

# **Towards an Urban Sustainability Assessment Framework: Supporting Public Deliberation around Sustainability of Specific Contexts**

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## Abstract

Few cities in the world have the appropriate models, tools and skills required to translate broad commitments to urban ecological sustainability into practical policies, programs and projects. Many cities are compelled to act in the absence of rigorous analysis and modelling to provide a better evidence base of how their environments behave at present, let alone following planned interventions. A number of computer-based urban simulation models are being employed to forecast and evaluate land use change (Landis & Zhang, 1998a, 1998b; Batty, *et al.*, 1999; Batty, 2003; Wegener *et al.*, 2002; Benenson & Torrens, 2004, 2005; Waddell, 2000, 2002, 2004 & 2006). These models represent a spatial and dynamic approach that enables planners to view and analyse the future outcomes of current decisions and policies before they are put in action.

However, there remain several challenges. Modelling efforts have proceeded separately and disciplinary approaches have not adequately addressed the processes and variables that couple human and ecological systems and there exists a gap between most stakeholders and urban planners and the modellers who develop, operate and interpret these models.

In response, this empirical research aims to develop an urban sustainability assessment framework which integrates (1) a process approach in the form of a multidisciplinary participatory process (involving local and expert knowledge) and (2) an analytical approach in the form of a computer-based urban simulation system. To develop this approach to sustainability assessment, we are proposing to adopt a methodology of collaborative *design, adaptation and evaluation* (an adapted form of action research). To date, the study involved the search for an operational computer based urban simulation system and an appropriate participatory integrated assessment methodology. Hence the Open Platform for Urban Simulation (OPUS) and UrbanSim of Paul Waddell and the Integrated Sustainability Assessment (ISA) process of Rotmans & Weaver (2006) were selected. The following stage of the study will involve the design and

development of an urban simulation system prototype. Once a prototype has been developed, the final stage will involve the implementation and evaluation of the urban simulation system in combination with the participatory sustainability assessment process of Rotmans & Weaver (2006), as part of a case study.

## **Introduction**

Decisions regarding urban infrastructure investments or changes in urban land use policies have significant and long-term economic, social and environmental consequences. Within city boundaries, authorities are applying a combination of different planning strategies to guide development in ways that reduce environmental impacts and insure quality of life of all its citizens. While these planning strategies provide a starting point to plan for future land use and infrastructure provision, the strategies themselves do not necessarily result in sustainable development.

Firstly, planning strategies tend to be based on neat vision of future urban structure, characterised by limited suburban expansion, a strong multi-nuclear structure with high density housing around activity centres and transport corridors, and infill and densification throughout the current inner and middle suburbs. The aim is that residents should live closer to their work and in smaller, more environmentally friendly houses. Forster, (2006) questions the likelihood of this scenario, given what recent research has revealed about the changing structure of Australian cities (O'Conner, 2004, Searle, 2004a, Buxton & Tierman, 2005). According to Forster (2006) there are two key concerns about the direction of current planning practice. The first concern is the continued adherence to the concept of neatly structured suburban development organised around centres. The hope is that such a structure, together with higher residential densities, will deliver lower levels of dependence on the automobile and therefore greater environmental sustainability. One response to the unsustainable nature of cities has been urban consolidation. In Australia, this movement has been widely embraced with city planners, developers and policymakers increasingly adopting and responding to policies that support a more "compact city" in order to achieve a more sustainable outcome. According to Troy (2004, p9) there is little evidence that suggests that higher density housing reduces demand for and therefore investment in infrastructure, leads to increased public transport usage or reduces environmental stresses. Secondly, urban planning may recognise the issues of housing affordability and social exclusion, but they fall short of addressing those

issues in a convincing manner. Overall, urban planning strategies suggest an inflexible, over-neat picture of the future that, however well-intended, sits dangerously at odds with the picture of increasing urban complexity that emerges clearly from recent research on the changing internal structure of cities (Batty, 2007).

These are important decisions that will affect cities for many years to come. Thus, one major theme of planning practice is informing decision-making with the results from computer simulations, to help planners and decision makers understand the long-term consequences of different choices. The idea that computer models of urban land use and transportation might contribute to rational urban planning was born in the 1950s and culminated in the 1960s. Early urban models were thought to be a technological breakthrough that would revolutionise the practice of urban policy making (Harris 1965). However, the diffusion of urban models faltered soon after the pioneering phase, for a variety of reasons, though urban models have continued to be used (see Lee, 1974, 1984, Batty 1994; Harris 1994 for a broad account of this history).

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 be made by popular vote, or by representative government bodies, accountable to the people. Unfortunately, the norm in practice is that few stakeholders are aware of the decision making process and fewer still have access to the information. There exists a gap between most stakeholders and the urban planners and modellers who develop, operate and interpret these models. Thus, a second theme in planning practice is to increase stakeholder participation in the process of conducting urban simulations. This demands a new approach to applying operational urban simulation models. Such an approach has to take into account that urban simulation models should be part of a dialogue between science and society. This idea must be reflected in the whole process of model building, design and application.

Our research aims to develop an Urban Sustainability Assessment Framework to evaluate the consequences of urban policies, such as urban compaction, on urban sustainability. The framework represents an approach to sustainability assessment by integrating an urban simulation system with participatory integrated assessment (PIA). Within this framework, stakeholders are interacting with one another and with the urban simulation system in a structured and decision-orientated setting. The framework may be used to explain the decisions of various stakeholders and show the implications of these decisions on the environment and for other stakeholders. Moreover, the framework may be used to investigate stakeholder environment interaction by simulating changing perspectives and behaviour in response to urban change. Using the latest advances in Agent Based Modelling (ABM) techniques, it will allow for the systematic analysis of the relationships and dependencies between the social, economic and ecological developments. An agent-based modelling (ABM) approach is especially relevant in combination with participatory methods. Stakeholders may be involved in the system design to ensure that the system captures the issues of relevance and the subjective stakeholder perceptions.

This initial paper outlines the research program for this approach to sustainability assessment. The paper starts off with a historical overview of the role of computer models in support of urban planning. The concepts of sustainability and assessment are then explored. The paper concludes with a conceptual framework and program of research. Subsequent papers will provide an analytical account of the empirical findings, robustness and implications of actually employing this approach to sustainability assessment.

## **Computer Model Support for Urban Planning**

In his book *Self-Organization and the City*, Juval Portugali (2000) describes how, in the past sixty years, our conceptualisation of cities has shifted from a portrayal as isolated, stable and transparent systems, into open, self-organising and complex systems. To use the words of Portugali: *"Cities are chaotic and*

*unpredictable and they self-organise themselves independently of our scientific predictions and planning rules. All that is left for us to do, as scientists and planners, is to sit and watch, or at best become participants in this huge self-organising process"* (Portugali, 2000, p46). But is the role of the planner really limited to observing and participating? Perhaps it is not so much the role of the planner that needs to be reconsidered, but rather the tools that a planner relies on to articulate results?

In this regard, Batty (2006) proposes reliance on simulation models, not as reproductions of physical systems (as in a scale model), but as artificial worlds that exhibit self-organizing features similar to those observed in real life. A simulation model is not an objective expert, generating indisputable solutions, but is just another decision support tool, engendering and structuring discussion and debate, or as Resnick (1994, p50) has pointed out: *"The goal is not to simulate particular systems and processes in the world. The goal is to probe, challenge, and disrupt the way people think about systems and processes in general."* As such simulation models invite the planner to again take up a central role in the planning process, and grow from being a mere spectator into a mediator, who no longer only observes or simply takes part, but actually becomes able to steer urban development processes in a particular direction.

Urban simulation reflects a tradition of research in computer support for urban planning extending back to the 1960s. The modern era of urban modelling began in the 1960s with the intentionally simple and experimentally calibrated models of land-use dynamics (Chapin & Weiss, 1962, 1968, Lowry, 1964). Towards the 1970s, developments in the field bifurcated: some of the modellers proceeded with the pragmatic view of urban systems (Steinitz & Rogers 1970; Tobler 1970), while others (Forrester 1969) followed the complex system theory paradigm. During the 1970s, complex system theory took over, and urban models of the 1970s and 80s were almost exclusively based on the view of the city as a set of regions represented by *"stocks"* of population groups, jobs, goods, and connected by *"flows"* of these materials. In his *"Requiem for Large-Scale Models"*, Lee (1973) noted the widening discrepancy between the models and the changing planning context and was not surprised that the models failed to respond to

the new developments, because they "*symbolised the last offensive of the technocratic, hyper-comprehensive mode of planning*" (Lee, 1973, p172).

Nevertheless, more than 30 years have passed since Lee's damning critique. Extraordinary progress has since been made in computational capabilities, modelling methodology, empirical and theoretical understanding of spatial processes, and data resources to support modelling activities. Planners and decision-makers have returned to these approaches to inform complex strategic planning questions.

We can now make a few distinctions amongst the types of technologies used in urban planning, to clarify our research. Firstly, during the last two decades, spatial analysis tools, Geographic Information System (GIS) and Remote Sensing (RS) technologies have been widely deployed to monitor, analyse and visualise urban growth phenomena (Masser, 2001; Jantz, *et al.*, 2003; Jiang, *et al.*, 2003; Miller & Small, 2003). However, maps and satellite images are limited to static displays of past and current data sets. They portray the current state of the system, with neither reasonable, nor possible futures. Recently, computer-based urban simulation models are being employed to forecast and evaluate land use change (Landis & Zhang, 1998a, 1998b; Batty, *et al.*, 1999; Batty, 2003; Wegener *et al.*, 2002; Benenson & Torrens, 2004, 2005; Waddell, 2000, 2002, 2004 & 2006). These models represent a spatial and dynamic approach that enables planners to view and analyse the future outcomes of current decisions and policies before they are put in action. These models have the ability to help improve our understanding of the dynamics of land use transformation and the complex interactions between urban change and sustainable systems. These spatial dynamic modelling techniques are becoming essential tools in the Planning Support System (PSS) literature (Klosterman, 2001, Geertman & Stillwell, 2003). However, to date, spatial dynamic urban modelling is still in its infancy. Few models have been built that are able to represent the complex dynamics of urban land use change that are consistent with observable data (Timmermans, 2003). As a result, few such models are operational and used to assist urban planning practices.

Secondly, models in urban planning may be either theoretical or operational (Waddell & Ulfarsson, 2004; Wegener, 1994). 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. The Urban Sustainability Assessment Model is intended primarily as an operational model, though it may also have uses in education and theory-building.

Thirdly, we wish to distinguish operational urban models from tools for sketch planning. Sketch planning is intended to support the rapid exploration of many different alternatives; a key feature is the suppression of detail (Harris, 2001). Because of its complexity and long running time, operational urban models are not well suited to sketch planning. Sketch planning tools can be used to compare many alternative visions of future development, but cannot predict the effectiveness of enacting particular urban policies today for achieving those visions in the future. Operational urban model use is complementary to sketch planning in that it can inform more accurate assessments once a relatively small number of alternatives have been selected for further consideration.

Finally, although visualisation and simulation are distinct domains, visualisation is important to understanding the results of simulations. Visualisations of model results in use today take the form of maps, tables, charts, and statistical graphics. The primary aim of the research is not to provide detailed, realistic visual representations of urban environments through three-dimensional modelling or illustration. Rather, our research will attempt to provide more abstract representations similar to those of geographical information systems (Langendorf, 2001). The focus of the research is not the development of sophisticated new visualisations of simulation results, but rather accounting for an improved understanding of the relationships and interdependencies between model results.

## Sustainability Assessment

An essential starting point for the research is the concept of sustainability and its definition. The definition of sustainability is central to the overall endeavour of assessment: sustainability assessment is, fundamentally, a *"sustainability defining and applying process"* (Varey, 2004, p8) Sustainable development is a (socially and scientifically) contested notion, because it is inherently complex, normative, subjective and ambiguous (Rotmans & van Asselt, 1999). The most cited definition is the one given in the Brundtland report (WCED, 1987): *"Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs"*.

There are, nonetheless, a number of commonalities, upon which the notion of sustainable development can be implemented in practice. These commonalities include that it is an intergenerational phenomenon, that it operates at multiple scale levels and requires trade-offs to be made between the social-cultural, economic and ecological dimensions. (Grosskurth and Rotmans, 2005). Sustainable development is the co-evolution of human and natural systems. For instance, in order to assess the sustainability of a city, we must first identify the different relevant sectors or subsystems of the societal system. This implies, including systems that constitute society as well as the systems on which human society depends. Bossel (1998, 1999) provides a useful distinction of these subsystems (Figure. 1).

"Insert Figure 1 here"

Waddell (2000) goes further and provides a framework through which a particular urban element can be assessed in terms of a sustainability balance: the balance of stocks and flows as influenced by households, businesses and developers (Figure 2).

"Insert Figure 2 here"

Sustainable development is about trade-offs (Kemp, Parto & Gibson, 2005). Trade-offs are intrinsic to the concept of sustainability and cannot be avoided. Trade-offs between different domains or dimensions of sustainable development, in particular between the social, economic and ecological dimensions, short and long term impacts, different geographical spaces, and different scales - from global to local. According to Weaver and Rotmans (2007), to implement sustainable development there must be both sustainability criteria and principles for making trade-offs between sustainability values visible and assessable. Lastly, according to Bossel (1999), sustainable development requires systems information. The total system of which human society is a part, and on which it depends for support, is made up of a large number of component systems. The whole cannot function properly and is not viable and sustainable if individual component systems cannot function properly, i.e., if they are not viable and sustainable. Despite the uncertainty of the direction of sustainable development, it is necessary to identify the essential component systems and to define indicators that can provide essential and reliable information about the viability of each and of the total system.

The challenge is to make the tensions between these scale levels and trade-offs explicit and to develop policy strategies to alleviate them. The concept of a sustainable city must therefore be approached more precisely than in the past. We need to specify: (1) what characteristics or variables should be sustainable; (2) whether they should be sustainable in perpetuity or for a shorter period of time; and (3) the extent to which it is desirable for a system or variables to be able to withstand shocks and recover to a level that can be sustained - that is, the extent to which resilience is required. (Tisdell, 1990, Alberti & Marzluff, 2004, Walker *et al.* 2004).

This leads to the definition of Integrated Sustainability Assessment (ISA). *"ISA is a cyclical, participatory process of scoping, experimenting, and learning through which a shared interpretation of sustainability*

*for a specific context is developed and applied in an integrated manner in order to explore solutions to persistent problems of unsustainable development"* (Rotmans, 2006, p12). Rotmans (2007) includes several elements in a sustainability assessment: a system of interest that is characterised by a persistent problem that gives rise to concern and that prompts the need for a prospective policy intervention; the development of a common interpretation of what sustainability is for a given context and what a prospective policy intervention should seek to achieve; indicators and metrics along which these impacts will be measured, a set of required criteria that must be met if a policy proposal is to be considered as sustainable and an overall decision basis for recommending or rejecting a proposal. Finally, the sustainability assessment must include the design and running of appropriate experiments, i.e. ones capable of exploring different scenarios. The use of an appropriate urban simulation model is especially important here where the assessment must include the projected impacts – the advantages and disadvantages – not only of each policy proposal, but also of the *"do-nothing"* or *"business as usual"* options (Rotmans, 2006, p11). Table 1 summarises the key differences between Sustainability Impact Assessment (SIA) and Integrated Sustainability Assessment (ISA).

"Insert Table 1 here"

## **A Conceptual Framework**

This leads to our conceptual framework. The framework (see Figure 3) integrates (1) a process approach in the form of a multidisciplinary participatory process (involving local and expert knowledge) and (2) an analytical approach in the form of a computer-based urban simulation system. The following sections explain in more detail the various parts of this framework.

"Insert Figure 3 here"

## **Assessment Process**

In the search for an appropriate participatory integrated assessment (PIA) process, we looked for a process where the application of tools, such as urban simulation models, plays an integral part to a process of deliberation. In this regard the *Integrated Sustainability Assessment Methodology* by Rotmans & Weaver (2006) was found to be most appropriate. The methodology includes several stages, consisting of *scoping, envisioning, experimentation and evaluation*. The experimentation stage involves the use of models to test sustainability visions and policy proposals in terms of consistency, adequacy, robustness and feasibility. Notably, is the requirement of the process to evaluate different transition pathways (i.e. development of scenarios), in which case the use of an urban simulation system, such as those intended in the study, may play a fundamental role.

## **Assessment Support**

An urban simulation system will be used to perform the sustainability assessment experiments. Moreover, the simulation system will be used to investigate stakeholder environment interaction by simulating changing perspectives and behaviour in response to urban change. The literature reports a large number of agent-based urban simulation model applications, which are known under a variety of different but similar names (agent-based modelling, agent-based social simulation, multi-agent simulation, etc.). In this study, we interpret the term agent-based model as any type of model containing distinct, identifiable entities (called agents) usefully characterised by some cognitive representation (Edmonds & Mohring, 2005). Current agent-based applications can be broadly organised along a continuum between (1) the agent-based models with a simple cognitive representation (*simple agents*) and a high level of interaction and (2) the agent-based models with more detailed agent representations (*cognitive, deliberative agents*), with a smaller focus on interaction processes (Hare & Deadman, 2003). The agent-based modelling approach selected for our study falls into the second group.

We can now also define the types of urban simulation models considered in this study. The first distinction is that the term simulation model is used here to indicate mathematical models implemented on a computer and designed to analyse and forecast the development of urban systems. This excludes qualitative or hermeneutic representations of urban theory irrespective of whether they can be empirically tested. The second distinction is that the simulation model must be comprehensive, i.e. it must integrate the most essential processes of spatial urban development; this implies that it must include at least urban land use and transportation, where land use denotes a range of land uses such as residential, industrial and commercial. This excludes partial models addressing only one urban subsystem such as transportation, housing or retail. Furthermore, the simulation system must be operational in the sense that it has been implemented, calibrated and used for policy analysis for at least one metropolitan region. This excludes models presented only in theoretical terms as a set of equations.

It is not the intension of this research to conduct a review of a representative range of operational urban simulation system packages, but rather use previous reviews as a means to guide the selection process. A reasonable number of urban modelling systems currently exist, in varying degrees of completeness and usability. Hunt, *et al.* (2005), building on the reviews of Wegener (1994), focused on six model systems, assessing them in considerable detail. The six model systems fall into two main categories. The first three are operational, commercially available "packages" with an established history of use (ITLUP, MEPLAN and TRANUS). The second group of three (MUSSA, NYMTC-LUM and UrbanSim) are also currently operational and freely available as part of a modular and extensible open source frameworks. These models provide a good representation of the range of approaches used in current planning practice for comprehensive, integrated urban modelling, where the intent is to simulate or predict the evolution of urban systems over time (and various elements within these systems). However, of the six models, only three are freely available for use (under a General Public License) and of these, only UrbanSim provides enough supporting documentation and tools to support understanding and operation. Hence, the Open Platform for Urban Simulation (OPUS) and UrbanSim (see [www.urbansim.org](http://www.urbansim.org)) were selected for the

process of experimentation, as part of the sustainability assessment process. For key features of OPUS and UrbanSim, refer to table 2.

### **Assessing the Results**

Currently, there are several policy instruments that can potentially be incorporated into the simulation system. However within the scope of this study the focus of the modelling experiments will be on urban consolidation as a major planning policy in Australia. Examples of model results include:

- Distribution at a fine level of detail, the future year projections of dwellings, households and population.
- Levels and patterns of projected growth/change in residential and non-residential buildings that need to be accumulated over the planning period.
- The availability and distribution of land suitable and available for development.
- Areas of potential for urban consolidation to address urban containment.

The results of modelling experiments will be assessed against pre-defined sustainability principles and criteria. Evaluation forms the basis and input for the next sustainability assessment cycle, eventually leading to a possible reframing of the shared problem perception, an adjustment of the sustainability vision and related pathways (scenarios), and reformulation of the experiments to be conducted. The Human-biophysical Conceptual Model of Alberti (2003) is especially relevant here since it has already been applied in a similar context by Alberti and Waddell (2000). Depicted in figure 4, the model identifies forces driving urban development. For example, population growth in an area (driver) leads to increased buildings (patterns), leading to increased runoff (processes), causing lower water quality and decreased fish and wildlife habitat (effects), which may lead to a new policy to regulate land use (driver). We suggest that the model may be useful in structuring sustainability principles and outcome criteria.

"Insert Figure 4 here"

## **Program of Research**

Unlike many other models, our motivation for the research is not accurate forecasting, which is simply not attainable for complex urban systems, but rather to create a platform for learning by modelling as well as exploring and discussing different policy options, scenarios and alternative futures. As an innovative contribution to improve on the way that urban modelling is done, we are proposing to adopt a methodology of collaborative design, adaptation and evaluation (an adapted form of action research). This type of action research was originally undertaken in terms of the Soft Systems Methodology (SSM) developed by Checkland and Scholes (1989) but is now sufficiently well known as a methodology for a range of research and participatory development projects (Rose, 1997). The program of research consists of two stages over a three year period:

### **Stage 1 – Design and adaptation**

The design and adaptation stage will focus on the development of an urban simulation system prototype, by adapting the UrbanSim. UrbanSim is a rapidly evolving operational urban simulation system that has been under development since 1996 by the research team of Paul Waddell at the University of Washington.

A number of characteristics led to the decision to adapt it for this research. First, it is open source and therefore freely available and its code can be changed and adapted by whomever would like to use it. Second, it is disaggregate. Geographically, it operates at the level of gridcells (normally 150 x 150 metres), parcels or zones. With respect to population it operates at the level of individual households and with regard to employment it operates at the level of individual jobs or establishments. Compared to most other urban models that operate at the level of much larger traffic analysis zones (TAZ), this characteristic of UrbanSim allows a much finer-grained approach to urban modelling.

While such fine-grained approach allows for a great deal of flexibility in analysing many aspects of an urban system (e.g. different planning strategies and zoning policies), this does not come without costs. In particular, the data requirements for an operational UrbanSim are large. It is for this reason that a more cautious approach would be followed, consisting of a process of iterative improvement, consisting of three steps, namely familiarisation, experimentation and evaluation.

Within the scope of this study, the intension is to add an Environmental Impact Model which will contain indicators of greenhouse gas emissions from transportation, and have a component that simulates land cover change. Land cover is important in its own right, and is also useful as a factor in producing other environmental indicators, for example, impervious surface affects water runoff characteristics. The Model will also contain air quality and resource consumption indicators. These indicators may end off not currently feeding back into the operation of the other submodels in the simulation system, although adding such feedback is a research topic for the future.

Recognising that for the research to have value, it cannot be done devoid of context or without recognising the multiple identities and (often conflicting) worldviews of researchers, officials and decision-makers within a specific context, the design and adaptation stage will involve focus groups. Group interviews will focus on the conceptual design of the urban simulation system, how it represents the urban system, how it deals with potential drivers influencing development and the results it intends to generate. Results will be coded, analysed and fed back into the design and adaptation process.

The expected outputs of this stage are:

- Conceptual urban system models, describing the urban system, as a social-ecological system, and potential drivers influencing development.
- Urban Sustainability Assessment Process Specification.

- Urban Simulation System Design.
- Urban Simulation System Prototype.
- Results from focus group participation.

## **Stage 2 - Implementation and Evaluation**

Once an urban simulation system prototype has been developed, the next stage will involve the application of the prototype as part of applying the *integrated sustainability assessment (ISA) methodology* of Rotmans & Weaver (2006) for a case study area. Sustainability assessment will focus on urban consolidation as a major planning policy. Model implementation will consider four kinds of potential limits on urban consolidation: (a) infrastructure and land capacity, (b) maximum density (c) demand for open space and (d) market demand. The results will be in the form of a set of spatial narratives to guide infill and redevelopment decisions. The patterns revealed in these narratives will provide conceptual materialisations of various aspects of urban consolidation and their likely consequences. The expected outputs of this stage are:

- Final Urban Simulation System.
- Results of scenario testing.
- Results from case study focus group participation.

## **Significance of the Research**

The research is intended to contribute both to improving the technical modelling capacity as well as improving the process of applying urban simulation models in a democratic decision making context.

## **Research Limitations**

### **Familiarity with UrbanSim**

Despite the amount of literature on UrbanSim and a reputation for heavy data requirements, there has been relatively little research that evaluates the difficulty of using Urban Models, such as UrbanSim. The literature tends to concentrate on the efforts required for a fully developed, operational model. Little guidance exists on the minimum requirements and steps involved in getting a basic version of the UrbanSim running. In response, research time and effort will have to be conveyed to get familiar with the overall architecture, basic functionality and data requirements of UrbanSim, before any sort of amendments or additions could be made.

### **Dealing with uncertainty**

Predicting the future is a risky business. There are numerous, complex, and interacting sources of uncertainty in urban simulations of the sort we are considering in this research, including uncertainty regarding exogenous data, the model structure and specification, the parameters of the model, and from the stochastic nature of the simulation. Ideally, we should represent the uncertainty in our research conclusions as far as possible, both for truthfulness and as important considerations for future research.

### **Comprehensiveness of the Model**

We do recognise that there may be a need to increase the comprehensiveness of the Model to include other actors and processes in the urban environment. For example, for households, we might model additional demographic processes or for environmental impacts, we might model consumption of additional kinds of resources. There are important pitfalls and tensions associated with the level of increasing the comprehensiveness of models: namely what Lee (1973) called the problem of hyper-comprehensiveness. Among the pitfalls of overly ambitious modelling are increasing model complexity, additional data requirements, and in some cases the credibility of the overall modelling effort.

## **Conclusion**

Substantial progress has been made in urban modelling in support of urban planning. Nonetheless, the community of urban modelling practitioners and developers are, at best, in the early stages of this development and there are many conceptual, technical and implementation challenges ahead if these models are to fulfil their potential as key tools in support of urban policy making for sustainable development. There is a need to develop and explore new, innovative tools, enhance current operational urban system models and develop indicators, and learn how to combine these effectively. There is a need to explore the role of sustainability assessment and its contribution to social learning at the science-policy-society interface. Exploring the potential of sustainability assessment and how best this might be captured therefore defines a very rich field for applied research. Through such exploration, our overall objective within the research project is to deliver a new approach to assess the sustainability of specific contexts that will enable a wide variety of stakeholders to explore the potential consequences of alternative urban policies and investments using credible, unbiased analysis, thereby facilitating a more effective democratic deliberation on contentious policies such as urban compaction.

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**Table 1 Comparison of sustainability impact assessment and integrated sustainability assessment**

	<b>Sustainability Impact Assessment (SIA)</b>	<b>Integrated Sustainability Assessment (ISA)</b>
<b>Paradigm</b>	<ul style="list-style-type: none"> <li>▪ Incremental</li> </ul>	<ul style="list-style-type: none"> <li>▪ Transition</li> </ul>
<b>Scope</b>	<ul style="list-style-type: none"> <li>▪ Narrow problem formulation</li> </ul>	<ul style="list-style-type: none"> <li>▪ Broader systems view</li> </ul>
<b>Scale</b>	<ul style="list-style-type: none"> <li>▪ Single level</li> </ul>	<ul style="list-style-type: none"> <li>▪ Multi-level</li> </ul>
<b>Stakeholder</b>	<ul style="list-style-type: none"> <li>▪ Management</li> </ul>	<ul style="list-style-type: none"> <li>▪ Local &amp; expert knowledge</li> </ul>
<b>Goals / Constraints</b>	<ul style="list-style-type: none"> <li>▪ Given</li> </ul>	<ul style="list-style-type: none"> <li>▪ Searching, explorative</li> </ul>
<b>Object</b>	<ul style="list-style-type: none"> <li>▪ Partial</li> </ul>	<ul style="list-style-type: none"> <li>▪ Holistic</li> </ul>
<b>Learning</b>	<ul style="list-style-type: none"> <li>▪ Cognitive / Once-off assessment</li> </ul>	<ul style="list-style-type: none"> <li>▪ Social learning / iterative</li> </ul>
<b>Power</b>	<ul style="list-style-type: none"> <li>▪ Structural</li> </ul>	<ul style="list-style-type: none"> <li>▪ Innovative / empowering</li> </ul>

Source: Adapted from Weaver and Jordan (2006, p3)

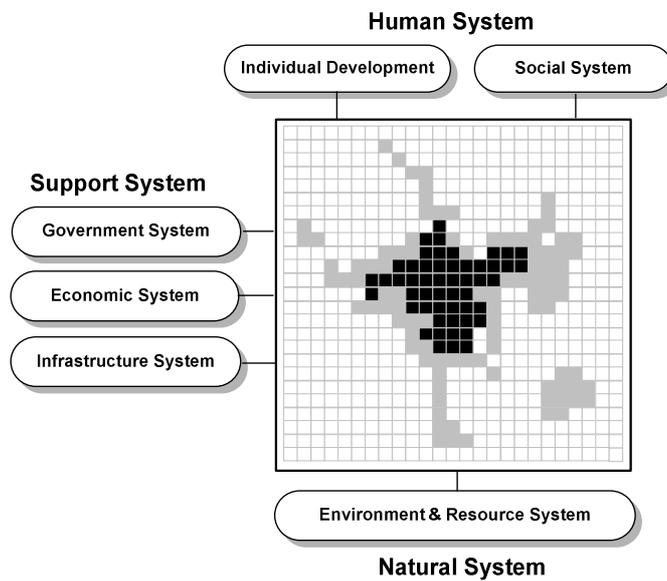
**Table 2 Key Features of OPUS and UrbanSim**

In 2005, the Centre for Urban Simulation and Policy Analysis at the University of Washington began a project to re-engineer UrbanSim as a more general software platform to support integrated modelling, and has launched an international collaboration to use and further develop the Open Platform for Urban Simulation (Opus). The broad vision for the effort is to develop a robust, modular and extensible open source framework and process for developing and using model components and integrated model systems, and to facilitate increased collaboration among developers and users in the evolution of the platform and its applications.

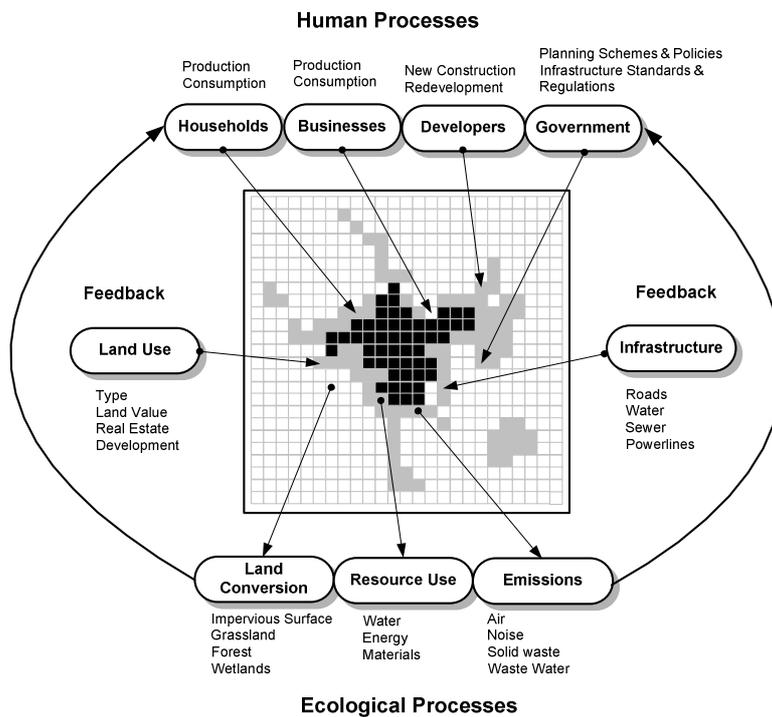
<b>Open Platform for Urban Simulation (OPUS)</b>	<ul style="list-style-type: none"> <li>▪ <i>Graphical User Interface (GUI)</i> - From the 4.2 release of OPUS, a flexible, cross-platform user interface has been added that organizes the functionality in OPUS into conveniently accessible tabs oriented towards the workflow of developing and using models.</li> <li>▪ <i>Python as the Base Language</i> - One of the most important parts in the system is the choice of programming language on which to build. Python's ability to work well for quick experiments, access high-performance libraries, and script other applications means that modellers need only learn one language for these tasks. Opus extends the abstractions available in Python with domain-specific abstractions useful for urban modellers, as described below.</li> <li>▪ <i>Integrated Model Estimation and Application</i> - Model application software in the land use and transportation domain has generally been written to apply a model, provided a set of inputs that include the initial data and the model coefficients. The process of generating model coefficients is generally handled by a separate process, generally using commercial econometric software. Opus designates a single repository for model specification, by incorporating parameter estimation as an explicit step in implementing a model, and by providing well-integrated packages to estimate model parameters.</li> <li>▪ <i>Data Base Management, GIS and Visualisation</i> - The extensive use of spatial data as the common element within and between models, and the need for spatial computations and visualisation, make clear that the Opus platform requires access to these functions. Database management and GIS functionality are accessed by coupling with existing Open Source database servers such as MySQL (<a href="http://www.mysql.org">www.mysql.org</a>) and Postgres (<a href="http://www.postgresql.org">www.postgresql.org</a>), and GIS libraries such as QuantumGIS. An interface to the ESRI ArcGIS system has been implemented and is</li> </ul>
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	<p>being refined.</p> <ul style="list-style-type: none"> <li>▪ <i>Documentation, Examples and Tests</i> - Documentation, examples and tests are three important ways to help users understand what a package can do, and how to use the package. Documentation, examples and tests are available locally with an installation, or can be accessed at any time from the UrbanSim web site.</li> <li>▪ <i>Open Source License</i> - Opus has been released under the GNU General Public License (GPL). GPL is a standard license used for Open Source software. It allows users to obtain the source code as well as executables, to make modifications as desired, and to redistribute the original or modified code, provided that the distributed code also carries the same license as the original.</li> <li>▪ <i>Test, Build and Release Processes</i> - Any software project involving more than one developer requires some infrastructure to coordinate development activities, and infrastructure is needed to test software in order to reduce the likelihood of software bugs, and a release process is needed to manage the packaging of the system for access by users. For each module written in Opus, unit tests are written that validate the functioning of the module. A testing program has also been implemented that runs all the tests in all the modules within Opus as a single batch process.</li> </ul>
<p><b>UrbanSim Model System</b></p>	<ul style="list-style-type: none"> <li>▪ The model simulates the key decision makers and choices impacting urban development; in particular, the mobility and location choices of households and businesses, and the development choices of developers.</li> <li>▪ The model explicitly accounts for land, structures (houses and commercial buildings), and occupants (households and businesses).</li> <li>▪ The model simulates urban development as a dynamic process over time and space, as opposed to a cross-sectional or equilibrium approach.</li> <li>▪ The model simulates the land market as the interaction of demand (locational preferences of businesses and households) and supply (existing vacant space, new construction, and redevelopment), with prices adjusting to clear market.</li> <li>▪ The model incorporates governmental policy assumptions explicitly, and evaluates policy impacts by modelling market responses.</li> <li>▪ The model is based on random utility theory and uses logit models for the implementation of key demand components.</li> <li>▪ The model is designed for high levels of spatial and activity disaggregation, with a zonal system identical to travel model zones.</li> <li>▪ The model presently addresses both new development and redevelopment, using parcel-level detail.</li> </ul>

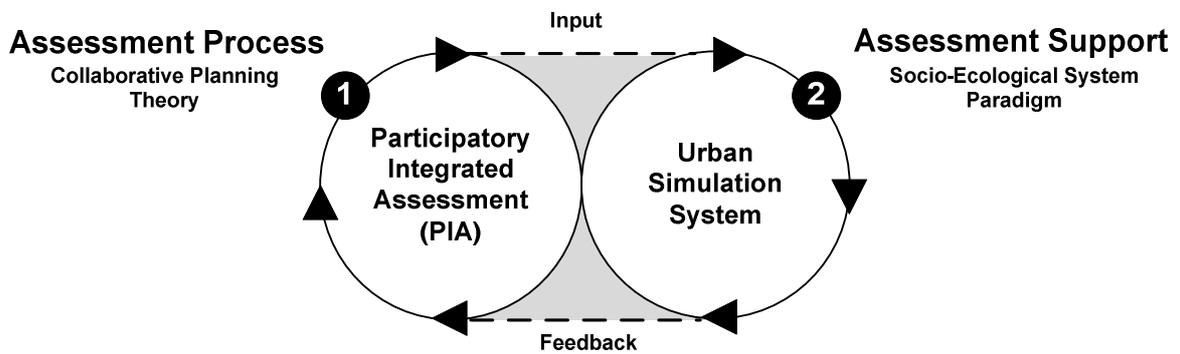
Source: Centre for Urban Simulation and Policy Analysis (2008), University of Washington.



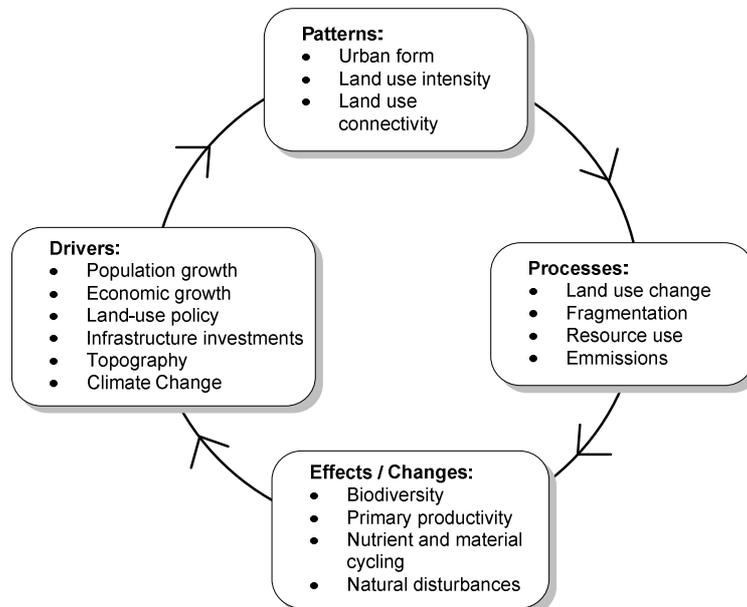
Source: Adapted from Bossel, 1999  
**Figure 1 - Urban Systems**



Source: Adapted from Alberti & Waddell, 2000  
**Figure 2 - Urban Actors and Processes**



**Figure 3 – Conceptual Framework**



Source: Adopted from Alberti *et al.* (2003)

**Figure 4 - Human-biophysical Conceptual Model of Alberti (2003)**