Accessibility of Computer-Based Simulation Models in Inherently Conflict-Laden Negotiations

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Abstract

The use of computer-based simulation models has a long history in areas such as environmental planning and policy-making, and particularly in water management. Policy making in these areas is often characterized by inherent conflict among diverse stakeholders with divergent interests. Although simulation models have been shown to be helpful for such problems, they are typically under the control of a technical analyst or governmental agency and are not available to negotiators in real time. Recent trends in computer technology and user expectations raise the possibility of real-time, user-controlled models for supporting negotiation. But is such accessibility likely to be helpful? This study used a "compressed" longitudinal experiment to investigate the impacts of different scenarios of accessibility of computer-based simulation models. The task was based on a real-life problem in Colorado River water management. Results revealed no significant differences among conditions for either solution quality or satisfaction. These results suggest that the common notion of "more is better" may be inappropriate, and resources for improving computer support of negotiation might best be focused elsewhere.

Key Words: computer-aided negotiation, computer simulation, group decision, group support systems, environmental conflict, resource allocation

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INTRODUCTION

The use of computer-based simulation models to support negotiation has a long history. Simulation models range from models of physical systems for water resource planning (Mays 1996; Palmer, Keyes, and Fisher 1993), to accounting-type models for analyzing the fiscal impact of urban development patterns in local governments (Kraemer 1985), to models of the negotiation process itself (Jelassi and Foroughi 1989). Models of physical systems—the focus of this paper—can be very complex and expensive to run, with costs as high as $100,000 per model run (Andrews 1991). The model itself is often a scarce resource that is controlled exclusively by one of the parties involved in the negotiation, typically a mediating governmental agency. Even in situations where other parties have access to a model, the model usually reflects the needs and situation of the original developers. In either situation, the resulting negotiation process is likely to be problematic.

The trend in modern technology is toward ubiquitous, real-time accessibility of computer-based information. In negotiation situations, this would mean that all parties would have access to the same simulation model at any point during the negotiations. The commonly held belief is that such universal accessibility is likely to improve negotiation processes and outcomes. But is such a view warranted? Does increased accessibility lead to better negotiation outcomes? Does accessibility to the same simulation model help negotiators achieve an understanding of each other's positions and thus facilitate consensus? These questions deserve attention if we are to provide negotiators with computer-based tools that help, rather than hinder, negotiation processes.

The current study was designed to address the above questions in the context of water management—an important public policy arena and a good example of an inherently conflict-laden domain. Water is a scarce resource and its allocation requires negotiation by different parties who often hold opposing views. Water management has also been conducted for many years with the help of complex simulation models, which until recently have largely been controlled by government agencies such as the U.S. Bureau of Reclamation (USBR). More powerful computer technology and rising user expectations point toward providing greater accessibility of simulation models for all parties involved in negotiations. However, no systematic investigation has been conducted to determine whether such a trend is desirable. This paper reports the results of a longitudinal experiment that investigated the effects of increased accessibility of a computer-based simulation model, using a negotiation task based on a real problem that occurs in the management of Colorado River water.

THEORETICAL FOUNDATION AND HYPOTHESES

Characteristics of Negotiation

Negotiation is a basic form of social interaction in which people collectively allocate scarce resources (Thompson and Hastie 1990). Negotiation has been studied from the theoretical perspectives of personality and motivational models, situational approaches, and decision-making approaches (Bazerman et al. 1990). The decision-making approach appears to be the most promising for being able to describe and predict behavior in a wide variety of situations (Thompson 1990). From a descriptive perspective, the objective is to identify factors that lead to errors in information perception, processing, and retrieval. Prescriptively, the focus is on developing methods to decrease judgment errors and increase negotiator performance (Bazerman et al. 1990). The decision-making perspective—the approach adopted in the current study—is particularly appropriate for computer-supported negotiation, given the emphasis on the role of information and the information-handling capabilities of negotiators.

Negotiation processes and outcomes have several characteristics that lend themselves well to computer support. First, although the majority of negotiation research has been conducted with two-person groups, there are many cases in real-life situations where more than two people are involved. Special challenges arise with groups of three or more negotiators (Bazerman et al. 1990). The information processing load increases and the interaction process becomes more complex, thus there is a greater potential leverage for computer support.

Another area for support is helping negotiators develop a good understanding of their own and others' interests—a critical element of effective negotiation. Negotiators who ask the other party for information about their interests, or who provide information about their own interests, make more accurate judgments and earn higher payoffs (Thompson and Hastie 1990). Negotiators need to make accurate judgments about the amount of resources to be divided, their own interests, and the interests of others (Thompson and Hastie 1990), and there is evidence that computer models can increase group members' understanding of these issues (Sengupta and Te'eni 1993).

Finally, the need for feedback is a natural area for computer support. Feedback improves negotiators' judgments, but manual feedback may often be incomplete or delayed (Thompson 1990). Computer-based models can provide rapid and accurate feedback, again potentially improving negotiator performance (Bui and Loebbecke 1996; Sengupta and Te'eni 1993).

Conceptual Model

The current study uses water resource policy-making for its context because it is representative of the inherently conflict-laden domains that are of interest in the current research. Water problems are characterized by breadth of impact, uncertainty, scarcity of evidence, and involvement of parties from multiple institutions with multiple objectives. In addition, the policy-making process is an "...iterative, explorative, learning process that redefines the problems as much as it seeks solutions to them" (Loucks et al. 1985, p. 96). Models are important elements of such a learning process and a number of useful effects of computer-based models have been observed.

In studies of fiscal impact negotiation in local governments, computer-based models were helpful in: (1) informing participants of practical constraints and marginal differences in policy alternatives; (2) involving participants and securing their commitment to outcomes; (3) separating individual positions from policy problems; and (4) setting agendas by focusing participants on the problem and constraining the scope of conflict (Johnson 1986; Kramer 1985). In a separate study of labor negotiation, the use of a computer-based model increased the information handling capacity of negotiators and improved communication among negotiators by focusing on areas of uncertainty (Winter 1985). A model for water management also had beneficial effects, in that stakeholders who were involved in developing the model understood the overall system better and were more willing to appreciate the concerns and objectives of other participants in the process (Palmer et al. 1993).

Major benefits from models were also found in four case studies of modeling in public policy-making situations (Andrews 1991). The benefits included encouragement for experimentation, learning about the system being modeled, development of new strategies, development of a more closely shared understanding of strengths and weaknesses of different technical options, and a higher quality of debate. The negotiation situations in the four case studies were similar to the current study, in that they were characterized by dispersed decision-making power, controversy, uncertainty, and technical complexity (Andrews 1991).

Overall, the prior research suggests that the key elements for successful negotiation in these kinds of situations are: (1) development of a shared view of the task; (2) development of shared information on the requirements of others; (3) involvement of negotiators and commitment to outcomes; and (4) depersonalization of conflict. A computer-based simulation model can contribute by providing capabilities for rapid exploration of alternatives, testing of proposed policies against constraints, sharing of information, depersonalization or rationalization of the process; and a sense of engagement. These factors should lead to increased quality of and satisfaction with the outcomes of the negotiation. Figure 1 shows the conceptual model for this research, based on the ideas previously discussed. The model is consistent with prior frameworks for the study of group and negotiation support systems (Nunamaker et al. 1991; Stevens and Finlay 1996), and focuses on the specific concepts of interest in the current research. Note, however, that the intended positive effects of model access may be accompanied by unintended negative impacts. There is little discussion in the literature of the conditions under which model accessibility becomes burdensome rather than helpful, and one of our objectives is to explore these boundaries.

Figure 1 about here

Hypotheses for the Current Study

Traditional approaches to policy modeling have been from a “product” perspective, i.e., a focus on providing output from the analysis of alternatives. What is needed, however, is a “process” perspective that focuses on generating, exploring, and synthesizing alternatives (Loucks et al. 1985). As the process becomes more important, there should be a greater shift toward giving individual negotiators greater accessibility to models. Accessibility relates to who controls the model as well as when it is available. A model may be controlled by an individual negotiator or a third-party facilitator, and the model may be available either real time or in delayed time.

Accessibility is a critical factor because of its impact on shaping negotiator attitudes, model use, and the nature of the negotiating process itself. Accessibility affects negotiators’ initial willingness to use a model (Samarasan 1988) and partly determines whether initial use will become an on-going practice (Kraemer 1985). Increased accessibility has led to an enhanced sense of and willingness to cooperate and share information (Samarasan 1988). Since models tend to support the interests of those who are influential in the modeling process, accessibility also changes the dynamics of the modeling process (Dutton and Kraemer 1985; Kraemer 1985).

Current thinking and evidence from the fields of decision support systems, group support systems, and negotiation support systems suggest that real-time, individual accessibility to computer-based tools promotes better and more extensive problem exploration and more effective outcomes (Fedra et al. 1986; Dennis and Gallupe 1993; Johnson 1990; Loucks et al. 1985; Strzepek and Chapra 1990). Evidence shows that increased information availability and sharing lead to higher quality outcomes in traditional negotiation environments (Thompson and

Hastie 1990). In computer-supported environments, the feedback provided by models can increase quality by helping clarify intentions, adjust judgments, and increase consistency (Bui and Loebbecke 1996). Thus,

H1: Higher levels of accessibility of a simulation model will be associated with higher solution quality.

In addition to increased quality, accessibility to modeling should also be accompanied by more positive perceptions of group process and outcomes. A greater sense of control over the nature and outcome of the process is typically associated with greater satisfaction (Lim and Benbasat 1992-93), and model accessibility is expected to provide such control. Second, the increased involvement in and commitment to decision-making that modeling provides is likely to increase satisfaction (Kramer 1985). Finally, improved communication about the problem should enhance negotiator satisfaction as well (Winter 1985). Therefore,

H2: Higher levels of accessibility of a simulation model will be associated with more positive attitudes toward group process, as exemplified by:
H2a: perceived quality,
H2b: group behavior assessment,
H2c: decision scheme satisfaction,
H2d: personal task participation, and
H2e: negative socio-emotional behavior.

H3: Higher levels of accessibility of a simulation model will be associated with higher solution satisfaction.

The third area where greater accessibility to modeling should have positive effects is on the perceived usefulness of the model for negotiators' understanding of the problem, their own interests, and the interests of others. These effects have been demonstrated in prior studies of similar conflict-laden situations (Palmer et al. 1993; Andrews 1991). Computerized models that provide feedback and model manipulation capabilities have enhanced group members' understanding of their own situation and the views of others (Bui and Loebbecke 1996; Sengupta and Te'eni 1993). Thus,

H4: Higher levels of accessibility of a simulation model will be associated with higher perceived usefulness of the model for:
- H4a: understanding policy consequences for one's self and one's constituents,
- H4b: understanding policy consequences for other negotiators,
- H4c: communicating policy consequences to other negotiators, and
- H4d: achieving consensus.

The hypotheses all predict that the higher the levels of accessibility of computer-based simulation models, the more positive the effects. The simulation model should help negotiators uncover information about their own interests as well as those of other parties in the negotiation.

METHOD

Task

The experimental task for this study was based on the real-world problem of how to establish and allocate surplus Colorado River water among seven of the western United States (Colorado, Wyoming, New Mexico, Utah, Nevada, Arizona, and California). Whereas a complex set of laws, inter-state compacts and U.S. Supreme Court decrees determines much of the annual operations of the Colorado River, including operations in times of water shortage (USBR 1980; Reisner 1987), no comprehensive regulation of the use of river water surplus exists. However, moderate increases in water allocations during times of plenty could augment the supply of "thirsty" states such as California without impeding the availability of the normally available amounts. The reason for this is that water not released during years of abundant rain or snowfall is stored in the more than forty reservoirs on the Colorado River. This, in turn, increases the likelihood of periodically having to incur wasteful releases from the reservoirs in order to prevent flooding. This situation explains California's past and current attempts to regulate the use of surplus water.

The other side of this issue is that extra allocations increase the risks of future shortages. Since shortages are mostly borne by states other than California, the other states have been very reluctant to develop a surplus agreement. In an attempt to resolve this issue, USBR—the river's governing agency—suggested a series of surplus policy negotiation sessions supported by modeling of the river's behavior over time. These exercises took place in 1993, 1994 and 1995.

Although the experimental task for this study was based on these model-supported surplus negotiations, matters were simplified significantly in order to make the experiment feasible. The problem was limited to releases from a single reservoir only: Lake Mead (Nevada/Arizona) and only three states were involved in the negotiations: California, Nevada, and Arizona. Negotiations were mediated by a fictitious organization, the Colorado River Operations Commission (CROC), loosely modeled after USBR's Annual Operating Plan executive team. Each participant in a group represented a constituency. The representatives from the states had the people of their state as their constituency, and CROC representatives had all the other state representatives as their constituency. The role descriptions emphasized the importance of representing constituents' interests and getting the best possible policy in place from the constituents' perspective.

The task required participants to decide on a policy of when to declare a water surplus in Lake Mead and to determine how much of the surplus should be allocated to each of the three states. The task was a strategic-level task in that the surplus policy would be in effect for many years to come. Motivation for achieving consensus on a surplus policy was induced by the threat that in the case of no agreement, the problem would be arbitrated through the court system and therefore be mostly out of the control of the state representatives. Each of the three states was in a different position with respect to the amount of water currently being allocated and the amount that was likely to be needed in the future. One common theme was that everyone would need more water in the future. A good surplus policy would allow for wise use of water from Lake Mead, i.e., a proper balance between the likelihood of flooding and shortages, thereby slightly increasing the average amount of water available for allocation. To develop such a policy required considering projected future demands versus expected future hydrologic inflows, and examining various alternatives for declaring a surplus and releasing surplus water.

Design and Procedures

A laboratory experiment was designed to provide relatively controlled conditions for in-depth study of the effects of model accessibility. Our interest was in examining the conditions that are most likely to occur in practice, given the current use of and expected advances in computer-based technology and simulation software. Current practice consists of delayed access that is facilitator-controlled during group negotiation, that is, parameters for model run requests are agreed upon during group meetings, and the model is run off-line with results available sometime after the meeting. Between group meetings, negotiators can use the model output to evaluate their current position and prepare for the next group negotiation session, but no additional model runs are possible, i.e., the model is not available during individual deliberation.

Given technological advancements, the next step from the status quo would be to provide model access to negotiators during the individual deliberations that take place between group meetings. The next step beyond that would be to introduce real-time access during group negotiations. Indeed, one of the often-stated advantages of environmental decision support systems is real-time modeling (Fedra et al. 1986; Johnson 1990; Loucks et al. 1985; Strzepek and Chapra 1990). We refer to these three negotiation environments as *Limited*, *Enhanced*, and *Maximal*, respectively. The Maximal condition represents as closely as possible the envisioned future for water resources negotiation.

Ten groups were randomly assigned to each of the three conditions of Limited, Enhanced, and Maximal. Each group contained four participants, who were randomly assigned to one of four roles: (1) representative of the Arizona Water Board, (2) representative of the California Water Board, (3) representative of the Nevada Water Board, and (4) representative of the Colorado River Operations Commission (CROC).

The experiment consisted of two parts—a two-hour training session, and a five-hour negotiation session. Training consisted of: (1) a background questionnaire; (2) information on the Lake Mead Reservoir, including predicted demand for water and historical and predicted water inflows; (3) an exercise to reinforce understanding of graphical displays of water information; (4) information on the task; (5) information on the model, such as how to request model runs and read model outputs; (6) rules of process for the specific condition; and (7) additional role information for each participant.

The five-hour negotiation session consisted of five one-hour periods that alternated between group negotiation and individual deliberation, i.e., there were three group negotiation and two individual deliberation periods. A questionnaire on group process was administered at the end of each of the three group negotiation periods. This "compressed" longitudinal design allowed for ample time to adapt to the modeling environment and negotiation roles, while retaining control over participant availability for repeated periods. The purpose of alternating periods of group negotiation with individual deliberation was to simulate real-world water management negotiation processes.

The three experimental conditions were implemented based on different modes of accessibility of a computer-based simulation model. Table 1 shows the type of access, control, and maximum number of model runs allowed during group and individual periods of each condition. Note that the Limited condition allowed five delayed access runs, whereas the other conditions only allowed three delayed access runs. Since the only runs that were permitted in the Limited condition were delayed access ones, the number of permissible delayed access runs in that condition was increased slightly, so as not to confound the argument about mode of access by introducing arbitrary quantitative limits. Each condition is described in more detail below.

Table 1
Access, Control, and Model Run Limits by Condition

Condi-tion	**Group Negotiation Periods #1 & #2**	**Individual Deliberation Periods #1 & #2**	**Group Negotiation Period #3**	**Maximum # of Model Run Outputs Given to Each Individual in a Group**
Limited	Delayed access— 5 runs maximum; Facilitator control	No model access	No model access	10
Enhanced	Delayed access— 3 runs maximum; Facilitator control	Real-time access— 3 runs maximum; Individual control	No model access	12
Maximal	Real-time access— 3 runs maximum *and* Delayed access— 3 runs maximum; Facilitator control	Real-time access— 3 runs maximum; Individual control	Real-time access— 3 runs maximum; Facilitator control	21

Limited condition. The Limited condition was designed to best represent the status quo in many actual water management negotiations, namely *delayed access* and *facilitator control* for group negotiations and *no model access* during individual deliberation. Delayed access meant that model runs could only be requested at the end of a group meeting; model output was delivered to all negotiators at the beginning of individual deliberation. Facilitator control meant that all model run request forms (called Policy Proposal Forms, or PPFs) were filled out by the CROC representative (the facilitator of group meetings); the three state representatives had to agree on the parameters for a model run before the CROC representative would fill out the PPF.

Enhanced condition. The Enhanced condition represented the next logical step in terms of increasing model accessibility. Group negotiations were the same as in the Limited condition, in that group members had *delayed access* to the model and the model was *facilitator-controlled*. During individual deliberations, however, each person had *real-time access* to the model and *individual control*. Real-time access meant that a PPF could be submitted any time during individual deliberation. Individual control meant that the model parameters were decided by the individual negotiator; the negotiator filled out the PPF and was the only one to receive model output from that run.

Maximal condition. The Maximal condition represented what some consider the ideal of model accessibility—an ideal that has yet to be realized in real-world water management. During group negotiations, in addition to the *delayed access* available at the end of the meeting, groups also had *real-time access* during the meeting. *Facilitator control* was retained during group negotiations, however. Individual deliberations were the same as the Enhanced condition, in that each negotiator had *real-time access* to and *individual control* of the model.

In all three conditions, requests for model runs were submitted to a modeler who actually conducted the model runs and delivered output to the participants. Two different modelers were used for all experimental sessions. Both modelers were equally well trained in the operation of the simulation model. The reason for using a trained modeler rather than having experimental participants run the model themselves was to avoid an exploration of user interface issues per se. This practice is consistent with Nyhart and Samarasan (1989), who argue for transparent and accessible technology that allows users to focus their attention on the conceptual issues of modeling rather than the technical details. In addition, a prior study in model-based water management found that difficulties with hands-on model use for novice users in a one-time negotiation session interfered with effective task performance (Reitsma et al. 1996).

The Simulation Model

Being able to provide real-time, individual accessibility to modeling has implications for model design. Kraemer (1985) found that simplicity, implementation flexibility, and comprehensibility were important contributors to effective use of modeling for facilitating consensus. Loucks et al. (1985) argued for smaller, simpler models that would place users more centrally in the processes of model development and use. In keeping with these recommendations, our study used a relatively simple model that was easy for negotiators to use and understand.

A computer-based simulation model ("SimRiver") was custom-designed for this study. The model was implemented in Microsoft Excel 6.0, running on a Pentium machine. Required input to the model consisted of: (1) a surplus policy and water allocation specification (see Appendix A for a sample Policy Proposal Form); and (2) future river hydrology (inflows). The hydrology could be specified either deterministically (scenarios) or stochastically. The latter method employed a so-called index-sequential scheme where several random samples from the historical hydrology were run and average and extreme results were reported.

Output consisted of a time graph (see Appendix B for sample output) for each of the following predicted (modeled) variables: (1) Lake Mead contents; (2) surpluses and/or shortages; (3) spills from Lake Mead; (4) annual releases to Arizona; (5) annual releases to California; and (6) annual releases to Nevada.

Participants

Participants were students at a large university in the western United States, majoring in a variety of disciplines that included business, engineering, law, and geography, among others. Only graduate students were recruited for this study, to ensure mature participants. Average age of participants was 27.8 years; 38% were female. Overall average of self-reported experience in working with groups was 2.56 (on a 5-point scale, where 1 was "very low" and 5 was "very high") and overall average of experience in making business decision was 3.45 (on the same 5-point scale). Average number of months of full-time employment was 49. Participation in the experiment was voluntary and each participant was paid for a seven-hour time commitment. In addition, a monetary prize was advertised and awarded to the highest-performing person in each of the four role categories. Extensive pilot testing was conducted to ensure participants' understanding of the task, their roles, the model, and the questionnaires.

Measures

Data were collected via pre- and post-session questionnaires, policy recording sheets, video and audio tapes, and model transaction logs. Quality of the decision was based on a standardized, ex-post, 35-year stochastic model run using a group's final policy. The quality Q of a policy p for a specific state s (Q_{ps}) was defined as:

$$Q_{ps} = 1 / \mathrm{Ln} \left(\sum_{i=1}^{I} e^{(D_{is} - R_{is})} \right)$$

where:

D_{is} = predicted demand in year i
R_{is} = predicted release in year i
I = length of the prediction period in years (here I = 35).

Note that Q_{ps} employs the exponential norm (e^x) to express the severe consequences of increasing water shortages. The maximum value for Q (all demands met) = 1/Ln(35) = .28. The minimum value is undetermined, since it depends on the size of the demands. Table 2 shows an example of the values of Q for a ten-year period (I = 10) under two alternative release policies. In the table, even though Policy 2 incurs shortages only in years 9 and 10, versus Policy 1 incurring shortages in all but one year, the individual shortages incurred by Policy 2 are so large that the policy as a whole scores much lower than Policy 1.

Table 2
Example of Quality Measure for Two Hypothetical Policies

		Policy 1		**Policy 2**	
Year (i)	**Demand (D_{is})**	**Releases (R_{is})**	**Shortages ($D_{is} - R_{is}$)**	**Releases (R_{is})**	**Shortages ($D_{is} - R_{is}$)**
1	5	1	4	5	0
2	5	2	3	5	0
3	5	3	2	5	0
4	5	4	1	5	0
5	5	5	0	5	0
6	10	6	4	10	0
7	10	7	3	10	0
8	10	8	2	10	0
9	10	9	1	0	10
10	10	10	0	0	10
Total	**75**	**55**	**20**	**55**	**20**
Q		**.16**		**.09**	

Measures were normalized between states through a simple state-specific ranking. The CROC representative's performance was calculated from state rankings. The higher the rank of the worst state representative in a group, the better the performance of the CROC representative. If a tie resulted, then the next worst state's score was compared, and so on.

Negotiators' attitudes toward solution quality and group process were assessed using questionnaire-based scales with demonstrated reliability and validity (Gouran et al. 1978; Green and Taber 1980) and considerable prior use in studies of negotiation support systems and group support systems. The following factors were measured: (1) *perceived quality* (8-item scale), (2) *group behavior assessment* (8-item scale), (3) *personal task participation* (5-item scale), (4) *solution satisfaction* (5-item scale), (5) *decision scheme satisfaction* (5-item scale), and (6) *negative socio-emotional behavior* (5-item scale). For the first five scales, the higher the value, the more positively a group member assessed the session. The sixth scale—negative socio-emotional behavior—was reversed to make it consistent with the other scales, with a higher number indicating a more positive attitude. Group members' scores on the attitude scales were averaged to derive a group score and indexed on a scale from 0 to 100 for easier comparability. In addition, a number of single-item questions assessed participants' attitudes toward the model, its impacts, and other aspects of group process. (Appendix C shows the single-item measures, which were developed for this study.)

RESULTS

Initial analyses were done at the group level for all hypotheses. H1 predicted differences in the quality of outcome among groups, with Maximal groups expected to have the highest quality outcome. Table 3 shows the rankings achieved by groups for each condition and the mean ranking for all groups within each condition (the highest-performing group was ranked 1). A rank sum difference test (Kanji 1993) showed no significant differences between conditions for quality of outcome. All differences between conditions fell well below the critical value of 92.3 for a significance level of .05 (n=10, k=3). The same analysis was performed by role between conditions, to ensure that differences were not being washed out by averaging across roles. Again, no significant differences were found.

Table 3
Rankings on Group Quality by Condition

Limited	Enhanced	Maximal
4	1	3
5	2	8
7	6	10
9	14	11
12	20	13
17	23	15
18	25	16
19	27	21
22	28	26
24	30	29
mean rank = 13.7	**mean rank = 17.6**	**mean rank = 15.2**

To explore the quality issue further, we developed a second measure of quality that focused on the three state representatives and their ability to meet demand for water. This measure allowed a quantitative comparison rather than a simple ranking, and was based on the difference between release of and demand for water, calculated as:

$$\text{Quality} = \left(\sum_{i=1}^{35} \text{Release}_i \right) / \left(\sum_{i=1}^{35} \text{Demand}_i \right)$$

The measure varies between 0 and 1, since policy constraints said that under no condition could releases exceed demand. Again, ex-post 35-year stochastic hydrology runs were used to compute the quality of all policies. Overall, performance ranged from .83 to .92, indicating fairly high performance, although this is partly a function of there being sufficient water in the system to avoid severe shortages. Nevada representatives generally performed better than Arizona representatives, while California covered the entire range. However, there were no significant differences by role across the three experimental conditions ($r = -.14$ for Arizona; $r = .24$ for California; $r = -.16$ for Nevada). The data apparently fail to support Hypothesis H1.

H2 through H4 predicted differences in attitudes toward group process and outcomes. These hypotheses were examined at the group level through analysis of variance; Table 4 summarizes the results. No significant differences were found for any of the hypotheses.

Table 4
Results of ANOVA Tests for H2 Through H4

Hypothesis	Means			F	prob.
	Limited	Enhanced	Maximal		
H2a: perceived quality	84.07	87.45	85.00	.2537	.7778
H2b: group behavior assessment	83.69	87.28	84.76	.4783	.6250
H2c: decision scheme satisfaction	85.63	85.75	83.88	.0684	.9341
H2d: personal task participation	65.75	69.41	67.50	.7455	.4840
H2e: negative socio-emotional behavior	11.50	14.00	12.38	.1419	.8684
H3: solution satisfaction	71.38	71.75	68.94	.1269	.8814
H4a: understanding policy consequences for self and constituents	81.67	72.08	76.67	1.054	.3624
H4b: understanding policy consequences for other negotiators	79.17	70.42	77.50	.7280	.4921
H4c: communicating policy consequences to other negotiators	77.92	75.00	77.50	.1271	.8811
H4d: achieving consensus	81.25	75.00	75.83	.5003	.6118

Note: H2a-e and H3 are averaged across all four roles in a group, while H4a-d are averaged only across the three state representatives, since the single-item questions address concerns that relate primarily to state representatives.

Given the lack of significant results, we explored the data further. First, we looked for significant differences *by role* across the three conditions, focusing on multiple-item scales for state representatives only. No significant differences were found for any of the multi-item measures by role, via analysis of variance for each attitude measure with role as the single factor. We conclude that there were no systematic differences in attitudes toward outcome or process among the state representatives across the three conditions.

Second, we explored the differences between high and low quality groups, in order to ascertain whether the multiple-item attitude scales varied systematically between groups that performed relatively well versus those performing poorly. Such an analysis might point out problematic elements of group process and therefore potential areas for improvement. To maximize the differences between comparison groups, we chose the top five ranked groups and compared them to the bottom five groups. There were no significant differences on these measures (see Table 5). However, for all but solution satisfaction, the higher-performing groups had less positive attitudes than the lower-performing groups, showing that higher performance was associated with a more critical assessment of process and outcomes.

Table 5
Comparison of Top Five and Bottom Five Performing Groups

	Top Five	**Bottom Five**	**F**	**p**
Perceived quality	79.53	86.41	.5442	.4818
Group behavior assessment	81.06	90.63	2.492	.1531
Decision scheme satisfaction	79.75	85.50	.2939	.6025
Personal task participation	66.25	70.88	1.047	.3363
Negative socio-emotional behavior	12.25	12.00	.0016	.9690
Solution satisfaction	67.63	69.19	.0257	.8766

Finally, we looked at differences among the attitude measures themselves, averaged across all the groups (Table 6). The second column of Table 6 shows the overall means in the current study for each of the multiple-item scales, ranked in order from most to least positive. Four of the six scales are relatively high, while two are noticeably lower than the rest—solution satisfaction and personal task participation. Solution satisfaction includes satisfaction with quality of solution, sense of responsibility for and participation in the solution, and confidence in and commitment to solution. Personal task participation—the lowest of the attitude scales—includes such elements of group process as contributing information and suggestions, asking others for thoughts, opinions, and suggestions, and showing attention and interest in the group's activities. The low scores on these measures suggest that group members are relatively dissatisfied with their ability to contribute to or affect the process.

Table 6
Overall Means of Multi-Item Attitude Measures
for Current Study and Two Prior Studies

Attitude Measures	**Overall Means**		
	Current Study	**1994 Study***	**1991 Study****
Negative Socio-Emotional Behavior	87	89	72
Perceived Quality	86	67	86
Group Behavior Assessment	85	71	81
Decision Scheme Satisfaction	85	65	85
Solution Satisfaction	71	61	78
Personal Task Participation	68	72	69
Overall Means	**80**	**71**	**79**

*Zigurs et al. 1994
**Zigurs et al. 1991

The third and fourth columns of Table 6 show attitude means from two prior studies that used identical measures and had some similarity with the current study. The 1994 study used a task that required determining water releases, using a simulation model for calculating the consequences of release policies. The 1991 study had a very different task and used a group support system without a simulation model, but the study was a longitudinal one and, as in the current study, the measures were taken at the end of a series of meetings. Table 6 shows that the 1991 study is more similar in attitudes to the current study than the 1994 study is—the majority of attitude measures are quite high in both those studies, while personal task participation is relatively low. It seems that increasing familiarity with the technology via repeated use over time results in higher satisfaction.

DISCUSSION AND CONCLUSION

Neither the hypothesis testing nor the additional exploratory analyses showed any significant differences among conditions—a disappointing finding, yet a potentially important one. After all, we do not really know the point at which model access becomes burdensome. The study failed to support the popular notion that "more is better," i.e., that increased accessibility of computer-based simulation models would increase quality of decisions and satisfaction of negotiators. Given the amount of resources—both human and machine—that are being devoted to model development and diffusion, the potential implications from this study could be significant. We first examine several alternative explanations for the results.

The *task* is central to any study, but particularly one that attempted a realistic simulation of an actual negotiation process. Given the desire for realism, the task was of necessity quite complex. Participants had to understand the basics of water flows and reservoir management, as well as interpret the results of the simulation model runs in light of their own and others' interests. Although no explicit measure of task understanding was taken, observation of the sessions and task output indicated that participants did not have serious difficulties understanding the task. The overall mean on Hypothesis H4a (understanding of one's own situation) for all participants was 76.8, indicating that participants perceived no significant difficulties with the task, even though there is still room for improvement. Although a correlation of this measure with the role-specific measure of quality was significant and inverse ($r = -.26$, $p = .02$), that correlation was quite small, explaining only 4% of the variance. Thus we conclude that participants understood and were able to fill their roles in this task.

Another aspect of the task is its integrative versus distributive nature. This task was designed to be an integrative task, i.e., there were opportunities for mutual gain. However, at least from the evidence of their performance in the final policies, it appears that participants approached the task in a distributive, “zero-sum” way. It may be that they were not able to see the integrative opportunities, even though we noted above that task understanding seemed to be adequate.

The *measures* used in a study can also be questioned. Attitudes toward group process and outcome were based on well-established scales that have been used often in group support systems research. Single-item measures might be more suspect, but there were no consistent and significant differences between the single-item and multiple-item measures in this study. Of all the measures, the quality variable was perhaps the most problematic, because of the very nature of the task. We attempted to simulate a realistic negotiation in an inherently conflict-laden domain. Several measures were explored, but the lack of significant differences across conditions was also consistent across different measures. We conclude, therefore, that the measures used in the study were meaningful and accessed the desired concepts.

Finally, the *manipulation* used in a study must have actually occurred for results to be meaningful. Our manipulation was of model accessibility, with increasing accessibility from the Limited to the Enhanced to the Maximal conditions. A manipulation check of the number of policies explored in each condition showed a significant difference ($F = 40.66$, $p < .001$), with Limited groups exploring an average of 9.7 policies, Enhanced groups an average of 22.2, and Maximal groups an average of 27.1 policies. In addition, a question on how available the participants perceived the model to be showed a significantly greater perception of availability in Maximal groups. Thus, the manipulation appears to have been effective.

An interesting result is the overall high satisfaction of all groups on most of the attitude measures. Informal discussion with participants after the experiment reflected a high degree of involvement and interest in the study. These positive attitudes—at the end of an intensive five-hour session—further support the significance of the results. However, the relatively low satisfaction with personal task participation deserves further attention. In the 1994 study used for comparison in Table 6, a control group that used no computer-based support at all averaged 81 on personal task participation (Zigurs et al. 1994). An effect that computer-based modeling reduces a sense of participation in the group would be ironic, given that a typical goal of group support systems is to enhance participation.

Our conclusion is that increased accessibility of computer-based simulation models is *not* worth the cost of their development and deployment, *under the conditions examined in this study*. Maximal groups were not the most satisfied with group process, as reflected in the means on the attitude measures. This result is consistent with part of an earlier study of simulation modeling (Reitsma et al. 1996), in which the model helped groups to understand task constraints but the groups with model support were less satisfied than non-supported groups. A conclusion in that earlier study was that participants might need more time to become familiar with the model, but the current longitudinal study shows that time is not the issue.

The findings suggest that resources for improving computer support for negotiation might be applied more effectively elsewhere, rather than focusing on increased accessibility. The question remains: what are the important leverage points for improving performance and satisfaction in group negotiation processes similar to the one studied here? The conceptual model (Figure 1) suggests several alternatives for future research. The current study focused on the input-output relationships of the model and not the process factors. Although an analysis of the process factors would be outside the scope of this paper, one way to assess the extent to which participants developed shared views of the task and shared information on each others' requirements is to examine differences in the extent to which groups searched the solution space. Preliminary analyses of search behavior suggest that the "less powerful" roles—Arizona and Nevada—benefited from searching a larger solution space, while California's solution quality suffered. Still, there were no significant differences across conditions in terms of solution space searched. Again, accessibility does not seem to be the key leverage point, at least at the levels studied here.

Several factors have potential for explaining the lack of expected results in this study. First is the issue of information use. Recent evidence from a study of group support systems shows that computer-based systems help groups *exchange* more information, but still do not improve their successful *use* of it (Dennis 1986). That may have been the case here, suggesting the need for better analyses of whether and how people are actually using the information that is developed in the solution space they search. An analysis of the verbal interaction of the groups in the current study could reveal the extent to which information from each of the model runs was used in discussion and whether that information was incorporated into the next policy iteration.

A second and related issue is that of information load. Increased model accessibility is typically accompanied by higher information load, to a point where saturation is reached and negotiators simply are not able to process any additional information. That point may have been reached in the current study, which would explain the lack of differences in quality. If information load was already heavy in the Limited condition, then potential increase in decision quality in the higher accessibility conditions might have been offset by the negotiators' inability to handle the increased information load. This speculation bears further study, since the average number of policies explored increased by two and three times from the Limited mode to the Enhanced and Maximal modes. An intermediate mode between Limited and Enhanced would be a logical comparison for a follow-up study.

The nature of the computer-based model itself is a third factor. Our focus was on a computer-based model of the physical system that was the heart of the negotiation task, and not a model of group process. Group and negotiation support systems (Lewis and Shakun 1996; Nunamaker et al. 1991) that provide tools for idea commenting and organization could help groups manage and evaluate the information provided by the simulation model. Such tools have the potential to deal with information load, but there are many unanswered questions about how to integrate process support with simulation modeling.

Information technology in general, and group support tools more recently, have steadily increased the amount of information available, while lagging in helping decision makers and negotiators manage and use that information. Finding the leverage point for best performance remains an elusive but valuable goal for both research and practice.

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Appendix A
Sample Policy Proposal Form

Appendix B
Sample Output from Model Run (Monte Carlo run)

Appendix C
Single-Item Measures

H4a: perceived usefulness of model for understanding policy consequences for self and own constituents

How much did the use of SimRiver help you understand the consequences of policies for you and your constituents?
none little moderate substantial a lot
|------------|------------|------------|------------|

H4b: perceived usefulness of model for understanding policy consequences for other negotiators

How much did the use of SimRiver help you understand the consequences of policies for the other parties in the negotiation?
none little moderate substantial a lot
|------------|------------|------------|------------|

H4c: perceived usefulness of model for communicating policy consequences to other negotiators

How much did the use of SimRiver help you in *communicating* the consequences of policies for you and your constituents to the other parties in the negotiation?
none little moderate substantial a lot
|------------|------------|------------|------------|

H4d: perceived usefulness of model for achieving consensus

What impact did the use of SimRiver have on your group's ability to achieve consensus?
polarized the group neutral united the group
|---------------------|---------------------|

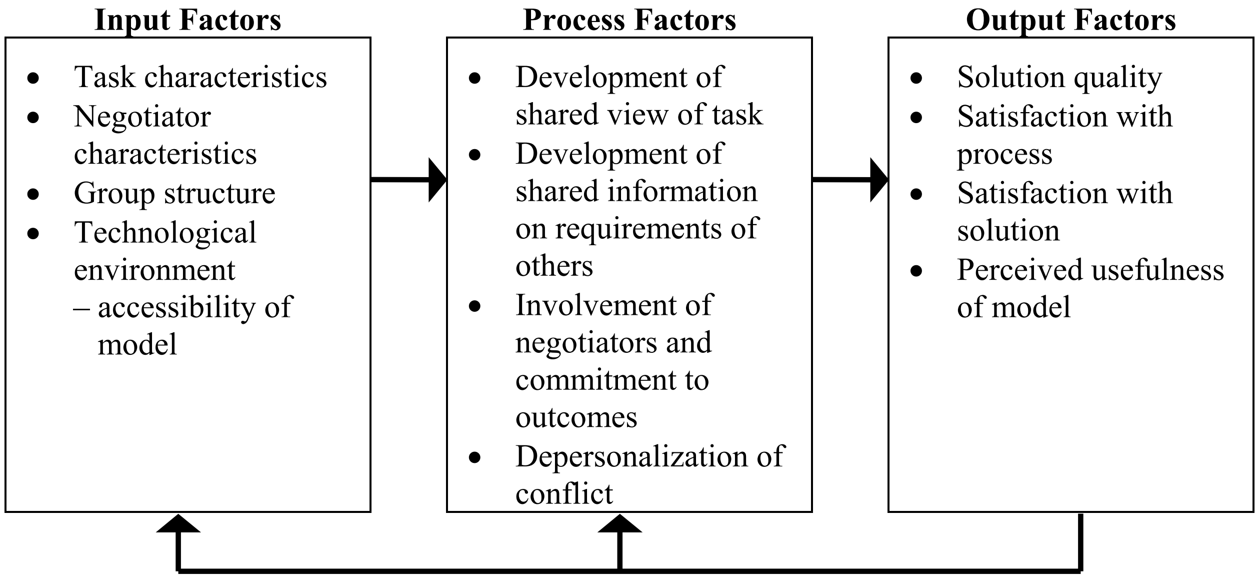
Input Factors
Task characteristics
Negotiator characteristics
Group structure
Technological environment
– accessibility of model
Process Factors
Development of shared view of task
Development of shared information on requirements of others
Involvement of negotiators and commitment to outcomes
Depersonalization of conflict
Output Factors
Solution quality
Satisfaction with process
Satisfaction with solution
Perceived usefulness of model

Fig. 1. Conceptual Model for Effects of Computer-Based Support on Negotiation (adapted from Zigurs et al. 1994)