Using an Urban Sustainability Assessment Framework to support Policy-making at a Neighbourhood level

Andre Brits[1], Matthew Burke[1] and Tiebei Li[1]
[1]Urban Research Program, School of Environment, Griffith University

Abstract: Integrated sustainability assessments are being employed by planners to help decision-makers understand the long-term consequences of policy options. This paper describes an urban sustainability assessment framework first presented at SOAC 2011 and explores its use with practitioners on a real-world case study in Logan City, Queensland. The framework includes four stages, namely scoping; visioning; experimenting and assessment and includes the use of system condition indicators, agent-based modelling and multi-criteria assessment. The framework uses formal methods to ensure that system understanding and description, policy design and policy outcome evaluation and assessment are well-coordinated with each other, each deliberatively informing the others as they all co-evolve. The focus of the paper is on how such frameworks may be applied in Australian planning practice, using results from workshops held with Logan practitioners in 2014/15. Key results include how the framework and its outputs are perceived by planning actors. Findings suggest that system analysis, timely identification of stakeholder's interests, the use of appropriate evaluation criteria, communication of modelling results and formal assessment all remain important. Tensions between the perceived rationality of the framework and how it connects with decision-making remain. But perhaps the most significant finding is the use of the framework in framing the integration problem by responding to five integrative functions: descriptive, evaluative, strategic, contextual and mutual.

Introduction

The need for integrated methodological frameworks for sustainability assessment has been widely discussed (Gibson, 2006; Ness *et al*., 2007; Hacking and Guthrie, 2008; Yigitcanlar, *et al*., 2015). Advances in this field are urgently needed to reconfigure urban areas so they consume fewer resources, generate less pollution, and are more resilient to the impacts of extreme events. As centres of population and economic activity, urban areas represent concentrated opportunities for addressing issues of sustainability. However, this involves complex interactions between residents, government and industry that can impede the development of integrated strategies whose combined effects can be more beneficial than when individual organisations take action alone.

Australian research studies within this field appear to employ sophisticated methods for predominantly only one (or occasionally two) assessment functions. For example, some focus on developing an integrated description of the urban problem by developing large-scale computer simulation models (Stimson *et al*., 2012). Others focus on the selection of evaluation criteria, sustainability indicators, or methods for trading off amongst diverse competing criteria in order to evaluate policy options, as in cost-benefit and multi-criteria analysis (Moglia *et al*., 2012; Hezri and Dovers, 2009). Other studies focus on achieving integration of the assessment process itself with the community, achieved mainly by involving stakeholders and resources dedicated to communication (Rosemary *et al*., 2012). There are few holistic studies in Australia that have exploited systematic methods for the design of integrated policy options to achieve urban sustainability outcomes. Still fewer studies use formal methods to coordinate four aspects of an integrated sustainability assessment: (1) system understanding and description, (2) policy design, (3) policy outcome assessment and (4) context (Blair et.al. 2004; Brinsmead, 2005). With good coordination, these aspects may inform one another as they all co-evolve. International studies exhibit more sophisticated integrative methodology. In particular the European integrated assessment community has had several decades of experience in integrated assessment in general and has recently turned its attention to integrated assessment of urban sustainability (Dawson, *et al*., 2014; Rotmans and Weaver, 2006; De Ridder *et al*., 2007; Weaver and Jordan, 2008).

We seek to contribute to this understanding by developing a multi-dimensional assessment framework for Australian planning practice. This program of research was first introduced at SOAC 2009 and progress was reported at SOAC 2011 and 2013 (Brits *et al*., 2009, 2011; Brits, 2013). This paper describes a structured framework and explores its use with practitioners on a real-world case study in Logan City, Queensland. Our proposed 4-stage urban sustainability assessment framework (USAF) is intended to

provide a coherent, deliberative platform where a combination of support tools, such as system condition indicators, conceptual modelling, agent-based modelling and multi-criteria analysis, are used to inform different stages of the assessment process. The framework is designed primarily for city-regions to assess the long term impacts of urban growth management policies at a neighbourhood level.

Sustainability Assessment

Sustainability assessment is often described as a process by which the implications of an initiative on sustainability are evaluated, where the initiative can be a proposed or existing plan, policy, program, project or piece of legislation (Pope, *et al.* 2004). However, sustainability assessment is an evolving concept.

Let's start by clarifying what the term "sustainability assessment" should mean if it is to fulfil its potential as a tool for promoting urban sustainability. Sustainability assessment involves a process whereby assessment tools form the equipment to perform the assessment (Rotmans, 2006). Devuyst *et al.* (2004) define sustainability assessment as a tool that can help decision-makers and policy makers decide which actions they should or should not take in an attempt to make society more sustainable. Ness *et al.* (2007, p499) extends this definition, and states that the purpose of sustainability assessment is "to provide decision-makers with an evaluation of global and local integrated nature-society systems in short and long term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable."

Assessment frameworks are increasingly being used to serve as procedural tools in the sense that they do not carry out a particular kind of analysis, but are procedures designed to connect to a decision-making process and within which a range of participatory and analytical support tools can be applied (Rotmans, 2006; De Ridder *et al.*, 2007, and Ness *et al.,* 2007). One such framework is Integrated Sustainability Assessment (ISA). ISA is defined as "a cyclical, participatory process of scoping, envisioning, 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 and Weaver, 2006, p12). According to Rotmans and Weaver (2006), ISA requires, together with the development of more integrative scientific thinking, a broad scope of modelling activities. Lotze-Campen (2007) argued for more intensive stakeholder involvement in the application of ISA. For the use of sustainability assessment frameworks to increase in urban planning practice it is imperative to examine the kind of methods, tools and conditions for its practical application. What conceptual and methodological foundations need to be taken into account when designing sustainability assessment frameworks?

Methods

To respond to this question, we committed to a program of research that involved practitioners throughout the process of framework development, testing and use. Design-based research (DBR) was used in the study (Wang & Hannafin, 2005). DBR requires interactive collaboration of researchers and practitioners to ensure that the designed innovation (in this case the framework) achieves its goal (Reeves, Herrington & Oliver, 2005). Research and development take place through continuous and iterative cycles of design, enactment, analysis and redesign.

The first cycle focused on the development of a preliminary framework (Brits, et al, 2011) based on key conceptual and theoretical insights drawn from systems theory, integrated assessment, planning support systems and modelling literatures, scoped to the problem of urban sustainability assessments for urban sub-regions of large Australian cities. This preliminary framework was used to inform a series of workshops with a panel of planning practitioners and modellers from Logan City in Queensland, who agreed to assist with aiding the framework's development and reflecting on key aspects of the process over time. One authority only was selected based on the limited resources available to the project and the very large effort required for data gathering, model development, and workshop exercises.

The second cycle involved identifying modelling issues, requirements and adapting UrbanSim for framework implementation (Brits, 2013; Brits et al. (2013). Designed by Paul Waddell of the University of

California, UrbanSim is a rapidly evolving agent-based modelling system that has been under development since 1996 (see Waddell, 2002, 2010; Waddell, *et al*., 2003, 2004, 2006).

This paper reports on the final cycle which involved the implementation of a revised framework for Meadowbrook in Logan City. Importantly, the implementation of the framework involved a comparative assessment of three urban growth policy options (scenarios) for Meadowbrook, exploring issues of urban densification and likely impacts. The focus of this paper is not on these policy options, it is instead on the initial insights of a panel that participated in five workshops, each between one and three hours long, which were held over a period of four months in 2014/15.

Workshop participation was entirely voluntary, and the panel was comprised of ten planning practitioners (five social-, three land use-, one infrastructure- and one environment-orientated) and one land use modeller from one local government, which had varied experience in using assessment frameworks to aid policy development. Preparatory work for the implementation of the framework was undertaken by the lead researcher prior to the start of the review process. The preparatory work involved the development of a series of methodological booklets for each of the stages of the USAF and corresponding implementation reports for Meadowbrook. Participants were requested to study each booklet prior to a workshop event and record aspects that they felt were either unclear, unnecessary or perhaps absent. Four workshop events followed, each focusing on a stage of the framework (e.g. scoping, visioning, experimenting and assessment). Each workshop commenced with an overview of steps involved, followed by a presentation of implementation results for Meadowbrook and recording participant feedback. Informal interviews were conducted after each workshop event to obtain a deeper understanding of the challenges faced when implementing the framework. The case study concluded with a workshop event that asked panel members to reflect on all stages and evaluate the value of the USAF for planning practice.

The 4-Stage Urban Sustainability Assessment Framework

According to Wiek and Binder (2005) assessing the sustainability of city-regions requires a multi-dimensional approach that fulfils the normative, systemic and procedural requirements as elaborated in the technical literature (see Nijkamp and Vreeker, 2000). The study added planning support tools as a fourth dimension.

Guided by the theoretical framework the study adapted Weaver and Rotman's (2006) approach as a basis for design of the urban sustainability assessment framework (USAF). The USAF aimed to advance the state-of-the-art ISA approaches by presenting a coherent platform where a combination of participatory modelling activities form an integral part of the assessment process. With this approach, stakeholders are interacting with one another and with support tools and modelling instruments in a structured and decision-orientated setting. The framework may be used to explain the views and opinions of various participants and show the implications of urban policies on liveability, economic prosperity and environment.

The USAF included four stages, namely (1) scoping; (2) visioning; (3) experimenting and (4) assessment (figure 1). An eight-step feedback and learning process spans all four stages, and includes: stakeholder identification and selection; problem scoping; objectives and evaluation criteria; alternative policy scenarios; model preparation and confidence building; simulation; assessment and review; and preferred policy. Each of these stages is defined by a series of more detailed steps. At the core of the USAF is participatory reflective learning by scientists, practitioners, modellers and decision-makers. Unlike some impact assessment approaches, the motivation for the USAF is not accurate assessment and forecasting, which is simply not attainable for complex urban systems, but rather to create a framework that facilitates more effective understanding (Batty, 2012).

The assessment of sustainability requires that the diverse values of stakeholders are represented in the context-specific interpretation of sustainability. Context management forms an integral part of framework implementation. Many methods for context management rely on stakeholder involvement and there are numerous participatory methods for engaging stakeholders. Stakeholder input in the framework leads to an awareness of the importance of social-economic context and the importance of organisational and/or institutional factors.

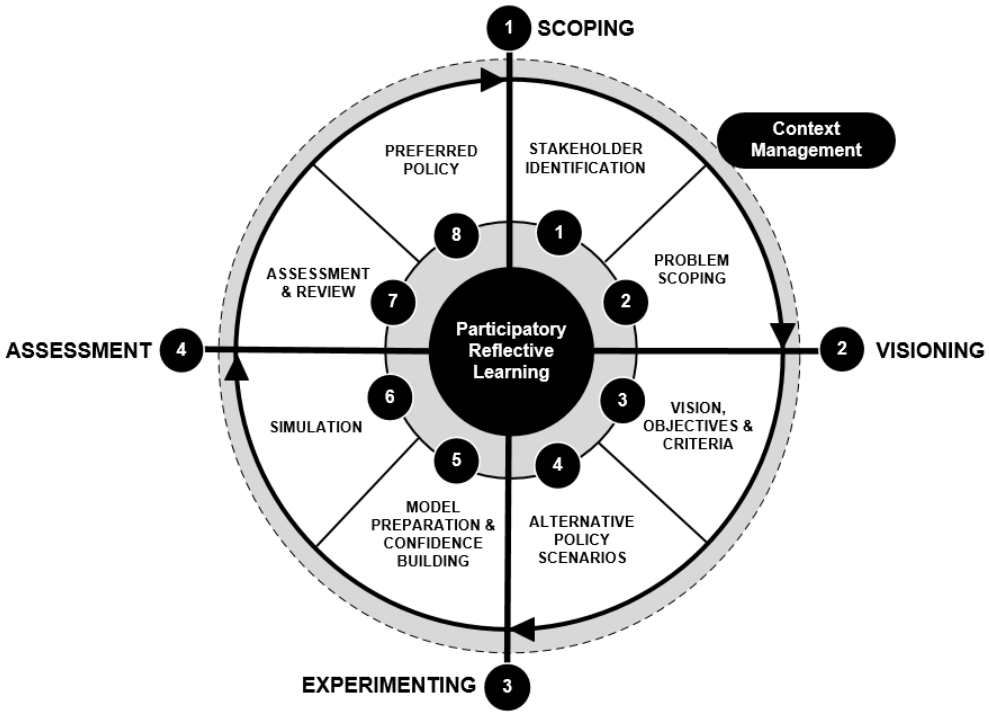

Figure 1 - The 4-Stage Urban Sustainability Assessment Framework (USAF)

At a minimum, the procedure involves one iteration of each of the four stages, and preferably, further iterations. After the first iteration, and on the basis of the review in stage four and the results of the other stages, a further round of stakeholder involvement in each stage could include new stakeholders, while others can be left out of the sustainability assessment process. The quality of the assessment process depends on the consistency and coherence of the assessment process itself, on the quality of the analytical rigor in terms of the methods and tools used, and the consistency and transparency of the process.

The use of support tools forms an integral part of framework implementation. The USAF uses a combination of support tools across all four stages and includes system condition indicators and conceptual modelling in stage 1; sketch planning and scenario workshops in stage 2; agent-based modelling in stage 3 and multi-criteria assessment (MCA) in stage 4.

Key findings and lessons learned

This section summarises the key findings and lessons learned from the research. To avoid providing a list addressing every facet of the framework that deserves attention, this paper focuses on those aspects that the panel of planners and modellers in Logan City viewed as the most relevant to improve framework use in planning practice. Each of these aspects are discussed in more detail below. Focus is placed both on the perceptions of the panel members, and particularly on the reflections by the lead researcher at the completion of the study.

The design problem

The choice of methods for the framework was seen as a design problem. For example, some panel members suggested that the problem scoping stage, that includes system analysis, should be “accurate”, “detailed” and “wide in scope” to identify and understand urban problems. Yet participants also felt that it is desirable that this stage is "simple" and "clear" enough so not to require sophisticated expertise to manage.

Further, the panel raised concerns around the perceived rationality of this stage and the capacity to work with the sometimes “irrational views” of stakeholders when it comes to problem identification. Participants

felt that while there is a risk that identified problems might not always align with the interests of key stakeholders, it remains important to retain all to ensure legitimacy.

While the study identified key methods and tools for framework implementation the combination of methods and support tools ultimately depend on the context and the type of policy responses being pursued. Designing the framework to suit the various imperatives of the panel's participants proved difficult. For example, while the implementation of the framework in Logan City focused on urban densification as an urban growth policy response, for some practitioners the imperative may have been energy consumption, for others optimising existing infrastructure or protecting valuable agricultural land. Accounting for different views of what is important becomes a major design challenge. Participants felt that reaching agreement on the purpose of the assessment (i.e. prospective, retrospective or concurrent) at the start of the process is important as it will affect the scope of the assessment activities and the type of support tools that may be required.

Stakeholder engagement

The panel felt that engaging stakeholders was an important feature of framework implementation. From the case study implementation of the framework it became clear that often, none of the stages of problem scoping, visioning, experimenting and assessment may be definable in advance. Only their relationships to one another are known, resulting in a classic case of an open problem. An important first step is choosing a project scope sufficiently broad to encompass all reasonable considerations, while being sufficiently specific enough so it can reach a satisfactory conclusion within the limitations of time and resources.

Stakeholder identification is one of the first steps in the problem scoping stage. Stakeholder selection influences decisions about the purpose and scope of the assessment process and what information needs to be collected. However, detailed objectives and evaluation criteria may not be known at a study's commencement, and participants felt that stakeholder learning during the sustainability assessment process may alter objectives. "Be careful to engage too early and too much" was voiced as a key consideration by one of the participants. Key stakeholders, including the community, will get stakeholder fatigue and potentially lose interest in the process if engaged too often.

Differentiating between different types of stakeholders at different stages are critical – "be clear why you need stakeholder involvement, what inputs you need and how these inputs will be used in the process". Consider the inclusion of a communication strategy when planning the assessment process. In particular, participants felt that it is important to identify the stakeholders that are the source of the project's legitimacy, and involve them in early decisions that define the scope of the assessment process. Several techniques can be used to assist in stakeholder identification, such as the use of a generic list, asking a set of guiding questions, using a snowballing technique and stakeholder analysis. The first three kinds of techniques are primarily oriented towards identifying stakeholders, whereas stakeholder analysis, although useful for identifying stakeholders, serves a more strategic purpose in terms of designing and planning subsequent engagements for each stage of the assessment process.

The cost of integration

Participants felt that integration of stakeholder views and new information throughout all stages of the framework was a significant challenge that may require the implementation of information management and version control procedures. There are technical reasons for this as differences in quantitative and qualitative information are not easily combined – their integration needs to be planned, designed and centrally coordinated. The nature of the process also requires multi-disciplinary perspectives and inputs that take time to integrate. Moreover, the participants felt that there are practical challenges of interpreting complex results from the process and assimilating the evidence into a decision making process. Inevitably this additional overhead of people and time has an associated cost. Communicating the benefits of framework implementation was viewed by participants as an essential prerequisite for success. However, with an increase in urban complexity and options available to decision-makers, the panel felt that it is hard to see how urban policy making could succeed without the support of such integrated assessment frameworks.

Computer model support

An integral part of the framework is to use modelling to simulate and analyse alternative policy scenarios in stage 3. Creating alternative policy scenarios and testing these in agent-based models is not easy. Recognising the substantial barriers that exist in model use by practitioners, the study developed a set of detailed modelling requirements to assist with model preparation and confidence building in stage 3 (see Brits *et al*., 2014).

Mixing quantitative and qualitative information

Some remarks have been made on the issue of integrating qualitative and quantitative information in the framework. For example, describing the behaviour of households and those of nature is particularly challenging because the latter are often expressed in formal, precise, quantitative terms, but the former are often available qualitatively. This brings about tension, on the one hand, trying to accommodate differing, and often contrasting worldviews between stakeholders. The framework sought to overcome these problems by including two groups of support tools. The one group supports the process of creating a better understanding of the key elements, linkages and relationships of the urban system and the other to quantify the implications of alternative policy scenarios.

Figures 2 displays the position of these support tools in relation to the four stages of the USAF.

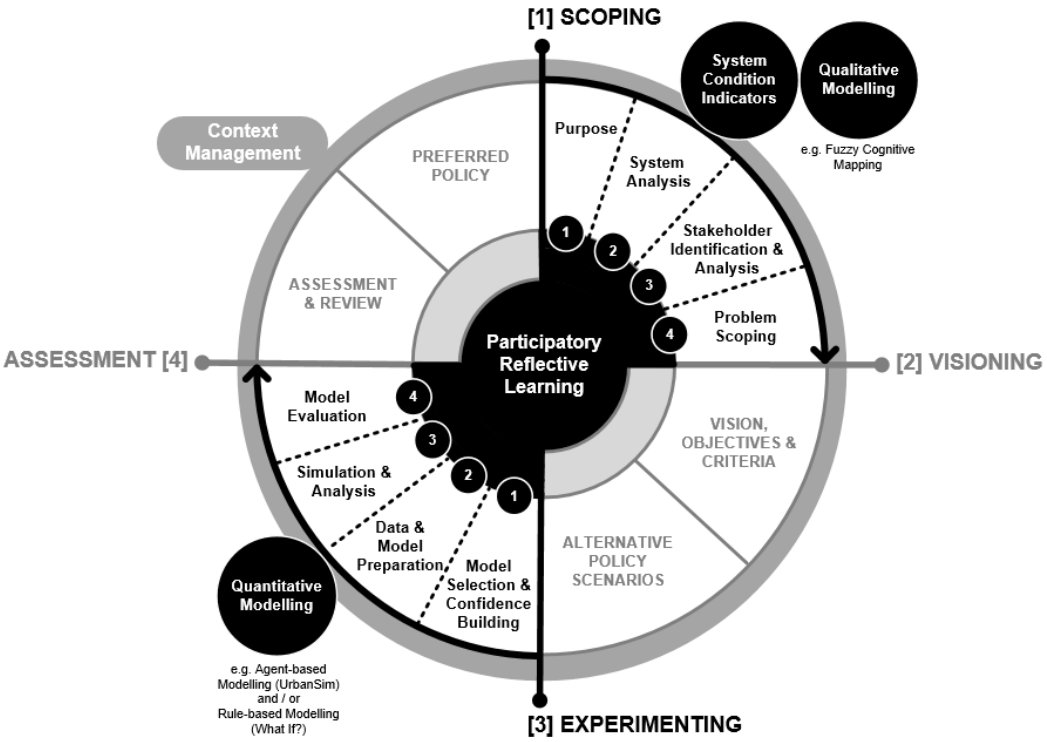

Figure 2 – Qualitative and Quantitative Modelling in the framework

- *System condition indicators and qualitative modelling* in stage 1 are used to quantify the condition (performance) of the study area and assist group thinking processes into the linkages and relationships between elements in the study area. For example, fuzzy-cognitive mapping was used to define qualitatively the relationships and interdependencies between Logan Hospital, Griffith University-Logan Campus and key student and worker accommodation. System condition indicators formed the basis of quantitative information, and included for example indicators such as population growth rate, household composition, crime rate, dwelling type, highest level of school attainment, employment per sector and water consumption.

- *Quantitative modelling and multi-criteria analysis* in stages 3 and 4 are used to simulate changes in urban behaviour based on empirical information and draft policy scenarios and to assess the results qualitatively with decision-makers. For example, UrbanSim was used to simulate the outcomes of policy scenarios quantitatively in stage 3 and multi-criteria assessment was used to assess modelling results qualitatively in stage 4.

Mixing quantitative and qualitative information involved using the base year conditions (i.e. system condition indicators and qualitative modelling results) from stage 1 to assist in the process of analysing the quantitative modelling results in stage 3. The outcomes of the study suggests that the combined use of qualitative and quantitative information from stages 1 and 3 for conducting a process of multi-criteria assessment in stage 4 may provide an important contribution in situations where "facts are uncertain, values in dispute and decisions urgent (Funtowics and Revetz, 1994).

Flexibility and continuous learning

Integrating multiple issues, and working with an extensive group of stakeholders, required flexibility. As the modelling and analyses revealed new insights, interactions between those undertaking the sustainability assessment and stakeholders led to new understandings. For example, modelling results from UrbanSim in stage 3 revealed that the introduction of higher residential densities in one part of the study area will delay expected higher returns on investment for that area by almost 10 years, only to be realised in 2031. As a result, participants agreed that land use policy constraints, defined earlier in stage 2, had to be changed to bring about the intended outcome. Sufficient flexibility and adaptability is therefore essential if lessons are to be assimilated and acted upon whilst the assessment is underway.

Whatever steps are initially implemented for each stage, we found that they must be sufficiently flexible to accommodate changes in the implementation of the others as they become elaborated. For example, in the Logan City case the evaluation criteria developed in stage 2 were unknown in advance and changed as the process matured. Initial explicit descriptions of the study area in stage 1, therefore, ought to be somewhat open, allowing detailed evaluation criteria to emerge and change over time as more is understood about the study area. Figure 3 indicates the role and position of evaluation criteria in stage 2 as a basis of informing the type and scope of modelling activities required for experimentation in stage 3 and for assessing draft policy options, using multi-criteria assessment, in stage 4.

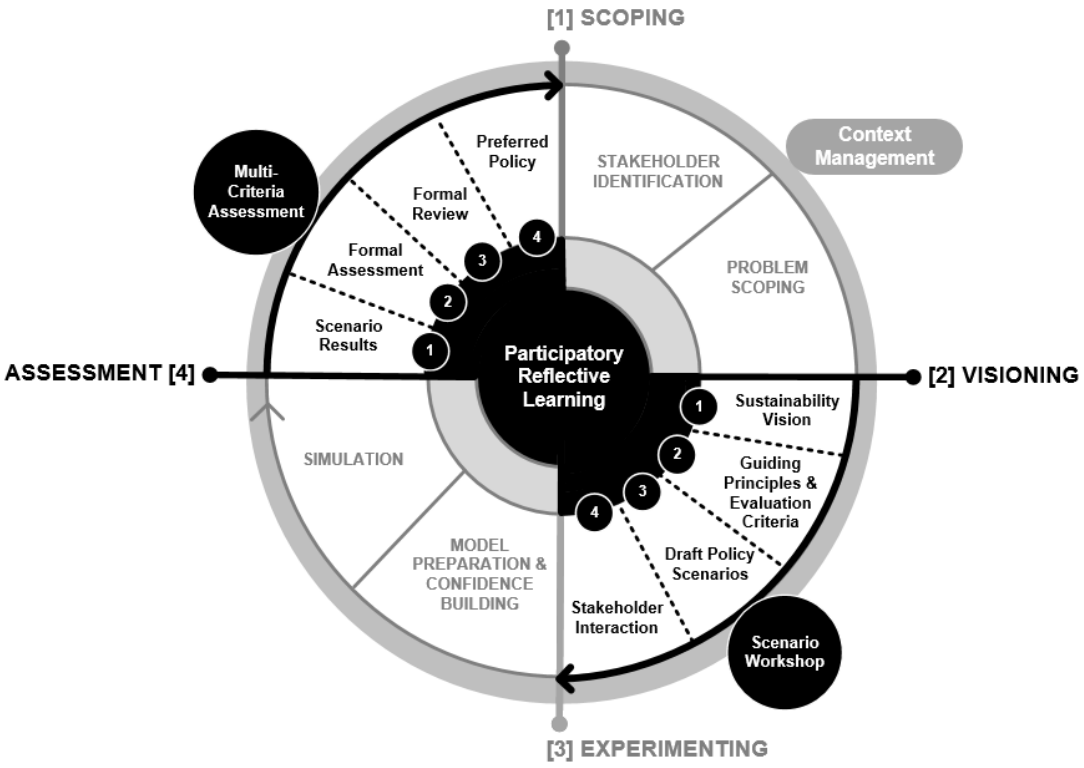

Figure 3 - Role and position of evaluation criteria in the framework

Mutual integration and coherence

Participants felt that there should be an explicit awareness of each of the steps for each of the four stages of the sustainability assessment process: problem scoping, visioning, experimenting and assessment. Iterative cycles of development and refinement of the four stages should be explicitly planned for, in order to enhance mutual integration. Unless the urban sustainability challenges are initially well understood, there will need to be staged, iterative development of the problem scoping, visioning, experimenting and assessment processes.

There should also be explicit awareness of the management of interfaces between stages and steps within stages to ensure mutual integration. Participants felt that coherence among the stages is one of the most significant factors contributing to the overall quality of the assessment outcome. For example, there remains a gap between problem scoping at the start of the process and the development of strategies (draft policy options) in stage 2. To the extent that they are undertaken as separate tasks, careful attention needs to be made to the design of the interfaces between "problem" and "solution" so that all relevant information is transferred between them. The panel felt that this could be achieved by comparing the draft policy scenarios (options) with the results from problem scoping at the end of stage 2.

Ultimately, the integrated nature of the assessment process will define problems that cannot be resolved within the scope of a single process or the powers and functions of a single authority. These unresolved problems should be recorded and communicated to the relevant external organisation for response. Advocacy plays an important role in the process of communication.

Uncertainty and scale

Modelling in the framework combined data at different temporal and spatial scales. This gave rise to uncertainties in model predictions which are rarely taken into account in the decision-making process. The sources of uncertainty arise mostly from input data, model assumptions and model structure. Participants felt that for any model to be useful in the framework, it needs to model the “whole city”. The problem with that, especially when looking at sub-regional planning issues, is that where transport flows

across city boundaries or areas of interest, we can never close the system and the models we use are bound to be incomplete. As Batty (2015) notes we are increasingly breaking the rule that for a good model we need to close the system effectively. So does this mean the use of modelling in the framework is pointless? Consistent with Batty (2015), the panel felt that user friendly models are indeed required for sustainability assessment because they impose a framework, an order on our thinking about the present and the future and as a result try and address urban problems rigorously. Without discipline, we can only hope to resort to intuition and to responses that are influenced by the politics of the situation (Batty, 2015, p193).

Communication and acceptance of results

Then there is the communication of results. Because sustainability assessment has several (or many) different dimensions and perspectives, the process generated a complex set of results. For example, UrbanSim in stage 3 produced a large volume of complicated data. It is clear from our experience that analysing model results, and deciding on the best way to communicate these to decision-makers, has to happen between urban scientists, modellers and practitioners.

One possibility is to communicate results in a summarised form e.g. set of multi-year scenario maps. This was done in the study. However, participants felt that this obscures important findings, which provide the real added value of this type of assessment. Most conclusions from system analysis in stage 1 and model use in stage 3 involved complex results, which are difficult to communicate effectively to decision-makers. Graphs, tables, maps and visually appealing infographics were all used in the Logan City case study. UrbanSim model results were also displayed in 3D with GeoCanvas. Although these all provide alternatives to communicate results, participants felt that results remained difficult to interpret and still required a dialogue of explanation. This can be achieved by using a mediator to communicate modelling results to decision-makers. Such a mediator will have both modelling and policy making experience.

Training and skills

The coordination of tasks for framework implementation is crucial to ensure coherence and timeliness. The skills required to manage this evolution are high level project management skills. The importance of managing stakeholder engagement and the informal interactive nature of many of the steps involved in framework implementation means that social and political skills are also important. The use of extensive project planning and formal methods of ongoing project management were seen as beneficial by the lead researcher. The lead researcher is of the view that training planning practitioners in project management would be a valuable means of supporting the implementation of the framework. Those elements of project management that involve managing the interactions between sub-projects are crucial, particularly managing the interactions between tasks so that, as the conception of the problem and draft policy option changes, model instruments also need to be adjusted and hence the formal assessment, the resultant process is still coherent.

Future Research

From the research, we identified a number of key limitations. These suggest a set of research priorities associated with urban sustainability assessment. To avoid providing a list addressing every facet of sustainability assessment that deserves further attention, we focus on those issues that we believe are most pertinent to improving future urban sustainability assessment.

Improving understanding of urban systems and behaviour

It is clear that there are many urban processes relevant to sustainability that we do not yet fully understand. The complex dynamics of coupled socio-ecological systems in cities introduce substantial complexity, and evidently there are many instances where collection of more data and development of higher resolution, more sophisticated tools may help. Factors that we believe are priority areas include:

- exploitation of new and increasingly available data sources, including longitudinal datasets, which urban planning processes are yet to harness effectively;

- further analysis of the many interdependencies that exist but remain unnoticed without structured observation and study, or only emerge at wider spatial scales. Holderness *et al.*,(2011) highlights this challenge in the context of measuring urban heat island effects; and
- development of models for coupled systems simulation, to better model the coupled socio-ecological systems within cities. These might include network theory to analyse socio-technical interactions, agent-based (Parker *et al*., 2003; Dawson *et al*., 2011; O'Connell and O'Donnell, 2013) and other "bottom-up" models, such as pattern-oriented models that use observed patterns to optimise model structure (Grimm *et al*., 2005). New approaches should also consider qualitative systems modelling (Tur, 2002).

Accelerating the uptake of modelling in sustainability assessment

There is a need to facilitate the development of more holistic approaches to integrated modelling and assessment through a range of advances such as:

- better tools for integrating models and data, which at present requires additional intermediary stages and significant expert input; and
- adoption of open standards and platforms in urban modelling software, such as OpenMI (http://www.openmi.org/) and CityGML (http://www.citygml.org/) that facilitate construction of complex model and data interactions, facilitate the process of future integrated assessments, and enable the sharing of urban models.

Building capacity and improved decision-making

It is clear from our experience that a shared understanding has to develop between researchers and stakeholders over time. Some developments that would improve the use and application of integrated sustainability assessments to inform decisions around urban sustainability include:

- improved valuation metrics for urban sustainability, including better identification of the values of socio-economic and other amenity benefits and costs of urban development, such as the large-scale transition of social housing underway in many Australian cities;
- improved non-monetary approaches for valuation, including multi-criteria analysis; and
- training and education of planning practitioners in sustainability assessment, to help embed these approaches within government and to help turn results into policy.

The importance of improved urban experimentation

Even if the opportunities highlighted above are maximised, sustainable cities will remain an abstract concept unless we take a more systemic approach to understanding and engaging with our cities to build the evidence base for sustainable decision-making. An integrated systems view of multiple urban functions, influences and feedbacks is crucial to understand urban systems. To date, urban sensors have been used to develop visualisations that show the movement of people and resources through the city (e.g. Phithakkitnukoon and Ratti, 2011). Yet, a large disconnect remains between these visualisations and the urban scientists and urban modelling communities who might exploit the richness of this data to better understand how cities work. A key aspect of urban system experimentation would be to bridge this gap and combine these multi-sector datasets to deliver a considerable advance in urban simulation modelling. Moreover, by monitoring across multiple urban functions and their interdependencies it will become possible to understand these interactions, and how they are affected by policy interventions.

Conclusions

The scale of the challenge facing the world's cities through the 21st century is immense. Multiple drivers are placing a number of pressures on urban planners, politicians and engineers that require thinking over extended timescales, broad spatial scales - often beyond the boundary of the city. We believe that sustainability assessment frameworks are fundamental tools to address this challenge from a management and policy-relevant perspective. Integrated sustainability assessments are more complex than single disciplinary assessments, because they involve multiple stakeholders and multiple data sources. However, data is easier to collect and computational power is more readily available. The most serious challenge is giving modelling an effective role in the decision making process, because the

assessment may take some time to perform and modelling results tend to be complicated and difficult to communicate.

We have used the experience of a single implementation instance to identify some lessons. However, neighbourhoods in cities all have unique social, cultural, economic and physical contexts - such that how a neighbourhood may evolve and how change is managed will be distinct. The challenge of implementing the framework for large cities with diverse neighbourhoods should not be underestimated. The implementation of the framework for large metropolitan governments may require a combination of scientific, practitioner and modelling expertise, while implementation for smaller, more resource constraint local governments, may require less specialised resources on the basis that the scope of stakeholder engagement may be smaller and problems less complex. Context management remains a key consideration of framework implementation (see figure 1).

At the same time the rewards and benefits are potentially enormous. In urban areas around the world, researchers, urban policy-makers and decision-makers across disciplines need to start engaging with each other and developing the capacity to respond to urban problems in an integrated manner. The framework aims to make a contribution towards this end.

Acknowledgements

The authors wish to thank Logan City Council for its continued support and participation. The views expressed are solely those of the authors and do not represent the views of the Logan City Council or any other organisation. The authors take full responsibility for all errors and omissions.

References

Batty M, (2012). Managing complexity, reworking prediction. *Environment and Planning B: Planning and Design* 39 607–608

Blair, j., Prasad, D., Judd, B., Zehner, R., Soebarto,V. I. and Hyde, R. (2004). Affordability and sustainability outcomes: a triple bottom line assessment of traditional development and master planned communities - Volume 1. AHURI. No 63: 1-73.

Brinsmead, T. S. (2005). Integrated Sustainability Assessment. Identifying Methodological Options. Canberra.

Brits, A., Burke, M. and Han, H. (2009). Towards an Urban Sustainability Assessment Framework: Supporting public deliberation around sustainability of specific contexts', proceedings of the Fourth National Conference on the State of Australian Cities, 24-27 November 2009, Perth. (ISBN: 1863081569).

Brits, A., Burke, M. and Li, T. (2011). An Urban Sustainability Assessment Framework: Role and integration of modelling activities', proceedings of the Fifth National Conference on the State of Australian Cities, 29 November – 2 December 2011, Melbourne.

Brits, A. (2013). 'Embedding Urban Growth Modelling in Urban Planning', proceedings of the Sixth National Conference on the State of Australian Cities, 26 - 29 November 2013, Sydney.

Brits, A., Burke, M. and Li, T. (2014). Improved Modelling for Urban Sustainability Assessment and Strategic Planning: local government planner and modeller perspectives on the key challenges. Australian Planner, 51(1)

Dawson, R. J. (2011). Potential pitfalls on the transition to more sustainable cities … and how they might be avoided, *Carbon Management*, 2(2):175-188.

Dawson, R.J., Wyckmans, A., Heidrich, O., Köhler, J., Dobson, S. and Feliu, E. (2014). Understanding Cities: Advances in integrated assessment of urban sustainability, Final Report of COST Action TU0902, Centre for Earth Systems Engineering Research (CESER), Newcastle, United Kingdom

De Ridder, W., Turnpenny, J. Nilsson, M and Von Raggamby, A (2007). A Framework for Tool Selection and use in Integrated Assessment for Sustainable Development. *Journal of Environmental Assessment Policy and Management*. 9(4): 423-441

Funtowicz, S. and Ravetz, J.R. (1994). Emergent Complex Systems. Futures. 26(6), 568-582.

Gibson, R.B. (2006) Beyond the Pillars: Sustainability Assessment as Framework for effective integration of social, economic and ecological consideraitons in significant decision-making. *Journal of Environmental Assessment Policy and Management*. 8(3): 259

Grimm V., Revilla E., Berger U., Jeltsch F., Mooij W.M., Railsback S.F., Thulke H.-H., Weiner J. et al. (2005). Pattern-oriented modelling of agent-based complex systems: lessons from ecology. *Science* 310, 987–991.

Hacking, T. and Guthrie, P. (2008). A framework for clarifying the meaning of Triple Botton-Line, Integrated and Sustainability Assessment. *Environmental Impact Assessment Review*. 28(2-3): 73-89.

Hezti, A.A. and Dovers, S.R., (2009). Australia's Indicator-Based Sustainability Assessments and Public Policy. *The Australian Journal of Public Administration*. 68 (3): 303-318.

Holderness T., Barr S.L., Dawson R.J. and Hall J.W. (2013). An evaluation of thermal Earth observation for characterising urban heatwave event dynamics using the urban heat island intensity metric, Int. J. Remote Sensing, 34(3):864–884.

Liu J., Dietz T., Carpenter S.R., Folke C., Alberti M. *et al*. (2007). Coupled human and natural systems Ambio, 36(8): 639-649.

Lotze-Campen, H. (2007) Review of Experience with existing models and their suitability for Integrated Sustainability Assessment (ISA). MATISSE Working Papers 16:7.

Moglia, M., Kinsman, D. and Maheepala, S. (2012). Multi-Criteria Decision Assessment Methods to Identify Total Water Cycle Management Strategies. Urban Water Security Research Alliance Technical Report No 101. CSIRO.

Ness, B., Urbel-Piirsalu, E., Anderberg, S. and Olsson, L. (2007). Categorising tools for sustainability assessment. *Ecological Economics* 60: 498-508.

Nijkamp, P. and Vreeker, R. (2000) Sustainability assessment of development scenarios: methodology and application to Thailand. Ecological Economics. 33: 7-27.

O'Connell P.E., O'Donnell G. (2013). Towards modelling flood protection investment as a coupled human and natural system, Hydrology and Earth Systems Science Discussions, 10, 8279-8323.

Parker D.C., Manson S.M., Janssen M.A., Hoffmann M.J. and Deadman P. (2003) Multi-agent systems for the simulation of land-use and land-cover change: a review. *Annals of the Association of American Geographers*, 93(2): 314-337.

Phithakkitnukoon, S. and Ratti, C. (2011). Inferring Asymmetry of Inhabitant Flow using Call Detail Records. *Journal of Advances in Information Technology*, 2(2).

Pope, J., Annadale, D. And Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. Environmental Impact Assessment Review. 24: 595-616. Elsevier.

Reeves, T.C., Herrington, J. and Oliver, R. (2005). Design research: A socially responsible approach to instructional technology research in higher education. *Journal of Computing in Higher Education* 16(2): 96-115

Rosemary, H., Grant, C., George, M., Robinson, C.J., Jackson, S. and Abel, N. (2012). A Typology of Indigenous Engagement in Australian Environmental Management: Implications for knowledge Integration and Social-ecological System Sustainability. *Ecology and Society*. 17(1): 23

Rotmans, J. (2006). Tools for Integrated Sustainability Assessment. Matisse Working Papers. Paris. 4(10), 21p.

Stimson, R., Bell, M., Corcoran, J. and Pullar, D. (2012). Using a large scale urban model to test planning scenarios in the Brisbane-South East Queensland region. *Regional Science Policy and Practice*. 4(4): 373-392.

Tur J.M.M., Cellier F.E., Huber R.M. (2002). Variable selection procedures and efficient suboptimal mask search algorithms in fuzzy inductive reasoning, *International Journal of General Systems*, 31(5): 469-498.

Waddell, P. (2002). UrbanSim: Modelling urban development for land use, transportation, and environmental planning. *Journal of the American Planning Association*, 68(3):297–314, Summer 2002.

Waddell, P., Borning, A., Noth, M., Freier, N., Becke, M. & Ulfarsson, G. (2003). Microsimulation of Urban Development and Location Choices: Design and Implementation of UrbanSim. *Networks and Spatial Economics*, 3: 43-67.

Waddell, P. & Ulfarsson, G.F. (2004). Introduction to urban simulation: Design and development of operational models. In P. Stopher, K. Button, K. Haynes, and D. Hensher, editors, Handbook of Transport, Volume 5: Transport Geography and Spatial Systems. Pergamon Press.

Waddell, P., Ulfarsson, G., Franklin, J & Lobb, J. (2006). Incorporating land use in metropolitan transportation planning. Transportation Research Part A: Policy and Practice, 2006.

Waddell, P. (2010). Microsimulating parcel-level land use and activity-based travel: Development of a prototype application in San Francisco. *The Journal of Transport and Land Use*, 3(2): 65-84.

Wang, F. & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5-23.

Weaver P.M. and Rotmans, J. (2006). Integrated Sustainability Assessment: what is it, why do it and how? *International Journal of Innovation and Sustainable Development.* 1(4): 284-303.

Weaver P.M. and Jordan, A. (2008). What roles are there for sustainability assessment in the policy process? *International Journal of Innovation and Sustainable Development*. 3(1-2): 9-32.

Wiek, A. and Binder, C. (2005). Solution spaces for decision-making – a sustainability assessment tool for city regions. *Environmental Impact Assessment Review*. 25(6): 589-608

Yigitcanlar, T., Dur, F. and Dizdaroglu, D. (2015). Towards prosperous sustainable cities: A multiscalar urban sustainability assessment approach. *Habitat International*. 45(1): 36-46