

Modeling Intergovernmental Collaboration: A System Dynamics Approach

Anthony M. Cresswell
Theresa A. Pardo
Fiona Thompson
Donna S. Canestraro
Meghan Cook
*Center for Technology
in Government,
University at Albany-SUNY*

Laura J. Black
*Sloan School of
Management (MIT)*

Luis F. Luna
Ignacio J. Martinez
David F. Andersen
George P. Richardson
*Rockefeller College of Public
Affairs and Policy,
University at Albany-SUNY*

1. Introduction

This paper describes the development and testing of a system dynamics model of collaboration, trust building, and knowledge sharing in a complex, intergovernmental information system project. The model building and testing activity was an exploration of the feasibility of applying these modeling methods to a complex interorganizational process about which only qualitative data were available. The process to be modeled was the subject of qualitative field research studying knowledge and information sharing in interorganizational networks. This research had produced a large volume of observational and interview data and analyses about the technology project. In the course of collecting and analyzing data from this project, the researchers noted evidence of what appeared to be important feedback effects. The feedback loops appeared to influence the collaboration and knowledge sharing, critical parts of how the information system design and construction progressed. These observations led to conversations with colleagues who have extensive experience in dynamic modeling. All agreed that applying dynamic modeling methods to this process had considerable potential to yield valuable insights into collaboration. As a novel application of the methods it could yield new modeling insights as well. The modeling experience supported both propositions and was judged a success that will lead to continued exploration of these questions.

2. The project context

The system dynamics model was intended to capture dynamics of a project undertaken by the Center for Technology in Government between 1999 and 2001.

The purpose of the project was to develop a new management information system that would assist the New York State Bureau of Housing Services (BHS) and state-funded homeless shelter providers better manage and evaluate programs. New York State and its localities spend millions of dollars and devote substantial effort in providing both housing and services to homeless single adults and families. BHS manages the temporary housing services program in New York State. The program is comprehensive in that it determines eligibility and need for services, provides case management, direct services, and referrals to outside service providers. Total expenditures on programs for the homeless in New York State is estimated to be \$350 million annually, of which \$130 million is spent on service programs.

Interorganizational relationships are central to the operation and regulation of homeless shelters. BHS has regulatory oversight responsibility for both nonprofit and local government service providers that receive financial support from the State. In this role, BHS certifies and regulates shelters and programs. In New York City, BHS shares its regulatory role with the New York City Department of Homeless Services for those providers that also receive funding from the City. Eighty percent of the homeless population in New York State resides in New York City, Westchester County, and Suffolk County. The overwhelming majority of service providers are nonprofit organizations. Some are very small operations serving only a few people or families at a time. Others are major programs of large well-established organizations. Outside New York City, county social services agencies have similar responsibilities to oversee shelter and service programs.

The field research focused on a project to design an integrated information system to support decisions about programs for the homeless population and evaluate their

effectiveness. The outcome of this project was the creation of the Homeless Information Management System (HIMS), a prototype that draws upon data from multiple existing case management and financial systems. To be successful, the project required participants from the state agency responsible for shelter oversight to work in a highly collaborative way with managers from a wide range of homeless shelters in New York City, Westchester, and Suffolk counties. Over a 2+year period, the project participants were able to achieve the necessary collaboration and share highly detailed and complex operational knowledge. The result was the design and development of a successful prototype information system.

3. Knowledge sharing, collaboration and trust

The kinds of interorganizational collaboration and knowledge sharing in this project have been examined in research ranging from communication and direct relationships [13] to factors affecting knowledge exchange and learning [8]. There has been some attention to collaboration that involves innovations in the operation of government, but knowledge sharing has received relatively little attention [17]. Difficulties in information technology innovations and reforms often involve and sharing operational knowledge across agency boundaries. This is so whether knowledge is tacit or explicit [8], held by individuals or groups such as communities of practice [33], or is embedded in organizational procedures [32].

How knowledge is shared can depend on its type and location. Some views of knowledge locate it "in the heads (or brains) of an organization's members. Learning to be assimilation of information that is able to modify mental contents, behaviors, and actions" [15, p.10]. Sharing of this kind of knowledge may be relatively easy. However, much of the knowledge of interest here is tacit, embedded in the social context, and much more difficult to transfer. This includes knowledge about how the work gets done and how that will change as a result of making the operational information available outside the organization. Just sharing the formal knowledge about work procedures and policies would not capture the necessary depth and nuance of knowledge embedded in practice needed for this particular innovation.

Collaboration and knowledge sharing also requires solving problems of trust, conflict, and risk among different communities of practice. These are largely matters of perception and beliefs about other participants in a network that can influence interactions and decision making [11]. Members' perceptions of power may also be related to the centrality of their organizations or

community of practice relative to the others [18]. These perceptions of power would also be likely to influence evaluations of risk and trust, since a more powerful participant in a relationship can shape outcomes for itself or other members of the network.

Trust has consistently been found to be a critical factor in interorganizational knowledge sharing relationships. Cross-organizational collaboration and knowledge sharing can increase risks and potential conflicts. The strength and value of committed resources, including knowledge, influence those risks [6]. Some level of trust is both an initial condition for the formation of the relationships as well as a result of positive interactions over time [30]. Interorganizational trust is also related to transaction costs [34]. The processes of social interaction through which these risk and conflict issues are resolved or mitigated are the main focus of the modeling described here.

Other environmental factors may limit the success of interorganizational collaboration in this kind of setting [10]. Turbulence or intense time pressures inhibit collaboration and effective key environmental factors limit the success of information systems that attempt to integrate work and information flow between state agencies and local governments. The intervention of CTG in this case was specifically designed to enhance collaboration, and sharing, as well as leadership and sponsorship of sharing relationships. These are known to influence the success of innovation [16] [20] [7].

4. System dynamics modeling of project work and knowledge sharing

The basis of System Dynamics is that dynamic behaviors (performance over time) are closely linked to an underlying structure of feedback loops [25]. Furthermore, in order to get a better understanding about linkages between behavior and structure a computer model is needed because the human mind has not the capability to manage the behavior of these complex structures [12]. Thus, a system dynamics computer model is the result of an iterative process of comparing and contrasting a set of assumptions about the system structure and the known behaviors of it [28].

Research employing system dynamics modeling has provided insights to several issues relevant to the project of interest. Cooper's [9] study of change orders in a ship-building project and Abdel-Hamid's [1] study of a software development effort explicitly portray the creation, identification, and resolution of problems during project work and their effect on the timeliness and quality of the completed project. They also demonstrate that assigning too-few resources to a project at its initiation can result in snowballing needs for resources in the final stages of project work. Repenning [21] and

Repenning, Goncalves, and Black [22] examine the allocation of resources to multiple projects in product development. Observed biases toward allocating resources to projects whose deadlines are imminent can lead to systematic under allocation of people to early phases of projects. Thus a temporary increase in project workload can “tip” a project development organization to produce work at a permanently lower level of quality than potentially possible, even though the same number of resources are available before and after the temporary change in workload.

System dynamics modeling has also been used to explore the role of knowledge in creating collaborative patterns of interaction. Black, Carlisle, and Repenning [4] draw on a case study by Barley [3] documenting interactions between doctors and technicians during the implementation of computed tomography scanning to model how working with the new machine and its images affected expertise that doctors and technicians could bring to bear on the tasks at hand. The resulting model suggests that relative expertise among doctors and technicians dynamically affects which group performs which task, which in turn affects who knows how to do what. These feedback dynamics play a significant role in whether technicians and doctors unfold collaboratively or not.

A social constructivist view would hold that methods for representing who knows what when, and the ways in which relative expertise can change through time. So dynamic models should prove valuable to the study of knowledge sharing. Theories of structuration [5] [14] view social life as unfolding through a recursive process in which accumulated values and properties (sometimes called “capital”) of institutions or individuals shape daily activities, which in turn can conserve or transform actors’ accumulated capital. Often momentary activities and enduring properties reinforce each other as people choose to recreate the patterns and practices they have experienced in the past, but sometimes people draw differentially on accumulated experiences to create activities viewed as “new” or “changed.” System dynamics modeling provides a particularly useful method for representing interactions between activities and actors’ accumulations of capital through time. It moves from the researcher to computer simulation some of the burden of reasoning about outcomes of complex, recursive relationships; its stock-and-flow grammar is well suited to represent accumulations of capital (such as knowledge) and their effect on activities; and it is an inductive tool appropriate to building models beginning with salient elements of a field setting.

5. The Group Modeling Process

For more than 15 years, the modeling group at the University at Albany has been experimenting with techniques for building computer models directly with groups [19] [23] [27] [29]. More recently, these techniques have been used to construct system dynamic models [24] [27]. Researchers in the group have identified and described five distinct roles to be played during the modeling session: facilitator, modeler/reflector, process coach, recorder, and gatekeeper [24]. The modeling team interacts with the client group to elicit, in the iterative way described above, the behavior and structure of the system to be modeled following a well-identified set of scripts [2]. The work in group model building at Albany links to other similar efforts in the field [31].

According to the scripts described in previous work, the modeling group prepared the sessions through several interviews with CTG researchers involved in the development of HIMS. During these preliminary interviews both groups made decisions about the schedule and the people to be involved in the modeling sessions. The participation and intervention of one of the authors of this paper (Cresswell) was particularly relevant to the modeling project. Because of his good understanding of the System Dynamics modeling methodology and its applications, he played the role of gatekeeper [24].

Once the CTG research team consented to the modeling experience, the modeling group designed two one-morning sessions. During the first of them, the CTG group was introduced to the System Dynamics ideas of stocks, flows, causal loops, structure, and behavior through the discussion of a “concept model” (Figure 1) as proposed by Andersen and Richardson [2] [24]. This session served as a fast introduction to System Dynamics the starting point for the group discussion about the system to be modeled. During the first session the CTG group made several decisions about the purpose of the model, its boundaries, the key variables, the main reference modes, and the major loops of the model.

During the second modeling session, the group focused on the discussion of the preliminary model presented in the next section of this paper. After comparing and contrasting the formulated model with the set of conceptual maps developed in the first meeting, the modeling group ran some simple experiments with the model in order to get a better understanding of the feedback processes embedded in the model. The resulting discussion enriched the initial model conceptualization.

6. The Preliminary Model

6.1. Model Overview

The preliminary model developed from the behavior and structure elicitation of the first modeling session is the four-sector model depicted in Figure 1. (Full documentation of the model itself as well as a description of the modeling process is available at www.albany.edu/cpr/sdgroups/HIMS/index/htm).

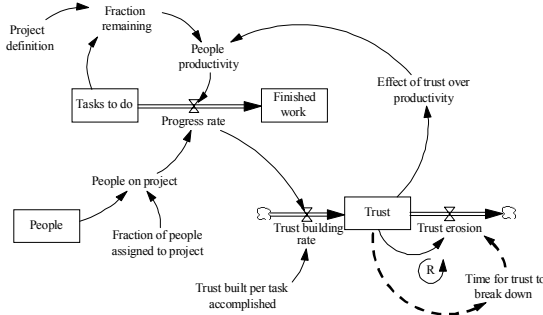


Figure 1-Concept model used in the first modeling session

The main sectors of the model are the Project Sector, the Providers Sector, the State and Bureau of Housing

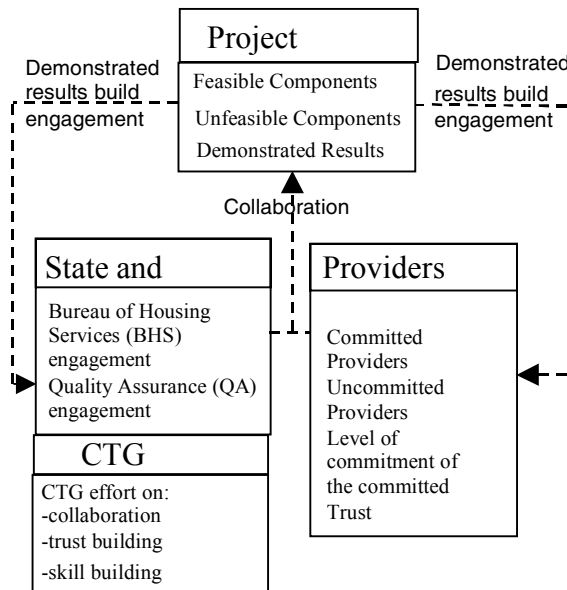


Figure 2 – Trust model sectors

Services (BHS) Sector, and the CTG sector (Figure 2).

On the other hand, prototype development depends on the collaborative effort and level of involvement of the two groups, state agency and service providers, facilitated by the CTG research team. State agency has two feasible outputs. They could promote prototype component development, but they could prevent project progress if there is no collaboration or peoples' participant engagement in the project. CTG Sector.

The Project Sector includes the prototype development tasks and the accumulation of prototype components. Some of these components are imperfect

and have attached to them some problems caused by the lack of group agreement. Project progress, combined with the average problems per component, constitutes the demonstrated results of the HIMS prototype. These demonstrated results promote engagement by both the State and the Providers participants.

6.2. CTG Sector

This preliminary model considers the CTG research team as an exogenous factor. That is to say, CTG team activities are not involved in any feedback loop and they are considered as constants. As it is shown in Figure 3, the model assumes that CTG effort is divided between two main activities, project tasks and collaboration. The effort in project tasks represents people working in task development, and the effort on collaboration represents people working on tasks associated with the facilitation process and collaboration management (responsibility of collaboration).

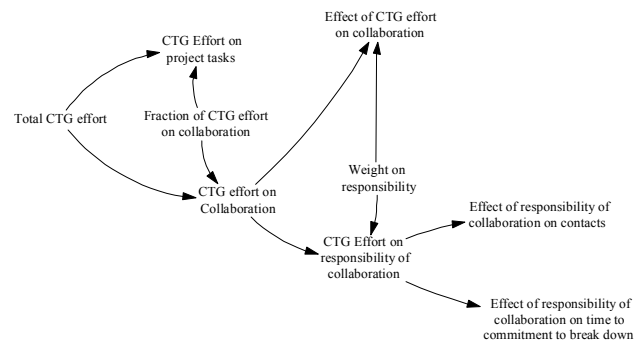


Figure 3-CTG effort allocation in Trust1 (CTG Sector)

Some of the tasks associated with collaboration management and facilitation include making phone calls to service providers, facilitating meetings, and writing reports. Because of the nature of these activities, the model considers three different effects associated with this effort. The facilitation portion works to catalyze the collaborative efforts of service providers and government. The collaboration management fraction promotes a higher level of contacts among providers by calling them to meetings and work sessions. On the other hand, the effort devoted to the responsibility of collaboration sustains participant engagement by reminding them of project progress and achievements through phone calls, progress reports, etc.

6.3. State and BHS Sector

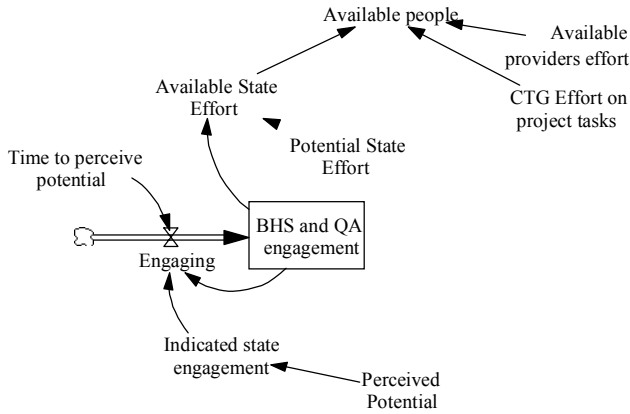


Figure 4 – BHS and state sector

The State Sector in Trust1 represents the BHS and QA effort committed and the level of engagement to the project (Figure 4). The level of engagement is influenced by the project perceived potential. As it was stated above, the perceived potential is one of the variables in the Project Sector that depends on project progress and the extent of agreement in project components.

Engagement is defined in the model as a dimensionless value between 0 and 1. Thus, the effort allocated to the project is proportional to the level of engagement and the maximum effort that the State is willing to allocate to the project (Potential State Effort). State effort is added to CTG effort and providers' effort

Similar to the State Sector, the Providers Sector represents the quantity of providers committed to the project and the level of provider engagement to the project (Figure 5). Both, the level of engagement and the number of committed providers grow as functions of the perceived potential of the project. Both levels are drained in proportion to the average time for commitment to break down. The number of committed providers is modeled as an epidemic process, where the virulence of the commitment "infection" is a function of the average engagement per provider. The average engagement per provider is modeled as a weighted average of the engagement of the providers committed to the project. That is to say, providers join the committed group with a level of engagement based on the perceived potential of the project. This new engagement level is averaged with the engagement of the providers previously committed. As shown in Figure 5, the number of contacts among providers and the time for commitment to break down depends on CTG effort on collaboration. Finally, the number of committed providers and the average engagement per provider determine the total provider effort on project development. This effort is added to State and CTG efforts on project development.

6.5. Project Sector

The core of the *Trust1* model is a simple project

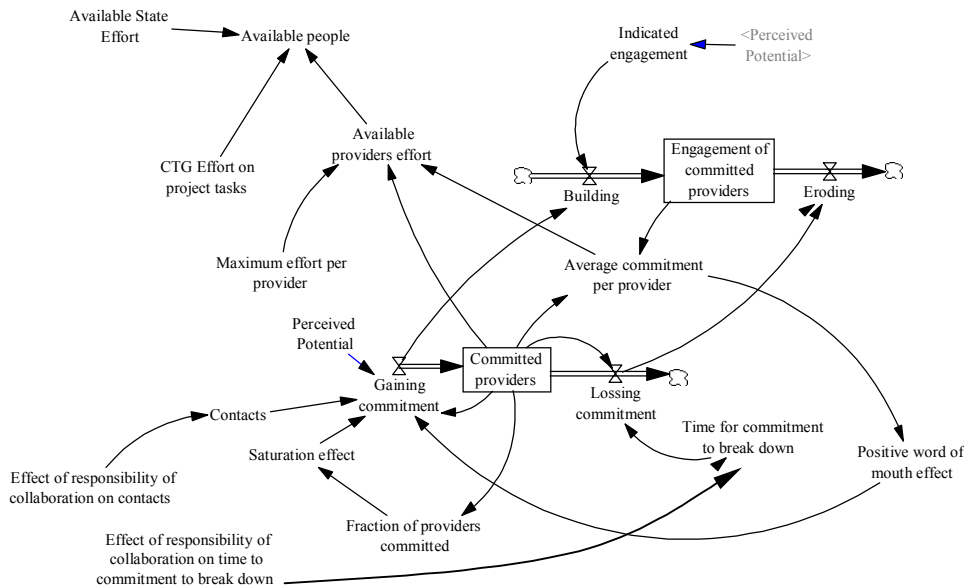


Figure 5-Provider sector in TRUST1

in order to get the available people to work on the project (Figure 4)

6.4. Providers Sector

management model that tracks progress throughout the Homeless Information Management System (HIMS) project (the section within the broken lines of Figure 6). The project is modeled as the accumulation of HIMS components developed through time. People dedicated

policy settings. However, these results are very preliminary and *Trust1* model needs further work.

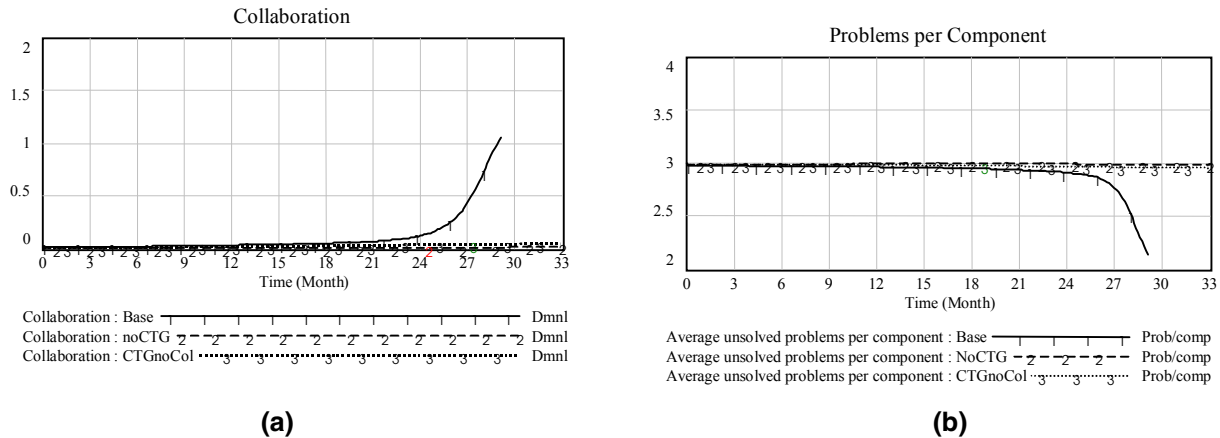


Figure 1 - Comparative plots of collaboration and problems per component in the base run and the No-CTG and No-facilitation-effort scenarios

VIII. Future Research

After analyzing model behavior during the second modeling session, the CTG research team found the preliminary model to be a valuable tool to analyze collaboration in intergovernmental settings, showing interesting and realistic behavior. The team identified several areas of further work in the model. (Newer versions of the model and additional documentation are in development currently and will be available at www.albany.edu/cpr/sdgroups/HIMS/index/htm)

1. Fixing known problems. One problem in *Trust1* is the need to include a quality control structure to review the unsolved problems per component. The lack of this quality control structure and the accumulation of problems are the main explanation for satisfaction never taking off.
2. The “epidemic” nature of committed units ends with an all or nothing behavior. Alternative structures may better represent provider commitment.
3. On this preliminary model, collaboration is a CTG burden, that is to say, providers are assumed not to have the ability to collaborate or learn how to collaborate. Future versions of the model should add to providers the capacity to learn how to collaborate.
4. Exploring how CTG allocates effort dynamically is another path to further model development.
5. The initial model considers a one-stage project, while HIMS is a 4-stage project. Expanding to a multi-phase view would allow exploring providers’ project understanding as an iterative process, since project understanding and learning continue during project development.

6. Trust dynamics need to be explored in future model versions.

References:

[1] Abdel-Hamid, T.K. The Economics of Software Quality Assurance: A Simulation-Based Case Study. *MIS Quarterly* 12(3), 1988,395-411.

[2] Andersen, D. F. and G. P. Richardson Scripts for Group Model Building. *System Dynamics Review* 13(2), 1997, 107-129.

[3] Barley, S.R. Technology as an Occasion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments. *Administrative Science Quarterly*, 31(1), 1986, 78-108.

[4] Black, L.J., Carlile, P.R., & Repenning, N.P. A Dynamic Analysis of Different Cross-Boundary Behaviors Emerging from Similar Organizations. Paper presented at the Academy of Management, Washington, DC, 2001.

[5] Bourdieu, P. *The Logic of Practice*. R. Nice, Trans. Stanford, CA: Stanford University Press. (Originally published in 1980 as *Le Sens Pratique* by Les Editions de Minuit.), 1990.

[6] Burt, R. S. The Contingent Value of Social Capital. *Administrative Science Quarterly*, 42, (June) 1997, 339-365.

[7] Cheng, Y.-T., & VendeVen, A. H. Learning the Innovation Journey: Order out of Chaos? *Organization Science*, 7(6), 1996, 593.

[8] Cook, S. D. N., & Brown, J. S. Bridging Epistemologies: The Generative Dance Between Organizational Knowledge and Organizational. *Organization Science*, 10(4), 1999, 381-400.

- [9] Cooper, K.G. Naval Ship Production: A Claim Settled and a Framework Built. *Interfaces* 10(6), 1980, 20-36.
- [10] Cresswell, A. M., Pardo, T. A., Dawes, S. S., & Kelly, K. Partnership Effectiveness in Public Sector Information Technology Innovation. Paper presented at the Academy of Management, Toronto, 2000.
- [11] Elg, U., & Johansson, U. Decision Making in Inter-firm Networks as a Political Process. *Organization Studies*, 18(3), 1997, 361-384.
- [12] Forrester, J. W. Counterintuitive Behavior of Social Systems. *Technology Review* 73(3), 1971, 52-68.
- [13] Galbraith, J. R. *Designing Complex Organizations*. Reading, MA: Addison-Wesley, 1973.
- [14] Giddens, A. *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley: University of California Press, 1984.
- [15] Gherardi, S., & Nicolini, D. The Organizational Learning of Safety in Communities of Practice. *Journal of Management Inquiry*, 9(1), 2000, 7-18.
- [16] Larson, A. Network Dyads on Entrepreneurial Settings: A Study of the Governance of Relationships. *Administrative Science Quarterly*, 36, 1992, 76-104.
- [17] Milward, H. B., & Provan, K. G. Principles for Controlling Agents: The Political Economy of Network Structure. *Journal of Public Administration Research and Theory*, 8(2), 1998, 203-221.
- [18] Mizuchi, M. S., & Galaskiewicz, J. Networks of Interorganizational Relations. In S. Wasserman, & J. Galaskiewicz (Eds.), *Advances in Social Network Analysis: Research in the Social and Behavioral Sciences*. Thousand Oaks, CA: Sage, 1994.
- [19] Mumpower, J., Schuman, S & Zumbolo, A. "Analytical Mediation: an Application in Collective Bargaining" in *Organizational Decision Support Systems*. Lee, R., McCosh, A. and Migliarese, P. eds. Amsterdam, 1998.
- [20] Pardo, T. A. Reducing the Risks in Innovative Uses of Information Technology in the Public Sector: A Multidisciplinary Model. Unpublished Doctoral Dissertation, University at Albany-SUNY, Albany, NY., 1998.
- [21] Repenning, N.P. "A Dynamic Model of Resource Allocation in Multi-Project Research and Development Systems." *System Dynamics Review* 16(3), 2000, 173-212.
- [22] Repenning, N.P., Gonçalves, P.M., & Black, L.J. Past the Tipping Point: The Persistence of Firefighting in Product Development. *California Management Review*, forthcoming.
- [23] Richardson, G. P., Andersen, D.; Rohrbaugh, J., and Steinhurst, W. "Group Model Building". *System Dynamics 1992: Proceedings of the 1992 International System Dynamics Conference*. Utrecht. Cambridge: System Dynamics Society, 1992.
- [24] Richardson, G. P. and D. F. Andersen Teamwork in Group Model Building. *System Dynamics Review* 11(2), 1995, 113-137.
- [25] Richardson, G. P. Problems for the Future of System Dynamics. *System Dynamics Review* 12(2), 1996, 141-157.
- [26] Rohrbaugh, J. "Cognitive Challenges and Collective Accomplishments: the University at Albany" in *Computer Augmented Teamwork: a Guided Tour*. R. Bostrom, R. Watson, and S.T. Kinney, eds. Van Nostrand Reinhold, New York, 1992.
- [27] Rohrbaugh, J. "The use of System Dynamics in Decision Conferencing" in *Handbook of Public Information Systems*. David Garson, ed. Marcel Dekker. New York, 2000.
- [28] Saeed, K. Slicing a complex problem for systems dynamics modeling. *System Dynamics Review* 8(3), 1992, 251-262.
- [29] Schuman, S. and Rohrbaugh, J. "Decision Conferencing for Systems Planning". *Information and Management*. 21, 1991, 147-159.
- [30] Sheppard, B. H., & Sherman, D. M. The grammars of trust: a model and general implications. *Academy of Management Review*, 23(3), 1998, 422-438.
- [31] Vennix, J. A. M. *Group Model Building: Facilitating Team Learning Using System Dynamics*. Chichester, Wiley, 1996.
- [32] Weick, K. E., & Westley, F. Organizational Learning: Confirming an Oxymoron, *Handbook of Organizational Studies*. Thousand Oaks, CA: Sage Publications, 1996.
- [33] Wenger, E. *Communities of practice : learning, meaning, and identity*. New York: Cambridge University Press, 1998.
- [34] Williamson, O. E. Comparative Economic Organization: The Analysis of Discrete Structural Alternatives. *Administrative Science Quarterly*, 36, 1991 269-296.