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COMPARING METHODS OF INCORPORATING MULTIPLE PERSPECTIVES INTO COLLECTIVE MAPS

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Abstract

There has been little formal comparative evaluation of different approaches to building collective maps which are able to combine multiple perspectives. This study formally compares three approaches found in the literature: aggregate mapping, congregate mapping, and workshop mapping. It provides a conceptual comparison of the three methods and empirically compares derived models of the methods through objective and subjective measures. Objective measures include map complexity and map distance ratios; subjective measures include problem representation, solution implications, stakeholder representation, and multiple perspective implications. The aggregate method was found to produce highest complexity collective map, followed by the congregate method. In terms of distance ratios between collective maps and individual maps, the workshop method was found to produce a collective map having smallest distance ratios to individual maps, followed by the aggregate method. There was no consensus on what model was best in terms of problem representation although the workshop model received higher rating than the aggregate model, which was rated higher than the congregate model. The workshop model seemed to better capture the perspectives of various stakeholders such as elected officials and city departments, the differences were, however, not significant. In terms of multiple perspectives, the workshop model was able to capture the political and technical perspectives of the problems better than other models.

Keywords: Multiple perspectives, collective models, aggregate mapping, congregate mapping, and workshop mapping

Introduction

Researchers (Checkland, 1981; Courtney, 2001; Linstone, 1984; Mitroff and Linstone, 1993; Senge, 1990) have proposed that systems-based multiple perspective approaches are required to deal with problems in organizations and society today. To gain the precision necessary to compare, contrast, and combine multiple perspectives it is necessary to build models of the situation. Several researchers (Ackermann, et al., 1997; Massey and Wallace, 1996; Vennix, 1996) have maintained that collective maps can be used to broaden problem solvers' perspectives by taking alternative views into defining a messy problem situation. Therefore collective maps can be viewed as a means access to multiple perspectives for problems with no definitive formulation.

Different perspectives are assumed to hold different models, and it is through the juxtaposition and combination of models that perspectives can be mediated. Boland, et al. (1994) argue that cognitive mapping can be used as a potential tool to capture a perspective. This research focuses on the use of modeling to mediate multiple perspectives on problems using cognitive mapping. The research is devoted to finding out existing modeling approaches that are capable of representing multiple perspectives and whether some approaches are "better" than others. The research question was: what approaches are available to formulate models of problems based on multiple perspectives? Are some approaches superior to others?

This paper starts with a conceptual comparison of three methods for constructing a collective map or model, followed by a research design for the case of Houston's infrastructure decision making system. Third, the results – three collective models are presented. Finally, the three models are compared.

Methods for Constructing a Collective Map/Model

Three methods found in the literature are able to represent collective mental models: aggregate mapping, congregate mapping, and workshop mapping. A conceptual comparison of these approaches is provided in Table 1.

Table 1. A Comparison of Different Approaches to Building a Collective Map/Model

	Aggregation	Congregation	Workshop
Authors or related works	Lee et al. (1992), Kwahk and Kim (1999), Eden, et al. (1981), and Eden (1989)	Bougon (1992) Hall (1984) Diffenbach (1982)	Langfield-Smith (1992), Massey and Wallace (1996), Vennix (1996)
Core processes	Joining, merging individual maps through common concepts.	looking for congregating labels, forming loops	Workshop mapping, group meeting/ discussion, Consensus, group facilitation
Procedure	Unique concepts are merged directly to the composite map while common concepts are merged taking care not to introduce conflicts. Merge two maps at a time. Use common concepts as coupling device to combine two maps.	Individual maps are connected to form loops through 'cryptic' labels, which are repeatedly used by the participants. Individual maps remain separate, intact in the congregate map.	Group members add concepts (or labels) and relationships (or connections) between concepts, discuss and decide whether they should be included in the group map under group facilitation.
Application	Organizational memory (Lee et al., 1992), Business Process Reengineering (BPR) (Kwahk and Kim, 1999). Distributed decision making (Zhang, et al., 1994)	Strategy understanding, organizational identity (Bougon, 1992) Understanding the dynamics of organizations (Hall, 1984)	Group decision support systems (GDSS) (Eden, 1989) Solving messy problems (Vennix, 1996)
Advantages	Merging is simple and straight forward; Able to automate with an algorithm; Conflict detection;	Loops help understand the dynamics of the system; Better at capturing multiple perspectives on the problem situation.	May have more beliefs than that in individuals' maps; Individual biases can be overcome with group interaction
Disadvantages	A simple merging of all maps may not be a 'shared' map; There is no chance to mitigate biases in individual maps.	Difficult to identify the congregating labels; Complex and difficult to automate; Hard to apply as it requires perspectives of all stakeholders	Premature consensus (groupthink) due to dominant perspectives; Unresolvable conflicts.

In the *aggregate mapping approach*, all the labels and links from each individual cognitive map are included in the collective map. As a result, the aggregate map may become quite complex. As the aggregate approach does not emphasize the causal loops in the collective map, it may not be effective in representing social systems, because typically social systems consist of many actors with significantly diverse viewpoints. *Aggregating* is also referred to as 'merging' or 'overlaying' (Eden, 1989; Eden, et al., 1983), or the 'structural/relational join' operation (Lee et al., 1992), or 'combination' (Kwahk and Kim, 1999).

The *congregate mapping approach* is based on the concept of loops (Bougon, 1992). The study of causal loops or cycles in cognitive mapping and causal modeling is central to many researchers (Bougon, et al., 1990; Forrester, 1961; Senge, 1990). To these researchers, if a cognitive map or model is used to represent a social system, causal loops are essential elements that are responsible for the system's identity and change (Bougon, 1992) and for the systems' complex behaviors (Forrester, 1961). In the congregate approach, only labels and links that contribute to forming loops are entered into the collective map. As a result, the congregate map may be simpler than the sum of individual map (the composite map).

In the *workshop mapping approach*, group members exchange their perceptions of a problem situation to foster consensus (Vennix, 1996). Workshops are group meetings where group as a whole builds a model aided by a facilitator. The purpose of the workshop is to reach agreement on what elements should be entered into the collective map. As a result of group discussion and interaction in the workshop, the workshop collective model is expected to be shared among group members. Often, individual maps are not used in the workshop method.

Research Design

An experiment was designed for the case of Houston's infrastructure decision making system (Lomax, et al., 1998). The objective was to construct collective beliefs and represent them as collective cognitive maps using different methods in order to compare the methods. The first step was to define a problem/issue. After consultation with members of the research group, we framed the issue as "the impact of infrastructure growth on quality of life of Houstonians." The second step was to select participants. We had seven members, who were involved in developing a conceptual framework[1] for the city's infrastructure decision making system, participate in the experiment. The experiment consisted of two stages: individual cognitive mapping and building group maps.

We followed the procedure described in Markoczy and Goldberg (1995) to capture individual mental models. Individual maps provided the basis for building collective maps and also provided a standard of comparison for the final group maps. Participating in the individual stage provided the participants with an opportunity to learn and become accustomed to the mapping method. Based on the interview transcripts[2] and related literature (Forrester, 1969; Lee, 1995), we developed a list of 16 factors or constructs. The participants were asked to select factors that are relevant to the problem of study and assess possible causal relationships between pairwise selected factors. The purpose was to gather information that would enable us to draw a causal diagram that shows how the participants believed infrastructure resource allocation affects the city. The process was assisted using a questionnaire (available from the authors).

After the individual maps were constructed, we applied the aggregate and congregate methods to build the aggregate and congregate maps based on the individual maps. The participants were then gathered in a workshop under the researcher's facilitation to build the workshop map. The three group maps were compared using both objective and subjective dimensions. Subjective ratings were made by the participants via an evaluative questionnaire (available from the authors).

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[1]This framework and a prototype of sustainable decision support systems were developed to improve policy planning and decision making regarding urban infrastructure investments such as investments in roads and bridges, fresh water supply systems, waste water treatment, drainage and so forth.

[2]These interviews were made by the participants and other researchers with people who are involved with the city's infrastructure management.

Results - Collective Models

Seven individual maps were used to build collective maps for the aggregate and congregate methods. On average, an individual map has 19 factors (with a standard deviation of 5.4), 43 links or relationships (with a standard deviation of 8), an L/N ratio of 2.36 (with a standard deviation of .44), and a density ratio of 0.15 (with a standard deviation of .07).

The *aggregate model* was built by the researcher without the assistance of the group. In the aggregate method, all the factors and links from each individual map were included in the collective map. The result was that the aggregate map has 39 factors and 193 unique links. Its L/N ratio is 4.95 and complexity ratio is 0.13. Because the aggregate map is very complicated, we split it into two parts: unique map and common map. The unique map contained unique relationships extracted from individual maps. Relationships that appear in at least two individual maps were entered into the common map. Splitting the aggregate map is for the purpose of simplifying presentation.

The *workshop model* was built with five researchers (out of seven) of the group in a workshop mapping. The workshop started with a problem description that is based on the interview transcripts. Each participant received a 10 step instruction sheet to guide discussions. The subjects took turns to describe the problem situation by identifying problem variables, consequent factors, and causal factors that affect the problem variables, and causal relationships between them. The facilitator (the researcher) recorded these factors/variables and their relationships on a blackboard and asked other members whether they agreed to include these elements and agreed with the story being told in the group map. The process was repeated until element entries were exhausted. The workshop took about an hour. The result was that the workshop model has 38 factors and 57 links. Its L/N ratio is 1.50 and density ratio is 0.04.

The *congregate model* was built by finding out the common causal loops in individual mental models about the problem situation with Houston's infrastructure decision making. The process consists of four steps: (1) identification of actors and their goals and behaviors in the system, (2) formulation of reference knowledge based on the interview transcripts, (3) identification of causal loops in individual maps matching reference knowledge and formulation of hypothetical causal loops to match the unexplained reference knowledge, (4) building a theory of the problem based on a model that congregates causal loops identified in (3) with a consideration of time factor. The result was that the workshop model has 16 factors and 32 links. Its L/N ratio is 2.00 and density ratio is 0.13.

Comparing Collective Models

Comparison was based on objective measures and subjective measures. Objective measures consist of map complexity and distance ratios between collective models and individual models. Subjective measures include problem representation, solution implications, stakeholders representation, and multiple perspective implications, which were incorporated into the evaluative questionnaire. These subjective attributes are based on the Multi-Attribute-Value (MAV) model (Massey and O'Keefe, 1993; Massey and Wallace, 1996; Sakman, 1985). These attributes were used as criteria to measure the effectiveness or utilities of the derived collective maps. All the participants were asked to evaluate the maps. There were three cases in which raters evaluated the maps with the help of the researcher in answering questions. Other cases, evaluations were done via email. Six (out of seven) returned questionnaires were complete and usable.

To measure cognitive *map complexity*, Eden and Ackermann (1992) suggest that *links-to-nodes* ratio (L/N) can be used to represent maps' density. A higher links-to-nodes ratio "indicates a densely connected map and supposedly a higher level of cognitive complexity" (Eden and Ackermann, 1992, p.313). Hart (1977) proposed an alternative measure of map complexity – map density as a measure of degree of interconnection. It is measured by dividing the total number of links by the maximum possible number of links (L/N(N-1)).

In terms of map complexity, we found that the aggregate method produced highest complexity collective map, followed by the congregate method; the common aggregate map is simpler than the whole aggregate map but it is still more complex than the workshop and the congregate maps (in terms of L/N). Although the workshop map has a great number of factors, it is the simplest map in terms of L/N and map density.

Table 2. Comparing Group Maps in Terms of N, L, L/N and Density

Maps	N	L	L/N	Density
Congregate	16	32	2.00	0.13
Workshop	38	57	1.50	0.04
Aggregate	39	193	4.95	0.13
Common Aggregate(*)	21	51	2.43	0.12
Individual Average	29	83	2.72	0.11

Note: (*) Common Aggregate map contains those beliefs (or relationships) that appear in at least two individual maps.

Compared to individual maps, only the congregate map has fewer factors, while the workshop and aggregate maps have more factors. In terms of the number of links, both congregate and workshop maps have fewer links, while the aggregate map has more links than individual maps. In terms of L/N ratio, both congregate and workshop maps are simpler or less complexity but the aggregate map is more complexity than individual maps. In terms of map density, the workshop map is less dense while both congregate and aggregate maps are denser than the individual maps.

Distance ratio (DR) was developed by Langfield-Smith and Wirth (1992) to measure map differences. A DR of 0 means that two maps are identical and 1 is maximal distance between maps. DR is measured by the ratio between the sum of the differences (node by node, and link by link) and the total maximum difference between the maps. Markoczy and Golberg (1995) extended and generalized Langfield-Smith and Wirth's formula to take missing nodes into account. In this research, we used the distance ratio (DR) proposed by Markoczy and Goldberg (1995) to measure the distance between collective maps and individual maps. We used the programs provided by the authors for calculation and analysis. On average, DR between group maps and individual maps is 0.07 with a 0.02 standard deviation. The maximum DR is 0.12 and the minimum 0.05.

We observed from the result that the method used to construct group maps might have some impact on the average DR from the collective map to the individual maps. To test this observation, we used one-way ANOVA with one factor (method) and one dependent variable (DR). For each method, we had 7 cases. The results of ANOVA revealed a significant main effect for the method factor that had an impact on DR ($F = 3.941$, $df = 3/27$, $p = .02$). Post-hoc tests (LSD) further revealed that the workshop map gives lower DRs than the congregate method ($p < .002$), that the common aggregate map gives lower DRs than the congregate method ($p < .04$).

Problem representation (PR) is the degree to which the cognitive map has a sufficient number of concepts/factors and relationships between them to describe the problem situation adequately. In this study, *problem representation* indicates how adequately a group map represents the problem under study: the impact of infrastructure growth on quality of life of the city. The problem description was provided in the questionnaire. A preparatory step asked the rater to place a check by each factor and relationship (arrow) that he/she agreed should be in the model. Based on this activity, the rater was asked to give a number on a scale from 0 (strongly disagree) to 10 (strongly agree) to indicate how adequately the model represents the problem.

Overall, the ranking pattern was as follow: PR (Congregate) < PR (Aggregate) < PR (Workshop). On a 10 point scale, the model derived from the workshop method received highest rating – over 7, while the aggregate model about 6.5 and the congregate model nearly 6. There was no consensus on what model was best in terms of problem representation. Three raters believed that the model based on the workshop method was best, while two raters chose the model based on the aggregate as the best and one rater preferred the model based on the congregate method.

Solution implications (SI) is the degree to which the cognitive map has some implications for problem solving based on one or more relationships. In this study, *solution implication* indicates how potentially a group map could be useful in developing resolutions to Houston's problem with the impact of infrastructure growth on quality of life of the city. A preparatory step asked the rater to identify critical paths that indicated where the problem was and that he/she agreed could be useful in developing some resolution directions for the problem. Based on this activity, the rater was asked to give a number on a scale from 0 (strongly disagree) to 10 (strongly agree) to indicate how potentially the model could help in developing policies to resolve the problem.

Overall, the ranking found in this study was as follow: SI (Workshop) > SI (Congregate) > SI (Aggregate). On a 10 point scale, the model derived from the workshop method received highest rating – about 5.7, while the model from the aggregate method about 4.7 and the congregate model nearly 5. The differences are, however, not significant.

Stakeholders representation (SHR) is the degree to which the cognitive map reflects consideration of needs, interests, and power of stakeholders. In this study, *stakeholders representation* indicates how adequately a group model represents the needs and interests of stakeholders in the model. Six groups of stakeholders were provided in the questionnaire: Elected officials, City department, Citizens, Businesses, Contractors, and Media. Raters might identify additional stakeholder groups that were not listed in the questionnaire. As a result, two stakeholder groups were added were environmentalists and engineers. For each group of stakeholder, the rater was asked to circle a number on a scale from 0 (strongly disagree) to 10 (strongly agree) to indicate how strongly the needs and interests of that group of stakeholder was incorporated into the model.

On average, for the model derived from the workshop method received highest ratings for all stakeholders while the aggregate model received the lowest ratings; the congregate model was in between. Although the workshop seemed to better capture the perspective of elected officials and city departments, the differences were not statistically significant at 10% level. Other differences were not statistically significant.

Multiple perspective implication (MPI) *is* the degree to which the cognitive map is able to capture various aspects of the problem situation. In this study, *multiple perspectives implication* indicates how adequately a group map represents six perspectives: Economic, Political, Technical, Environmental, Social, and Ethical. Raters might identify additional stakeholder groups that were not listed in the questionnaire. As a result, no additional perspective was added by the respondents. For each perspective, the rater was asked to circle a number on a scale from 0 (strongly disagree) to 10 (strongly agree) to indicate how strongly the perspective was represented in the model.

On average, for the model derived from the workshop method received highest ratings for all perspectives, while the aggregate model received the lowest ratings with an exception for the environmental perspective; the congregate model was in between. ANOVA tests revealed that the workshop model was able to better capture the political and technical perspectives of the problems. Other differences are not statistically significant.

It was interesting to find that there was no consensus among the judges participating in evaluating the three models in terms of problem representation. In general, the workshop model was able to capture political issues (such as short-term focus, politicians' job performance, competition for funds, budgeting process, political constituency for infrastructure, etc.) and technical issues (deterioration, maintenance, DSS, database, sharing information, etc.). All the raters believed that the congregate model was simplest in terms of the number of factors (nodes). The one who rated the congregate model as the best probably preferred simple models. Generally, the aggregate model received lowest ratings in terms of solution implications, stakeholders implications and multiple perspectives implications. The aggregate model is the most complex and has more variables (the full aggregate model). One rater indicated that he preferred the aggregate model because it has more variables than others.

It is interesting to note that subjective judgments of complexity are different from objective measures of complexity. Our observation during the study was that human subjects tend to emphasize the simplest measure (the number of nodes) while objective measures are based on both nodes and links (L/N or density). A rater complained that the workshop map was too busy and many things were going on there. Most raters believed that the congregate map was the simplest. A rater commented that "I don't like it [the congregate map] because it is too simple" (personal communication) as compared to others. However as indicated in Table 2, the congregate map is actually more complex than the workshop map in terms of L/N and map density. It can be concluded that human subjects tend to count the number of factors (nodes) rather than both the number of factors and links to measure complexity.

Summary and Conclusions

Three collective models were built for the case of Houston's infrastructure decision making system based on three methods: aggregate mapping, congregate mapping, and workshop mapping. The aggregate and congregate models were built based on individual maps without assistance from the participants. The three models were evaluated using a structured questionnaire.

We found that the aggregate method produced highest complexity collective map. Generally, the ranking of three methods in terms of complexity of collective models that methods may generate follows the pattern: Complexity (workshop) < Complexity (congregate) < Complexity (aggregate). But this observed generalization was not fully tested in this study. In terms of distance ratios (DR) between collective maps and individual maps, we found a ranking pattern: DR (workshop) = DR (aggregate) < DR (congregate). However, the difference between the workshop method and the aggregate method was not clearly observed. An implication of this pattern is that the workshop method may enhance the effects of knowledge sharing among group members, while the congregate mapping method may have difficulties to get acceptance (or shared) from group members.

There was no consensus on what model was best in terms of problem representation (PR). Three raters elected the workshop model; two raters chose the aggregate model as the best; one rater preferred the congregate model. The ranking pattern among three methods of building collective models in terms of adequacy of problem representation found in this study was as follow: PR (Congregate) = PR (Aggregate) < PR (Workshop). However, there was not enough evidence to support the differences in the ranking. Although the workshop model seemed to better capture the perspectives of various stakeholders such as elected officials and city departments, the differences were not significant. In terms of multiple perspectives implications, the workshop model was able to capture the political and technical perspectives of the problems better than other models.

There has been little formal comparative evaluation of different approaches to building group maps which are able to combine multiple perspectives. This study formally compared three approaches to building collective maps found in the literature: aggregate mapping, congregate mapping, and workshop mapping. Although this study has provided some preliminary observed patterns, there was not enough evidence to conclude that one method is superior to others. Further research may be directed to find out in what conditions a method is superior to others.

References

Ackermann, F., Eden, C. and Williams, T. "Modeling For Litigation - Mixing Qualitative and Quantitative Approaches," *Interfaces* (27:2), 1997, pp. 48-65.

Boland, R.J., Tenkasi, R.V. and Teeni, D. "Designing Information Technology to Support Distributed Cognition," *Organization Science* (5:3), 1994, pp. 456-475.

Bougon, M.G., Baird, N., Komocar, J.M. and Ross, W. "Identifying Strategic Loops: The Self-Q Interviews," In *Mapping Strategic Thought*, A. S. Huff (Ed.), Wiley, New York, 1990, pp. 327-354.

Checkland, P. *Systems Thinking, Systems Practice*, Wiley and Sons, New York, 1981.

Courtney, J.F. "Decision Making and Knowledge Management in Inquiring Organizations: A New Decision-Making Paradigm for DSS," *Decision Support Systems* (31:1), 2001, pp. 17-38.

Diffenbach, J. "Influence Diagrams for Complex Strategic Issues," *Strategic Management Journal* (3:2), 1982, pp. 133-146.

Eden, C. "Using Cognitive Mapping for Strategic Options Development and Analysis (SODA)," In *Rational Analysis for a Problematic World: Problem Structuring Methods for Complexity, Uncertainty, and Conflict*, J. Rosenhead (Ed.), Wiley, Chichester, 1989, pp. 21-24.

Eden, C. and Ackermann, F. "The Analysis of Cause Maps," *The Journal Of Management Studies* (29:3), 1992, pp. 309-323.

Eden, C., Jones, S. and Sims, D. *Messing about in problems : an informal structured approach to their identification and management*, Pergamon Press, New York, 1983.

Eden, C., Jones, S., Sims, D. and Smithin, T. "The Intersubjectivity of Issues and Issues of Intersubjectivity," *The Journal of Management Studies* (18:1), 1981, pp. 37-47.

Forrester, J.W. *Industrial Dynamics*, Productivity Press, Cambridge MA, 1961.

Forrester, J.W. *Urban Dynamics*, Productivity Press, Cambridge MA, 1969.

Hall, R.I. "The Natural Logic of Management Policy Making: Its Implications for the Survival of an Organization," *Management Science* (30:8), 1984, pp. 905-927.

Hart, J.A. "Cognitive Maps of Three Latin American Policy Makers," *World Politics* (30:1977), 1977, pp. 115-140.

Kwahk, K.Y. and Kim, Y.G. "Supporting Business Process Redesign Using Cognitive Maps," *Decision Support Systems* (25:2), 1999, pp. 155-178.

Langfield-Smith, K. "Exploring the Need for a Shared Cognitive Map," *The Journal of Management Studies* (29:3), 1992, pp. 349-368.

Langfield-Smith, K. and Wirth, A. "Measuring Differences Between Cognitive Maps," *The Journal of The Operational Research Society* (43:12), 1992, pp. 1135-1150.

Lee, S., Courtney, J.F. and O'Keefe, R.M. "A System for Organizational Learning Using Cognitive Maps," *Omega* (20:1), 1992, pp. 23-36.

Lee, S.Y. "An Integrated Model of Land Use/ Transportation System Performance: System Dynamics Modeling Approach," unpublished Ph.D. Dissertation, University of Maryland, 1995.

Linstone, H.A. *Multiple Perspectives for Decision Making : Bridging the Gap Between Analysis and Action*, North-Holland : Elsevier Science Pub., New York, 1984.

Lomax, T.J., Smith, E.R., Courtney, F.J., Vedlitz, A., Matlock, D.M. and Associates "Exploring the Interface of Urban Dynamics and Infrastructure Knowledge," project proposal submitted to the National Science Foundation Texas Transportation Institute, Texas A&M University, 1998.

Markoczy, L. and Goldberg, J. "A Method for Eliciting and Comparing Causal Maps," *Journal of Management* (21:2), 1995, pp. 305-333.

Massey, A.P. and O'Keefe, R. "Insights from Attempts to Validate a Multi-Attribute Model of Problem Definition Quality," *Decision Sciences* (24:1), 1993, pp. 106-125.

Massey, A.P. and Wallace, W.A. "Understanding and Facilitating Group Problem Structuring and Formulation: Mental Representations, Interaction, and Representation Aids," *Decision Support Systems* (17:4), 1996, pp. 253-274.

Mitroff, I.I. and Linstone, H.A. *The Unbounded Mind: Breaking the Chains of Traditional Business Thinking*, Oxford University Press, New York, 1993.

Sakman, M. "An Empirical Study of Three Methods of Problem Definition in Illstructured Situations," unpublished Ph.D. Dissertation, University of Wisconsin at Madison, 1985.

Senge, P.M. *The Fifth Discipline : The Art and Practice of the Learning Organization*, Doubleday/Currency, New York, 1990.

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

Zhang, W.R., Wang, W. and King, R.S. "A-Pool: An Agent-Oriented Open System Shell for Distributed Decision Process Modeling," *Journal of Organizational Computing* (4:2), 1994, pp. 127-154.