Participatory Methods in Environmental System Dynamics Projects

Ines Winz, Gary Brierley
School of Geography, Geology and Environmental Science
University of Auckland
Private Bag 92019, Auckland, New Zealand
Tel. +64 (0)9 373 7599 ext. 88956, Fax. +64 (0)9 373 7434
i.winz@auckland.ac.nz, g.brierley@auckland.ac.nz

Abstract

Today there is widespread agreement that participatory methods are useful if not legally required to understand and effectively address environmental management problems. What participatory methods should be used in which situations and particularly how they should be applied are still insufficiently addressed questions. There is limited understanding about the interconnections between project purpose, participatory methods and their application. Participatory methods are often selected on the basis of familiarity or cost considerations. We argue that these trade-offs may compromise the potential outcomes and effectiveness of a project. To address these shortcomings we summarise current knowledge and understanding in the public participation literature.
System dynamics projects can benefit substantially from public participation particularly through participative modelling. Much research effort focuses on group model building. For projects where group model building is not a prudent choice, we suggest and discuss alternatives.

1 Introduction

Involving stakeholders in environmental decision making processes has become increasingly popular over the last few decades. Reasons are manifold. Some authors suggest that there is a democratic deficit that has developed because people increasingly distrust organisations that aggregate opinions, are disappointed with the lack of transparency and ineffective decision making in public institutions and expect a better quality in the services delivered by these institutions. As a result, public managers attempt to increase their

legitimacy through public participation (Bishop and Davis, 2002). Furthermore, benefits of participation may now be more widely known. In addition to benefits associated with higher quality decisions (Beierle, 2002), participation also supports capacity building (Fitzpatrick and Sinclair, 2003; Ford and Sterman, 1998; Yearley et al., 2003), promotes social learning (Kelsey, 2003; Pahl-Wostl, 2006; Pahl-Wostl and Hare, 2004), helps to resolve conflict and build consensus (Walkerden, 2006; Wilson and Howarth, 2002), and creates networking opportunities (Roux et al., 2006).

Opponents of participatory practice may point out that laypersons lack an understanding of concepts such as uncertainty and the scientific process, have insufficient knowledge and reasoning skills, and are susceptible to irrationality (Beierle, 2002). Proponents counter that value judgements must be made at all stages of the decision making process (Gregory, 2000), that expert knowledge is similarly limited, and that even experts are often in disagreement or argue irrationally. Besides, proper knowledge dissemination, fair choice of participants and effective structuring of the process can circumvent many of the issues that opponents set out (Beierle, 2002; Laurian, 2003). System dynamics practitioners may also be aware that in order to address environmental problems systemically, all actors that are part of the system need to be a part of the decision making process.

However, in the public participation literature many questions are insufficiently addressed (Kapoor, 2001; Rouwette and Vennix, 2006; Rouwette et al., 2002; Rowe and Frewer, 2005; Smith et al., 1997). How (methods), when (timing) and to what extent (intensity) should stakeholders be involved? How should one best enact involvement? What makes a participatory method effective? What are the links between problem situation and participatory method? Are some methods better suited for different stages of an intervention? Participation is not an end in itself, but rather a means to an end. As such the participation process is qualitative – even a proven participatory method will fail when applied in the wrong situation and in an ineffective way. This paper has the modest goal of teasing out some of these issues by examining current knowledge and understanding. The review is by no means exhaustive but should be understood as an initial inquiry.

A definition of terms may guide the reader. We adopt the definition of the term *stakeholder* by Glicken (2000), see also Hare and Pahl-Wostl (2002): "A stakeholder is any individual or group influenced by – and with an ability to significantly impact (either directly or indirectly) – the topical area of interest." This strong definition of stakeholder compares to weaker definitions which classify stakeholders as anyone affected by a decision (Mitchell et al., 1997). *Public participation* then encompasses a set of methods (or processes) designed to involve stakeholders in the agenda setting, decision-making and policy-forming activities of organizations/institutions responsible for policy

development (Rowe and Frewer, 2000, 2005). In essence, public participation[1] addresses the political dimension of decision making through some form of deliberative process.

We start our paper with a broad overview of theoretical developments in the public participation literature as well as some developments in the field of environmental decision making in general and environmental system dynamics in particular.

2 Literature Review

General Observations

The field of literature addressing the theory of public participation appears unbounded and complex. Participation as a research method is commonplace in areas as diverse as political science, policy analysis, anthropology, sociology, psychology, philosophy, social geography and business (van Asselt-Marjolein and Rijkens-Klomp, 2002). Many authors address public participation from a deliberative democracy point of view (Abelson et al., 2003; Arnstein, 1969; Fiorino, 1990; Hendriks, 2002; Mansbridge et al., 2006; Pratchett, 1999; van Tatenhove and Leroy, 2003) while other focus on contributions to management decision making in social-environmental systems (Stringer et al., 2006; Vennix, 1996). There do not appear to be any established journals purely dedicated to the subject[2]. *Journal of Public Policy*, *Public Administration Review*, *Public Administration* and *Journal of Policy Analysis and Management* all contain many discussions and suggested frameworks. This list is by no means exhaustive. Articles on applications can be found in almost any environmentally focused journal. For instance, *Environment and Planning B* has a special issue on participation based on geographical information systems (Vol. 28(6), 2001). A number of books have been published on this subject over the years, a short selection being Pateman (1970), Clayton et al. (1998), Keen et al. (2005) and Kasemir et al. (2003).

Benefits and Costs of Participation

In an analysis of 239 case studies, Beierle (2002, p. 740) concludes that stakeholder processes result in higher quality decisions:

[1] *Public participation* and *stakeholder involvement* are here used interchangeably although we are aware that some authors may view the latter as a more intense form of the former (Hare and Pahl-Wostl, 2002).

[2] The *Journal of Public Participation* published by the International Association of Public Participation (`http://www.iap2.org`) was discontinued in 1998 after two years. The *Journal of Public Deliberation* (`http://services.bepress.com/jpd/`) has so far published two issues since 2005.

> *"The majority of cases contain evidence that stakeholders are making better decisions, contributing new information and ideas, utilizing technical resources in their decision processes. Interestingly more intense stakeholder processes are more likely to produce high-quality decisions than traditional public participation processes."*

Similarly, Burby (2003) shows, by drawing on evidence from 60 plan-making processes, that with greater stakeholder involvement comprehensive plans are stronger and proposals are more likely to be implemented.

Drawing on this evidence there is currently widespread agreement that effective participation of stakeholders benefits the outcome of any environmental management project. Apart from legal requirements to involve stakeholders in the decision making process (Pahl-Wostl, 2002), participation has a place in three broad areas: problem identification, information provision, and implementation.

Problem identification. Projects can only be successful when they address the right problem at the right scale and scope. Participation can help to create a shared understanding about the identity and extent of the problem. In addition, the process by which the problem will be addressed can be defined. As a result, the purpose of the model and the project, as well as any deliverables, are clearly defined at the outset (Hjortso, 2004). The exchange of viewpoints at this stage is an important part of consensus building as it clarifies any divergent views and through managed interaction helps shape the project (Winch, 1995).

Information provision. Participation ensures that relevant mental, written and numerical information is accessible. Forrester (1994) advises that the mental information containing informal causal relationships and value judgements is paramount in building system dynamics models. Using information provided by participants has numerous beneficial effects as it creates trust in the modeller and the model-building process (Ford and Sterman, 1998); it can improve communication by developing a shared language; in a group setting it creates alignment and thus promotes consensus building (Andersen et al., 1997); it educates participants and enables efficient learning about the system and their role in it which can lead to changes in mental models and behaviour (Rouwette and Vennix, 2006). It is argued that this learning is a necessary condition for institutional change (Senge, 1992).

Implementation. As stakeholders contribute to the project and make it more transparent, their acceptance of and commitment to its outcomes increases. Participation thus results in an increased willingness of stakeholders to own and implement the end-products of the project. This ensures that stakeholders maintain the project's dynamic which is expected to lead to a more effective and sustainable system change. Another positive outcome can be increased independence, self-awareness,

Cost type	Example
Monetary	staff time (paid and unpaid), staff expenses, consultant fees, fees to participants, participants' expenses, training for staff and participants, administration, venue hire, other event costs (e.g. equipment), newsletters, leaflets, monitoring and evaluation fees.
Non-monetary	time contributed by participants, time contributed by staff (coordination, administrative effort), time for training, time for processing results and analysis, opportunity costs (taking time off from other work).
Potential hidden costs	reputation (from bad participatory practice), stress, uncertainty and conflict, shifting the burden from governmental to local management (Clayton et al., 1998).

Table 1: *Overview of costs associated with participatory practice.*

and empowerment of stakeholders to address local problems independently (Elliot et al., 2005; Fraser et al., 2006; Kapoor, 2001).

The above description outlines benefits resulting from perfect participation. The effectiveness of a single participatory method clearly depends on the circumstances, the timing and the quality of its application.

In contrast to these benefits, there are numerous costs associated with stakeholder involvement. These can be categorised as monetary, non-monetary and potential hidden costs (Table 1) and can affect individual participants, institutions or society as a whole (Involve, 2005). Moynihan (2003) points out that the instrumental costs and benefits are often overvalued compared to normative benefits such as an increase in governmental legitimacy.

The Question of Choice

Participation can take many forms and as a result, methods can be categorised according to a variety of themes. Various approaches exist that attempt to define participation through categorisation. Many authors (Arnstein, 1969; Hale, 1993; Lynam et al., 2007; Pateman, 1970) define participation through a continuum of interaction (or levels of participation) between the public and the decision-maker/government. Arnstein (1969) distinguishes eight levels of increasing interaction ranging from pure manipulation of participants to full-blown citizen control. As participatory methods move across the continuum, the degree of public power over the process outcome increases. Hale (1993) distinguishes three levels of participation according to process objec-

tives: awareness (a top-down process aimed at increasing public knowledge about a problem[3]), education (a top-down process aimed at providing information so the public can understand government policies and actions[4]) and involvement (a two-way process where the public has the opportunity to assist in decision-making or takes some action to support policy implementation[5]).

Other continuum frameworks categorise with respect to the scale at which processes take place (national, regional, local); the role participants play as either passive beneficiaries, informants, cost-sharers, consultees, or counterparts; the type of participants ranging from lay persons to experts which may include stakeholders with differing levels of representativeness; the structure of the method (structured, unstructured, active, passive); the goals of the process or method (decision-making/planning, consensus building, information gathering, etc.) (Figure 1); how well the method is accepted by the public (lack of confidence, alienation, inadequate information, advisory models, public consultation models, information models); and whether participation is voluntary or compulsory. The distribution of technical expertise can vary widely between methods with some drawing heavily on expert input and others on public input. Categories that have not yet been addressed are the extent to which the method supports consensus building or how well it supports independent thinking among participants and is thus suited to tease out a broader range of mental models.

Practitioners can use these continuum frameworks to characterise their situation and thus narrow down the methods that may be used to address it. This can reduce the number of methods that need to be further evaluated.

A second approach in defining participation attempts to link participatory methods to policy problems. Here, the specific type of problem determines whether and how participation takes place. The decision whether participation is appropriate is left to the initiator of the process. It is argued that the discontinuous nature of policy problems, the influence of local history on participation and the use of overlapping participatory methods needs a descriptive categorisation rather than a normative one (Bishop and Davis, 2002; Shand and Arnberg, 1996; Thomas, 1993). As noted by Bishop and Davis (2002, p. 21):

> *"Participation is shaped by the policy problem at hand, the techniques and resources available, and ultimately, a political judgement about the importance of the issue and the need for public involvement. Participation arrangements tend to be local and ad hoc, and any realistic categorisation will reflect diverse and unrelated practices."*

[3]e.g. using the final model to show policy effects or gathering of feedback

[4]e.g. eliciting mental models for model development or the use of a management flight simulator to test preconceived policies (Ford, 1996)

[5]e.g. testing of policies suggested by the participants or a full mediated modelling intervention/facilitated group model building (Stave, 2003; Tidwell et al., 2004)

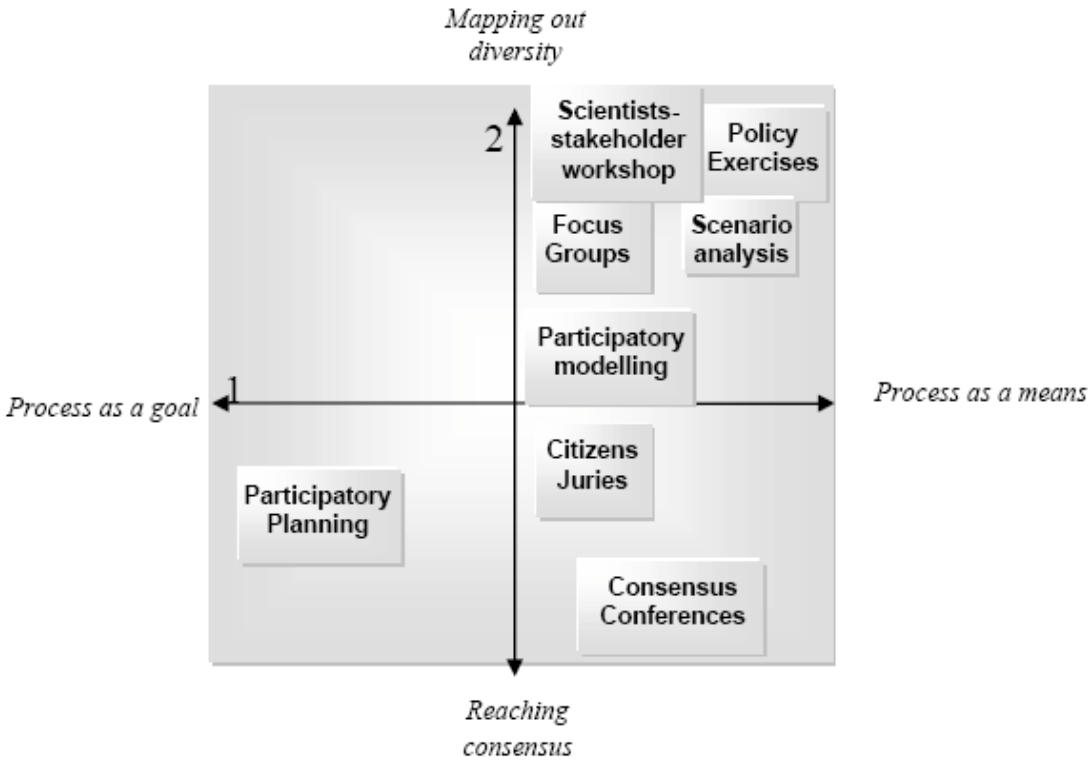

Figure 1: *Categorising methods according to process goals. Reproduced from van Asselt-Marjolein and Rijkens-Klomp (2002).*

Thomas (1993) distinguishes five situations: *autonomous managerial decision making* with no public involvement; *modified autonomous managerial decision making* where the manager may seek public information which may or may not influence his decision; *segmented public consultation* where the problem is shared with segments of the public separately and the decision reflects any suggestions made; *unitary public consultation* where the problem is shared with the public simultaneously, i.e. with a single group, and the decision reflects any suggestions made; and *public decision* where information is shared with the public simultaneously and a decision is made based on consensus reached between all segments of the public and the manager. Each situation is supported by a particular method which also depends on the public make-up, i.e. the range of individual and/or interest groups. For example, for a small number of stakeholders/organised interest groups a manager with a high degree of autonomy will rely on key contacts to seek information from each group, but when the number of stakeholders becomes too great or disorganised a survey becomes a more appropriate method of participation. If the manager decides that public consultation is required, s/he can either meet with each group or create a citizens advisory committee in the case of a large number of stakeholders or a disorganised public (Thomas, 1990).

Shand and Arnberg (1996), and similarly Bishop and Davis (2002), match a number of methods to five contemporary policy types (Table 2).

Purpose	**Suggested methods**
Information	surveys, focus groups, public information campaign
Consultation	key contacts, interest group meetings, discussion papers, town hall meetings, circulation of proposals, public hearings
Partnership	advisory board/committee, policy communities
Delegation	public enquiries, impact assessment studies
Control	referenda

Table 2: *Participation purpose and corresponding suggested methods. Reproduced from Shand and Arnberg (1996).*

Fey and Trimble (1992) list methods for the tasks of knowledge acquisition[6] and knowledge representation[7]. Elliot et al. (2005) suggest that five elements should be considered when selecting a participatory method: objectives, topic, participants, time, and budget.

The number of participative methods is large and steadily increasing. Rowe and Frewer (2005) list more than 100 traditional methods ranging from interviews in different formats to questionnaires, various mapping methods for individual or group use that can be facilitated or not, and large-scale facilitated group processes. In addition, a large number of innovative approaches exist that combine traditional methods of participation (e.g. Bostrom (2003); Gregory et al. (2001); Hermans et al. (In press 2007); Lowndes et al. (2001a); Regan et al. (2006)).

Of particular interest to system dynamics practitioners is *participatory modelling*, also referred to as *group model building* (Vennix, 1996, 1999; Vennix et al., 1992), *mediated modelling* (Van den Belt, 2004) or *adaptive ecological modelling* (Costanza and Ruth, 1998). Participatory modelling sees model users (and often stakeholders) actively involved in the modelling process, particularly during the conceptual (design) phase (van Asselt-Marjolein and Rijkens-Klomp, 2002).

The Question of Effectiveness

The research literature usually describes the outcomes of participatory methods as they would have been achieved under ideal circumstances. However,

[6] interviews, process tracing techniques, task analysis, job analysis, repertory grid technique, protocol analysis, nominal group technique, free group discussion, survey, Delphi method

[7] various maps, graphs and diagrams, prose and verbal descriptions, rules, conditional statements, tables and scenarios

there is no agreed understanding of these required circumstances, what makes a participatory method effective or even what appropriate benchmarks for effectiveness could be. Effective participation has been defined as *"maximising the relevant information from the maximum number of all relevant sources and transferring it (with minimal information loss) to the other parties, with the efficient processing of that information by the receivers (the sponsors and the participants) and the combining of it into an accurate composite"* (Rowe and Frewer, 2005, p. 263). Rowe and Frewer (2000) suggest the following acceptance and process criteria (Table 3) for evaluating and comparing participatory methods:

Webler et al. (2001) develop five criteria of process "goodness": acquisition and maintenance of legitimacy, facilitation of ideological discussion/search for common values, realisation of democratic principles of fairness and equality, equal power among participants and viewpoints, responsible leadership and compromise. Further discussion, suggested criteria and benchmarks for effectiveness can be found in Beierle and Konisky (2000); Brody (2003); Chess and Purcell (1999); Hale (1993); McCool and Guthrie (2001); Palerm (2000) and Davies (2001).

Much of the success or failure of a particular exercise will stem from whether the method was selected appropriately for the situation and how well the method was applied. However, structural features can limit or enhance effectiveness. An example would be the provision of a facilitator vs. the quality of facilitation. As a result there is no best-choice method suitable for all problems although some authors agree that the most appropriate techniques are hybrids of more traditional methods (Rowe and Frewer, 2000; Smith et al., 1997). Other pitfalls in participatory practice include the inability of stakeholders to resolve conflicts over equity, the distributive effects of natural resources, and competing visions about project goals (Singleton, 2002); the management of fragmentation among stakeholders from the top (Pellizzoni, 2003); a lack of stakeholder interest[8] (Laurian, 2004; Lowndes et al., 2001b); inadvertent or deliberate exclusion of key groups from the dialogue (Barnes et al., 2002; Lane and Corbett, 2005); ongoing communication where scientific language terminology is appropriately translated into lay terms (Glicken, 1999, 2000); and the loss of mutual respect (Andersson, 2004).

Participation in Environmental Management

Participation is now considered to be an integral component of effective environmental management. The shift in emphasis from discipline-bound 'command-and-control' perspectives towards participatory adaptive management over the past few decades has been accompanied by transitions in the sources and forms of information used, processes applied, decision-making procedures,

[8]The *inverse-scale effect* applies: more people are interested in participating in processes at local scales than at regional or national scales (Carver et al., 2001).

Acceptance criteria	**Explanation**
Representativeness	The public participants should comprise a broadly representative sample of the population of the affected public particularly with a view of integrating multiple knowledge systems (Kelsey, 2003).
Independence	The participation process should be conducted in an independent, unbiased way (managers and facilitators).
Early involvement	The public should be involved as early as possible in the process as soon as value judgements become salient.
Influence	The output of the procedure should have a genuine impact on policy.
Transparency	The process should be transparent so that the public can see what is going on and how decisions are being made.
Process criteria	
Resource accessibility	Participants should have access to the appropriate resources to enable them to successfully fulfil their brief.
Task definition	The nature and scope of the participation task should be clearly defined.
Structured decision making	The participation exercise should use/provide appropriate mechanisms for structuring and displaying the decision-making process.
Cost-effectiveness	The method should in some sense be cost-effective.

Table 3: *Acceptance and process criteria suggested to evaluate the effectiveness of participatory methods. Reproduced from Rowe and Frewer (2000).*

and implementation/maintenance of adopted measures (cf. Hermans et al. (In press 2007); Hillman and Brierley (2005); Holling and Meffe (1996)). Engagement and inclusion are increasingly recognized to be key starting points in defining, let alone addressing, environmental problems, such that practices 'work with' rather than being 'imposed upon' community perspectives. Today, few projects in natural resource management are supported unless they include substantial community involvement in planning, design and implementation. These initiatives are especially effective when the benefits of collabo-

ration are clear, a collective vision is developed, and learning and adaptation accompany decision-making, implementation and maintenance. True participatory projects build local skills, interests and capacities that continue after the project ends. Given these traits, participatory processes form a part of the rapid growth in environmental justice literature (e.g. Hillman (2005, 2006)), in emerging approaches to co-management (e.g. Folke et al. (2005)), in environmental impact assessment – and here particularly *Participatory Integrated Assessment* – (e.g. Hartley and Wood (2005); Palerm (2000); Persson (2006); Vicente and Partidrio (2006)) and in the resilience movement (e.g. Adger (2000); Fiksel (2006); Folke (2006); Gunderson (2000); Holling (1996)). As noted earlier, key concerns that are expressed in the adoption of participatory processes relate to time and resource costs, and difficulties in implementing outcomes across differing scales and managerial hierarchies (e.g. Kapoor (2001); Matthies et al. (2007); Steel and Weber (2001)). In addition to requiring sufficient resources (time, money and skills), participatory processes also have to deal with issues of representativeness, transparency and accountability. These developments, and limitations, parallel those observed within the literature on environmental applications of systems dynamics principles that apply participatory procedures.

Participation in System Dynamics

Stakeholder participation in system dynamics (SD) is not limited to participatory modelling alone, although this is a key factor. Rouwette et al. (2002) trace the history of stakeholder participation in SD applications back more than 50 years and remark on the exponential growth in case studies with client involvement. In the beginning, stakeholders were mainly seen as information providers. During the last 20 years however their involvement became more intense and was characterised by continuous information feedback processes, e.g. through social learning and the exchange of knowledge. The intent was to increase uptake, generate a sense of ownership and support in the implementation of models (Rouwette and Vennix, 2006).

In the system dynamics research literature most attention has been directed to *group model building* (GMB) interventions. These are projects where people work together in groups and jointly construct models to tackle 'messy' problems (Vennix, 1999). Facilitated group projects are particularly useful when stakes are high and stakeholder objectives conflicting. A GMB intervention consist of three broad phases: pre-meeting activities, the actual meetings and post-meeting follow-up activities. Andersen et al. (1997) describe in more detail best practices in GMB. The time frame of group model building interventions can range from one day to several years and group sizes can vary between a handful to up to 100.

Rouwette and Vennix (2006) note a lack of understanding of the effects of individual processes and techniques in a GMB intervention which is com-

monly replaced by intuition and experience. GMB interventions are either aimed at modelling for decision-making or modelling for consensus building (Rouwette and Vennix, 2006; Zagonel, 2002). The choice between these two options will result in markedly different models and necessitates the use of distinct methods. Models aimed at decision-making will be more parsimonious with due focus on validity testing, whereas a model designed for consensus building will integrate potentially conflicting views that are elicited e.g. in open discussions.

The process of GMB interventions is structured by way of meticulously planned activities known as *scripts*. A large variety of scripts exist to support, among others, problem definition, model conceptualization and policy development (c.f. Andersen and Richardson (1997); Luna-Reyes et al. (2007); Rouwette and Vennix (2006) and references therein).

3 Alternatives to Group Model Building

While GMB interventions clearly seem to be the best practice in SD participatory projects, full-scale group workshops may neither always be feasible nor desirable. Group processes are particularly time-expensive and require extensive scheduling — and often rescheduling — of meetings for all involved. Student research projects are particularly at risk of becoming involuntarily prolonged, for examples see Holmström (2004) and Den Exter (2004). Moreover, the effectiveness of interventions may be compromised if they are long-term and have a high participant turnover. For large numbers of stakeholders a full GMB intervention may prove prohibitive for actual model development. In these instances, group workshops are usually reduced to one or two meetings where problem definition, system conceptualization and model evaluation take place (Andersen et al., 1997). GMB requires an effective rapport between client institution/stakeholders and the modelling team. This may necessitate multiple interviews before the actual intervention can start, extending the lead time. Group processes can also be foreclosed by substantial conflict. In some countries or areas experienced facilitators familiar with system dynamics may not be available. Furthermore, institutional boundaries and barriers may impede group processes. Examples include cross-agency issues, where different agencies are concerned with individual (but interconnected) parts of the ecosystem, but all aim to protect their own agendas, staff and resources. Additionally there are countless examples of cross-boundary conflicts over natural resources. Here, institutions and/or interest groups may even be keen to hijack prospects of any mutual agreement or joint work.

On the basis of these criteria a fully facilitated group model building intervention may sometimes no longer be suitable. The question then becomes which other participatory methods can be utilised instead, at what stage and how? For example, cognitive mapping methods have proven useful in teasing out mental models of single participants during problem definition and system

conceptualization phases. These maps can then be aggregated and converted into causal loop diagrams or stock and flow diagrams (Eden, 1994). Table 4 makes suggestions as to which participatory methods are useful at the different stages of a system dynamics project. The reader/reviewer is asked to reflect and feed back to the authors any suggestions and concerns.

4 Conclusions

From the public participation literature a number of criteria emerge that should be considered when selecting a participatory method: the overall purpose of the project, how well the problem is understood, the conflict potential of the problem and decision making process, the number of stakeholders available, the level of their interest and support, the type of stakeholder (influence, power, salience), type and amount of data available to support the method, the phase in the project the method will be applied to, any relevant historic processes, and other resources available particularly time and money. From this it becomes clear that decision makers need to carefully balance active participation with technical limitations and political interests.

Despite some unresolved issues in participation practice, it is clear that considerable progress has been made over the past decade. Increasingly, decision makers and officials rely extensively on public participation. Significant empirical research has investigated the effectiveness of these participation practices. Frameworks have emerged that help decision makers in their choice of method for their individual situation. Of concern is the fact that similar research efforts in different fields occur in parallel, without knowledge of one another. This has resulted in a misnaming of methods and uncertainty about the equivalence of terms: the same method can go by a variety of names (Rowe and Frewer, 2005)! This doubling of efforts is not only inefficient but, together with the vastness of the literature, impedes prospects to generate a beneficial synthesis.

5 Bibliography

J. Abelson, P.-G. Forest, J. Eyles, P. Smith, E. Martin, and F.-P. Gauvin. Deliberations about deliberative methods: issues in the design and evaluation of public participation processes. *Social Science & Medicine*, 57(2):239–251, July 2003. doi: 10.1016/S0277-9536(02)00343-X.

W. N. Adger. Social and ecological resilience: Are they related? *Progress in Human Geography*, 24(3):347–364, 2000.

D. F. Andersen and G. P. Richardson. Scripts for group model building. *System Dynamics Review*, 13(2):107–129, 1997.

D.F. Andersen, G.P. Richardson, and J.A.M. Vennix. Group model building: adding more science to the craft. *System Dynamics Review*, 13(2):187–201, 1997.

Stage	Method	Reasoning
Problem definition	individual: key contacts, interviews	top management decision
	group: key contacts, workshop, 'hopes and fears' script, open group discussion	when consensus is required, creates a common vision
System conceptualization	individual: interviews, oral history, discourse analysis, content analysis	to captures a wide variety of individual mental models while avoiding groupthink (information will then need to be synthesised in order to create a conceptual system model), to establish consensus on reference mode and dynamic hypothesis
	group: focus group, hermeneutics, open group discussion, group consensus, joint development of a concept model, reference mode elicitation script, structure elicitation script (Luna-Reyes et al., 2007)	to create shared language and improve communication about system components and relationships.
Model formulation	individual:	not applicable as commonly performed independently from stakeholders
	group: facilitated group discussion, capacity utilisation script, data estimation script, model refinement script (Andersen and Richardson, 1997), variable elicitation script	when stakeholders are familiar with system dynamics or when it will be used for more than one project; validates model components and relationships during the process; stakeholders can point to relevance of different model sectors and thus influence model breadth and depth; use of democratic processes for the quantification of qualitative variables; access to expert knowledge and other sources of information/data; increases transparency and thus salience of the final model
Model evaluation/testing	individual: structure/behaviour testing, policy implication testing (Barlas, 1989)	individual play with the simulation can yield extensive feedback on its performance and potential policies
	group: facilitated group discussion	to test whether there is general consensus on model performance has been achieved
Policy analysis	individual: multi-attribute utility evaluation or other decision analysis methods	if simulation tool used by analyst/manager only
	group: facilitated group discussion, reflector feedback	learning
Implementation	individual:	if simulation tool used by analyst/manager only
	group: community monitoring projects	policies are closely monitored for intended and unintended effects

Table 4: *Suggested participatory methods for different stages in a system dynamics project.*

L. Andersson. Experiences of the use of riverine nutrient models in stakeholder dialogues. *International Journal of Water Resources Development*, 20(3):399–425, September 2004. doi: 10.1080/0790062042000248547.

S.R. Arnstein. A ladder of citizen participation. *Journal of the American Planning Association*, 35:216–224, 1969.

Y. Barlas. Multiple tests for validation of system dynamics type of simulation models. *European Journal of Operational Research*, 42:59–87, 1989.

M. Barnes, J. Newman, A. Knops, and H. Sullivan. Constituting the 'public' in public participation. *Public Administration*, 81(2):379–399, 2002. doi: 10.1111/1467-9299.00352.

T.C. Beierle. The quality of stakeholder-based decisions. *Risk Analysis*, 22(4):739–749, 2002. doi: 10.1111/0272-4332.00065.

T.C. Beierle and D.M. Konisky. Values, conflict and trust in participatory environmental planning. *Journal of Policy Analysis and Management*, 19:587–602, 2000. doi: 10.1002/1520-6688(200023)19:4⟨587::AID-PAM4⟩3.0.CO;2-Q.

P. Bishop and G. Davis. Mapping public participation in policy choices. *Australian Journal of Public Administration*, 61(1):14–29, 2002. doi: 10.1111/1467-8500.00255.

M. Bostrom. Environmental organisations in new forms of political participation: Ecological modernisation and the making of voluntary rules. *Environmental Values*, 12(2):175–193, May 2003.

S.D. Brody. Measuring the effects of stakeholder participation on the quality of local plans based on the principles of collaborative ecosystem management. *Journal of Planning Education and Research*, 22(4):407–419, 2003. doi: 10.1177/0739456X03022004007.

R.J. Burby. Making plans that matter: Citizen involvement and government action. *Journal of American Planning Association*, 69(1):33–49, 2003.

S. Carver, A. Evans, R. Kingston, and I. Turton. Public participation, GIS and cyberdemocracy: evaluating on-line spatial decision support systems. *Environment and Planning B: Planning and Design*, 28(6):907–21, 2001.

C. Chess and K. Purcell. Public participation and the environment: Do we know what works? *Environmental Science & Technology*, 33(16):2685 –2692, 1999. doi: 10.1021/es980500gS0013-936X(98)00500-8.

A. Clayton, P. Oakley, and B. Pratt. *Empowering People: A Guide to Participation*. UNDP, 1998.

R. Costanza and M. Ruth. Using dynamic modeling to scope environmental problems and build consensus. *Environmental Management*, 22(2):183–195, 1998.

A. Davies. What silence knows: Planning public participation and environmental values. *Environmental Values*, 10(1):77–102, 2001.

K. Den Exter. *Integrating Environmental Science and Management: The Role of System Dynamics Modelling*. PhD thesis, CRC Sustainable Tourism School of Environmental Science and Management, Southern Cross University, Queensland, Australia, 2004.

C. Eden. Cognitive mapping and problem structuring for system dynamics model building. *System Dynamics Review*, 10(2–3):257–276, 1994.

J. Elliot, S. Heesterbeek, C.J. Lukensmeyer, and N. Slocum. Participatory methods toolkit - a practitioner's manual. Technical report, King Baudouin Foundation and the Flemish Institute for Science and Technology Assessment (viWTA), September 2005. URL `www.viWTA.be`. ISBN 90-5130-506-0.

W. Fey and J. Trimble. The evaluation and development of knowledge aquisition in system dynamics studies. In *Proceedings of the International Conference of the System Dynamics Society*, pages 173–182, Utrecht, The Netherlands, 1992.

J. Fiksel. Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice, & Policy*, 2(2):14–21, 2006. URL `http://ejournal.nbii.org/archives/vol2iss2/0608-028.fiksel.html`.

D.J. Fiorino. Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, Technology, & Human Values*, 15(2):226–243, Spring 1990.

P. Fitzpatrick and A.J. Sinclair. Learning through public involvement in environmental assessment hearings. *Journal of Environmental Management*, 67(2):161–174, 2003. doi: 10.1016/S0301-4797(02)00204-9.

C. Folke. Resilience: The emergence of a perspective for social-ecological systems analysis. *Global Environmental Change*, 16:253–267, 2006.

C. Folke, T. Hahn, P. Olsson, and J. Norberg. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, 30:441–473, 2005.

A. Ford. Testing the Snake River Explorer. *System Dynamics Review*, 12(4):305–329, Winter 1996.

D.N. Ford and J.D. Sterman. Expert knowledge elicitation to improve formal and mental models. *System Dynamics Review*, 14(4):309–340, Winter 1998.

J.W. Forrester. System dynamics, systems thinking, and soft or. *System Dynamics Review*, 10(2-3):245–256, 1994.

E. D. G. Fraser, A. J. Dougill, W. E. Mabee, M. Reed, and P. McAlpine. Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management*, 78:114–127, 2006. doi: 10.1016/j.jenvman.2005.04.009.

J. Glicken. Effective public involvement in public decisions. *Science Communication*, 2(3):298327, 1999.

J. Glicken. Getting stakeholder participation 'right': A discussion of participatory processes and possible pitfalls. *Environmental Science & Policy*, 3:305–310, 2000.

R. Gregory. Using stakeholder values to make smarter environmental decisions. *Environment*, 42(5):34–44, 2000.

R. Gregory, T. McDaniels, and D. Fields. Decisions aiding, not dispute resolution: Creating insights through structured environmental decisions. *Journal of Policy Analysis and Management*, 20(3):415–432, 2001. doi: 10.1002/pam.1001.

L. H. Gunderson. Ecological resilience - in theory and application. *Annual Review of Ecology and Systematics*, 31:425–439, 2000.

E.O. Hale. Successful public involvement. *Journal of Environmental Health*, 55(4): 17–19, 1993.

M. Hare and C. Pahl-Wostl. Stakeholder categorisation in participatory integrated assessment processes. *Integrated Assessment*, 3(1):50–62, 2002.

N. Hartley and C. Wood. Public participation in environmental impact assessment-implementing the aarhus convention. *Environmental Impact Assessment Review*, 25:319–340, 2005.

C. Hendriks. Institutions of deliberative democratic processes and interest groups: Roles, tensions, and incentives. *Australian Journal of Public Administration*, 61 (1):64–75, 2002. doi: 10.1111/1467-8500.00259.

C. Hermans, J. Erickson, T. Noordewier, A. Sheldon, and M. Kline. Collaborative environmental planning in river management: An application of multicriteria decision analysis in the white river watershed in vermont. *Journal of Environmental Management*, In press 2007. doi: 10.1016/j.jenvman.2006.07.013.

M. Hillman. Justice in river management: Community perceptions from the Hunter Valley, New South Wales, Australia. *Geographical Research*, 43(2):152–161, 2005.

M. Hillman. Situated justice in environmental decision-making: Lessons from river management in Southeastern Australia. *Geoforum*, 37:695–707, 2006.

M. Hillman and G. Brierley. A critical review of catchment-scale stream rehabilitation programmes. *Progress in Physical Geography*, 29(1):50–70, 2005. doi: 10.1191/0309133305pp434ra.

C.N. Hjortso. Enhancing public participation in natural resource management using soft OR – an application of strategic option development and analysis in tactical forest planning. *European Journal of Operational Research*, 152:667–683, 2004. doi: 10.1016/S0377-2217(03)00065-1.

C. S. Holling. Surprise for science, resilience for ecosystems, and incentives for people. *Ecological Applications*, 6(3):733–735, August 1996.

C. S. Holling and G. K. Meffe. Command and control and the pathology of natural resource management. *Conservation Biology*, 10(2):328–337, 1996. doi: 10.1046/j.1523-1739.1996.10020328.x.

P. Holmström. Group modeling in system dynamics - a case study. Master's thesis, Department of Applied Information Technology, IT University of Göteborg, Göteborg, Sweden, 2004.

Involve. The true costs of public participation. Full report, London, UK, November 2005.

I. Kapoor. Towards participatory environmental management? *Journal of Environmental Management*, 63(3):269–279, 2001. doi: 10.1006/jema.2001.0478.

B. Kasemir, J. Jager, C.C. Jaeger, and M.T. Gardner, editors. *Public participation in sustainability science*. Cambridge University Press, Cambridge, Massachussetts, USA, 2003.

M. Keen, V. Brown, and R. Dyball, editors. *Social learning in environmental management : building a sustainable future*. Earthscan, London, UK, 2005.

E. Kelsey. Integrating multiple knowledge systems into environmental decision-making: Two case studies of participatory biodiversity initiatives in Canada and their implications for conceptions of education and public involvement. *Environmental Values*, 12(3):381–396, August 2003.

M. B. Lane and T. Corbett. The tyranny of localism: Indigenous participation in community-based environmental management. *Journal of Environmental Policy and Planning*, 7(2):141–159, 2005. doi: 10.1080=15239080500338671.

L. Laurian. A prerequisite for participation: Environmental knowledge and what residents know about local toxic sites. *Journal of Planning Education and Research*, 22(3):257–269, 2003. doi: 10.1177/0739456X02250316.

L. Laurian. Public participation in environmental decision making: Findings from communities facing toxic waste cleanup. *Journal of American Planning Association*, 70(1):53–65, 2004.

V. Lowndes, L. Pratchett, and G. Stoker. Trends in public participation (part 1): Local government perspectives. *Public Administration*, 79(1):205222, 2001a. doi: 10.1111/1467-9299.00253.

V. Lowndes, L. Pratchett, and G. Stoker. Trends in public participation (part 2): Citizen's perspectives. *Public Administration*, 79(2):445–455, 2001b. doi: 10.1111/1467-9299.00264.

L.F. Luna-Reyes, I.J. Martinez-Moyano, T.A. Pardo, A.M. Cresswell, D.F. Andersen, and G.P. Richardson. Anatomy of a group model-building intervention: building dynamic theory from case study research. *System Dynamics Review*, 22(4):291–320, 2007. doi: 10.1002/sdr.349.

T. Lynam, W. De Jong, D. Sheil, T. Kusumanto, and K. Evans. A review of tools for incorporating community knowledge, preferences, and values into decision making in natural resources management. *Ecology and Society*, 12:5, 2007. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art5.

J. Mansbridge, J. Hartz-Karp, M. Amengual, and J. Gastil. Norms of deliberation: An inductive study. *Journal of Public Deliberation*, 2(1):7, 2006. URL `http://services.bepress.com/jpd/vol2/iss1/art7/`.

M. Matthies, C. Giupponi, and B. Ostendorf. Environmental decision support systems: Current issues, methods and tools. *Environmental Modelling & Software*, 22(2):123–127, 2007.

S.F. McCool and K. Guthrie. Mapping the dimensions of successful public participation in messy natural resources management situations. *Society & Natural Resources*, 14(4):309–323, 2001. doi: 10.1080/713847694.

R. K. Mitchell, B. R. Agle, and D. J. Wood. Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review*, 22(2):853–886, October 1997.

D.P. Moynihan. Normative and instrumental perspectives on public participation: Citizen summits in Washington D.C. *American Review of Public Administration*, 33(2):164–188, 2003. doi: 10.1177/0275074003251379.

C. Pahl-Wostl. Participative and stakeholder-based policy design, evaluation and modeling processes. *Integrated Assessment*, 3(1):3–14, 2002.

C. Pahl-Wostl. The importance of social learning in restoring the multifunctionality of rivers and floodplains. *Ecology and Society*, 11(1):10, 2006. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art10/.

C. Pahl-Wostl and M. Hare. Processes of social learning in integrated resources management. *Journal of Community & Applied Social Psychology*, 14(3):193–206, 2004. doi: 10.1002/casp.774.

J.R. Palerm. An empirical – theoretical analysis framework for public participation in environmental impact assessment. *Journal of Environmental Planning and Management*, 43:581–600, 2000.

C. Pateman. *Participation and democratic theory*. Cambridge University Press, Cambridge, Massachussetts, USA, 1970.

L. Pellizzoni. Uncertainty and participatory democracy. *Environmental Values*, 12 (2):195–224, 2003.

J. Persson. Theoretical reflections on the connection between environmental assessment methods and conflict. *Environmental Impact Assessment Review*, 26(7): 605–613, October 2006. doi: 10.1016/j.eiar.2006.04.005.

L. Pratchett. New fashions in public participation: towards greater democracy? *Parliamentary Affairs*, 52(4):617–33, 1999. doi: 10.1093/pa/52.4.616.

H.M. Regan, M. Colyvan, and L. Markovchick-Nicholls. A formal model for consensus and negotiation in environmental management. *Journal of Environmental Management*, 80(2):167–176, July 2006.

E.A.J.A. Rouwette and J.A.M. Vennix. System dynamics and organizational interventions. *Systems Research and Behavioral Science*, 23:451–466, 2006. doi: 10.1002/sres.772.

E.A.J.A. Rouwette, J.A.M. Vennix, and T. van Mullekom. Group model building effectiveness: a review of assessment studies. *System Dynamics Society*, 18:5–45, 2002.

D.J. Roux, K.H. Rogers, H.C. Biggs, P.J. Ashton, and A. Sergeant. Bridging the sciencemanagement divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecology and Society*, 11(1):4, 2006. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art4/.

G. Rowe and L.J. Frewer. Public participation methods: A framework for evaluation. *Science, Technology & Human Values*, 25(1):3–29, 2000.

G. Rowe and L.J. Frewer. A typology of public engagement mechanisms. *Science, Technology & Human Values*, 30(2):251–290, 2005. doi: 10.1177/0162243904271724.

P. M. Senge. *The Fifth Discipline*. Random House, Australia, 7th ed. edition, 1992.

D. Shand and M. Arnberg. Responsive government: Service quality initiatives. Technical report, Organization for Economic Cooperation and Development, Paris, France, 1996.

S. Singleton. Collaborative environmental planning in the american west: The good, the bad, and the ugly. *Environmental Politics*, 11(3):54–75, 2002. doi: 10.1080/714000626.

L.G. Smith, C.Y. Nell, and M.V. Prystupa. The converging dynamics of interest representation in resources management. *Environmental Management*, 21(2):139–146, March 1997. doi: 10.1007/s002679900013.

K.A. Stave. A system dynamics model to facilitate public understanding of water management options in Las Vegas, Nevada. *Journal of Environmental Management*, 67:303–313, 2003.

B.S. Steel and E. Weber. Ecosystem management, decentralization, and public opinion. *Global Environmental Change*, 11:119–131, 2001. doi: 10.1016/S0959-3780(00)00062-5.

L.C. Stringer, A.J. Dougill, E. Fraser, K. Hubacek, C. Prell, and M.S. Reed. Unpacking "participation" in the adaptive management of social-ecological systems: A critical review. *Ecology and Society*, 11(2):39, 2006. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art39.

J.C. Thomas. Public involvement in public management: Adapting and testing a borrowed theory. *Public Administration Review*, 50(4):435–45, 1990.

J.C. Thomas. Public involvement and governmental effectiveness: a decision-making model for public managers. *Administrative Science and Society*, 24(4):444–69, 1993.

V.C. Tidwell, H.D. Passell, S.H. Conrad, and R.P. Thomas. System dynamics modeling for community-based water planning: Application to the Middle Rio Grande. *Aquatic Sciences*, 66:357–372, 2004. doi: 10.1007/s00027-004-0722-9.

B.A. van Asselt-Marjolein and N. Rijkens-Klomp. A look in the mirror: reflection on participation in integrated assessment from a methodological perspective. *Global Environmental Change*, 12:167184, 2002.

M. Van den Belt. *Mediated Modelling - A System Dynamics Approach to Environmental Consensus Building*. Island Press, Washington, USA, 2004.

J.P.M. van Tatenhove and P. Leroy. Environment and participation in a context of political modernisation. *Environmental Values*, 12(2):155–174, May 2003.

J.A.M. Vennix. *Group-Model Building: Facilitating Team Learning Using System Dynamics*. John Wiley & Sons, Chichester, UK, 1996.

J.A.M. Vennix. Group model-building: tackling messy problems. *System Dynamics Review*, 15(4):379–401, 1999.

J.A.M. Vennix, D.F. Andersen, G.P. Richardson, and J. Rohrbaugh. Model-building for group decision support: Issues and alternatives in knowledge elicitation. *European Journal of Operational Research*, 59:28–41, 1992.

G. Vicente and M.R. Partidrio. SEA – enhancing communication for better environmental decisions. *Environmental Impact Assessment Review*, 26(8):696–706, November 2006. doi: 10.1016/j.eiar.2006.06.005.

G. Walkerden. Adaptive management planning projects as conflict resolution processes. *Ecology and Society*, 11(1):48, 2006. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art48/.

T. Webler, S. Tuler, and R. Krueger. What is a good public participation process? Five perspectives from the public. *Environmental Management*, 27(3):435–450, March 2001. doi: 10.1007/s002670010160.

M.A. Wilson and R.B. Howarth. Discourse-based valuation of ecosystem services: Establishing fair outcomes through group deliberation. *Ecological Economics*, 41: 431–443, 2002. doi: 10.1016/S0921-8009(02)00092-7.

G. Winch. Developing consensus: reflections on a model-supported decision process. *Management Decision*, 33(6):22–31, 1995. doi: 10.1108/00251749510087623.

S. Yearley, S. Cinderby, J. Forrester, P. Bailey, and P. Rosen. Participatory modeling and the local governance of the politics of UK air pollution: A three-city case study. *Environmental Values*, 12(2):247–262, 2003.

A.A. Zagonel. Model conzeptualisation in group model building: a review of the literature exploring the tension between representing reality and negotiating social order. In *Proceedings of the International Conference of the System Dynamics Society. Palermo, Italy, July 28August 1*, 2002.