AN URBAN SUSTAINABILITY ASSESSMENT FRAMEWORK

Role and Integration of Modelling Activities

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INTRODUCTION

In recent years climate change and other urban growth considerations have put sustainable urban development at the forefront of most strategic policy discussions in almost every city across the world, including Australia (Commonwealth of Australia, 2011). The increased and urgent environmental agenda has engendered the need for employing sustainability assessment frameworks as key mechanisms to guide urban planning and policy development.

Urban systems emerge as distinct entities from the complex interactions among three interconnecting and overlapping primary systems: the environment, the economy and society. Such complexity poses a challenge to identify the causes of urban environmental problems and how to address them without causing greater deterioration. Urban planning has traditionally addressed these problems with policies regulating the location and intensity of urban activities, often based on assumptions about urban and environmental dynamics that are rarely revisited (Alberti, 1999; Neuman, 2005). Given the complexity of urban systems and the environment that supports them, the key intellectual challenge of urban sustainability is an improved understanding of the dynamic spatial relationships and interactions among different urban and environmental systems. Such an understanding can inform policy and decision making of the consequences and challenges faced when responding to urban needs.

We seek to contribute to this understanding by developing a multi-dimensional assessment framework. The assessment framework consists of normative guiding concepts on how the concept of sustainable development can be applied (the normative dimension), a target system to be assessed (the systemic dimension), an appropriate procedure to integrate the relevant stakeholders and to bridge the normative and systemic aspects (the procedural dimension) and the use and integration of modelling activities (the supportive dimension). In this paper we focus on the role and use of modelling activities in urban planning and policy development in general. The focus here is on "applied" models, i.e. models which try to simulate real-world processes based on or calibrated to empirical information. Detailed information on specific models, their strengths, weaknesses and major applications are not included in this paper.

The sustainability literature has acknowledged that new methods and tools are needed to support an improved understanding of the dynamics and interrelationships between social, economic and ecological systems (Weaver and Rotmans, 2006; Weaver and Jordan, 2008). However, despite significant progress towards the development of computer models to support policy formulation, their use is far away from being trivial or the norm.

From literature (Lee, 1973, 1994; Brugnach *et.al.*, 2007; Harding, 2007; Waddell, 2010) and interviews with key local government officers, we find that there are common challenges to appropriating a modelling system in government. Officers' limited understanding of urban modelling and a lack of system thinking skills are some of the challenges that need to be addressed before they can take advantage. The paper explores these modelling challenges, using them to inform the development of a set of modelling imperatives that supports the implementation of an improved assessment framework. Views from respondents indicate that implementation of these imperatives is likely to improve the level of confidence of officers to use models to support policy development and assessment practices. The paper concludes with a roadmap, briefly outlining the testing and evaluation of the framework as part of a case study implementation in Logan City.

PREVIOUS APPROACHES

Integrated sustainability assessment (ISA) is still immature, but a rapidly maturing field of research practice (Pope, *et.al.*, 2004; Weaver and Rotmans, 2006). As a consequence the field is not well defined theoretically, nor are there well developed, well-documented, standard methods. Most of the successful integrative experiences to date have been due to learning-by-doing and much of the practice is informal. The majority of the

approaches appear to employ specialised computer models for predominantly one (or occasionally two) of the tasks associated with a well-integrated sustainability assessment process. These models have mostly been developed within traditional scientific disciplines and differ in theoretical background and paradigms, mathematical structure, time scales, spatial scales, thematic coverage, modelling objectives, and outcomes. As defined in the MATISSE project (Weaver and Rotmans, 2006), ISA requires, together with the development of more integrative scientific thinking, a broader scope of modelling activities. Model integration and model coupling across disciplines are key challenges for providing appropriate tools for the combined assessment of environmental, economic and social processes. Lotze-Campen (2008) has conducted a detailed review of existing modelling tools for sustainability analysis and concluded that model integration from the perspective of ISA is still in its infancy and that the ultimate test of model applicability for the challenging tasks in ISA can only be achieved through intensive stakeholder involvement.

Several prerequisites have to be dealt with to increase stakeholder involvement. Based on empirical material from recent studies on the use of models in stakeholder dialogues (see Antunes, *et.al*. 2006; Van den Belt, 2010; Te Brömmelstroed and Schrijnen, 2010; Olsson and Andersson, 2007), two central problems are identified: (a) models are laden with choices and thus depend on the assumptions and priorities of modellers and (b) the ability and willingness of stakeholders to criticise or accept modelling results. Recognised factors likely to influence stakeholders' acceptance of model derived results include issues at stake, stakeholders' ability to criticise model derived information, and their trust in the modellers that have developed or applied the models.

For the use of models to increase in urban planning and assessment it is imperative to examine the conditions for their practical application. What prerequisites are there to ensure that models can be used as valuable tools in urban sustainability assessment processes?

METHODS

To respond to this question, we have committed to a program of research that is experientially developing and using with practitioners an improved framework, involving and learning from practitioners throughout the process of framework development, testing and use. The approach has involved the development of an initial framework, as outlined below, based on key conceptual and theoretical insights drawn from systems theory, planning 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 a single large local government in Queensland, who have 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. This paper reports on only the initial insights of the panel for the first workshops held over a period of two months. The panel involved in the workshops comprised both planning practitioners and modellers, who had varied experience in developing and using models to aid policy development. Respondents were tasked with completing two questionnaires, the one rating the importance of a list of modelling challenges and the other a list of modelling prerequisites (imperatives). A total of sixteen responses were received. Although the sample size is too small to do any statistical analysis, the responses provide useful indicators of user sentiments. Key challenges identified and a summary of modelling imperatives only are provided in this paper.

THE URBAN SUSTAINBILITY ASSESSMENT FRAMEWORK

Our proposed urban sustainability assessment framework is intended to provide a coherent, deliberative platform where participatory modelling activities structure the assessment process, using both qualitative and quantitative modelling activities and multi-criteria analysis (MCA). The framework fulfils the systemic, normative and procedural requirements of an appropriate sustainability assessment as elaborated in the technical literature (i.e. see Nijkamp and Vreeker, 2000).

Firstly, it has been shown that an assessment is more likely to yield good results if it is designed to follow an iterative, yet logical process, and involve stakeholders from various disciplines (See Ravets, 2000). Guided by the theoretical foundations of rational (Kaiser *et al*., 1995) and communicative planning (Healy, 1997), the framework was developed in 2010 and early 2011. The Integrated Sustainability Assessment (ISA) methodology of Weaver and Rotmans (2006) was adapted to provide a coherent, deliberative platform, where participatory modelling activities structure the assessment process (see Fig.1). The procedure forms a six-stage feedback and learning process, which includes stakeholder identification and selection; problem framing and scoping;

visioning, setting of objectives and sustainability criteria, development of draft policy options; model preparation and confidence building; simulation and assessment; evaluation and review. A corner-stone of the procedural dimension is the process of stakeholder selection and building the confidence of participants in the modelling process.

Secondly, we cannot hope to explore and assess different pathways towards a more sustainable future for our cities unless we have at least a crude, but essentially realistic understanding of the urban system, its structure, essential component systems and its behaviour. This requires a conceptual understanding in the form of at least a good mental model. One technique that can be applied to assist us in our understanding of urban systems is Systems Thinking (ST). ST is the art of identifying and connecting the crucial elements of systems in a qualitative manner and has a long history in the planning literature (i.e. see McLoughlin 1969).

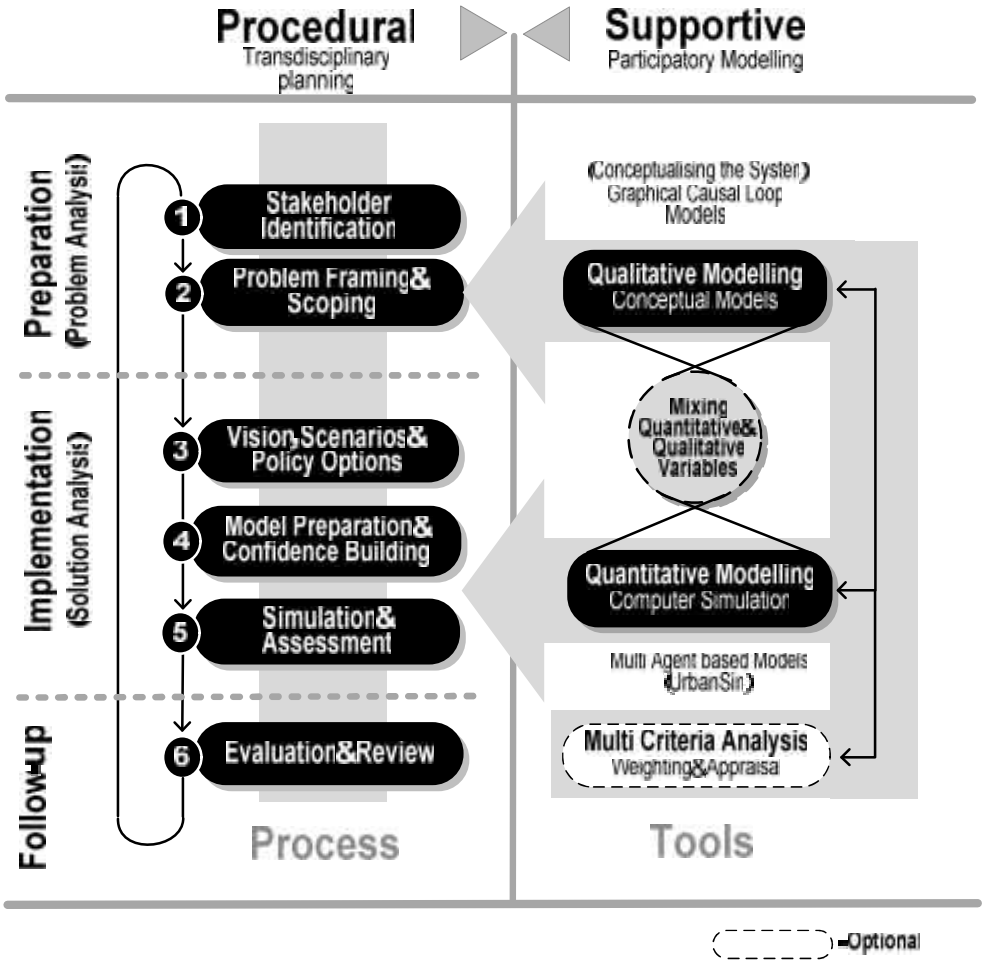

Figure 1: The Procedural and Supportive Dimensions of the Urban Sustainability Assessment Framework

Lastly, the supportive dimension is necessary to assist discussion, analysis, assessment and decision making. The supportive dimension consists of two groups of tools, the one supporting the process of creating a better understanding of the key elements, linkages and relationships of the urban system (problem analysis), the other to analyse the implications of draft policy responses on the system (solution analysis). The framework asserts that for modelling to be useful to the sustainability assessment process, the modelling process has to be complemented with some kind of formal appraisal of alternatives. Our framework suggests that the integration of qualitative and quantitative modelling with multi-criteria analysis (MCA) may provide an important contribution in situations where there is uncertainty, decisions are important and there is urgency required.

WORKSHOP PANEL RESPONSES

To investigate how the framework is likely to meet stakeholder needs and to assess how modelling can be used to support the procedural dimension of the sustainability assessment framework, the study held a series of workshops with planning practitioners and modellers, as described earlier. This involved 1) identifying key modelling issues, 2) rating the importance of dealing with these issues, and 3) developing a set of modelling imperatives.

Identification of Key Issues

During the first phase of the workshops, participants were tasked with exploring the issue of "improving the confidence of planners in the use of models to support policy development". The end result of these sessions produced a list of reasons for this apparent lack of confidence. These issues or challenges are summarised below.

Professions and institutions

Planners do not understand models and the modelling process: Participants felt that poor integration of modelling in the policy and decision making process was due to poor communication between planning practitioners and modellers. In particular, there was a need to simplify explanation around what questions the model can potentially answer and the strengths and limitations of the model, such that planning practitioners and other non-technical stakeholders could understand why it has been designed in a certain manner. During the workshop, it was agreed that this situation was mainly a consequence of a poor understanding of computer models on the part of planning practitioners.

Modellers do not understand the policy development and decision making process: In comparison, there were a poor understanding on the part of modellers of the policy-making processes that planning practitioners are required to facilitate, and the types of decisions they have to make. Greater clarity was needed on the role of models and how their results were being used and interpreted. This included issues such as how well the model has been shown to match reality, what its restrictions were, and even how to express modelling concepts to a wider audience.

Fragmented organisations: The fragmented nature of many government organisations was seen as another hurdle to effective modelling processes by modellers. More often than not, a modelling process leads to a question that requires different departments from the same organisation to be involved.

Project management: Participants recognised one consequence of lengthy and expensive modelling projects is the necessity for strong project management skills. Participants agreed that a greater emphasis should be placed on developing the simplest possible (but functioning) version of a model, on getting that well documented and on producing outputs containing illustrative results within the project budget and timeframe.

Changing participants: Participants also recognised that the somewhat voluntary nature of participation and the potential for changing participants during a modelling project can disrupt a successful modelling process.

Modelling concerns per se

Model accuracy: When it came to the meaning of model validation or level of certainty achieved, planning practitioners were keen to confirm that they knew and accepted that a certain amount of uncertainty is and will always surround model prediction. What however, was missing was more information on the level of uncertainty of any model result or outcome and how this arose from the limitations or assumptions of the model.

Flexibility of models: Modellers felt that we continue to see improvements in theory, in empirical methods, in software development and in data. As a result, models and software platforms that are too rigid become a serious constraint, and limit applicability. Different users will have different data and needs, and it is clear that models need to be adaptable to these conditions if they are to be widely used. A flexible model design means the ability to make changes to the model with minimal disruption. Modularisation of models is one of the key factors in ensuring that a model maintains its flexibility and longevity.

Changing models: A further compounding factor was that practitioners were unhappy with models changing throughout a project, such that different results could be produced for the same assumptions. What practitioners

really wanted was "one model" allowing an answer to be associated with a specific model version and measure of uncertainty or confidence indicator.

Behavioural validity: Participants felt that for a model to be credible for use in government, it must have sufficient common sense or behavioural validity of how the world works to be believable as an independent tool, within a clearly defined scope of applicability. Models that lack any form of behavioural and theoretical foundations cannot pass the credibility test, and are not ultimately useful in supporting the assessment process.

Empirical validity: It was argued that models must be tested against observed data in order to assess their empirical validity. That is, no matter how much or little common sense a model might have, it is not useful unless it can respond to input assumptions and make predictions that reasonably well correspond to observed reality. This is the process that some refer to as model validation. Many models do not go through any form of validation, and leave it to the stakeholders to simply believe the results.

Unbiased: Participants also wanted models able to withstand scrutiny from the perspective of being free from bias. If a model was perceived as having significant biases in its empirical validation it will lose credibility.

Ease of use: Beyond the conditions outlined above, respondents noted that if a model is too complex to explain, it also will ultimately not succeed in practice. If it requires the model developer to provide extensive and ongoing support, with no building of capacity to use and modify the model system by its users, it will be far less compelling than a model that accomplishes this aim.

Resourcing

Data preparation: Probably, the most daunting problem in implementing a model remains input data. Input data such as land parcels, building, employment, demographic and price data are notoriously incomplete and error prone. Further, it is quite difficult to integrate them into a coherent database that is internally consistent. Notably, participants' highlighted two key data issues: first, the scope and size of the base year dataset that needs to be prepared and secondly, data quality, especially in those instances where micro data are absent and need to be derived from aggregated datasets. These remain very important obstacles, and must be addressed.

Time constraints - not enough time to model: In addition, participants also highlighted the limitations implicit in the process of utilising modelling during stakeholder participation due to time constraints placed on group learning and decision making.

Budget: The construction of an integrated model, of a quality suitable to be used to underlie important government policy decisions, can be an expensive and time consuming exercise. Participants recognised the importance for modellers to be open about just how expensive such models are to build, so that they can help ensure that government do not embrace such projects with unrealistic expectations.

Computational requirements: Traditionally, large scale models required large computers to run and in addition, required run times for a single year extending over several days to simulate basic urban behaviour changes. Advances in computing power and speed have contributed significantly in the last few years towards scaling down running time. Ultimately, several factors will influence computational requirements, ranging from the size of the study area, the geographical unit of analysis (e.g. grid cell-, parcel- or zone-based) and whether the database structure of the model allows parallel processing of data. The modellers felt that careful consideration of these aspects is required, prior to the implementation of a model.

Differences in participant's knowledge and experience

The findings of the workshops were compared with the literature and one of the issues earlier hypothesised as a key concern had been omitted by participants but may be described as '*Differences in knowledge and local experience between participants*' which was noted by Te Brommelstroet and Bertolini (2008) as a major factor in soliciting information, building and reaching consensus during a modelling process. They ascribed these differences to the gap between tacit and explicit knowledge. Explicit knowledge is characterised as easily codified, formalised and expressed in words and numbers. Tacit knowledge on the other hand is deeply rooted in action, meaning and personal experience in a specific context. The real issue may be less whether qualitative or quantitative epistemologies are more or less correct, than whether some combination of them can be used to

provide sufficient behavioural and empirical validity to become useful as basis for facilitating discussion. This issue was added to the set of challenges facing modelling for the next phase of the research.

Importance of these Challenges for Resolution within the Framework Development Process

Workshop participants were next asked to rate the importance of dealing with these challenges on a scale from 1 (unimportant) to 5 (critical importance), where the intervening points on the scale were given labels of low, average and of high importance. In addition, the survey was circulated to other practitioners and modelling experts. A total of sixteen responses were received. Although the sample size is too small to do any statistical analysis, the responses provide useful indicators of user sentiments. Table 1 contains a summary of the responses, in decreasing order of ranking, with the average rating in parenthesis:

Table 1: Comparative Importance of Modelling Challenges

No	Modelling Challenge	Average Rating
1	Data preparation	4.8
2	Planners do not understand models & the modelling process	4.6
3	Modellers do not understand the policy development and decision making process	4.4
4	Changing models	4.4
5	Flexibility of models	4.4
6	Project management	4.3
7	Empirical validity	4.2
8	Ease of use	4.2
9	Model accuracy	4.1
10	Behavioural validity	4.0
11	Unbiased	4.0
12	Budget	3.9
13	Fragmented organisations	3.6
14	Time constraints - not enough time to model	3.8
15	Changing participants	3.3
16	Computational requirements	3.1
17	Differences in knowledge & experiences of participants	3.0

From the responses, it is clear that data preparation remains of critical importance, followed by a lack of understanding by planners of models. In addition, modellers' lack of understanding of the policy development process, changing models and the flexibility of models were also seen as important considerations. Differences in the knowledge and experiences of participants in the modelling process were of least importance. However, what is important to note is that all these issues received an above average importance rating of more than 3, indicating that all of these issues remain important considerations when modelling in government settings. Also, some respondents found it difficult to rate individual issues and felt that issues should be grouped, before rating them.

In addition to the above modelling issues, respondents felt that there is (generally) insufficient investment in model design and specification, which leads to the following consequences:

- sub-optimal design, which becomes difficult to maintain as modelling progresses.
- insufficient understanding of the nature and scope of the problem. This relates both to modellers' apparent lack of understanding of the policy development and decision making process and planning practitioners' failure to reach consensus and agree on the nature and scope of the problem.
- generation of unreliable and/or inadequate model results leading to a loss in legitimacy and management support.
- planners find it difficult to translate their requirements into a "modelling language". This becomes especially apparent when planning practitioners are expected to provide input into model design and specification. A lack of an intermediate language (interface) and poor dialogue between planners and modellers further exacerbates the problem.
- assumptions included in the model may be incomplete and inaccurate. In some cases, these assumptions may be valid for a certain time period, but are not reviewed as new information becomes available and documented properly to inform model refinement.

- incomplete understanding of the time and effort required to build, prepare data, use and maintain a model.
- sustaining institutional capacity and management support, especially where officers are expected to maintain operational models.

Modelling Imperatives to be Employed

Using the modelling challenges as input (see Table 1) the study has developed a set of modelling imperatives to support the implementation of an improved assessment framework. Table 2 contains a summary of these imperatives. Workshop participants were asked to rate the likelihood of each imperative making a contribution towards resolving the modelling challenge on a scale from 1 (no contribution) to 5 (significant contribution) where the intervening points on the scale were given labels of low, average and moderate.

The average importance (rating) for each imperative is displayed in the last column.

Table 2: Comparative Assessment of Modelling Imperatives

No.	Modelling Challenge	Modelling Imperative	Average Rating
1	Data preparation can be excessive and time consuming	Limit and prioritise the initial list of questions the model are expected to answer	4.3
		Use the most recent Census results as the base year. Conduct rigorous quality tests and validate derived data sets, prior to the running of any simulations.	3.2
		Define and justify the geographical boundaries of the study area.	3.6
		Collect and prepare major datasets (e.g. parcels, buildings, jobs and demographics), prior to the official start of the assessment and stakeholder engagement process to ensure active participation.	3.6
2	Planners do not understand models & the modelling process	Communicate the questions (or indicators) the model can answer. For each question, provide examples of model outputs (e.g. map, chart and table).	4.3
		Develop and agree on an appropriate model design and specification. The model design and specification will include the list of questions to be answered as well as associated assumptions.	4.0
		Explain the modelling process and opportunities where practitioners can make inputs or additions to the model system.	3.8
		Communicate key strengths and limitations of the model system by listing design features that contribute to the relevance, attractiveness and ease of use of the model system, preferably comparing it with similar models.	3.4
		Appoint/nominate a mediator that can serve as an interface / translator between planners and modellers. The mediator should have a thorough understanding of both urban policy development and modelling.	3.3
3	Modellers do not understand the policy development and decision making process	Communicate how the modelling results are expected to be used to inform planning and policy development.	4.3
		Explain the draft policy options under consideration and identify the areas of uncertainty	3.6
		Appoint/nominate a mediator that can serve as an interface / translator between planners and modellers.	3.1
4	Changing models	Manage additions and changes to the model system by implementing a change request and management procedure.	4.4
		Document change requests, implementation status and method of incorporation.	4.3
		Associate model changes with a model version and model results.	3.9
5	Inflexible models	Select an existing operational modelling system with a proven track record and flexibility to accommodate changes and additions	3.3
6	Project planning and management	Appoint/nominate a project manager, preferably with extensive experience in model development and implementation in	4.3

No.	Modelling Challenge	Modelling Imperative	Average Rating
		government.	
		Get buy-in from key stakeholders during the preparation stage - make sure you understand who the key stakeholders are.	4.2
		Develop a project plan, containing the details of the initial set of questions to be answered, modelling method and associated assumptions, model system to be used, data requirements, stakeholder involvement, communication and decision making points and protocols and milestones	4.1
		Implement and report regular progress to participants, using the project plan as a baseline.	3.4
7	Empirical validity	Design an appropriate validation method, based on feasibility, local context and participant support.	4.2
		Validate the model system so that it makes predictions that reasonably correspond to observed reality.	3.8
8	Establish a model that is easy to use	Document the model system by developing an appropriate set of manuals containing information on model use, processes and procedures to make it easy for participants to become capable users.	4.0
		Establish an easy-to-use model system, but maintain behavioural and empirical validity.	3.3
9	Model Accuracy/ Uncertainty around what the model can do	Specify the set of questions to be answered.	4.3
		Specify and communicate to stakeholders the method, associated assumptions and model system to be used to answer these questions.	4.0
		Communicate model results and associated uncertainties to stakeholders.	4.0
		Define uncertainties around model specification, validation and model results.	3.9
		Determine the level of confidence (confidence indicator) of stakeholders in the model system and model results.	3.1
10	Behavioural validity	Explain the theoretical foundations of the model system and how it relates to the local context and stakeholders' own experiences.	4.0
11	Unbiased	Incorporate modelling changes and additions by way of mutual consensus	3.3
12	Insufficient Budget	Apply lifecycle costing, spanning all phases of the modelling project (e.g. preparatory, model development and implementation and ongoing maintenance).	4.1
		Validate initial budget estimates with similar modelling projects elsewhere.	3.4
13	Fragmented organisations	Ensure leadership and management support for the modelling project by clearly communicating the purpose of the modelling project and each participant's role in relation to the project.	4.6
		Establish clear lines of communication and decision-making protocols.	4.4
14	Time constraints - not enough time to model	Collect and prepare major datasets (e.g. parcels, buildings, jobs and demographics), prior to the official start of the assessment and stakeholder engagement process, to ensure that participation by practitioners does not get unnecessary delayed during the process due to extensive data preparation requirements.	4.1
		Limit / prioritise the questions to be answered by the model.	3.7
15	Changing participants	Clarify, agree and document roles and responsibilities. Distinguish between participants likely to share local experiences, those with expert opinion and those that will be responsible for making decisions.	4.0
		Select stakeholders to purposefully participate in the modelling	4.0

No.	Modelling Challenge	Modelling Imperative	Average Rating
		process. Limit the scope and duration of modelling cycles, in an attempt to allow for the timely generation and evaluation of results, thereby keeping participants engaged.	
		Collect and prepare major datasets (e.g. parcels, buildings, jobs and demographics), prior to the official start of the assessment and stakeholder engagement process, to ensure that modelling cycles remain short and do not incur unnecessary delays.	3.3
		Provide regular progress updates to all stakeholders	3.1
16	Computational requirements	Investigate whether the chosen modelling system is compatible with the operating system environment of the government institution where the model gets implemented.	4.4
		Select an appropriate model system with a proven track record.	3.9
17	Differences in knowledge & experiences of participants	Provide for both qualitative and quantitative modelling activities to occur, thereby providing sufficient opportunity for democratic discussion between various participants.	4.0

From the responses, ensuring leadership and management support for a modelling project received the highest rating. Model imperatives aimed at improving communication and the confidence of participants, prior to the start of model design, development and implementation, all received high ratings. These include the need to develop a project plan, containing the details of the initial set of questions to be modelled, modelling method and associated assumptions, model system to be used and whether it is compatible with the operating system environment of the government institution, data requirements, who the stakeholders are, communication and decision making protocols and key milestones. Central to all of this is the need to appoint/nominate a project manager, preferably with extensive experience in model development and implementation in government.

MODELLING IN THE FRAMEWORK

From the workshop panel responses it is clear that the successful use and integration of modelling activities in government is dependent on the implementation of a set of modelling imperatives. The primary aim of these modelling imperatives is to increase stakeholders' confidence in the modelling effort (See Table 2).

Attempts to increase the participation and confidence of stakeholders in modelling are not new. Participatory modelling, an approach combining participatory procedures with modelling techniques, is increasingly recognised as an effective way to involve stakeholders (Voinov and Gaddis, 2008; Videira, *et.al*, 2010). While a model may assist in a number of ways it is important to recognise that using an existing model system and then adjusting it to accommodate user needs and local conditions, is essentially a subjective process. The legitimacy of the decision-making process relies partly on the acceptance of the model system used to help solve a problem. This brings about tension, on the one hand, trying to accommodate differing, and often contrasting worldviews, and on the other, the ability of a single modelling tool to respond and accommodate these. In our framework we sought to overcome these problems by including two groups of tools. The one group supports the process of creating a better understanding of the key elements, linkages and relationships of the urban system (problem analysis), the other to evaluate the implications of draft policy responses (solution analysis).

The two groups of tools can be summarised as follows:

- *Qualitative modelling tools* that aim to assist group thinking processes in which participants play an active role. Soft systems thinking, causal loop diagramming and scenario workshops are examples of such tools.
- *Quantitative modelling tools* to simulate changes in urban behaviour based on empirical information and with some relevance to actual draft policy options. Computer models, such as UrbanSim and MatSim are examples of such tools. UrbanSim, as an integrated land use modelling system, was chosen for this study.

Mixing quantitative and qualitative variables involves interpreting the graphical causal loop diagramming onto the computer based model system, which enables uncertainty analysis and testing (See Fig. 1). Table 3 contains a list of the potential outcomes that are likely to be derived when using both qualitative and quantitative modelling in the assessment process. Supporting the introduction and integration of computer modelling tools is the set of derived modelling imperatives (see Table 2).

The framework asserts that for modelling to be useful to planning and policy development, the modelling process has to be complemented with some kind of formal appraisal of alternatives. The framework suggests that the integration of qualitative and quantitative modelling with multi-criteria analysis may provide an important contribution in these situations, especially where "facts are uncertain, values in dispute, stakes high and decisions urgent (Funtowics and Revetz, 1994).

Table 3: Role of Qualitative and Quantitative Modelling in the Framework

Qualitative Modelling (Causal Loop Diagramming)	Quantitative Modelling (Computer Modelling, e.g. UrbanSim)
1 Understanding	1 Reflective Learning
2 Problem Analysis	2 Solution Analysis
3 Qualitative (local experience)	3 Quantitative (empirical data)
4 Tacit Knowledge	4 Explicit Knowledge
5 Normative	5 Deterministic
6 Identification	6 Verification

OTHER IMPLICATIONS

Our results suggest that in the Australian urban modelling context, the view of modellers and planning practitioners are much in line with the international literature in terms of what are the key challenges confronting such activities. What was perhaps more noteworthy was the ratings given by the panel members and the significant emphasis they placed on data preparation and on mutual understandings between planners and modellers of each others domains, as the most important modelling challenges. This suggests that, firstly, the ever-present problem of data availability and useability remains a concern, at least for this cohort. Secondly, it appears collaborative, participative modelling approaches, that generate mutual learnings between planners and modellers, are a likely way forward for improved urban analysis. Admittedly, the panel involved only one group of practitioners from a single large local government authority, but the study findings suggest that improved models derived from the academy may not translate into better practice in the field, unless the procedural dimension of modelling activities is improved.

The ultimate test of model applicability for the challenging tasks in urban sustainability assessment can only be achieved through stakeholder involvement. This requires a continuous, participatory process of social learning. Model developers have to make the underlying assumptions, functions and results of their tools as transparent as possible. Planning practitioners and stakeholders have to be trained to understand basic functionalities and model outcomes as well as the possible consequences of underlying structural choices and paradigms. Stakeholders have to become aware of the trade-offs between model specialisation and integration. Models with broader thematic coverage required for urban sustainability assessment may not at the same time provide all the levels of details expected by a single stakeholder.

Finally, for the integration of modelling activities in the framework to be successful, we claim that a shift in attitude within both the modelling and planning communities is needed. To modellers, this means making models more understandable and improving the measurement and communication of uncertainty and model limitations, promoting the use of models as communicating, learning and exploratory tools. For planners this means a need to view modelling not as a way of achieving certainty but as a device to inform planning and policy development in an uncertain world.

FUTURE RESEARCH

The results of this study are directly informing the development, testing and evaluation of a revised framework, which is being done as part of a case study implementation in Logan City. The project will now seek to assess how the implementation of an improved framework may influence the modelling process, modelling results and participation by planning practitioners, and urban planning and policy development outcomes.

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