresolved design issues concerning the categorization of indicators, tools for on-demand testing of indicators, incorporating region-specific documentation, and maintaining the visibility of unused indicators. To answer these and related questions, we conducted a small user study focusing on the Technical Documentation with urban planners interested in UrbanSim, who constitute the primary audience for the Technical Documentation.

4.4.1 Participants and Method

Eight current or prospective UrbanSim users (2 women; 6 men) participated. Participants were recruited at an UrbanSim user group meeting and had at least some urban planning experience (Range: 1 to 22 years; M = 10.5 years).

Each participant was engaged in a semi-structured interview for approximately one hour and fifteen minutes [36]. The value-oriented interview questions and tasks drew in structure on prior research [43]. The first group of questions explored the participants' current work practices, including their estimates of the time it would take to complete various tasks related to indicators and the number of sources they would need to consult. The participants were then asked to identify values and policies important to land use and transportation in their own regions, and to record these on cards. Following a demonstration of the Indicator Browser, participants were asked to perform short tasks using the Technical Documentation (e.g., defining an indicator in their own words, describing the relationship between two indicators, identifying three indicators to assess a particular concern). Participants were then asked about design tradeoffs with respect to ten current or future design decisions for the Technical Documentation. Each design trade-off was presented in terms of two alternate views with the rationale tied to transparency and comprehensibility supporting each view, e.g., for live SQL code:

> View 1: One person told me that including the SQL code in the documentation is helpful. Reading the code helps you to know whats really going on when the indicator is computed. Including the code in the documentation makes it easy to find. Its also easy to compare the code to the definition of the indicator and the specification of how it should be computed. Even if I don't read the code, its reassuring to see it there and know that its the actual code that is run to compute the indicator values. Its just more transparent that way.
>
> View 2: Another person told me that including the SQL code in the documentation is not very helpful. Other sections of the documentation, like the definition and the specification, provide all the information you will usually need about how the indicator is defined and how its computed. The code is lengthy and hard to read compared to these other sections. If you need more information, you can always go find the source code somewhere else.

Participants were asked to identify the view more like their own. Finally, participants were asked to identify indicators that would be informative for evaluating scenarios with respect to the values or policies they identified at the beginning of the interview. A subsequent telephone interview was conducted with seven of the eight participants to supplement incomplete work practice data.

All interviews were audio recorded for later transcription. A coding manual was developed to code evaluations and responses to content questions. Data were coded by two independent coders trained in the coding manual. Intercoder reliability was assessed through testing Cohen's kappa at the $\alpha = .05$ significance level; all tests were statistically significant, with $k = .74 - .94$ depending on question type. For the short tasks, time to complete each task was recorded, as well as whether the participant consulted the Technical Documentation. A domain expert assessed whether each task was completed correctly.

4.4.2 Results

For the task performance questions, participants required much less time to complete each of the four tasks using the Indicator Browser than with their traditional work practices (Table 4.1). For 26 of the 27 tasks (96%) for which we have both estimates and data on task performance, the time it took the subject to complete the task using the Indicator Browser was less than the estimated time that they gave based on current work practice. The overall median estimated time was 20-60 minutes, while the actual median time to complete the tasks was only 2.1 minutes, indicating a substantial improvement. Participants were also asked to estimate the number of sources they would need to consult in their current work practice to complete the tasks. For each of the four tasks, the median was two to three sources. By comparison, each participant who successfully completed the task in the study did so using only one source, the Indicator Browser. Of the 31 tasks performed by the 8 subjects, 25 were completed successfully (81%).

The design tradeoff questions, in which participants were asked to select one of two views, were analyzed using a binomial test. Table 4.2 provides a description of the specific design features and summarizes the quantitative results. As shown in Table 4.2, nearly all participants preferred categorizing the indicators in the Indicator Browser opening screen ($p = .035$) as well as including sections for each indicator in the Technical Documentation on Interpreting Results ($p = .008$), Limitations ($p = .008$), Live SQL Code ($p = .004$), and

Table 4.1: Task Performance. An asterisk ($*$) denotes significant differences at the $p = .05$ level between estimated time to complete tasks in current practice and actual time using the Technical Documentation. A cross (†) denotes tests not appropriate due to repeated measures within subjects.

	Median Time to Complete Task			
Task	Estimated Time in Current Practice	Actual Time using Technical Documentation	Actual time less than estimate for current practice?	Wilcoxon p-value
1. Define Nonresidential Square Feet	10–20 min.	1.7 min.	6 out of 7 (86%)	.014*
2. Discuss relationship between Residential Density and Household Density	10–20 min.	2.8 min.	7 out of 7 (100%)	.009*
3. Find three indicators of economic growth	20–60 min.	2.4 min.	7 out of 7 (100%)	.009*
4. Explain what Jobs-Housing Balance says about commute times	20–60 min.	2.0 min.	7 out of 7 (100%)	.009*
All four tasks combined	20–60 min.	2.1 min.	26 out of 27 (96%)	†

Test Cases ($p = .008$).

Regarding linking values and policies with indicators, participants generated a total of 31 values and policies related to urban planning in their regions (Range: 3-4; M = 4), 18 of which were within UrbanSim's current scope of land use, real estate, employment, and demographic indicators (Range: 1-4; M = 2). Participants were later asked to identify indicators that they believed would inform discussion of those values and policies. Of the values that were within UrbanSim's current scope, 6 were not considered due to time constraints, and 2 were deemed by the participant to be unsuited to the use of indicators. For 9 of the 10 values and policies (90%) for which participants attempted to identify indicators, participants were able to find informative indicators.

Table 4.2: Design Tradeoffs. An asterisk ($*$) denotes features that were preferred by a significant number of participants at the $p = .05$ level.

Feature	Description	p-value
Categorize Indicators	In the Indicator Browser opening screen, the indicators are grouped according to some categorization scheme (the specific scheme is not specified) rather than alphabetized.	0.35*
Interpreting Results	In the Technical Documentation, the Interpreting Results section provides advice for understanding what the indicators signify and how to use them to answer different kinds of questions.	.008*
Limitations	In the Technical Documentation, the Limitations section provides information about pitfalls in using the indicator as well as when to avoid using the indicator altogether.	.008*
Live SQL Code	In the Technical Documentation, the live SQL code section provides access to the code used to compute the indicator; the live SQL code is extracted from the code-base at display time.	.008*
Do Not Display All Categories	In the Indicator Browser opening screen, the categories are always displayed even if not indicators from a given category are selected.	.060
Do Not Distinguish Diag. & Eval. Indicators	In the Indicator Browser opening screen, indicators are designated as evaluative or diagnostic.	.164
Do Not Include Test-On-Demand	In the Technical Documentation, the Test-on-Demand section allows the user to run the indicator test from the web.	.125
Layered Documentation	In the Technical Documentation include region-specific information alongside the UrbanSim software documentation.	.453
Specific Categorization Scheme	In the Indicator Browser opening screen, choose between two competing categorization schemes, one based on non-expert conceptions and one on the urban planning literature.	1.000
Comprehensive List of Indicators	In the Indicator Browser opening screen, provide a comprehensive list of indicators for stakeholder values about regional land use, transportation, and environmental impacts, including those that UrbanSim may not yet support.	1.000

4.4.3 Discussion

Taken together, the results on task performance and design trade-offs indicate that much is working here to support comprehensibility and transparency of indicators in UrbanSim. In particular, the results on current work practice and task performance with the Indicator Browser provide strong support that the current design—with cohesive ready-to-hand Technical Documentation—has made progress toward addressing the problem of information fragmentation. The significant positive assessments from the design trade-off questions confirm our decisions to include the Interpreting Results, Limitations, Live SQL, and Test Case sections to improve the policy relevance and transparency of the Technical Documentation. In addition, results provide some support that we were successful in providing indicators that are appropriate to values and polices that are important to the stakeholders in the participants' regions.

Other results point to directions for future design. For example, though all participants supported some form of categorization, there was no consensus on which scheme to use. These results suggest a need for further investigation of categorization schemes, as well as design of a ready-to-hand mechanism for choosing among multiple categorizations along the lines of our earlier implementation. Also, further work is needed on how to handle region-specific information.

4.5 Conclusion

Thus, our evaluation shows that, in reducing information fragmentation and providing ready-to-hand information about UrbanSim indicators, we have gone some distance towards achieving the key design goals of comprehensibly and transparency in support of UrbanSim's legitimation. Although technical information of this sort can be useful to a range of stakeholders, our primary audience here was the urban planners and modelers who are currently UrbanSim's direct stakeholders.

Chapter 5

SUPPORTING VALUE ADVOCACY WITH INDICATOR PERSPECTIVES

In formative evaluations of the Technical Documentation, much of the strongest feedback we received was with respect to neutrality. For example, early versions of the Technical Documentation included a section describing the desired direction of change for the indicator, which we thought would be useful in the context of decision-making. However, the information in this section reflected widespread disagreement about the desired direction for many indicators. Some participants indicated that even the section's name, "Desired Direction," conveyed bias. Based on this feedback, we eliminated the problematic section, and replaced it with a new "Interpreting Results" section that described how the indicator might be used in policy evaluation.

Given its context of use in a democratic society, for stakeholders to advocate for values and put forth opinions is an essential and integral part of the overall urban planning process, not an inconvenient blemish on an otherwise clean technical exercise. How then might stakeholders use the indicators to represent and express their strongly held views, while still maintaining the informative role of the Technical Documentation? Here we have taken an approach—Indicator Perspectives—that allows stakeholders to tell a story and advocate particular values and criteria for evaluating outcomes. Significant value issues are at stake: improving the quality of democratic deliberation, ensuring that stakeholders' values and interests are fairly represented, and continuing to foster the legitimacy of UrbanSim's use. Our goal is to balance the relatively neutral information provided in the Technical Documentation with a range of informed, coherent, well-reasoned views about which indicators are most important—and why—in the Indicator Perspectives.

We have partnered with three local organizations to construct perspectives for the initial Indicator Perspectives prototype: an environmental group (Northwest Environment Watch,

Figure 5.1: Screen shot showing the Northwest Environment Watch Indicator Perspective.

now Sightline), a government agency (King County Budget Office, which publishes the King County Benchmark Reports), and a business association (Washington Association of REALTORS ®). The content of each perspective is provided by the respective organization, with technical support provided by the UrbanSim team. In keeping with our explicitly supported value of representativeness, we chose initial partners who cover a range of views. Later, the UrbanSim researchers plan to provide opportunities for broader involvement, actively soliciting partners as needed to help ensure coverage of the political and policy space. Figure 5.1 shows one prototype perspective, based on the Cascadia Scorecard, a monitoring program developed by Northwest Environment Watch.

The work presented in this chapter was conducted jointly with Batya Friedman, Alan Borning, and Peyina Lin. I contributed to the rationale for selecting partner organizations, to technical support and initial drafts of the prototype Indicator Perspectives, and to the design and execution of the evaluation study.

In this chapter, I first present the process of designing Indicator Perspectives, followed by a discussion of the problem of selecting and prioritizing indicators to implement in Urban-

Sim. Finally, I present preliminary results from an evaluation with citizens of Indicator Perspectives in relation to the Technical Documentation.

5.1 Design Process

In this section, I present the design process for Indicator Perspectives. I begin by discussing the selection of partner organizations and the design of the prototype framework and perspectives. Then, I characterize each of the three designs. Finally, I present our reflections on the design process.

5.1.1 Partner Organizations

The Indicator Perspectives Framework is intended to provide a mechanism for different stakeholders to present their own perspectives on UrbanSim indicators, as well as on how best to evaluate alternative scenarios of land use and transportation in the Puget Sound region using these indicators. We started with a small number of organizations to investigate the concept and the framework. The organizations were chosen with an eye to providing a range of political and economic views, as well as serving a variety of roles in the region. Thus, our choice of partner organizations builds on our explicit commitment to freedom from bias, which served as a check on our own values as well as other potential reasons to select a non-representative set of organizations. Pragmatically, we had to find organizations interested in working with us. Finally, we gave preference to organizations who were already had published views on which trends were of particular concern to them, to make it easier to put together UrbanSim-specific perspectives.

In a fully developed set of Indicator Perspectives, we would want to include partner organizations that cover the full range of concerns regarding land use, transportation, and environmental impacts, including economic, equity, and environmental implications. We would also want to capture a range of political positions, including organizations with a strong emphasis on economic growth, on environmental protection, on equity and fairness, or on property rights. The organizations should be capable of collaborating with us in selecting suitable indicators, and in developing and maintaining documentation for them.

Clearly, the starting set of organizations won't cover the full range of concerns, but we wanted to have a good range of views and roles even in the initial prototype.

Our initial partners were a nonprofit environmental group, a government agency, and a business association: Northwest Environment Watch, King County Benchmark Program, and Washington Association of Realtors.

- Northwest Environment Watch (now Sightline, `http://www.sightline.org`) is a regional environmental organization that focuses on sustainability. One of its projects is the "Cascadia Scorecard Project," an indicators monitoring project that follows seven key trends including transportation, pollution, and health.

- King County is the most populous county in Washington State, and includes the cities of Seattle, Bellevue, and Redmond. It maintains a monitoring program, the King County Benchmark program (`http://www.metrokc.gov/budget/benchmrk/`), which tracks important trends in the county regarding growth, transportation, the environment, and other issues, as identified in adopted countywide planning policies.

- The Washington Association of Realtors (`http://www.warealtor.com/`) is a business association of Realtors in Washington State. It maintains a government affairs department, and provides training, consumer information, and other services. It also publishes a set of policy guides on housing, zoning, real estate development, land supply, and related topics that include discussions of trends and indicators of particular relevance to these issues.

5.1.2 Designing the Perspectives

We have used the Plone content management system (`http://plone.org`) to support the Indicator Perspectives work. Plone is somewhat complex to set up, but provided some significant advantages. In particular, it is easy to set up user accounts and groups, and to control read and write access of users and groups to individual directories or web pages. Thus, read and write access to web pages can be easily limited to particular individuals or groups, or the pages can be made public when desired. Plone also incorporates simple web site authoring tools, which can be accessed from any web browser.

For each perspective, then, we started by creating accounts for our contacts at the partner organization, as well as a Plone group that included those contacts and UrbanSim team members. The draft page was initially restricted to be readable only by the appropriate group. After as much iteration, editing, and discussion as was needed, the organization decided their page was ready to be made public, and we changed the permissions accordingly so that anyone could view it.

Our process for designing each partner organization's Indicator Perspective builds on participatory design; each organization took ownership of its own perspective. After making the initial contact, describing the project, and starting to build a working relationship, we asked our contacts in each organization whether they would like to put together an Indicator Perspective web site themselves, or would prefer to have us design an initial draft version that they could react to. In each case the partner asked us to write the initial draft. We based this draft on existing published material from the organization, and also sought to mirror the look-and-feel of the organization's website as much as possible, so that it would be clearly theirs.

We then invited our partner organizations to either edit the perspectives directly themselves, or to give us feedback and requests for changes. In all cases, our contacts in the organizations had write permission to edit their sites directly. One of the organizations in fact did edit their Plone site directly after the initial draft. The others gave us feedback and requests for several rounds of editing, and members of our project made the actual changes.

5.1.3 Characterizing the Designs

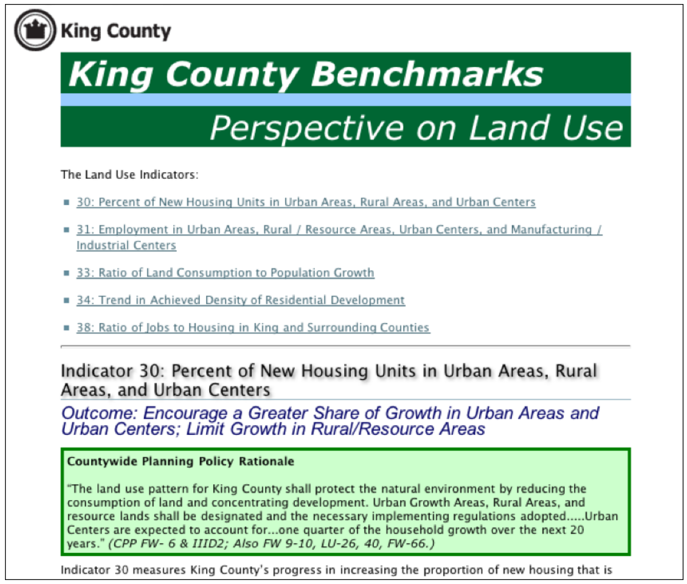
Each of the implemented Indicator Perspectives has a unique design reflecting the organization's published materials.

The Northwest Environment Watch perspective (Figure 5.1) first describes Northwest Environment Watch's Cascadia Scorecard project. It then concentrates on one particular issue in the Scorecard, namely sprawl: "dispersed, automobile-oriented urban development" [117]. It describes the costs of sprawl, including oil consumption, greenhouse gas emissions, destruction of farmland and open space, and relegating walking to recreation rather than transportation. The Scorecard uses population density as a key indicator of sprawl, and the Perspective does the same, linking to the UrbanSim population density indicator in the Technical Documentation. In addition to Population Density (which was already an indicator in the UrbanSim suite), the Scorecard uses a second indicator, "Fraction of Population Living in Compact Neighborhoods." Population Density is useful when computed at a neighborhood or finer level of geographic detail, and the results displayed as a choropleth map. One can then see the patterns of compact urban areas and low-density suburban and rural areas. "Fraction of Population Living in Compact Neighborhoods," on the other hand, provides a single number for the entire region, which characterizes whether the predominant development pattern is overall low-density sprawl, or has compact urban areas and lower-density rural areas. (Of the major Northwest cities, for example, Vancouver B.C. has the highest portion of its population in compact urban development; while Boise, Idaho is the most sprawling.) This was a newly-written indicator for UrbanSim, which we developed as part of supporting the Northwest Environment Watch perspective. Thus, our empirical work in working with partner organizations to design Indicator Perspectives has influenced directions for technical work on UrbanSim indicators.

The King County Benchmark Program perspective (Figure 5.2) first describes the benchmarking program. It lists the principal indicator categories in the King County Benchmark Program, which correspond to key areas of King County's growth management policy: land use, economics, affordable housing, transportation, and the environment. It then describes how benchmarking and simulation can be coordinated elements in a strategy for change: benchmarking to help determine whether public policy and programs are in fact making a difference in the county at present, and simulation to project the values of indicators into the future for alternate policy scenarios. The "land use" category is in turn a link to another page. (The other categories are ones that the program includes but for which UrbanSim did not provide indicators at the time the perspective was developed.) This second page provides descriptions of the land use indicators in the King County Benchmark Program. Each description provides the desired outcome for the indicator, based on the countywide planning rationale, and a link to the UrbanSim indicator.

The Washington Association of Realtors perspective (Figure 5.3) is organized around the Washington Realtors Quality of Life program, which includes both a set of principles and specific policy recommendations. The principles identified in the Quality of Life Program are a strong economy, plenty of housing opportunities, good schools and parks, safe neighborhoods and great transportation choices. The perspective then describes how UrbanSim can be used to simulate the long term effects of different transportation and land use plans with respect to one of the Quality of Life principles: Providing Housing Opportunities. There are a set of boxed policy recommendations regarding housing opportunities, for example: "Having an adequate supply of housing is dependent on having sufficient land capacity set aside for those housing units otherwise there will be multiple negative impacts on the community." The perspective includes links to relevant UrbanSim indicators that can help assess how well the policy recommendation is supported by alternate scenarios, such as "Population," "Number of Households," and "Acres of Vacant Developable Land." As a specific example, the Association is particularly concerned with having accurate forecasts for Population and Households, since these determine the demand for future housing.

Comparing the three perspectives, the Northwest Environment Watch perspective advocates in a straightforward manner for a particular point of view on sprawl and urban growth. It is a coherent viewpoint, which is valuable for stakeholders to see, yet because it is controversial it wouldn't be appropriate as relatively neutral technical documentation. The King County perspective covers many of the same issues, with a similar desired direction. For example, Indicator 30 ("Percent of New Housing Units in Urban Areas, Rural Areas, and Urban Centers") presents a desired outcome of encourage a greater share of growth in urban areas and urban centers, while limiting growth in rural/resource areas. It also quotes from the Countywide Planning Rationale that implements adopted regional growth management policy intended to achieve this result. While similar in desired outcome, this information is presented in a somewhat more neutral tone and is described as implementing adopted government policy, rather than itself advocating for a position. Finally, the principles presented in the Realtors perspective are described as ones that Washington residents have told the Association are important for building better communities, and as goals of both Realtors



King County

King County Benchmarks

Perspective on Land Use

The Land Use Indicators:

- 30: Percent of New Housing Units in Urban Areas, Rural Areas, and Urban Centers
- 31: Employment in Urban Areas, Rural / Resource Areas, Urban Centers, and Manufacturing / Industrial Centers
- 33: Ratio of Land Consumption to Population Growth
- 34: Trend in Achieved Density of Residential Development
- 38: Ratio of Jobs to Housing in King and Surrounding Counties

Indicator 30: Percent of New Housing Units in Urban Areas, Rural Areas, and Urban Centers

Outcome: Encourage a Greater Share of Growth in Urban Areas and Urban Centers; Limit Growth in Rural/Resource Areas

Countywide Planning Policy Rationale

"The land use pattern for King County shall protect the natural environment by reducing the consumption of land and concentrating development. Urban Growth Areas, Rural Areas, and resource lands shall be designated and the necessary implementing regulations adopted.....Urban Centers are expected to account for...one quarter of the household growth over the next 20 years." *(CPP FW- 6 & IIID2; Also FW 9-10, LU-26, 40, FW-66.)*

Indicator 30 measures King County's progress in increasing the proportion of new housing that is

Figure 5.2: Screen shot showing the King County Benchmarks Program Indicator Perspective.

QUALITY of Life

REALTORS® recognize the need to sustain and enhance the quality of life enjoyed by Washington's citizens. We believe we can build better communities by supporting quality growth and seeking sustainable economies and housing opportunities that embrace the environmental qualities we cherish, while protecting a property owner's ability to own, use, buy, and sell property.

The Washington REALTORS®' Quality of Life Program is based on the principles that Washington residents have told us are important for building better communities. REALTORS®, like other residents who live and work in the community, want a strong economy, plenty of housing opportunities, good schools and parks, safe neighborhoods and great transportation choices.

The Quality of Life Project is about creating communities where everyone thrives. Quality of life starts with a good job. It means having a roof over your head – and a range of choices in housing design, style, and price. It means the opportunity to live in communities with clean, safe neighborhoods, good schools, and efficient transportation. Our Quality of Life Project is designed to impact public policy in order to ensure economic vitality, provide housing opportunities, and preserve the environment that we cherish here.

REALTORS® are taking the lead in developing policy proposals that reflect our Quality of Life Principles.

In the Puget Sound region, UrbanSim is being used to simulate the long term effects of different transportation and land use plans in order to provide useful information for the discussion of the proposals. Below we explain how UrbanSim can help evaluate such alternatives with respect to one of the Quality of Life principles: *Providing Housing Opportunities*.

Providing Housing Opportunities

REALTORS® understand that home ownership is the cornerstone of the American Dream and deserves consideration as a top priority when it comes to quality of life. Home ownership contributes to community responsibility; civic, economic, business and employment stability; family security and well being.

Every citizen should have the opportunity to purchase an affordable, safe, and decent home near where they work, shop and play. Choice in style, price and location is critical to increasing home ownership. These objectives should be met through market-driven approaches that foster a wide-range of urban, suburban and rural housing choices at all prices.

When there is sufficient housing to accommodate growth in a community, it relieves pressures on housing prices and provides the opportunities of home ownership for all.

Home prices skyrocket when housing is not available where jobs are located – that causes people to buy homes further away from where they work, exacerbating traffic problems. Providing affordable housing choices close to where people work, live and play prevents long commutes and increased traffic on our roads. A community should plan for jobs, amenities, services and stores close to where people live in order to reduce traffic congestion.

Figure 5.3: Screen shot showing the Washington Association of Realtors Indicator Perspective.

as well as other residents who live and work in the community. The specific policy recommendations seem likely to be more controversial. For example, when the goal of increasing buildable land capacity is operationalized by opening a particular area for development, this may well collide with other stakeholder goals, such as open space preservation, or shoreline or riparian buffer protection.

5.1.4 Reflections on the Design Process

Identifying suitable partners and setting up the collaborations, not surprisingly, required a fair amount of effort. However, once the collaborations were established, each of the designs proceeded smoothly.

From a theoretical standpoint, we used a variant of Participatory Design. Within each indicator perspective, the partner organization had complete control of the contents, as well as the visual appearance and layout of the page. Ideally, we would simply turn over the design and implementation of each perspective to the partner organization, and simply provide technical expertise regarding UrbanSim's current capabilities, as well as the feasibility of future enhancements. However, we of course needed to respect the demands on staff time for the partner organizations, which then led to us offering to construct a draft perspective for each based on the organization's published material. We were satisfied with how this process worked out—all three organizations provided feedback and we went through several iterations of improvements (or in one case edits to the site by the partner organization).

The process was made easier in these cases because the organizations already had material that could be adapted to draft the perspectives. As the Indicator Perspectives framework expands to encompass a wider range of organizations, to support our values of fairness and balance, we may need to more actively solicit partner organizations to fill gaps, and to provide more in-depth assistance to these organizations in identifying suitable indicators, and developing and maintaining a perspective.

5.2 *Filling in the Gaps: Prioritizing the Implementation of Additional Indicators*

Part of the conceptual investigations for the Indicator Perspectives involved designing a principled approach to prioritizing additional indicators for the perspectives. While I was peripherally involved in these conversations, the work was primarily done by Batya Friedman and Alan Borning and will be reported in a forthcoming paper [11]. A description of this approach is included here for completeness.

UrbanSim has some 54 implemented and documented indicators as of July 2006. One would expect that any organization developing an Indicator Perspective would quickly want to have additional indicators—and indeed, this was our experience as we worked with our three initial partner organizations.

Given a world with limited resources—of time, money, data availability, and theoretical understanding of urban environments—how should we decide which additional indicators to implement, and in what order? We aimed to develop a principled answer to this question, rather than simply building new indicators on an ad hoc basis.

5.2.1 Triangulation Among Priorities

We view answering the question of which additional indicators and when as a kind of triangulation among priorities arising from three different sources, namely: coverage of the space of potential indicators, organizational partner (and stakeholder) concerns, and pragmatics.

Coverage of the space of potential indicators has perhaps the strongest theoretical grounding of these three sources. Early in the work on employing Value Sensitive Design for the design of interactions around UrbanSim indicators, Batya Friedman, Peter Kahn, and Alan Borning, in collaboration with students, developed a number of typologies of indicators of what people value in urban environments (see also the earliest version of the Indicator Browser, shown in section 4.2.1). Their goal was for the typology to be comprehensive—for any given value, people should be able to locate it in the typology. At its highest level, the three categories of indicators were Economic, Environmental, and Social. (These top-level categories are typical in taxonomies of indicators for sustainability as well [60].) Then under Environmental, for example, were the sub-categories Air, Water, Land/Vegetation, Animals, and Resource Consumption, with further sub-sub-categories under each of those. This taxonomy—or one like it—thus serves as one source of priorities for implementing additional indicators. If there are significant gaps in the indicator suite—for example, if a major category is not represented—then this gives a clear signal that work may be needed there.

There are some complications. First, even though there is some aspect of the urban environment that people value (perhaps highly), it may not fall within the realm of the modeling activity. (See section 5.2.3.) Second, many indicators pertain to multiple categories. For example, the indicator "Mean Household Income" is a kind of economic indicator; but when computed at the neighborhood level, it can also be classified as a social indicator, as a measure of concentrations of wealth and poverty in the region. In this case we view the indicator as filling multiple roles. Second, we don't want to apply a rigid counting scheme (for example, demanding that there be an equal number of indicators in all categories). A single compelling indicator that nicely captures some phenomenon is better than four somewhat relevant ones (even though the count would be one instead of four). Yet some rough parity is appropriate.

The second source of priorities is organizational partner (and stakeholder) concerns. If we are working with an organization to develop or extend an Indicator Perspective, a request from such a collaborator to develop a new indicator represents a significant priority for future work. Part of our job as UrbanSim designers and implementors is to serve as a source of expert information for the collaborators on what indicators are available, which are straightforward to develop, which are hard but possible, and so forth; but not to say that some indicator is not important.

But again, there are some further issues. One of our explicitly supported values is facilitating the democratic process. As part of supporting that value, if an issue is of importance to a significant number of stakeholders, then this implies a priority to develop one or more indicators that allow these stakeholders to assess alternate scenarios in light of that issue. Further, we don't want this to be a simple majority vote on what is important:

we also need to consider rights and other issues of moral import. If an issue has moral import, this also gives priority to those indicators, even though a minority might be affected. An example is transportation options for people in wheelchairs. Even though these are a minority in the population, having transportation options is essential for full participation in society, and so has moral import.

These stakeholder concerns relate to organizational concerns in the following manner. One of our criteria for selecting (or actively soliciting) partner organizations to develop Indicator Perspectives is to capture a wide range of political and economic positions in the set of perspectives, so that overall we cover the full range concerns regarding land use, transportation, and environmental impacts, including economic, equity, and environmental implications. By thoughtfully selecting partner organizations, we can in turn help ensure coverage of the space of stakeholder concerns.

What if there were some significant concern, but no organization that fills that advocacy role? In the current early stages of the Indicator Perspectives work, this question does not yet arise in practice; yet it is worth considering now. For the Indicator Perspectives framework as such, we believe that we do need to find an appropriate partner organization—it would not be appropriate for us (as UrbanSim designers) to craft a perspective to fill a missing role. There are two reasons for this. First, at least in the U.S., for most positions, there is already an advocacy group—perhaps small, but in existence. The group may not be in a position to construct an Indicator Perspective, and in that case it would be appropriate to give additional help to them. Second, we believe the legitimacy of the Indicator Perspectives framework is much stronger by having the perspectives come from real organizations in the community, not from researchers. Such organizations can present their genuine positions, while researchers would be presenting their interpretations of others' positions.

Another part of the response to this issue is likely to be the development of a complementary mechanism that lets individuals or small, less formal groups put together something like a perspective, but with less expectation of a polished presentation—something more like a structured discussion forum instead.

The third source of priorities is pragmatics: ease or complexity of implementing the indicator, data availability, legal requirements, interest by funding agencies, and similar considerations. These are clearly important, but we don't want them to dominate the decision-making process; indeed, our goal is that such pragmatic considerations might cause us to implement an indicator later than sooner, but unless it is simply not feasible technically, that we would not just drop it off the list, but would instead continue to keep it as a goal.

From a technical point of view, indicators that just involve writing a new SQL query (or OPUS variable) are the most straightforward. The indicator "Fraction of Population Living in Compact Neighborhoods," which we developed for the Northwest Environment Watch perspective, was one such indicator. More complex are indicators that also require additional component models. Such an indicator would be to simulate the return rate of wild salmon in rivers and streams that flow through urban regions. This is particularly relevant to the region around Seattle, because of issues of biodiversity and possible species extinction, cultural issues around the role of salmon in both Native American and current society, and legal and economic issues arising from an Endangered Species Act listing. However, producing such an indicator would require one or more new component models, which would need to take account of numerous factors that affect salmon return rate: the amount of impervious surface, pollutants from agricultural runoff, the number of fish caught by both commercial and sport fishers, oceanic conditions (including temperature, since the salmon grow to maturity in the ocean before returning to fresh water streams to spawn), and many others. Given this complexity, we have not yet tried to implement this indicator, but it is still on our list of ones that we would like to support.

5.2.2 Indicator Perspectives Evolution

As an example of this sort of triangulation in practice, a current effort is creating a set of indicators of environmental impact. Earlier this year we added an indicator of "Greenhouse Gas Emissions from Transportation," another of "Gasoline Consumption per Capita," and are currently developing a Water Consumption indicator. Even though "Environmental" is one of the three top-level categories in our taxonomy, until recently we didn't have any indicators of environmental impact. The goal of covering the space of potential indicators shows this as a glaring issue. This was not due to lack of interest in environmental impacts on our part, but instead due to significant technical obstacles that needed to be overcome.

5.2.3 *The Problem of Hyper-Comprehensiveness*

There are important pitfalls and tensions associated with expanding the number of indicators. One problem is that we could overwhelm the user with an excessive number of indicators that give slightly different perspectives on related phenomena. A few well-chosen, highly relevant indicators are preferable to a large number of more diffusely related ones.

Another problem can arise as we try to produce indicators for an increasingly wide range of phenomena. This will generally require additional modeling capabilities, not just more indicators. Lee [76], in his influential paper on large-scale urban models, termed this the problem of *hyper-comprehensiveness*. Among the pitfalls of such overly ambitious modeling are increasing model complexity, additional data requirements, and in some cases the credibility of the overall modeling effort.

One force toward such hyper-comprehensiveness is pressure to model more and more aspects of the urban environment because these aspects are important to someone, even though they might have little relation to land use, transportation, and environmental impacts of these. For example, there might be demands to model voter turnout rates, or the number of teenagers who start smoking each year. These pressures are relatively straightforward to deal with, by reminding stakeholders of the purpose of the modeling work and the need to remain focused.

A more difficult issue is that a seemingly endless number of factors are relevant to urban land use and transportation. For example, crime can be an important factor in people deciding where to live or in what mode of transportation they choose, with the influence varying by gender, age, and other factors. But we need not just data on current crime rates—and perhaps more importantly, on people's perceptions of crime—but also a predictive model of crime in the future under different possible scenarios. (Information about current crime rates is already incorporated into the model, in the form of observed data about people's actual housing and transportation choices. Assuming this rate is unchanging would not be useful in improving the aggregate output of our models of land use or transportation.) But constructing a predictive model of crime rates is both difficult and controversial. For example, what are the major determinants of the crime rate? Economic conditions? Family stability and moral instruction? The nature of the criminal justice system? How far should the modeler go down this path?

We don't have a simple rule to answer to these sorts of questions—nor do we believe one exists. However, the issue of hyper-comprehensiveness and its pitfalls must also be factored into the triangulation process.

5.3 Evaluation

To assess our success at simultaneously providing facts and relatively neutral technical information through the Technical Documentation, while also supporting value advocacy and opinion through the Indicator Perspectives, we conducted an evaluation study that engaged citizens in interacting with tools. We also investigated how these systems approach our ideal of freedom from bias.

5.3.1 Participants and Method

Twenty Seattle citizens (10 women; 10 men) participated. Participants were recruited through posters in four different Seattle neighborhoods and through posts to neighborhood email lists.

Each participant was engaged in a semi-structured interview for approximately 60 to 90 minutes [36]. Participants first interacted with the Technical Documentation and Indicator Perspectives. A few content-related questions were asked for the Technical Documentation and each of the three implemented Indicator Perspectives, to help ensure that participants engaged with the written materials. After participants had interacted with both the Technical Documentation and the Indicator Perspectives, they answered a series of Likert scale questions regarding their views of each component of the system: the Technical Documentation; each of the three implemented Indicator Perspectives; the three implemented Indicator Perspectives as a group; the Indicator Perspectives Framework including a larger, more diverse group of perspectives; and "everything as a whole," including both Technical Documentation and Indicator Perspectives.

Participants were asked eight questions about each of the system components. Notably, two questions were intended to elicit participants' judgments with respect to supporting the democratic process and freedom from bias:

1. If *[this component]* were the only information UrbanSim provided about indicators (so no other information ever existed), would that be alright or not alright?

2. If *[this component]* were the only information UrbanSim provided about indicators (so no other information ever existed), would that unfairly discriminate against someone or something?

Participants were asked a series of questions, circled responses on a written questionnaire to indicate their views, and then discussed their answers with the interviewer. Questions about the Technical Documentation and Indicator Perspectives were counterbalanced; questions about "everything as a whole" were always asked last. All interviews were audio recorded for later transcription.

5.3.2 Quantitative Results

Here, I present a brief, preliminary summary of quantitative results based on the written questionnaires. An analysis of qualitative findings based on interview transcripts is underway and will be reported in a future publication [11].

Quantitative results for questions 1 and 2 above are reported in Table 5.1. We compare particular components of the system with "everything as a whole," including both the Technical Documentation and the Indicator Perspectives Framework. Using McNemar tests for within-subjects comparison, "everything as a whole" is significantly more likely to be viewed as "alright" than the Northwest Environment Watch perspective alone ($p = .008$), the Washington Realtors perspective alone ($p = .008$), or the Technical Documentation alone ($p = .016$) In the other three cases (King County Benchmarks, the three perspectives, and the Indicator Perspectives Framework), a larger percentage viewed everything

Table 5.1: Judgments of Technical Documentation and Indicator Perspectives. Percentages shown indicate those responding “alright” to question 1 and “no, does not unfairly discriminate” to question 2, as opposed to “not alright,” “yes, unfairly discriminates,” or “not sure.” An asterisk (*) denotes significant differences at the $p = 0.05$ between judgments of “Everything as a whole” and particular system components.

	Question 1: Percent responding “Alright”	Question 2: Percent responding “No, does not discriminate”
Technical Documentation	20%* ($p = .016$)	35%
Northwest Environment Watch perspective	15%* ($p = .008$)	20%* ($p = .039$)
King County Benchmarks perspective	30%	25%
Washington Realtors perspective	15%* ($p = .008$)	10%* ($p = .016$)
All three perspectives	35%	35%
Indicator Perspectives Framework	25%	35%
Everything as a whole	55%	55%

as a whole as alright, but the difference was not statistically significant. Also based on McNemar tests, everything as a whole is significantly more likely to be viewed as not unfairly discriminating than the Northwest Environment Watch perspective ($p = .039$) and the Washington Realtors perspective ($p = .004$). No other pairwise comparisons yielded statistically significant differences.

5.3.3 Discussion

In responses to Question 1, participants were significantly more likely to judge “everything as a whole” as “all right” than the Technical Documentation alone. This quantitative finding suggests that the Indicator Perspectives do indeed provide valuable information beyond that provided in the Technical Documentation. Furthermore, “everything as a whole” was significantly less likely to be seen as biased than two of the three individual organizations’ perspectives, confirming the need for more diverse information sources to avoid the perception of bias. Ongoing qualitative analysis of the interview transcripts will elaborate on these preliminary qualitative findings by looking at participants’ justifications and explanations of their responses.

5.4 Conclusion

Thus, preliminary quantitative findings support our belief that Indicator Perspectives will provide valuable information in support of deliberation about urban planning decisions and that a representative group of participating organizations is needed to avoid perceptions of bias. Although further qualitative analysis will expand on these findings, Indicator Perspectives are a promising approach for balancing relatively neutral technical information with a range of advocacy positions, while avoiding perceptions of bias and continuing to support the system's legitimacy. The approach we have taken, in which the system designers provide technical information and a framework for organizations to advocate their own positions, is applicable to other domains in which stakeholders have deeply held, conflicting values and interests.

Furthermore, we believe that the work reported here contributes to the development both of Participatory Design and of Value Sensitive Design.

The Indicator Perspectives project represents a novel extension of Participatory Design. With each of the three partner organizations, it is more or less traditional Participatory Design—perhaps with even more autonomy than usual for the partner organizations within each perspective, since each organization had complete control within its perspective to decide what indicators were important and how to present them. We helped them write their perspectives, and when possible implemented additional indicators to their specifications, but really tried to give control over to the partner organization within the perspective. However, using the principles of Value Sensitive Design, we set up the overall structure in which the perspectives are embedded. Furthermore, part of our work was finding multiple partner organizations, trying to achieve fairness and balance overall. The different organizations don't need to agree on the perspectives—in fact, typically they will not. The system being developed thus includes multiple stakeholders as design partners, potentially with quite diverse views, in a way that gives the different stakeholder organizations much freedom but still puts together a coherent whole.

In terms of Value Sensitive Design, the work reported here provides a paradigmatic example of how to incorporate Participatory Design as one of VSD's empirical investigations.

In addition, it develops a nuanced approach to supporting a range of values. In the framework as a whole and in the ensemble of the current three perspectives, we explicitly support the values of fairness, transparency, and support for the democratic process. Within any individual perspective, we support the values advocated by the partner organization (for example, sustainability, or providing housing opportunities).

Chapter 6

ENGAGING AND INFORMING CITIZENS WITH HOUSEHOLD INDICATORS

While regional indicators such as population density and total vehicle miles traveled are familiar to urban planners who monitor or model regional trends, such aggregate measures may be not so familiar or compelling to citizens with less expertise in urban planning. How can we develop new ways of presenting simulation results to inform and engage citizens?

Household Indicators [18] are a new approach for enabling citizen interaction with UrbanSim results. Using personal information provided by the user, this web application attempts to address the question, "How will this decision affect *me*?" Rather than presenting a view of the entire region under different policy alternatives, Household Indicators provide a lens through which to view the simulation results from the perspective of a single household and its interactions with its immediate environment—the neighborhoods where members of the household live, work, learn, shop, and play, as well as their travels between those places. Potential Household Indicators include population and employment density of different places, the form of different neighborhoods, housing opportunities for different households, and travel times between different places.

Household Indicators are not intended to replace other means of citizen interaction with UrbanSim results, such as the Technical Documentation and Indicators Perspectives, but rather to augment these means. While traditional print and other mass media must present the same static data for all users, the web provides an opportunity to present simulation results that are tailored for each user. Interacting with Household Indicators could lead the user to greater understanding of the UrbanSim system and its results, or to greater interest in learning about the regional impacts of decisions. Key value issues include citizen engagement in urban planning decisions, the legitimacy of UrbanSim's use in decision making, and support for a democratic society overall; freedom from bias; and balancing self-interest with public interests.

Where existing tools such as the Ecological Footprint Quiz [101] let individuals learn how their personal decisions impact the public good, Household Indicators instead focus on how public decisions can impact individuals.

In this chapter, I first give an overview of the Household Indicators web application. After discussing the design problem, I provide an overview of the iterative and integrative design process. I discuss in greater depth design themes which recurred throughout the process. I then briefly explain the software architecture and implementation issues. I conclude with a discussion of contributions and future work.

Although I am grateful for support and feedback from colleagues, the work presented in this chapter is primarily my own. Peyina Lin contributed substantially to the development of the HTML mock-up.

6.1 System Overview

The Household Indicators prototype allows users to compare possible personal impacts of four so-called "sledgehammer runs." The sledgehammer runs are not intended to represent real alternatives for solving some urban planning problem, but rather to test the implementation of UrbanSim in the Puget Sound region with some extreme scenarios. Although they are not realistic scenarios, the sledgehammer runs also provide useful data with which to test the Household Indicators concept and user interactions. When Household Indicators are deployed in an operational context, these sledgehammer runs will be replaced with runs representing the actual alternatives under consideration.

A walkthrough of the Household Indicators prototype is shown in Figures 6.1–6.4. The user accesses Household Indicators from a start page in the My Indicators site. To get started, the user creates a a household profile, including the household name, home, other important places, and trips the household takes around the region. Once the household profile has been created, the user can view indicators of their own household's experiences, such as travel times (Figure 6.4), land use, employment, population, and average home value (Figure 6.9). For each indicator, a table shows the indicator's value for the base year and possible future outcomes for each alternative.

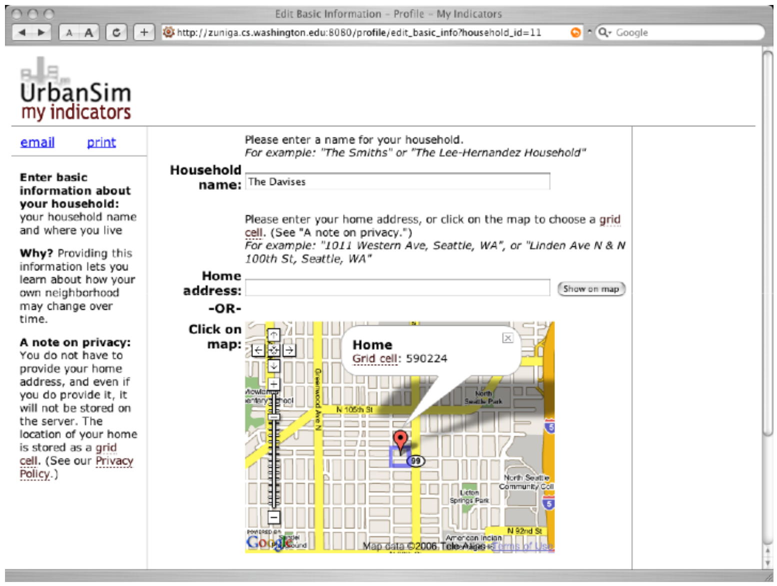


Figure 6.1: In the first step, the user creates a new household profile including the household's name and the location of the household's home.

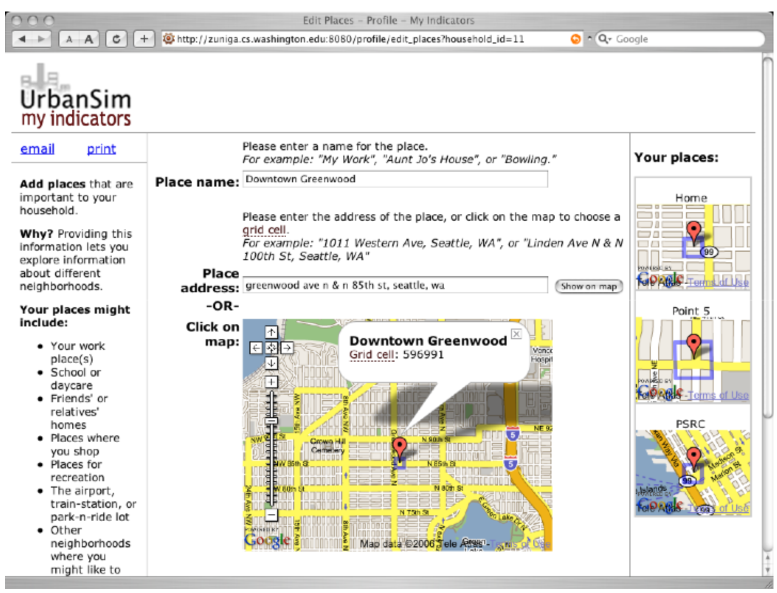


Figure 6.2: In the next step, the user adds a number of places of personal importance—for instance, their workplace, their child's school, homes of friends, or places they go for fun.

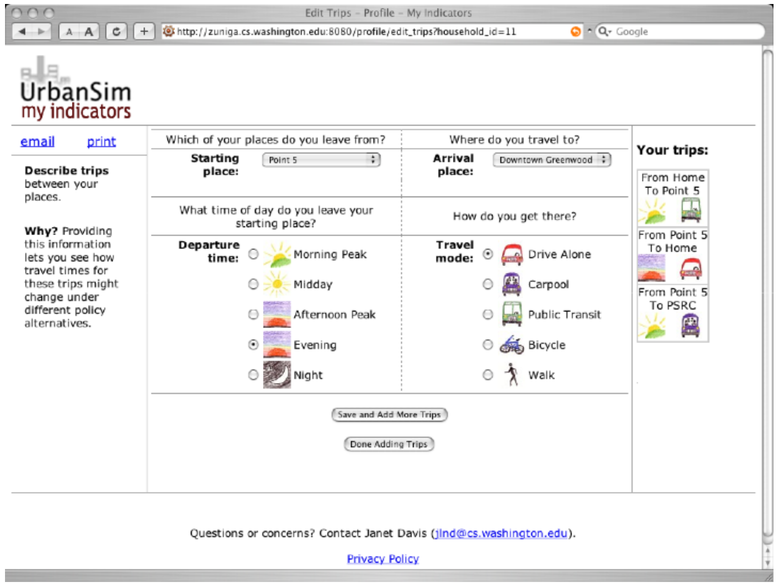


Figure 6.3: In the final step of creating the profile, the user describes trips, including the places where the trip begins and ends, the travel mode (drive alone, carpool, transit, bicycle, or walk), and the time of day for the trip.

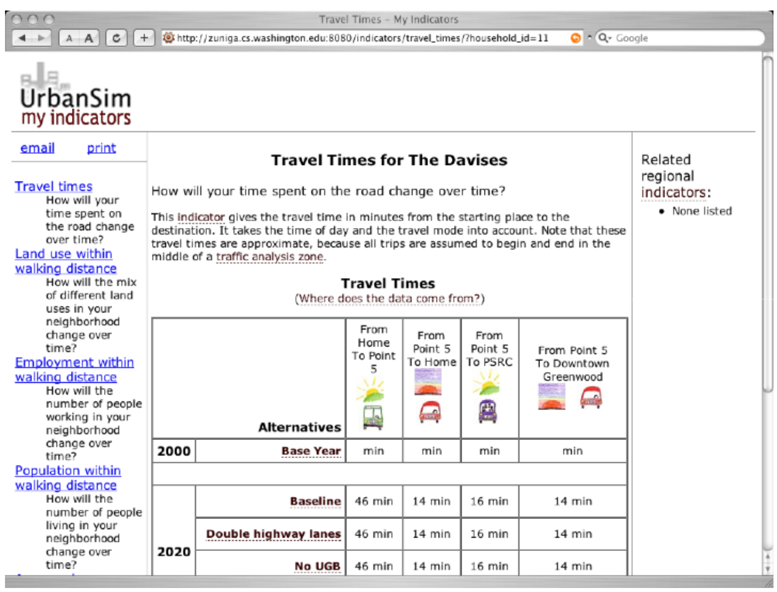


Figure 6.4: After the user is done entering trips, Household Indicators shows a table comparing travel times for these trips for the base year (2000) and the four alternatives in the year 2020.

6.2 The Design Problem

The overarching goal of Household Indicators is to support democratic engagement in regional land use and transportation decisions by providing citizens with information that addresses their values with respect to their own interactions with the city, at the scale of a single household. At the same time, I must uphold commitments to fairness and to fostering UrbanSim's legitimation potential.

Earlier work on the Technical Documentation aimed to provide comprehensible, accurate, transparent, relevant, and relatively neutral technical information to urban planners. By contrast, work on Household Indicators focuses on providing information that is comprehensible to citizens and clearly relevant to their own lives. However, commitments to accuracy, transparency, and freedom from bias remain. In particular, the commitment to accuracy requires that we not oversimplify simulation results in order to present more comprehensible information. The commitment to transparency presents the challenge of providing explanations of model behavior and results that are accessible to non-experts and ready-to-hand when questions arise. A focus on personal impacts might bias deliberation towards individual rather than societal or environmental impacts; I aim to balance this by linking Household Indicators to related regional indicators and to the Indicator Perspectives.

I face the additional challenge of appropriating results from a model that was designed with regional planners as its primary audience; planners' goals and expertise in interacting with UrbanSim may be quite different from those of citizens. Conversely, I have the opportunity to influence the future development of the system with this context of use in mind, thus making a move from empirical investigations to further technical investigations.

More specifically, I identified several concrete goals for selecting indicators, presenting information, and fostering democratic engagement through my design process. These goals stem from conceptual investigations of the explicitly supported values of freedom from bias and support for a democratic society, but also respond to what I have learned about the particular context of Household Indicators through empirical and technical investigations.

I aim to select indicators that

- are relevant to are relevant to citizens' values with respect to potential impacts on their own households, and that are appropriate to consider at the scale of individual households, in support of the system's legitimacy;

- avoid bias in the form of providing useful information to some citizens, but not providing similar information to other citizens whose circumstances are different (e.g., providing information about housing costs to homeowners but not to renters);

- and are feasible to implement, taking into account UrbanSim's current capabilities, plans for future development, and the theoretical and practical limitations of large-scale urban simulations.

Further drawing on our goals for legitimation potential and the explicitly supported value of freedom from bias, I seek to present information in an manner that is

- comprehensible to as many citizens as possible, including those who have no expertise in urban planning and modeling or who have limited numerical literacy [96];

- accurate in that it does not oversimplify or misrepresent simulation results;

- transparent with respect to the model's input data, results, assumptions, and limitations;

- and relatively neutral in that it does not favor any policy or group of stakeholders over any other, similar to the technical documentation.

Finally, I aim to support democratic engagement by providing ready-to-hand information about the decision context and opportunities for involvement, and to support users in balancing self-interest with the public interest.

Similar challenges will be faced by any designer who aims to develop interfaces that present tailored information on potential impacts on individuals that are intended to inform public decision-making. For instance, models used to project the impacts of changes to the tax structure could also be used to provide citizens with personalized information about

Table 6.1: Summary of four phases of the Household Indicators design process.

Phase	Design issues	Implementation	Evaluation
1	Conceptualization Potential harms and benefits Geographic abstractions	Indicator feasibility analysis	Informational interviews (N=9)
2	Problem scope Indicator selection Terminology Visualizations Profile-centric vs. indicator-centric	Paper prototypes	User study (N=6)
3	Indicator revisions Ready-to-hand FAQs Specifying locations and trips Page layout Sequencing	HTML mockup	Design critique
4	Prioritizing features Democratic engagement	Prototype web application	Focus groups (4 groups; N=13)

how they could be impacted by those changes. While I do not claim to fully address these goals in the current design of Household Indicators, I have made progress in understanding and addressing each of them. In the following sections, I explain my design process thus far in light of these challenges and then discuss themes that have recurred throughout the design work.

6.3 Design Process Overview

In this section, I present an overview of the design process for Household Indicators thus far. I first present my initial explorations in designing Household Indicators. I then discuss the development and formative evaluation of paper prototypes, followed by the development of an HTML mock-up. Finally, I describe the development and formative evaluation of a prototype implementation that uses actual UrbanSim results. Table 6.1 briefly summarizes these four phases of the design process. The next section discusses in greater depth themes that recurred throughout the design process.

6.3.1 Phase 1: Initial Explorations

Initial investigations of Household Indicators spanned the conceptual, technical, and empirical.

In conceptual investigations, I considered Household Indicators' potential benefits and harms to stakeholders. The potential benefits identified for citizens who use the system included greater access to information, increased transparency of the simulation models, and new opportunities for deliberation. Potential harms to users include taking action based on a misunderstanding of simulation data that does not correspond to the users' mental models or vocabulary, inappropriate confidence in uncertain data, and potential loss of privacy in entering personal data. Potential harms to a democratic society include a compounding of the digital divide and gaps between engaged and disengaged citizens—the concern that this only helps those who are already involved and have access to information. I was also concerned that presenting different information to different people could provide barriers to deliberation about common interests, and that this presentation of information could promote opinions that put self-interest above the interests of society.

In the initial technical investigations, I identified potential Household Indicators that UrbanSim could readily produce. I also encountered the problem that UrbanSim results are not reliable at the grid cell level, yet UrbanSim's larger geographic abstractions, such as Traffic Analysis Zones (TAZs), are designed to meet the needs of regional planners and are not necessarily meaningful as representations of neighborhoods.

To explore these concerns, I conducted informational interviews with citizens. Nine Seattle citizens (4 women, 5 men) ranging in age from 31 to 49 (M = 36) were recruited through posters in the Greenwood neighborhood and email to the Greenwood-discussion mailing list. Although these participants do not constitute a completely representative sample of potential Household Indicators users, they do fall into the group of likely users. Because these interviews were conducted as a formative evaluation, to inform the design process, my goal was to quickly gather information useful for guiding design, rather than to make generalizable claims.

I engaged the participants in semi-structured interviews lasting approximately 1.5 hours.

Interview questions addressed values and indicators of interest to citizens, potential harms and benefits of Household Indicators, self-interest in decisions about urban planning, democratic engagement in urban planning, and definitions of neighborhoods.

Most participants were positive about Household Indicators, and a few were quite enthusiastic. They saw a range of potential benefits with respect to democratic engagement, access to information about urban planning, and, surprisingly, information relevant to *personal* decision-making such as where to buy a house. Some participants were concerned about transparency of the information provided, and that information could be misleading or used inappropriately. Participants also cited concerns that the system could be difficult or time-consuming to use. Other issues are addressed in the discussion to follow this brief overview of the design process.

6.3.2 Phase 2: Paper Prototypes

Phase 2 of the design process comprised explorations of project scope and alternatives for interaction design, culminating in a formative evaluation of paper prototypes with Seattle citizens.

Based on the results of technical and empirical investigations in Phase 1, I chose to focus on a small number of indicators that were of interest to the interview participants and appeared feasible to implement with UrbanSim's current capabilities: indicators of population and employment density, land use mix, residential unit value, and commute times.

After exploring a number of map- and chart-based visualizations (e.g., as shown in Figure 6.5), I decided the initial prototype would provide visualizations consisting of tables comparing results across different alternative scenarios. Comparison is an essential task for users to understand the differences between the alternatives and consider which are preferred. Tables are simple to produce using HTML. And while trends are more easily seen in charts and graphs, tables are preferable to charts for many small datasets, and they facilitate comparisons [123]. This decision let me focus on the use of personal information as a lens through which to view simulation results, leaving the challenge of designing rich

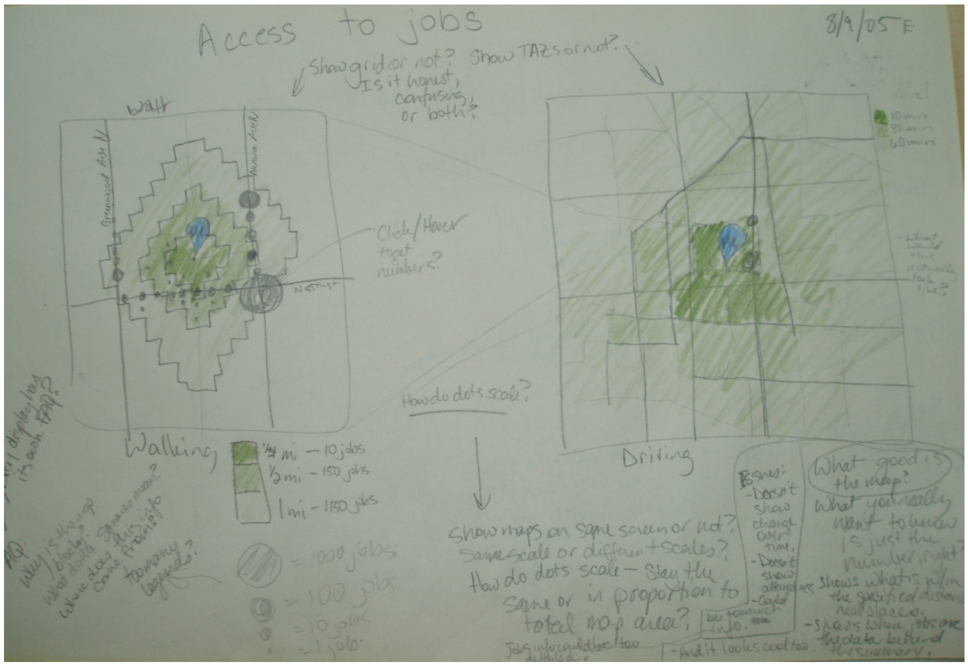


Figure 6.5: Sketches of map-based visualization of household access to jobs.

visualizations to later work. Finally, this decision acknowledged the limitations of UrbanSim's existing visualization support: producing maps and charts is time-consuming. The Indicator Browser [109] includes facilities for queuing and monitoring indicator visualization requests, which may take from minutes to hours to complete. With further software development effort, I believe it will be possible to interactively visualize small subsets of precomputed indicator data, as for Household Indicators, as maps and charts.

In this design phase, two contrasting approaches to interaction emerged: a profile-centric approach and an indicator-centric approach. In the profile-centric approach (Figure 6.6), the user creates one or more household profiles and then views simulation results through the lens of these profiles; in the indicator-centric approach (Figure 6.7), inspired by dynamic queries [114], initial regional views of indicators are personalized, or narrowed in scope, when the user enters personal data.

To compare these two approaches, I developed a series of paper prototypes [103]. I tested these with UrbanSim staff and in a formative user study with six Seattle citizens (3

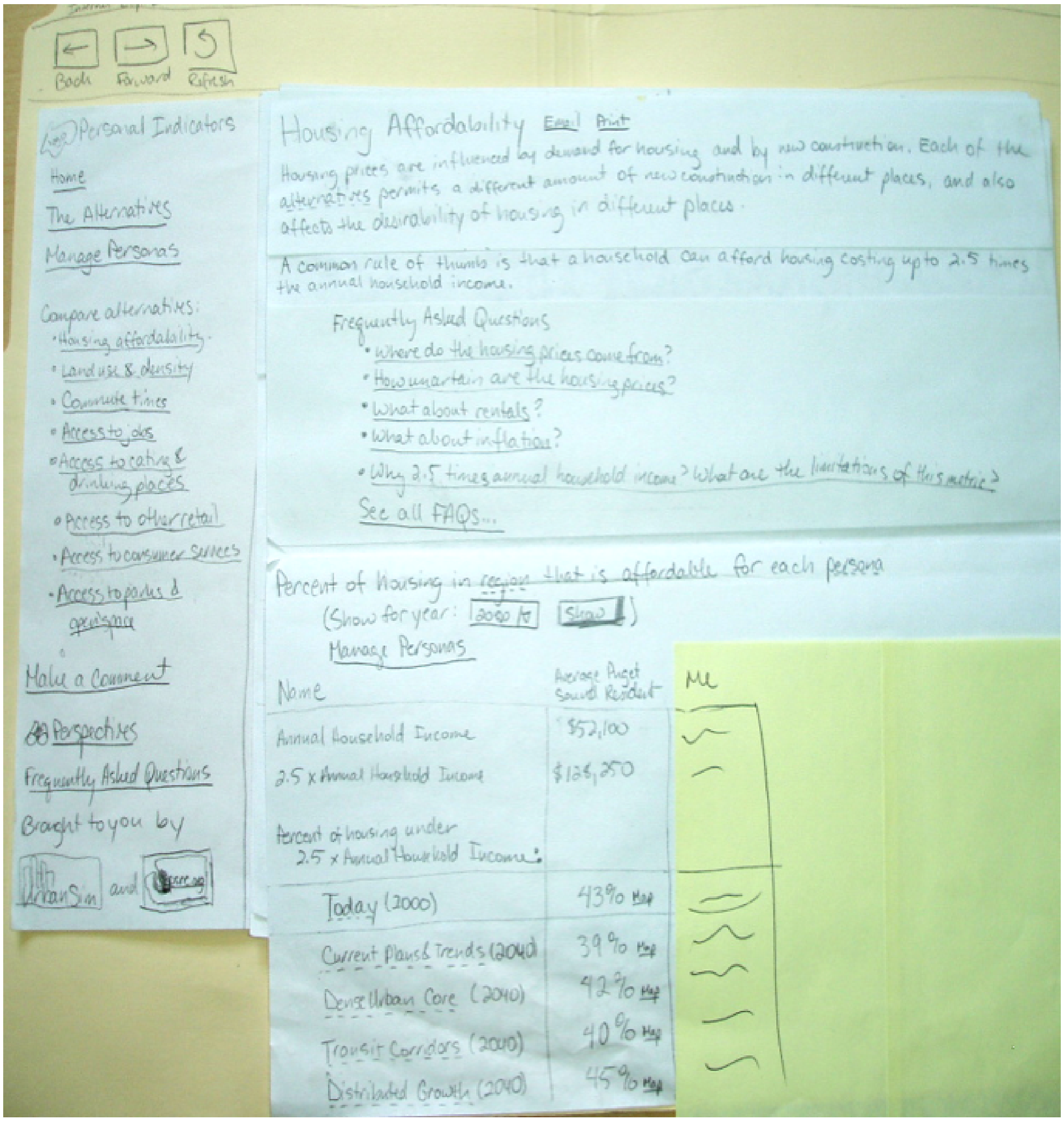


Figure 6.6: Paper prototype of the profile-centric approach showing the housing affordability indicator.

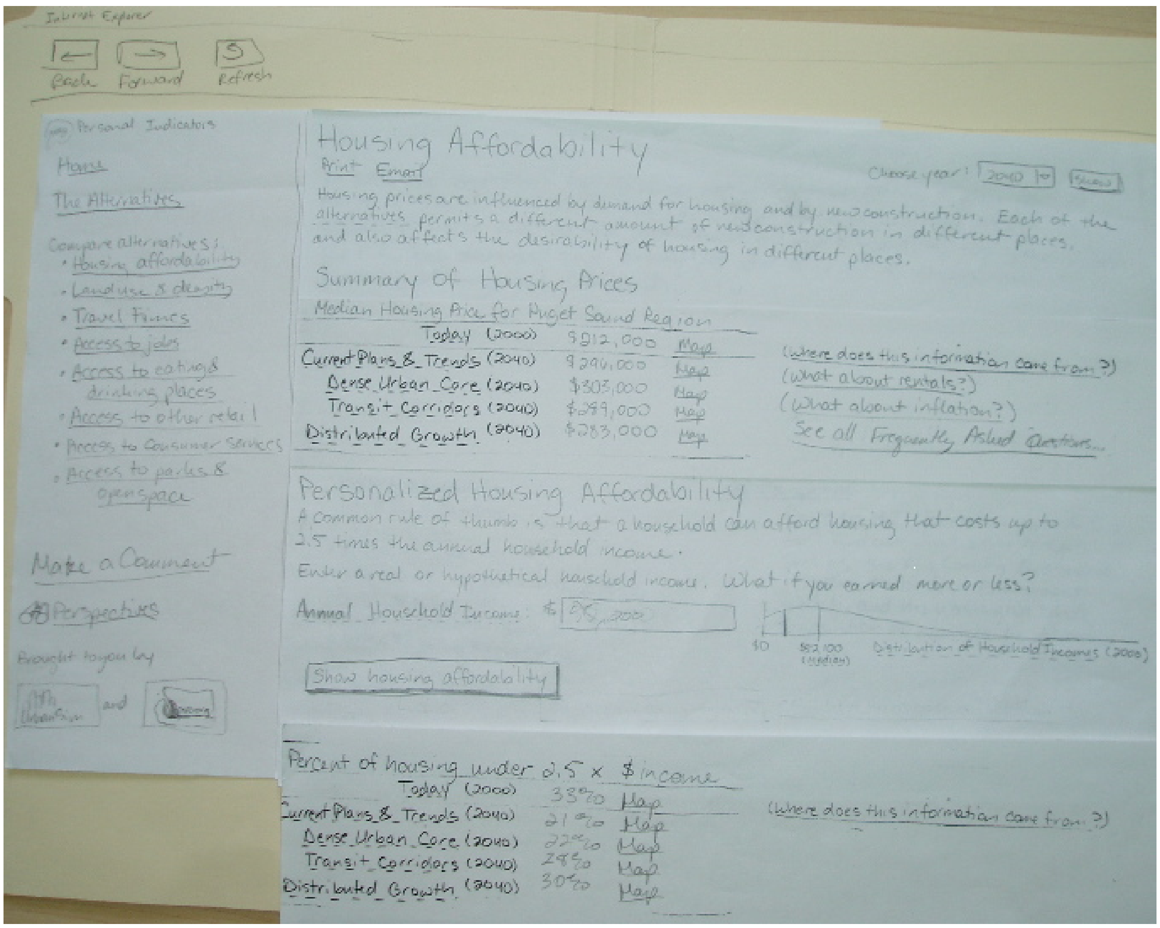


Figure 6.7: Paper prototype of the indicator-centric approach showing the housing affordability indicator.

women, 3 men) ranging in age from 32 to 53 (M = 43.5), recruited as for the exploratory interviews in Phase 1. I asked each participant to think aloud [10] while in the same task with both prototypes, with the order of the prototypes counterbalanced across the sections, as I took notes and played the role of the computer. I then asked for overall impressions of the prototypes. Each session lasted about one hour.

The user studies led me to reconsider the affordances of each approach. The given task involved exploring hypothetical future personal circumstances (e.g., living in different neighborhoods, or a substantial change in household income) and considering possible impacts on others. The indicator-centric approach very naturally supports rapid exploration of many hypothetical situations, as in this task, but the profile-centric approach required users to create and view several profiles, which was confusing and overwhelming to some participants. On the other hand, the profile-centric approach may foster a sense of identity that persists while viewing different indicators. From the standpoint of efficiency, this approach allows the user to easily view many indicators with respect to the same personal information (e.g., many different indicators about where one lives or works).

Faced with this dilemma, I returned to my initial goal: enabling citizens to ask the question, "How will this decision affect me?" This question implies a focus on concrete information about the user's own household. Therefore, I chose to pursue a modified version of the profile-centric approach that addresses some of the participants' concerns. The development of a working prototype for the profile-centric approach in Phases 3 and 4 also lays the groundwork for a future implementation of the indicator-centric approach.

6.3.3 Phase 3: Interactive Mock-Up

Based on participants' interactions with the paper prototypes in the Phase 2 user study, I decided it was time to develop higher-fidelity prototypes [125, 135] using HTML mockups. A sample page is shown in Figure 6.8. These mockups include a realistic layout of text, data, and widgets (including Google maps for specifying locations) on a web page; however, the displayed information is fixed rather than responding to the user's input and does not incorporate data from UrbanSim runs. To produce these mockups, I engaged in a series of

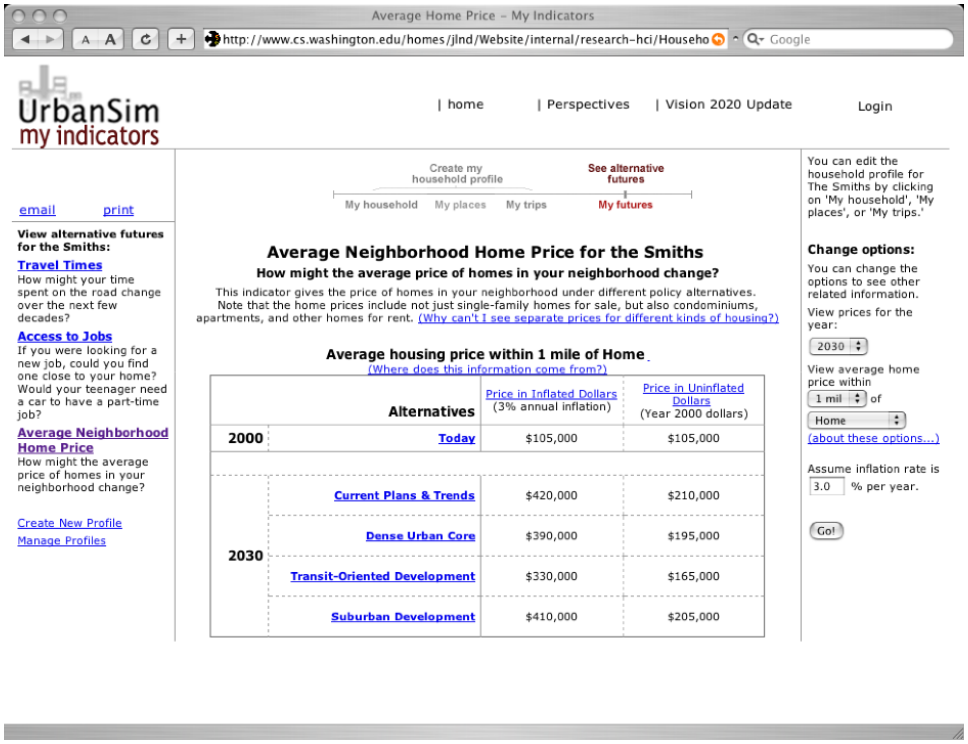


Figure 6.8: Screen shot of the Household Indicators mockup showing average neighborhood home price.

rapid design iterations, punctuated by design critique from colleagues in the Value Sensitive Design Research Lab.

Much of the work in this phase addressed visual layout and the sequencing of steps in creating the household profile. Concerns about the time required to set up the profile are addressed by streamlining the creation of the first profile and making this unambiguously the first step of the interaction, by giving estimates of the time required for data entry, and by giving examples of the kind of information the user will be able to access after creating a profile. Other changes to sequencing were to put selecting the home location in an initial “Basic Household Information” step and to identify other places in a separate step from configuring trips so that the same place can easily be used in several trips (and also neighborhood indicator data can be provided for these other places, not just home).

I also experimented with highlighting the "best" alternative for each indicator, but this was problematic for similar reasons to why the "Desired Direction" section of the Technical Documentation was problematic. In particular, there are many reasons why one might be interested in the average neighborhood home price: property owners who plan to sell and those who want an exclusive neighborhood might prefer to see prices go up, while those who wish to buy or who are concerned about housing affordability in general might prefer to see prices stay more steady. For this reason, I decided to abandon this feature. It might be considered again in the future with less concern of bias by allowing the user to specify which direction is preferred.

6.3.4 Phase 4: Prototype Implementation

In this phase, my goal was to develop a working prototype implementation of Household Indicators, incorporating real UrbanSim results. This positioned me to conduct a formative evaluation focusing on value issues, notably how well the system achieves the goal of presenting a set of indicators that are relevant and relatively free from bias, and presenting information in a way that is comprehensible, accurate, transparent, and relatively neutral. Finally, I wished to further explore ways in which Household Indicators could support democratic engagement.

The prototype web application implemented in this phase of design largely copies the mockup produced in the previous phase. A sample page is shown in Figure 6.9. However, features had to be prioritized for the implementation. Development started with a "thin vertical slice"—a minimal interface allowing the user to complete a single, simple task. For Household Indicators, the initial thin vertical slice included the specification of the household name and location, the specification of other places important to the household using a map interface, and display of a population density indicator (Population within Walking Distance) for the home and other places. Features subsequently added include additional neighborhood indicators (Employment within Walking Distance, Land Use Mix within Walking Distance, and Average Home Value within Walking Distance); an interface for configuring trips and the corresponding Travel Times indicator; links to glossary terms

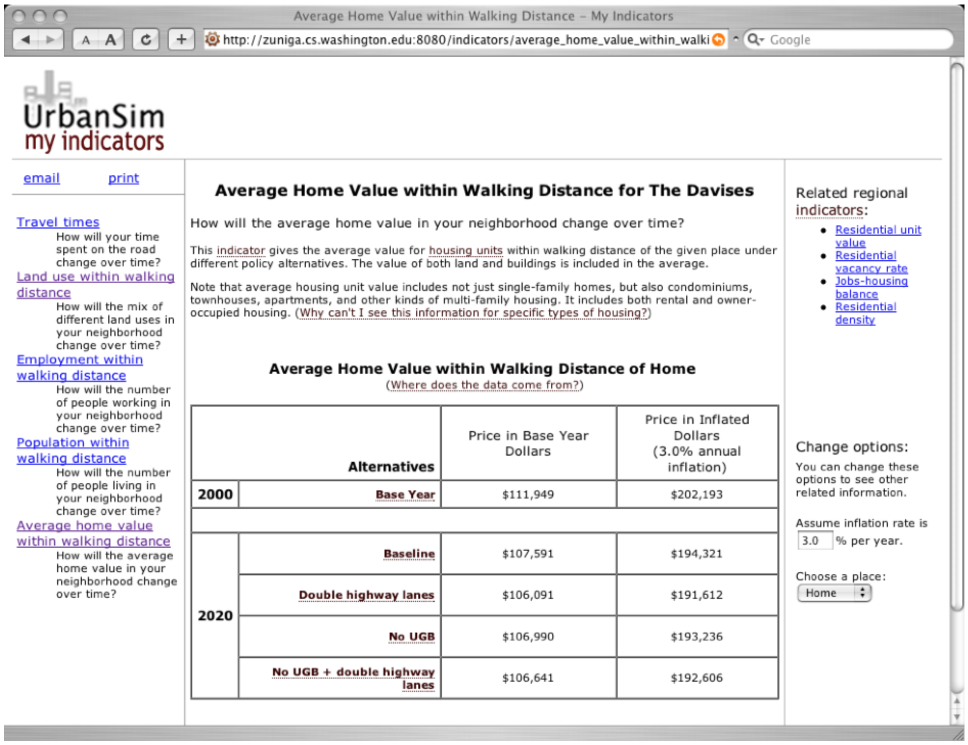


Figure 6.9: Screen shot of the Household Indicators prototype implementation showing average neighborhood home price.

and Frequently Asked Questions (FAQs); and links to related regional indicators. Features considered in Phase 3 but not implemented in Phase 4 include designing a better interface for trip chaining; incorporating further indicators and more sophisticated geographic abstractions, and adding links to Indicator Perspectives, the Indicator Browser, and regional government.

The prototype implementation is a working web application. It presents data from four "sledgehammer" runs—UrbanSim runs representing extreme scenarios such as eliminating the Urban Growth Boundary (UGB), intended for validation of the model in the Puget Sound region. I give more details about the implementation of the prototype system in Section 6.5.

To evaluate this prototype implementation with respect to the design goals of relevance, comprehensibility, transparency, accuracy, and freedom from bias, I conducted four focus groups with a total of 13 participants (7 women, 6 men) ranging in age from 19 to 63 (M = 49). Participants were recruited in four Seattle neighborhoods using neighborhood email lists, posters in public places, and word-of-mouth. In each focus group, I gave a brief demo of Household Indicators. I elicited questions about the tool and asked the participants about potential biases in the system, indicators of interest, and opportunities for the system to contribute to democratic engagement. Participants also volunteered concerns about the accuracy of the data, the “walking distance” geographic abstraction used in the prototype, and the visibility of data over time. Particular findings are presented in more detail in the discussion to follow.

6.4 Discussion

Presenting personalized, household-scale views is a novel approach to interaction with the results of sophisticated simulations to support decision making. The design and implementation of the Household Indicators prototype has shown that it is possible to implement such an interface for UrbanSim, and that this type of information can be relevant to the personal concerns of engaged citizens—those who have the resources and attitudes necessary for effective political participation. Such engaged citizens are a strongly impacted group of stakeholders who, for the most part, are not experts in modeling or urban planning.

In this section, I discuss themes that recurred throughout the design process: selecting indicators, potential biases, comprehensibility and transparency, geographic and temporal abstractions, and supporting democratic engagement. These themes suggest directions for further research into the design of such interfaces.

6.4.1 Selecting Indicators

Identifying potential Household Indicators and selecting those to actually implement requires balancing tensions between providing information that is relevant to stakeholders’ values and experiences, avoiding biases in what information is presented, and being true to the model’s abstractions, capabilities, and limitations. Selecting indicators will remain a challenge in the future: there is still work to be done to identify good Household Indicators for the Puget Sound region today, and the indicators included in the system should evolve in response to the model's changing capabilities and to new decision contexts.

To illustrate the challenges of selecting indicators, I trace the evolution of indicators about housing costs through the four phases of design conducted thus far and into the future.

Housing costs: An illustrative tale

In the initial explorations of Phase 1, I anticipated stakeholder interest in housing costs. Housing is the single largest expense for many households, and where one can afford to live has a large impact on overall quality of life. The informational interviews confirmed this; all participants expressed at least some interest in either home prices or rents.

It is reasonable to expect that UrbanSim's models of land use, real estate development, and household location would provide data about housing costs. At the same time, I knew that the abstractions used in UrbanSim did not exactly match the concept of the price or rent for a particular dwelling. UrbanSim does provide information about property values for housing, but the current abstraction of housing is the *residential unit*. This abstraction includes both owner-occupied and rental housing, and it does not include housing characteristics that one typically uses in searching for housing, such as the number of bedrooms or the square footage. At this phase of the design process, I believed that the information about property values would nonetheless be useful and relevant, and that accounting for the limitations of the model abstractions was a challenge of transparency—simply making these limitations very clear.

In Phase 2 of the design, I was concerned with the question, "Where can I afford to live in the region?"—a question of great relevance to stakeholders who do not currently own their home or who are considering a move. I designed paper prototypes of an indicator that, given a household's income, would show the percent of housing in the region that was affordable for that household. Maps showed where housing was and was not affordable for that particular household, giving a sense of the household's options in the region. To assess housing affordability, I needed to make some assumption about the relationship between household income and how much house one can afford. I drew on a rule of thumb sometimes used in the real estate industry: that a household can afford a home with a price up to 2.5 or 3 times annual household income [26, 52].

This assumption was problematic for several reasons: First, as one user study participant pointed out, new mortgage products and high real estate prices in areas such as Seattle make this rule of thumb less valid. Second, this rule of thumb was developed with purchasing a home in mind, and there is no reason to think it will be equally valid for renters. Third, it hides the raw data (property values) produced by UrbanSim without a principled reason for doing so. It makes assumptions about the mortgage interest rate, the size of the down payment, and the user's debt load and credit record [52, p. 32]; lenders' decisions in fact take all of these into account. Thus, while I was trying to make this indicator extremely relevant for households who might move to a new home in the future, I introduced problems with the transparency of the data and a potential bias against renters. At least one user study participant pointed out that an indicator of monthly costs would be far more relevant for renters, and would be useful for homeowners as well.

Therefore, in the next phase of design, I investigated providing indicators of monthly costs in the form of rent or mortgage payments. But the relationship between monthly payments and property values is complex. Computing monthly payments solely on the basis of property values would require making many questionable assumptions, posing the same problem as the rule of thumb used in Phase 2.

Furthermore, one's ordinary understanding of housing affordability encompasses not just the price of the housing, but what one is getting for that price—characteristics such as number of bedrooms that are not currently accounted for in the model.

So, I decided to postpone indicators of monthly costs until later—when UrbanSim's models are able to provide them directly, based on models that are theoretically sound and empirically validated—and instead focus on showing the data that UrbanSim actually does produce now. The HTML mockup I developed in Phase 3 aims not to answer the question, "Where can I afford to live in the region?" but rather "How could residential property values change in my neighborhood?" This is also the data that is shown in the prototype implementation developed in Phase 4.

So, this leaves the design at a not entirely satisfactory resting point. Because the residential unit abstraction combines housing units for rent and for sale, we can wonder whether participants truly understood the "average home value" indicator. The lack of a representation of monthly costs represents a potential bias against renters. And we are not able to adequately address the earlier question, "Where can I afford to live in the region?"

Yet, addressing these limitations and biases provides a clear direction for future development. This story illustrates how asking new questions, and providing new interactions with simulation results aimed at stakeholders who have no particular expertise in urban planning, can lead to a reexamination of the abstractions underlying the simulation model.

6.4.2 Potential Biases

Because one of our explicitly supported values for UrbanSim is freedom from bias, I have conducted conceptual and empirical investigations into Household Indicators' potential biases. In the previous section, I discussed one potential emergent bias against renters arising from appropriating an existing simulation model to ask new kinds of questions. Several more potential biases are discussed here: automobile bias, 9-to-5 bias, and stability bias. From previous work on freedom from bias [46], we can expect that further biases are likely to emerge as the system is used by a wider range of stakeholders. Finally, I discuss the problem of identifying and mitigating biases in Household Indicators.

Automobile bias

The current design of Household Indicators reflects a pre-existing societal bias in the United States that favors car travel over other modes of transit.

One manifestation of this bias is in the selection of a single "Travel Times" indicator, rather than a suite of indicators about travel. We make many assumptions about car travel that we cannot make about travel by mass transit. Transit riders are concerned not only about travel times but what form of transit it is (city bus, commuter bus, train, etc.), waiting times, walking distances to and from stops, number of transfers, and environmental conditions such as shelter and crime at those transit points. Thus, while the Travel Times indicator provides a fairly complete representation of the experience of traveling by car, it is not so complete for mass transit.

I also learned that, in current practice at the Puget Sound Regional Council, transit travel is only modeled for morning peak and daytime periods, not for afternoon peak, evening, or night [7]. Afternoon travel is considered to be symmetric to morning travel, and there is considerably less transit available for evening and night. Thus, this bias in the information that is available to some extent reflects a pre-existing societal bias against those who rely on mass transit, but probably reflects a technical limitation, in that the travel model takes a very long time to run, and reducing the scope of the model reduces the run time.

A longstanding concern in UrbanSim that is particularly relevant to Household Indicators is the lack of accurate travel times by walking and other non-motorized transit. The scale of geographic abstractions in the travel model is well suited to modeling relatively long trips by car, but is poorly suited to modeling short trips on foot. Furthermore, the model lacks a representation of barriers to walking such as restricted-access highways, as well as features that enable walking where car travel is not possible such as staircases and pedestrian overpasses. With additional data collection about the pedestrian transit network, a new activity based travel model could address this concern.

Finally, does listing car travel first among the travel mode options in the Household Indicators trip configuration interface constitute a bias? One could argue that no, it does not, because it is justifiable by reasons of efficiency and usability to put the most popular travel option first. On the other hand, as suggested by some focus group participants, putting car travel first simply perpetuates that societal bias. One approach suggested by another focus group participant would have users indicate their "transportation assets" in an earlier step of configuring the household profile, and list only those assets in the trip configuration interface. Another approach that cuts a middle ground would be for the user interface to remember which travel mode the user selected for each trip and present that as the default option for the following trip.

9-to-5 bias

Another societal bias related to travel is what I am calling the "9-to-5 bias": A bias towards travel as part of a conventional commute from home to the workplace on weekday mornings and returning in the evening.

The paper prototypes developed in Phase 2 made several simplifying assumptions: that morning travel was representative of travel at other times of day and that trips were round trips based at home. However, user study participants reminded me that people travel at different times of day and not all trips begin at home. The HTML mockup developed in Phase 3 addressed these concerns by allowing the user to specify a time of day for travel and a starting location as well as a destination. This data is, for the most part, produced by the existing travel model.

Another concern is the phenomenon of trip chaining [86], in which other stops are made, for instance to buy coffee or drop a child off at day care, before reaching the destination. This concern arose through the design critique in Phase 3 as was echoed by a focus group participant in Phase 4. It is partially addressed by the design developed in Phase 3—by allowing trips to start at a location other than home and assuming one-way rather than round trips—but could be better addressed through further interaction design. It is also important to note that trip chaining is not modeled in the existing travel model, but would be modeled in a new activity-based travel model.

Furthermore, focus group participants noted that data about weekday travel may not apply to weekend travel, and that many trips (e.g., family outings) are discretionary and may be very sensitive to the monetary cost of travel. Ideally, Household Indicators would distinguish between weekdays and weekends, but it cannot do so unless the underlying travel model does so as well. Household Indicators should also provide information about travel costs, such as transit fares, parking fees, and fuel costs.

Stability bias

Creating a household profile fundamentally presumes some stability in the user's life: that the user is willing and able to identify a home and other important places for the long term.

While everyone's circumstances change over time, some stakeholders such as college students or the homeless are in particularly unsettled circumstances. The indicator-centric approach considered in Phase 2, which lets the user personalize a regional view of an indicator, would allow for greater exploration and flexibility while viewing a particular indicator, rather than committing to elements of the household profile up front. This approach merits further exploration in support of stakeholders with less settled circumstances.

This design bias probably arose in part as a societal bias, in part from my own biases, and in part due to a participant recruiting method that favors participants who are more established in their neighborhoods over more transient residents such as college students.

Identifying and mitigating biases in Household Indicators

As Friedman and Nissenbaum suggest [46], identifying groups who suffer from societal biases (such as non-drivers and renters) can go some distance towards mitigating those biases in computer systems. Yet, conceptual investigations only go so far; empirical investigations with a well-chosen sampling of stakeholders can help to uncover unintentional biases. One challenge with Household Indicators (and with UrbanSim in general) is that stakeholders are so diverse; designing a study with balanced representation from every stakeholder group (see Table 3.1 for a partial list) would be overwhelmingly complex. Moreover, every individual has multiple stakeholder roles. A promising approach for addressing this is to identify participants based on known or likely biases, for example, to specifically recruit transit users, renters, and wheelchair users. Advocacy groups such as a renters' or transit riders' union are likely sources for such participants. Also including a broader sampling of the population, and ensuring that there is discussion of other issues, provides an opportunity for other unintentional biases to be uncovered.

The bias against people in less settled circumstances is particularly challenging. This bias is somewhat justified in that we wanted to design a system aimed at those who are committed to the region and have a long-term stake in the outcome of decisions. The answer here is perhaps that we cannot do everything at once—that both approaches have merit, but we have to start somewhere.

To avoid technical biases, Friedman and Nissenbaum guide designers to envision the system in a context of use [46]. One lesson here is that, for simulation models, we should be wary of abstractions such as the residential unit that erase morally significant distinctions between stakeholders—such as whether they are homeowners or renters. We should also be wary of simplifying assumptions such as the assumption that travel in the morning or on weekdays is representative of all travel. Addressing such biases can require not only significant software development effort, but significant research effort to design new models that are theoretically and empirically sound.

Prudence must be exercised in avoiding emergent biases—accounting for a given context of use is challenging enough that we cannot avoid biases for all contexts. For example, a city such as Mumbai where there is very little motorized travel and many people live in shantytowns would require very different land use and transportation models than those appropriate for cities in the United States. However, we should take care to draw a broad enough circle around the system's potential users and uses. For example, in designing Household Indicators we should consider not only Seattle residents but also residents of small towns and other areas of the region being simulated. And can we think forward to how Household Indicators might be used by elected representatives to explore possible impacts on their constituents, and not just themselves?

6.4.3 Comprehensibility and Transparency

One of my hypotheses is that Household Indicators can be more comprehensible to stakeholders without urban planning expertise by grounding simulation results in one's own experiences, such as choosing a place to live or commuting to work. Yet, framing the simulation in these terms can pose a challenge, as can avoiding jargon, giving context for the data, and providing for model transparency. Explanations and definitions need to be ready-to-hand [138] in the context of using the system.

Providing ready-to-hand information

One theme that emerged early in Phase 2, following on work with the Indicator Browser, was the need for ready-to-hand information about the indicators and other questions users might have about the system, in support of transparency and comprehensibility.

The paper prototypes developed in this phase included a block of Frequently Asked Questions (FAQs) intended to address questions likely to arise in the context of using Household Indicators. User study participants found FAQs in the middle of the page to be annoying, whereas a block of FAQs in the right margin of the page tended to be ignored, possibly because it occupied a space often occupied by advertisements [88].

Therefore, I experimented with the idea of "ready-to-hand" FAQs placed as near as possible to the place where the question arises. For example, definitions for particular terms are linked to the terms themselves; longer questions are inserted in-line. This approach was inspired by current practice on commercial websites such as Amazon.com and is similar to the GovStat project's Statistical Interactive Glossary [78]. The read-to-hand FAQs were implemented in Phases 3 and 4, but because focus group participants did not interact directly with the system but rather were shown a demo, this feature should be tested in future evaluations of the system.

Language and jargon

I also identified issues with language and jargon as a concern early in the design process. Household Indicators are designed for an audience who are not urban planners and modelers, and do not spend their entire workday with UrbanSim, and thus may not be familiar with terms such as "residential unit" or "grid cell." Where it is necessary to use terms such as "grid cell," they are defined using ready-to-hand FAQs, using contextual visual explanations where appropriate. For example, the user interface for selecting a location in Household Indicators shows a box around the grid cell that is selected, and the definition of a grid cell includes maps showing examples of grid cells around the Puget Sound region.

Yet, making discussions of UrbanSim indicators comprehensible is not just a matter of defining terms, but of choosing appropriate terms. There is a tension between choosing words that are familiar in the interest of comprehensibility, and those that indicate a particular abstraction in the interest of transparency. One such term from UrbanSim is the "residential unit," which encompasses all kinds of housing, in contrast to ordinary words like "house" or "apartment" or "condo." While the terms "home" and "housing" are familiar without necessarily implying a specific type of housing, the term "residential unit" has the advantage that it clearly has a specific definition which the user can investigate.

Giving context

Stakeholders need context in order to understand facts [118, p. 374]. Household Indicators—and indeed all tools for citizens to learn about UrbanSim results in the context of comparing alternatives for a particular decision—should include information about the why a decision is needed, what the alternatives are, and (as noted by one focus group participant) when, how, and by whom the decision will be made. Because the current prototype uses the "sledgehammer scenarios" as the alternatives for comparison, I wrote the background information on these alternatives. In a real context of use, this background information could be provided by the planning agency that is analyzing the alternatives or by a journalistic source.

Making the model's design, assumptions, and limitations transparent to non-expert users is challenging. We cannot assume the level of background knowledge possessed by urban planners and modelers. Explaining model jargon goes some distance towards improving the transparency of the model, but focus group participants raised many other questions about what is and is not accounted for in the model (e.g., "Is this limited to the four-county region?" and "Does this account for travel on surface streets or only on highways?")

Showing the data

Edward Tufte admonishes, "Above all else, show the data" [123]. The story of housing costs given in Section 6.4.1 represents a struggle in part to show the data as clearly as possible, so that it is comprehensible and transparent. Indeed, at the end of this process, focus group participants understood the data well enough to raise questions about its accuracy.

They asked pertinent questions, such as "Is this data from the year 2000?" "What is being averaged here?" and "Are homes depreciating?" Thus, making simulation results comprehensible has been seen to push back on the transparency of the system in leading users to ask further questions about how the data is arrived at.

6.4.4 Geographic Abstractions

Many indicators, such as those about housing costs or population density, are geographically based. Such results need to be aggregated over some geographic area to be meaningful. Grid cells, though easy to visualize and understand, are too fine an abstraction because simulation results are highly uncertain at this scale. I doubted that larger geographic tilings used by UrbanSim, notably Traffic Analysis Zones (TAZs) and Forecast Analysis Zones (FAZs), would map onto citizens' concepts of their neighborhoods. And in Seattle, there are many different ideas about neighborhoods and their names and boundaries [110]. Furthermore, to provide access to all citizens of the Puget Sound region, I would require definitions of neighborhoods throughout the populated portions of the Puget Sound region.

In the exploratory interviews of Phase 1, I presented participants with maps of possible neighborhood abstractions to elicit their thoughts about defining neighborhoods. Participants saw the Seattle City Clerk's unofficial map of neighborhoods [110] as more meaningful than the much smaller census tracts [99] (which are similar to FAZs and TAZs), or than council districts, which are much larger. Some participants reported thinking of neighborhoods at different geographic scales depending on their purpose and suggested the abstraction of a neighborhood falling within a certain radius of a location.

I experimented with this idea and, in Phase 3, allowed users to select from a list of different radii (one-quarter mile, one-half mile, one mile, three miles, five miles) when reporting results of geographically-based indicators such as population density. I also experimented with using travel times by different modes as a geographic abstraction for access to jobs, incorporating data from the external travel model.

In the interest of expedience in Phase 4, I used UrbanSim's "walking distance" metric as the single unit of geographic abstraction. This puzzled focus group participants. Of course, "walking distance" has a different meaning for everyone, depending on their physical abilities and inclinations, and the system obviously assumed a particular definition of "walking distance" that was not apparent. My intention in choosing this abstraction was also not clear to the users; I meant it as a representation of a relatively small neighborhood, but some participants thought it was silly as an abstraction for considering employment density when very few people can walk to work. Participants much preferred directly using units of distance (e.g., 1 mile) and choosing from a list of radii. Some focus group participants raised the concern that they have a poor sense of distance; showing the boundaries of the geographic region on a map would help users to understand the abstraction by putting it in context with local landmarks. For example, a map could show that one-quarter mile away from my home is near Interlake Avenue to the east or Greenwood Park to the south.

Furthermore, as I realized in Phase 2 of the design, users need a way to specify the location of their home and other important places. Although we ordinarily think about addresses, street intersections, and neighborhoods, Household Indicators needs locations specified at the grid cell level to access UrbanSim results—somewhat more specific than a neighborhood, but less specific than an address or intersection. My design allows users to identify locations by navigating to and marking the locations on a Google map [53], so that users do not need to specify an address if they do not know a specific address or prefer not to associate an address with other personal information that might be collected by the system (such as household income). For ease of use, it also lets users enter addresses which are then mapped to a location on the map using a geocoding service [50], but this address is not stored in the system and disappears once it has been located on the map.

6.4.5 Supporting Democratic Engagement

Finally, one of my goals in developing Household Indicators is to support democratic engagement. Even the "engaged citizens" recruited to participate in formative evaluations expressed cynicism about the land use and transportation planning process, and in particular that they could make a difference in the outcome. For example, one focus group participant said, "How much input does the ordinary citizen really have on that? Because it really is land use, and that's very political. Only if you're really active in that area do you ever get a voice. Usually you just wake up and go, where the heck did that building come from?"

Yet, many participants in Phase 1 exploratory interviews expressed enthusiasm for the concept of Household Indicators, as did many of the Phase 4 focus group participants who saw the system in action. Some participants indicated that access to quantitative data would enhance citizens' credibility and power when raising their concerns to elected representatives and public officials.

Several participants were interested in online deliberation about the use of UrbanSim results in decision-making, and most were interested in giving online feedback to government officials. With respect to self-interest, most participants readily named a range of stakeholders other than themselves. (Many of these are listed in Table 3.1.) Some participants spoke derisively of acting out of pure self-interests while others said that it is all right or even necessary to consider one's own interests in forming political opinions.

Reactions to introducing tools for online deliberation were mixed—some formative evaluation participants were very enthusiastic, others completely uninterested. Online deliberation could take the form of place-based discussions or discussions around real or hypothetical household profiles. Household Indicators could also support face-to-face deliberation among citizens by helping to make connections between interested households in the same neighborhood. In either case, privacy and informed consent are of particular concern in making information in household profiles publicly available.

Finally, I began this project with some concern that Household Indicators could promote self-interest at the expense of the public interests. The engaged citizens I spoke with in Phase 1 interviews were well aware of the public interest and of stakeholders beyond themselves and their loved ones. Using a tool that helps one to consider one's own interests does not guarantee a decision based on self-interest; public deliberation helps to promote decisions that are in the public interest. Furthermore, as Fraser argues [32], there is a place for discussion of private interests in the public sphere; it may be that the prevailing sense of the common good does not adequately include the interests of some individuals, and individuals can clarify their interests through deliberation.

However, it is still important to connect regional perspectives on the alternatives with Household Indicators. In Phase 2, I experimented with keeping the “big picture” in view by portraying both indicators at the household level with those at the regional level in a single display, but this proved unwieldy. Phase 4 instead includes links from each display of Household Indicator data to related regional indicators; improving the integration of all the interfaces to UrbanSim results is a concern for future work.

6.5 Software Architecture and Implementation Notes

I implemented the prototype as a standalone web application using the Turbogears [124] toolkit. I chose to work with Turbogears because it is implemented in Python, making it easy to incorporate components of the existing UrbanSim 4 implementation. Turbogears also provides a supportive, flexible, and easy to learn environment for rapid development of web applications, making it ideal for a prototype implementation.

The prototype implementation’s modular architecture is supported by TurboGears’ model/view/controller abstraction. I developed the models and controllers using the test-first methodology, in adherence to UrbanSim’s commitment to agile programming [33, 42].

Models represent the underlying data in the system. A key model is the household profile model, incorporating three classes: Household, Place, and Trip. Each household may contain many places and many trips, whereas each Trip refers to just two places: a starting location and a destination. These three classes are implemented using the SQLObject library [119], which facilitates storing the objects in a relational database such as MySQL [85]. Another key model is the MultiCacheAccessor, which enables access to output data contained in multiple UrbanSim run caches, allowing several scenarios to be compared. Finally, a group of coordinate converters employ the PROJ.4 toolkit [98] and UrbanSim grid cell data to translate between UrbanSim’s grid cell coordinates and the latitude/longitude coordinates used by other tools.

Views are what the user interacts with: the web pages themselves. Views are implemented using the Kid template language [70], which lets the developer embed Python snippets in HTML pages. Javascript is used to implement client-side web page behaviors such as fetching new indicator data when the user selects a different place to view. In the current implementation, each page viewed by the user has its own Kid template, although they share some generalized components.

Controllers bridge the gap between models and views and are the heart of the web server. As the user creates a household profile, the ProfileController validates the user's input, updates the household model based on that input, and configures the view that should be presented next based on what is in the profile. Each indicator has a controller for configuring the view, while a single IndicatorDataController class interfaces with the MultiCacheAccessor class to fetch the appropriate indicator data. Controllers are also provided for converting between grid cell coordinates and latitude/longitude, and for geocoding addresses to latitude/longitude coordinates using the free geocoder.us service [50]. Finally, a FAQ controller controls views of information about Frequently Asked Questions.

The greatest challenge in implementing the prototype system was coping with the sheer volume of data—on the order of megabytes for a single attribute of a dataset such as all of the grid cells in the Puget Sound region. UrbanSim's typical data access pattern is to access each attribute for every entity in a dataset (e.g., access the number of residential units attribute for every grid cell in the region). UrbanSim's data structures are designed for this access pattern in that attribute data is loaded from disk and flushed from memory in large chunks. By contrast, Household Indicators' goal of presenting a personalized view on simulation results means that it needs to access attribute data for only a small number of grid cells or other entities at a given time. The goal of comparing years and scenarios means that it must do so for several different run cache instances. A typical workstation's memory is not large enough to hold several attributes of several years and scenarios in memory at once, and loading all of the data for an attribute takes several seconds, making response time slow.

To address this challenge, I used Numarray's Memmap feature [91] to load the desired attribute of only a single entity (e.g., the number of residential units for one specific grid cell). This obviates the need to hold all of the data in memory and is much faster than loading the data for all grid cells. However, a production implementation may need to cache these single values in memory to reduce disk contention and improve scalability.

6.6 Future Directions

Household Indicators represent a novel approach to interacting with the results of sophisticated simulations intended to inform decision making. In the work presented here, I have shown it is feasible to implement such an interface for UrbanSim, and that this type of information can be meaningful to stakeholders who are not domain experts. Future directions for some issues, such as addressing potential biases have already been discussed and improving linkages between different interfaces to UrbanSim results, have already been considered. In addition, further work remains in testing and improving the usability of the prototype, as well as addressing issues that will arise in an operational context of use. Other avenues for future work remain: improving comprehensibility and transparency, implementing additional indicators, enhancing democratic engagement, and conducting a summative evaluation of the Household Indicators concept.

6.6.1 Improving comprehensibility and transparency

Findings in the focus groups suggest that users may be more skeptical about Household Indicators than about other presentations of UrbanSim results, because their experiences today give a point of reference that makes the data more comprehensible. Future empirical work should test this hypothesis, perhaps by asking participants to rate the accuracy or believability of indicator data presented in different ways and to reflect on any questions they have about the data.

Future usability testing should consider the effectiveness of ready-to-hand FAQs in conveying information about the alternatives, models, and simulation results in a manner that can be used without significant effort or distraction.

Enumerating and explaining what is and is not accounted for in the models in a way that is comprehensible and easy to use will pose a significant challenge. We also need a basic explanation of what UrbanSim does that is accessible to people who are neither urban planners nor programmers; the skills of a technical writer could help to address this gap.

Finally, Household Indicators present an opportunity—and a need—for giving detailed information about different alternatives: Where, specifically, will construction happen and where will policy changes take effect? Planned land use regulations, planned construction of buildings, roads, and transit, and other planned changes should be represented at the same level of spatial detail as the Household Indicators, so that users can understand how these planned changes contribute to indicator results. A challenge in to present this information so that it is sufficiently detailed to be relevant and useful, but is also comprehensible and ready-to-hand as such questions arise.

6.6.2 Geographic and temporal abstractions

Work thus far has suggested the use of maps to illustrate different distances from a particular place; in the spirit of Tufte's information density [123], these maps could also show actual indicator data. This idea should be implemented and tested to see whether it improves comprehension of geographic abstractions. It may be desirable for some indicators (e.g., of access to various goods) to use a maximum travel time by some transportation mode as a geographic boundary. These travel-time-based isocontours could also be shown on maps to improve their comprehensibility; the effectiveness of doing so should be tested and compared with distance-based isocontours.

One potential concern for deliberation is the need for shared geographic abstractions. In the current system, each user specifies their own places. In addition, the system could provide shared landmarks for deliberation (e.g., within one-half mile of Pike Place Market or 85th & Greenwood). Or perhaps we should consider making it easier to specify small areas with political, social, or administrative boundaries, such as an unofficial neighborhoods, an improvement district, or a "parkshed," based on stakeholder interest. Such areas could overlap and would not necessarily cover the entire region.

Focus groups also revealed an interest in showing trends over time for the indicator data, and for placing projections in context with respect to historical trends. Doing so in a manner that is comprehensible, transparent, and permits easy comparison of different alternatives may pose a challenge.

One last issue for comprehensibility is that the base year data for the Puget Sound region, collected in the year 2000, is now several years old and much has changed, notably in property values. Due to the time and expense required to gather data and calibrate the model, the base year data will always be somewhat behind the present day. Comprehensibility and transparency may be enhanced by presenting both real and simulated data for today, in addition to the base year data.

6.6.3 Implementing additional indicators

The problem of selecting and prioritizing among Household Indicators is analogous to the problem of prioritizing other UrbanSim indicators. Resources are limited, and developing a new indicator may require significant effort.

As discussed in the previous chapter, priorities for implementing indicators may arise from three different sources: coverage of the space of potential indicators, interest expressed by stakeholders, and pragmatic concerns. Prioritizing the implementation of new indicators for Household Indicators should also address potential biases of moral import, discussed below.

At this stage in the development of Household Indicators, the desire to produce a working prototype using real UrbanSim output data has brought pragmatic concerns to the forefront. The five indicators currently implemented as Household Indicators (average home value, population density, employment density, land use mix, and travel times) were relatively straightforward to implement given UrbanSim's current capabilities.

In empirical investigations, I have identified several other potential indicators that would be of use to Seattle citizens and merit further consideration:

- Indicators of monthly housing costs for rentals and owner-occupied housing, as well as the ability to filter according to housing characteristics such as number of bedrooms.

- Indicators of access to shopping, services, and recreation of various types. While UrbanSim does not directly address this interest now, a possible proxy that would build on UrbanSim's current simulation output is to report on the accessibility of urban villages—places above a certain threshold of population and employment density, which could be presumed to have many of these amenities.

- Indicators of neighborhood form, such as building height and open space. Previous efforts to visualize streetscapes based on UrbanSim data have taken UrbanSim's existing capabilities as given and attempted to extrapolate from the data to the height and footprint of buildings. With abstractions of land use that are based on parcels rather than grid cells, UrbanSim could itself use building codes together with data about existing buildings to model the height and footprint of new buildings.

- Indicators of crime. Stakeholders are interested in crime in their own neighborhoods, as well as neighborhoods they travel through. As discussed in Section 5.2.3, though crime is certainly a factor in choices relating to land use and transportation, developing a predictive model of crime is both difficult and controversial, and raises the concern of hyper-comprehensiveness. On the other hand, including static information about crime that doesn't vary with time or under different scenarios is potentially quite misleading. For example, crime 20 years from now at stops for a proposed light rail system might well be different from current conditions at bus stops in a given neighborhood. A greater number of transit users would likely change the crime situation; plus the presence of the light rail system itself may change neighborhood dynamics.

Finally, priority for implementing indicators can arise from the goal of covering the space of what people value. What stakeholders personally value about cities for themselves and their own households may differ from what they value from a generalized perspective (the stakeholder values discussed in section 3.2). This approach has not been addressed in the work presented here. One direction for future work is to investigate the intersection between a systematic taxonomy of what people value in the urban environment and a systematic accounting of personal values such as that developed by Rokeach [104] and employed by Voida and Mynatt in their exploration of using cultural probes to elicit families' values [126].

6.6.4 Enhancing democratic engagement

Several participants in empirical investigations have suggested that Household Indicators could link into existing structures for public deliberation and political engagement. For example, the paper prototypes developed in Phase 2 included a link to a form that lets the user submit a public comment about the Vision 2020 update project, which exists now on the Puget Sound Regional Council's web site. Since each household profile includes the location of the household's home, we can readily provide contact information for the household's elected representatives and other relevant government officials. Household Indicators could also link to contact information for neighborhood councils and local advocacy groups the user could join.

As far as online deliberation goes, one question is whether there is any value in publishing and discussing individual households' indicator results. If so, what concerns are raised with respect to privacy, anonymity, and accountability? Another question is whether we can aggregate comments about Household Indicators to let users learn the perspectives of many individuals throughout the region on how they will be affected by the alternatives under consideration.

The next chapter includes a more general discussion of directions for enhancing and evaluating democratic engagement in an operational context of use.

6.6.5 Summative evaluation

A summative evaluation of the Household Indicators concept should address my original goals in designing Household Indicators: to engage citizens in urban planning by presenting personalized information that is comprehensible and relevant to understanding the personal impacts of urban planning decisions. In response to these goals, the basic question the summative evaluation should address is, "Do Household Indicators contribute (beyond the existing regional indicators) to comprehensibility of UrbanSim results, to providing information relevant to decision making, and to supporting democratic engagement?" This evaluation should take place when a prototype system is mature enough that usability problems will not interfere with assessing the system with respect to this basic question.

6.7 Conclusion

In this chapter I presented my work on designing and evaluating Household Indicators, a new tool to give citizens a personalized view of UrbanSim results. Household Indicators attempt to address the question, "How could this decision affect me?" Household Indicators are a novel approach to interacting with the results of urban simulations such as UrbanSim. This work has shown that it is possible to develop such an interface and that it can provide information that is meaningful to its users. I have developed a working prototype implementation of Household Indicators, conducted formative evaluations, and sketched several directions for future work.

Household Indicators pose significant challenges in selecting indicators, presenting information to laypeople, and appropriating an existing modeling tool for a new context of use. Yet, Household Indicators have the potential to better engage citizens in the planning process and to enhance comprehensibility and transparency of UrbanSim results. Designers of other simulation systems intended to inform democratic decision making who wish to increase access to the system should consider developing interfaces that similarly support stakeholders in asking the question, "How could this decision affect me?" More generally, Household Indicators serve as an example of designing an interface that facilitates the transition of strongly affected stakeholders from indirect to direct. When a strongly affected group does not have direct access to the information system, it makes sense to consider whether the values at hand could be better supported by broadening access to the system.

Chapter 7

CONCLUSIONS AND FUTURE WORK

In this dissertation, I have presented the results thus far of applying Value Sensitive Design to the problem of designing interactions with UrbanSim indicators, with an eye towards freedom from bias and support for a democratic society. In this work, I and my colleagues face the challenge of designing for a complex context, in which many stakeholders bring strongly held, sometimes conflicting values to bear. Value Sensitive Design has helped us make progress on this problem, by directing our attention to indirect stakeholders as well as the urban planners who currently use UrbanSim, and by providing a structure for our investigations that incorporates not only technical considerations, but also conceptual investigations of the values at hand and empirical investigations into stakeholders' views of the technology.

Specifically, I have presented the design and evaluation of three tools for interacting with UrbanSim indicators:

- Technical Documentation designed to make information about indicators ready-to-hand in support of UrbanSim's legitimation potential;

- 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, in support of democratic engagement and comprehension of simulation results.

I have discussed conceptual investigations into UrbanSim's stakeholders, the distinction between explicitly supported values and stakeholder values, and the specific values of freedom from bias and support for a democratic society. I have placed this work into context with respect to previous work on the Value Sensitive Design framework, its application to UrbanSim, and related work in urban simulation, tools for citizen engagement in urban planning, access to government information online and the problem of the digital divide, and the fields of Computer-Supported Cooperative Work (CSCW) and Participatory Design.

This chapter concludes the dissertation. I first summarize my own contributions to designing interactions with UrbanSim indicators. Next, I discuss the contributions of this work in the form of lessons learned for other designers working in similar contexts. Before my concluding remarks, I consider directions for future work on UrbanSim indicators that extends beyond individual components of the system, including work on comprehensibility and transparency, democratic engagement, and evaluation in an operational context.

7.1 Summary of Joint and Individual Contributions

I contributed to work conducted jointly with Alan Borning, Batya Friedman, and Peyina Lin on the development of the Technical Documentation and Indicator Perspectives. Specifically, my contributions include

- the identification of design goals for legitimation based on Habermas's theory of communicative action [56, 57];
- a conceptual investigation of transparency;
- conceptual investigations into the relationship between system bias and perceptions of bias;
- participating in the iterative design of the Technical Documentation to address these goals;
- contributing to the design and execution of an evaluation of the Technical Documentation with urban planners;
- contributing to discussions of representativeness and freedom from bias as they pertain to organizations represented in the Indicator Perspectives Framework;

- identifying indicators that correspond to the platforms of the first three Indicator Perspectives organizations;
- providing other technical support for Indicator Perspectives;
- and contributing to the design and execution of an evaluation of the Indicator Perspectives and Technical Documentation with Seattle citizens.

I led the development of Household Indicators. My contributions here include

- conceptual investigations of democratic engagement and theories of democracy;
- the conceptualization of Household Indicators as a means for citizens to get a personalized view of simulation results;
- iterative design of Household Indicators, including the development of paper prototypes, an HTML mockup, and a prototype implementation, informed by an initial series of interviews, a small user study, design critiques, and a series of focus groups;
- and the design of a summative evaluation study.

7.2 Lessons Learned

We believe the research reported in this dissertation represents a successful application of Value Sensitive Design theory and methodology to the problem of informing public deliberation using sophisticated computer models. In this section we reflect on the lessons learned thus far and their broader implications.

First, the distinction between explicitly supported values and stakeholder values has held up well throughout our research. Because explicitly supported values are subject to a principled analysis of arguments for their inclusion, this distinction provides a strong response to the concern that the system simply reflects the personal values of the designers. We recommend making this same distinction in the conceptual analysis in other domains that feature multiple stakeholders with strongly held, divergent values.

Second, the identification of legitimation potential as an instrumental value has allowed us to draw on the rich theoretical work of Jürgen Habermas as well as that of some of his critics, and provided a useful way to reconceptualize the organization of some of our original explicitly supported instrumental values. Habermas's theory of communicative action in turn leads to a set of testable design goals (comprehensibility, accuracy, transparency, relevance, and freedom from bias). For UrbanSim, legitimation potential is in support of the moral value of fostering a democratic society, but an analogous move could be made in other domains in which the legitimacy of the use of a system may be in question.

Third, for complex systems such as UrbanSim, minimizing information fragmentation and providing ready-to-hand documentation can go some distance toward the goals of comprehensibility, transparency, and relevance. Specific techniques that we used, and that could be gainfully employed in other contexts, include live code and tests (integrated with the documentation), as well as integrated discussion of limitations and how to interpret results.

Fourth, to address the tension between possible perceptions of bias on the one hand, and value advocacy and engaging citizens in the democratic process on the other, we provide both relatively neutral technical information and also a diverse spectrum of advocacy positions, distinct but interlinked. As discussed earlier, work on the Indicator Perspectives is in prototype form. However, we are optimistic that this work will unfold to provide additional lessons for balancing value advocacy with freedom from bias in other contested domains.

Fifth, a goal in our work has been to design tools for interacting with UrbanSim output data that enable indirect stakeholders to become direct stakeholders. The development of Indicator Perspectives and Household Indicators represents a significant step in this direction, as they provide opportunities for engaged citizens and members of interest groups to interact directly with UrbanSim results. Providing access to the range of stakeholders supports our goal of democratizing UrbanSim's use and would support this goal in other democratic decision contexts where today only experts can access information systems. Expanding the group of direct stakeholders may also serve to enhance other values, for instance in supporting privacy and accountability by allowing patients or consumers to learn who has accessed records about them.

Sixth, Household Indicators provide a novel personalized view on simulation results intended to inform public decision making. Although not yet verified through a summative evaluation, findings in formative evaluations suggest that Household Indicators have the potential to enhance citizen engagement in the decision making process, comprehension of simulation results and model concepts, and transparency of the models themselves. Designers of other information systems to inform public decision making—for example, projections of the impacts of new tax laws—should consider incorporating personalized views to serve these ends.

Finally, the development of Household Indicators has thrown into sharp relief the gap between abstractions used in UrbanSim and the ordinary conceptions used by citizens who are not urban planning experts (e.g., between "residential units" and single-family houses, condos, apartments, and other types of housing). In order to ask questions such as, "Where can I afford to live in the region?" these concepts must be brought into greater alignment by developing model abstractions that account for more of the factors that people take into account in their personal choices such as where to live. At the same time, we must pay attention to the language used and strike a balance between presenting information in terms that are immediately comprehensible (but perhaps less accurate) and alerting stakeholders to differences between their concepts and those used in the model.

7.3 Future Directions

Continued Value Sensitive Design of interactions with UrbanSim indicators and tools to engage citizens in the use of UrbanSim for regional planning is a rich domain for future work. In addition to further work on each of the system components discussed in the proceeding chapters, work remains in integrating these components and developing "front door" interfaces for stakeholders with different roles in the use of UrbanSim (regional planners, municipal planners, interest groups, citizens, and so forth). Future work on enhancing the comprehensibility and transparency of the system, discussed below, will impact the development of all three of the tools discussed here as well as future tools for interacting with indicators. Enhancing opportunities for democratic engagement in the use of UrbanSim to inform deliberation could take many different directions as well. Finally, I look forward to the deployment of UrbanSim in an operational context and the new possibilities for evaluation this will provide.

7.3.1 Value Sensitive Design and Agile Programming

With respect to future work on methodology, I briefly consider the relationship between agile programming and Value Sensitive Design.

In earlier design efforts, we faced the problem of combining user-centered design and agile programming. While user-centered design is often regarded as decoupled from the software development process [111], McInerney and Maurer [80] report positively on their experiences with incorporating user-centered design in an agile programming methodology and recommend adjustments to user-centered design methods to fit in this process. Moving forward to current work on the UrbanSim project, agile programming methodologies clearly help us to support our explicitly supported values. But how can the iterative and integrative Value Sensitive Design methodology better mesh with agile programming? Furthermore, previous work has looked at prototype fidelity in relation to usability testing and shown that, for discovering some kinds of usability issues, low-fidelity prototypes are as effective as high fidelity prototypes [125, 135]. Inspired by work using prototype of different fidelity in the Household Indicators project, future work should systematically address the question of how low- and high-fidelity prototypes can be used strategically to uncover or assess different types of value issues.

7.3.2 Comprehensibility and Transparency

Most immediately, we face the problem of improving comprehensibility and transparency for the range of stakeholders—notably, those who have no particular urban planning expertise. To paraphrase Ben Shneiderman [116], we must bridge the gap between what users already know about cities, urban planning, and simulations and what they need to know to use UrbanSim results to inform deliberation. The development of Indicator Perspectives and Household Indicators are a significant step in this direction. But work remains in developing accessible, jargon-free explanations that are nonetheless accurate representations of model concepts and operation, and making these explanations ready-to-hand. The GovStat project's Statistical Interactive Glossary [78], which includes context-specific information presented through text, graphics, and animations may provide some guidance here. A challenge faced by both GovStat and UrbanSim is to present layered explanations that give just enough information when it is needed [78]; a further challenge for UrbanSim is to continue to keep more technical information accessible and visible in support of transparency.

Explanations of model's *causal* behaviors are related to explanations of what the model is, but are clearly distinct. When viewing simulation results, a natural question for experts and laypeople alike is, "Why did that happen?" Today, experts can test hypotheses about causal relationships by simulating variations on the scenario in question. But if the model could explain its own behavior, this would clearly enhance the transparency of the system. Work in this direction may build on Johnson and Johnson's theoretical treatment of explanation in interactive systems [67] and development and evaluation of explanation interfaces for a recommender system [61], a programming environment [73], and a word processor [84]. As with the recommender system [61], UrbanSim output is the result of a confluence of many individual actors in the system. Unlike any of these systems, UrbanSim is a stochastic simulation rather than a deterministic computation of inputs based on outputs. This will pose additional challenges in developing explanations.

Finally, current work on the UrbanSim project will provide information about the uncertainty of simulation results [113]. UrbanSim, like most simulation models, currently provides point results that do not reflect the uncertainty of simulation outcomes due to uncertainty in the input and stochasticity. Without information about uncertainty, it is much more difficult for stakeholders to make good judgments about how much confidence to have in the simulation results. Given that this ongoing work is successful, how can we present data about uncertainty in simulation results in such a way that it can effectively inform these judgments? A particular challenge is that people often find it difficult to take information about uncertainty into account in their reasoning [51].

7.3.3 Democratic Engagement

We have barely begun to explore the opportunities for enhancing public deliberation through the development of online tools that connect users together. Possible topics for online discussion tools include

- discussions of particular indicator results in the context of a decision;
- broader discussions of the set of indicators and concerns that are missing;
- discourse on confidence in UrbanSim results based on their accuracy and uncertainty;
- discussion about particular Indicator Perspectives;
- discussions that speak across the Indicator Perspectives, enhancing exposure to differing points of view;
- discussions based in particular neighborhoods;
- and discussion about the personal impacts of different alternatives, building on the Household Indicators.

The challenge is to build these tools in such a way that they enhance deliberation by fostering reciprocity and exposure to differing views, rather than "in-group" discussions and unanswered declarations of personal opinions [137]. We also face the problem of the digital divide and the challenge of integrating this deliberation into public discourse in other venues. To address this, we should explore the use of the indicator tools to inform face-to-face deliberation.

In addition to providing new opportunities for public deliberation on simulation results, we wish to open the process of proposing and selecting scenarios to simulate. We plan to develop a tool called U-Build-It, inspired by games such as the Seattle Times' You Build It [122]. This Seattle Times feature lets users select from a menu of transportation and funding policy alternatives. The success of a plan is evaluated based on whether it results in a balanced budget. UrbanSim's U-Build-It will also let users select from a menu of policy alternatives. But, we can run UrbanSim to simulate possible outcomes of the plan. Rather than just evaluating whether the budget is balanced, users can evaluate possible outcomes in light of the full range of UrbanSim indicators.

We envision U-Build-It as a tool for education, exploration of alternatives, and democratic engagement. In addition to trying out their own policy ideas, users could find out what other people have been trying. Tools for ranking and discussing different plans would provide opportunities for engagement with other citizens. However, U-Build-It raises concerns with respect to human values. For example, who decides what alternatives are on the menu? If some strategy is not represented, such as Bus Rapid Transit or providing bicycle facilities, it may not be considered on equal footing with other strategies. Furthermore, how can we allocate scarce computational resources among simulations of different scenarios? While popular scenarios should be considered, what about those that are less popular but address gaps in the space of previously explored possibilities, or morally significant concerns?

Finally, in this early stage of our work on democratizing the use of UrbanSim, we have limited the scope of the project thus far to focus on those citizens who are already politically engaged Internet users. Addressing the digital divide in its entirety is clearly beyond the scope of this work, and efforts to increase access to UrbanSim tools may be most successful when they are supported by broader efforts to address the digital divide. One possible future direction is to provide access to UrbanSim tools at public kiosks in science museums, neighborhood centers, senior centers, libraries, or other public places. Public kiosks seem most likely to be helpful in situations where potential users are seeking non-goal-directed learning experiences (as in a museum) or where potential users are in the habit of using online tools with the support of trained staff (as in a library or senior center). Another approach is to provide for mediated access to UrbanSim results, in which trained facilitators help small groups of citizens to learn about their concerns using web-based tools. This approach would also provide the opportunity for face-to-face deliberation among small groups of citizens.

As the design work presented here matures towards operational use, ensuring access to people with disabilities also merits greater attention in the interest of supporting fairness and democracy.

7.3.4 Use and Evaluation in an Operational Context

Finally, we look forward to UrbanSim's operational deployment—to its use to inform real decisions—in the Puget Sound region. UrbanSim's use in an operational context will provide new opportunities for the evaluation and use of the tools developed here. One clear direction is to validate the previous summative evaluation of Indicator Perspectives by performing the same lab study again—but this time with a real decision context, rather than a hypothetical one. Participants will bring their own knowledge and opinions about the decision to the study and can give genuine rather than hypothetical responses regarding their attitudes and behaviors.

Furthermore, of the three tools presented in this dissertation, only the Household Indicators prototype incorporates actual UrbanSim results for a range of scenarios, rather than just information *about* UrbanSim indicators divorced from the context of any particular decision. Even the Household Indicators prototype uses data from unrealistic "sledgehammer runs" intended to diagnose the system, not from simulations of real planning alternatives. Evaluation in an operational context will let us further study how stakeholders use the three tools in trying to make sense of UrbanSim results to inform their opinions and decisions, as well as how their views of these tools might change in this more concrete context.

Beyond this, we will no longer be limited to laboratory studies of tools for interacting with UrbanSim indicators, but can go out in the field of actual use. One direction would be to conduct a web-based survey of citizens who use the online indicator tools, with questions based on those in previous studies, to validate these results with a broader population. We could also solicit volunteers through the web tools to participate in interviews about their use of the tools. In so doing, we can learn about how the participants have used what they learned and what actions they have taken—rather than just asking them to speculate on their future behaviors. As well as interviewing citizens, we can observe how UrbanSim indicator data is used in public meetings, media coverage, and so forth, and interview urban planners and other stakeholders serving in a public capacity about their use of the tools. If online discussion tools are developed prior to operational deployment, we can study what kinds of discussion take place and how the tools serve democratic engagement and public deliberation. Furthermore, there is an opportunity to experiment with using indicator tools to inform face-to-face deliberation about planning decisions among small groups of friends and family, or in public meetings. An intriguing idea is to use UrbanSim results to inform deliberative polling, in which randomly selected citizens come together to engage in informed deliberation on a particular issue [29].

Finally, building on our identification of testable design goals in support of UrbanSim's legitimacy, in an operational context we can begin to speak with the range of stakeholders—not only urban planners at regional planning agencies, but also municipal, state, and federal officials, elected representatives, members of interest groups, and engaged citizens—about how they see the legitimacy of UrbanSim's use in decision making, and how the design of UrbanSim contributes or detracts.

In summary, deployment of UrbanSim in an operational context will both enhance our ability to accurately evaluate the indicator tools in a laboratory setting, and provide new opportunities to learn about how the tools support our explicitly supported values in a real context of use. Further deployments beyond the first will provide valuable opportunities to triangulate our findings.

7.4 Concluding Remarks

In conclusion, I have presented the results of three different explorations into informing public deliberation about controversial decisions with results from sophisticated simulation systems. I believe that the lessons learned so far can be valuable in other domains involving decision making by multiple stakeholders with strongly held, divergent views. Continuing the development of UrbanSim with the Value Sensitive Design methodology will both help make UrbanSim a better tool and provide further lessons for the application of Value Sensitive Design in similar contexts.

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VITA

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