Systems Thinking, Mapping, and Modeling in Group Decision and Negotiation

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Abstract

The use of systems modeling and simulation contributes an endogenous dynamic perspective to group negotiations and decision making. In the field of system dynamics, group (participatory) model building has a rich history and growing literature. This chapter provides an introduction. It discusses the roles required to handle the intricacies of facilitation and group modeling and identifies the tension inherent in models as 'microworlds' or 'boundary objects' (Ackermann and Eden in this volume). It overviews the group model building process and focuses most extensively on an accumulating body of scripts (Lewis in this volume) for group modeling, including scripts for introducing model concepts, initiating systems mapping, eliciting system feedback structure (Hujala and Kurttila in this volume), formulating formal models with client groups, and using them to help build a negotiated consensual view of their shared mental models (Ackermann and Eden in this volume). The keys to the success of group modeling building efforts appear to be engaging stakeholders, sharing mental models formally, assembling and managing complexity, using simulation to test scenarios and support or refute hypotheses, working toward alignment, and empowering people to have confidence in the strategies that emerge.

Introduction

The problems had been growing. Responsible people in the agency had some disagreements about the sources of the problems, and they had different perceptions about how they would play out in the future. Past efforts to deal with the problems hadn't worked out as people thought they would. They knew that decisions taken now would influence not only the future of the agency but also its environment, and those changes would influence other stakeholders and feed back to alter the playing field.

Addressing the problems meant not only trying to understand that complex dynamic playing field and policies that might improve the agency's place in it, but also working with the intricate stakeholder relationships within the agency and outside in order to build consensus toward policies that could actually be implemented.

They decided to bring in a group strategy support team skilled in using group facilitation and system dynamics modeling.

Such a setting is made to order for the potential contributions of system dynamics modeling in group decision and negotiation. Each of the characteristics mentioned are key: the problems are dynamic (developing over time); root causes of the dynamics aren't clear; different stakeholders have different perceptions; past solutions haven't worked; solutions that fail to take into account how the system will respond will surely fail to produce desirable long-term results; and implementing change within the agency will require aligning powerful stakeholders around policies that they agree have the highest likelihood of long-term success.

The fields of systems thinking and system dynamics modeling[1] bring four important patterns of thought to GDN: Thinking dynamically, thinking in stocks and flows, thinking in feedback loops, and thinking endogenously.

- Thinking dynamically refers to thinking about problems as they have developed *over time* and will play out in the future. The principle tool to facilitate dynamic thinking is graphs over time. Sketching graphs over time helps groups move from a focus on separate dramatic events to a focus on the persistent, often almost continuous pressures giving rise to the discrete events we see (Howick et al. 2006).
- Thinking in stocks and the flows (accumulations and their rates of change) that change them focuses on populations, physical stocks, inventories, backlogs, and other accumulating characteristics central to the problem, and on the production capacities, resources, and distinctive competencies available to deal with the problem (Warren 2002). Stocks change gradually over the time frame of interest, growing or declining as inflows compete with outflows. System capacities result not from quick changes, but from sustained investment. System policies must work through flows to change key stocks over time.
- Thinking in feedback loops focuses on *circular causality*, the likely extended ramifying effects of actions taken by actors in the system (Richardson 1991). Feedback loops are a source of policy resistance: Exposing reinforcing and balancing feedback loops active or latent in system structure gives planners the opportunity to avoid the natural tendencies of complex systems to compensate for or counteract well-intentioned policy initiatives.
- Thinking *endogenously* is the most powerful aspect of systems thinking. It grows out of feedback thought, but is really the foundation for it (Forrester 1968, 1969; Richardson 1991). Thinking endogenously refers to the effort to see the "system as cause," to extend the boundary we naturally place around our thinking about a problem to the point that root causes are seen not as independent forces from outside but linked in circular causal loops with internal forces over which we might have some control. "Systems thinking" drives many apparently diverse schools of thought, but at the core of them all is the mental effort to uncover endogenous sources of system behavior.

Merging GDN Practice with System Simulation—A Group Model Building Approach

[1] Important texts in the field include Forrester 1961, Richardson and Pugh 1981, Senge 1990, Wolstenholme 1990, Ford 1999, Maani and Cavana 2000, and Sterman 2000.

In the system dynamics literature, GDN using systems tools is referred to as "group model building" (Vennix 1995, Andersen et al. 2007). It could be said to trace its origins back to one of the early practices in the field, using a "model reference group" of experts (Stenberg 1980) to help guide problem definition, system conceptualization, model building and refinement, and model use.[2] However, until the late 1980s, virtually all system dynamics modeling work supporting group decision and negotiation took place out of sight of the client groups, surfacing at various times to show model structure and behavior, policy experiments, and model-based insights.

The first suggestion that model building could take place not in the closet but in front of a relatively large client group, in fact with the active participation of the group, comes from work done with the New York State Insurance Department striving to decide among policies to recommend to the state legislature to solve the impending bankruptcy of the state's five medical malpractice insurance companies (Reagan-Cirincione et al. 1991,). From that early beginning, the field has experienced a rather dramatic growth in diverse efforts to bring more and more of the modeling process into public forums.[3]

The goals of engaging a relatively large client group in the actual processes of model building are a wider resource base for insightful model structure, extended group ownership of the formal model and its implications, and acceleration of the process of model building for group decision support. However, the pitfalls generated by mixing group processes and the modeling process are formidable.

Roles in System Dynamics Group Model Building

Early in the development of system dynamics group model building it was realized that adding the complexities of group process to the arts and technicalities of model building created intricate and complicated conversations. At times the modeler would be working to facilitate the group's conversations and to elicit information about system structure, parameters, and behavior. At other times the modeler would be in the rather contradictory role of trying to explain something about the system dynamics approach or the structure or behavior of the model under development, in effect talking and teaching rather than listening and learning. Throughout a group model building intervention, the group modeler's attention would be split between being sensitive to group process on the

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[2] Another source of the originating ideas stems from the Group Decision Support Systems literature, including in particular Decision Conferencing (Quinn, Rohrbaugh & McGrath 1985, Milter and Rohrbaugh 1985, Schumann and Rohrbaugh 1991, Rohrbaugh 2000). Other supporting literatures include strategic management (e.g., Eden and Ackermann 1998, Eden and Ackermann with Brown 2005) and the European traditions that fall under the heading of soft operations research (see Lane 1994).
[3] See, e.g., Vennix 1996, Vennix, Andersen & Richardson 1997, and the special issue of the *System Dynamics Review* on Group Model Building that that article introduces.

one hand and on the other hand concentrating on translating what was being said into technical details of model structure.

The solution to these problems in the group modeling process was the recognition that there were multiple roles involved and that these multiple roles were best handled by different people. In their seminal article “Teamwork in Group Model Building” Richardson and Andersen (1995) outlined five distinct roles in system dynamics group model building, which they termed the “facilitator / knowledge elicitor,” the “modeler / reflector,” the “process coach,” the “recorder,” and the “gatekeeper.”

- The *facilitator / knowledge elicitor* works with the group to facilitate the conversation, to draw out knowledge of the dynamic problem, its systemic structure, necessary data and parameter values, and so on. The facilitator / knowledge elicitor translates the group’s conversation into the stocks and flows and feedback loops of system dynamics model structure. This person pays constant attention to group process, the roles of individuals in the group, and the business of drawing out knowledge and insights from the group. This role is the most visible of the five roles, constantly working with the group to further the model building effort.
- The *modeler / reflector* works more behind the scenes, listening hard to what is being said, thinking about how to clarify and improve the maps being created on the fly by the facilitator and the group. He or she focuses on the model that is being explicitly (and sometimes implicitly) formulated by the facilitator and the group. The modeler/reflector serves both the facilitator and the group. This person thinks and sketches on his or her own, reflects information back to the group, restructures formulations, exposes unstated assumptions that need to be explicit, and, in general, serves to crystallize important aspects of structure and behavior. Both the facilitator and the modeler/reflector must be experienced system dynamics modelers. They can trade roles in the middle of the process.
- The *process coach* focuses not at all on content but rather on the dynamics of individuals and subgroups within the group. Often not necessary in small group efforts (where the facilitator and reflector can often substitute), the role can be important in large group efforts. This person need not be a system dynamics practitioner. In fact, it may be advantageous that the person is not: such a person can observe unwanted impacts of jargon in word and icon missed by people closer to the field. The process coach tends to serve the facilitator; his or her efforts are largely invisible to the client group.
- The *recorder* (there may be more than one) strives to write down or sketch the important parts of the group proceedings. Together with the notes of the modeler/reflector and the transparencies or notes of the facilitator, the text and drawings made by the recorder should allow a reconstruction of the thinking of the group. This person must be experienced enough as a modeler to know what to record and what to ignore.
- The *gatekeeper* is a person within, or related to, the client group who carries internal responsibility for the project, usually initiates it, helps frame the problem, identifies the appropriate participants, works with the modeling support team to structure the sessions, and participates as a member of the group. The gatekeeper

is an advocate in two directions: within the client organization he or she speaks for the modeling process, and with the modeling support team he or she speaks for the client group and the problem. The locus of the gatekeeper in the client organization will significantly influence the process and the impact of the results.

In practice, experienced group modelers can get along with perhaps just two individuals taking (at various times) the first four roles. It should be noted that this formulation of the roles comes from the work of one set of practitioners. But the recognition of the differing natures of these roles, and skill in performing them, are essential to success in group model building efforts (Lewis, in this volume). Because of the difficulties of mixing modeling with group process, it is likely that all practitioners, whether or not they know of the writings on teamwork in group model building, carry out their work with groups in teams rather than as individuals (Andersen et al. 2006).

Boundary Objects in Group Model Building

Zagonel (2002, 2003), Zagonel dos Santos (2004) identified an archetypical dichotomy in system dynamics group model building between building “microworlds” and facilitating a conversation using “boundary objects.” (See Ackermann and Eden, in this volume, for the related concept of ‘transitional object.’) The distinction is blurred in practice, but nonetheless important to note. A “microworld,” as Zagonel used the term, is a model that is intended by its creators and users to be a close replica of some slice of the real world, a reliably accurate recreation, in smaller form of course, of the problematic piece of reality central to the group’s problems of negotiation and decision making. A “boundary object” (Star and Griesemer 1989, Carlile 2002, Black 2002) is intended by its creators to be a tool for facilitating conversation that spans the boundaries that separate perspectives, constituencies, and turf present in a group struggling with a tough decision.

In this sense, system dynamics modelers always strive in some sense for accurate microworlds; but group modelers must also realize the role of the model as a boundary object. In systems practice such boundary-spanning objects are maps and models constructed by the group (with help) that enable participants to move toward a shared view of a complex system and connects that shared structural view with endogenous system dynamics. Sometimes the process involves only pictures, stories, and diagrams developed by the group, and sometimes the process employs simulation.

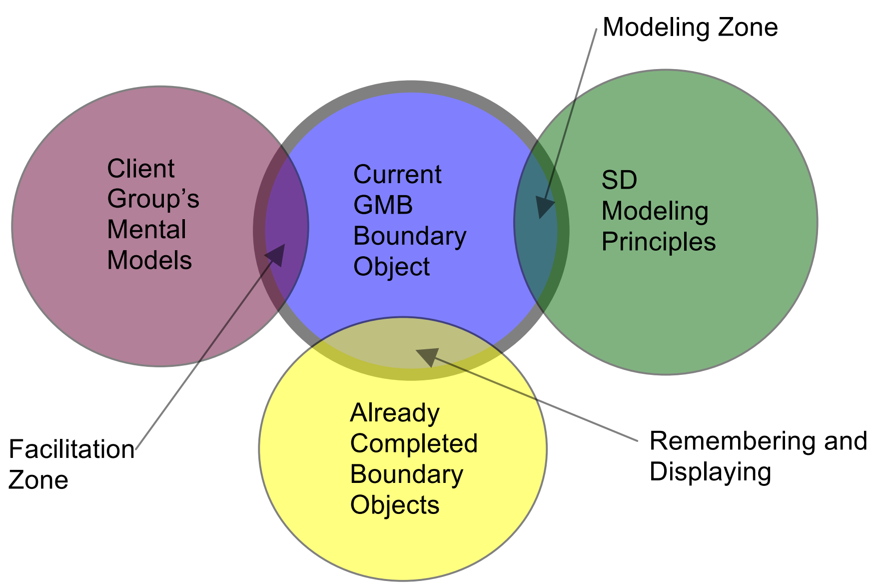


Figure 1: Boundary Objects in System Dynamics Group Model Building

Figure 1 presents a schematic overview of how this process works in practice. The facilitator / knowledge elicitor works in a teams with other skilled system dynamics modelers to help the client group produce pictures, sketches, word-and-arrow diagrams, and other boundary objects that are both based on the client group’s prior mental models while at the same time conform to specific format and syntax defined by good system dynamics modeling principles.

The System Dynamics Group Modeling Process, In Brief

The system dynamics group model building process involves a series of meetings much like those of any GDN support process. A typical sequence might look like the following:

- Problem definition meeting (small group of project leaders)
- Group modeling meetings (large group of stakeholders, with full group model building team, perhaps meeting more than once)
- Formal model formulation, testing & refinement (modeling team)
- Reviewing model with model building team (modeling team with stakeholder group; this and the previous step usually iterate)
- Rolling out model with the community (modeling team, the stakeholder group involved in model construction, and a larger group of potential stakeholders)
- Working with flight simulator (interested actors, working with the model in an accessible "learning environment" format; not a common part of the process, but possible)
- Making change happen (stakeholders, with facilitation, making decisions).

Vennix (1996) describes several other structured designs, exemplified in three cases. In a qualitative modeling intervention on the Dutch health care system he and his colleagues used a Delphi-like approach to elicit knowledge about the system from some 60 participants. The process enabled the group to function "at a distance" as well as in face-to-face meetings (p 189):

- Policy problem
- Knowledge elicitation cycles
    - Questionnaire
    - Workbook
    - Structured workshop
- Final conceptual model
- Project results and implementations

The reader will find other variations of group model building processes in several chapters in Morecroft and Sterman, eds. (1994).

Elements of System Dynamics Group Model Building Meetings: *Scripts*

Dynamics

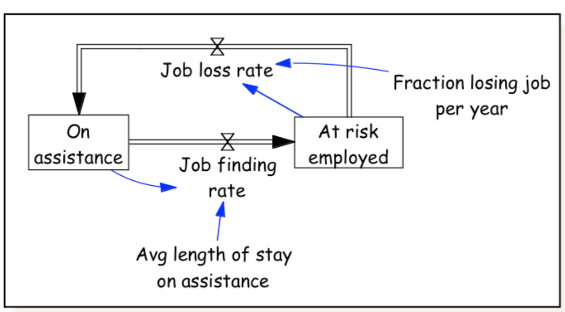
The problems that the field of system dynamics modeling and simulation can help with are dynamic, that is, they play out over time. Furthermore, vital aspects of their dynamic behavior come from *endogenous* forces and interactions, that is, pressures that emerge from *within* some appropriate system boundary. Thus, the initial stages of a system dynamics group modeling process help the group to focus on dynamics over time.

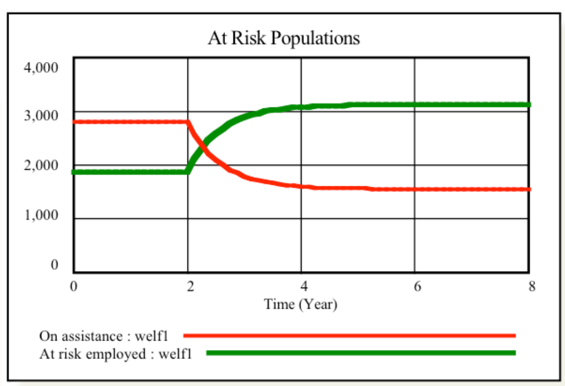
The principle method for drawing out dynamics is the simple tool of graphs over time. Working in pairs, clients in the group are asked to sketch graphs over time of variables that they think are central to the problem and the decisions that have to be made. Participants are advised to put "now" somewhere in the center of the horizontal time axis, so that dynamics of the past and hopes and fears for the future can be represented. Participants describe their graphs, and the group model building team clusters them to try to tell visually the interacting stories the participants are describing. We call such a repeatable process a group model building *script* (Richardson and Andersen 1995, Andersen and Richardson 1997, Luna-Reyes et al. 2006; see also Lewis, in this volume). This graphing script is a divergent group process that usually results in a wide diversity of candidate variables and their dynamic behaviors, which help the group to move toward dynamic thinking, to focus on key variables of interest, and to see each others' understandings of the dynamic problem.

Introducing elements of system dynamics modeling: Concept models
A puzzle for system dynamics group modelers is how to give the client group enough of a familiarity with the approach and its iconography of stocks and flows and feedback loops without spending much time doing that. One solution to that puzzle is a short sequence of what we term "concept models" (Richardson 2006).

The term reflects the conceptual nature of these little models in two senses. The models introduce concepts, iconography, and points of view of the system dynamics approach. In addition, the models are designed to try to approach the group's own concepts of its problem in its systemic context.

The intent is to begin with a sequence of simulatable pictures so simple and self-explanatory, in the domain and language of the group's problem, that the group is quickly and naturally drawn into the system dynamics approach. Within thirty minutes or less, we'd like to working with the group on their problem in their terms, listening hard to what they have to say, facilitating their conversations, and structuring their views of the problem.





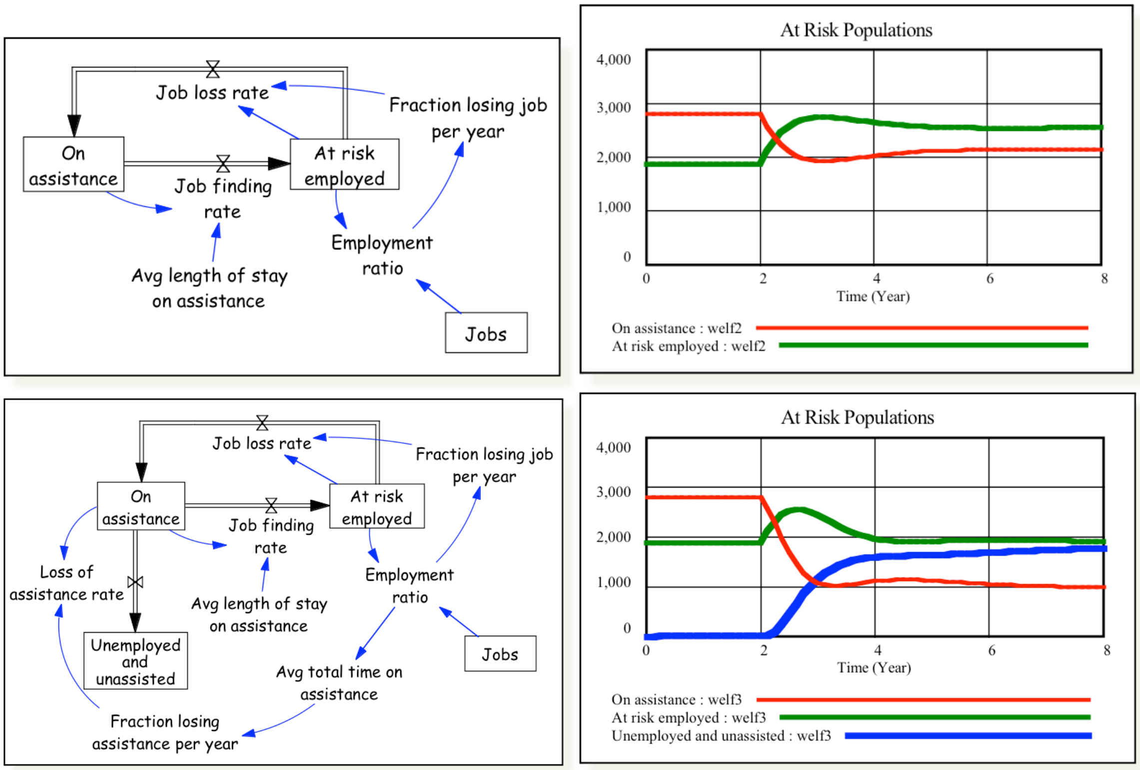


Figure 2: A concept model sequence for a group model building workshop on welfare reform, introducing elements of the system dynamics approach.

Figure 2 shows a concept model sequence used in several group model building sessions on U.S. welfare reform (Zagonel et al. 2004). The diagrams on the left show the sequence of models, moving from a simple view of population stocks and flows of families at risk, to the addition of a feedback loop, and ending with the addition of structure capturing the loss of assistance, which was at the heart of the welfare reform legislation. Each of these three figures was initially drawn on a white board in front of the client group, using the same hand-sketching techniques that the group would later use in mapping system structure on that same white board. When the hand sketch was completed, the computer drawn images as shown in Figure 2 were projected next to the hand drawn sketch. The point was immediately made that the system sketch created the basis for a formal simulation model. Each view in Figure 2 is increasingly complicated; one increasingly complicated hand sketch supported this elaboration of the concept model. Again, the point being hammered home is that the group could elaborate the formal model just by making a richer and more complete sketch on the white board.

The graphs on the right of Figure 2 show the dynamics of each of these little models, moving from what the drafters of the welfare reform legislation intended (more people in jobs, fewer on assistance) to eventually a "better before worse" situation in which the employment improvement is short-lived and many end up unemployed and ineligible for Federal assistance. Seeing this sequence, participants understood the stock-and-flow iconography, saw examples of how a model can be repeatedly refined, saw that changing model structure changes behavior, and were champing at the bit to correct these overly simplified, agonizingly inadequate pictures, all in less than thirty minutes.

Initiating systems mapping
Continuing the group model building process, three potential ways of helping the group to begin to conceptualize their complex system are in common use:

- Working from the concept model to expand a conserved system of stocks and flows that can form a "backbone" on which to hand feedback structure
- Identifying and drawing feedback loops implicit in the graphs over time drawn by the group
- Identifying stakeholder goals and perceptions, and sketching the feedback loops that result when pressures from those goal-gaps result in actions that feed back to alter perceptions.

Figure 3 shows an example of the results of the first strategy. The figure shows the stock-and-flow structure of families in the U.S. welfare system, as developed during the first day of a group model building workshop. The rich picture grew from group discussions that started from the simple concept model in Figure 2.

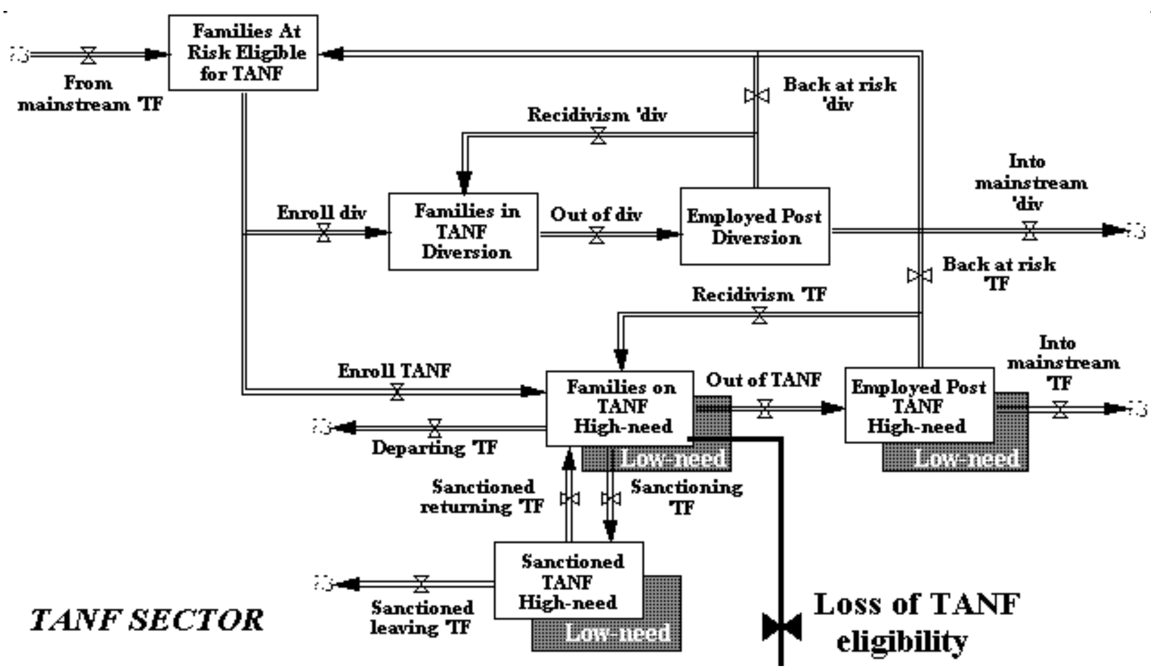


Figure 3: Stocks and flows of families in the U.S. welfare system, as developed by a group of experts in a group model building workshop. (TANF stands for Temporary Assistance to Needy Families.)

Beginning with loops rather than stocks and flows is somewhat more difficult to manage. People don't naturally think in feedback loops. But people do think occasionally about self-fulfilling prophecies, vicious and virtuous cycles, band-wagon effects, and similar self-reinforcing processes; some of those may be apparent in the clustered graphs over time and can be identified, sketched, and expanded to initiate systems feedback mapping.

Balancing loops tend to be initially less evident for most decision makers, but ultimately more ubiquitous. An excellent place to start focuses on stakeholder goals and perceptions; it is a small step from the gap between a goal and its related system condition to efforts to close the gap. Figure 4 shows the generic goal-gap feedback loop in bold, surrounded by other complicating influences.

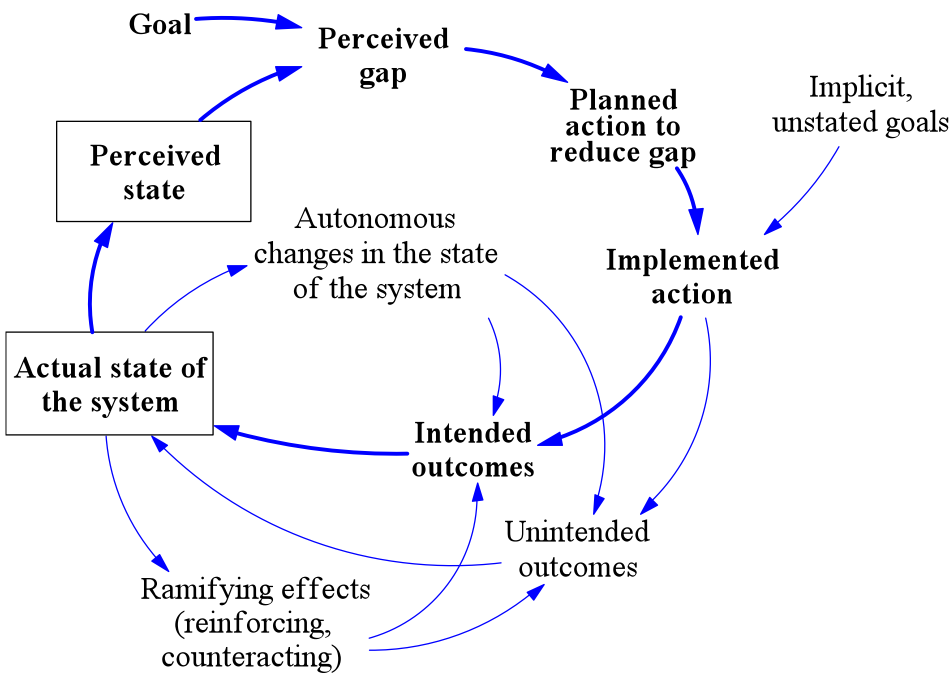


Figure 4: The generic goal-seeking feedback loop (in bold) showing how the gap between goals and perceptions generates action and intended outcomes striving to close the gap. Other influences and feedback loops complicate the picture suggesting sources of policy resistance.

While the client group may not have a picture such as Figure 4 in their heads, the facilitator / knowledge elicitor does, and he or she can use that image to guide the formulation of questions and the interpretation and visual representation of group suggestions.

There are numerous other scripts for eliciting feedback structure (see e.g., Akkermans 1995, Vennix 1996, Andersen and Richardson 1997, Rouwette 2003, Luna Reyes et al. 2006). One particularly generative example is the so-called "ratio script" in which some need in the system is compared to some identified capacity or resource striving to meet the need (Richardson and Andersen 1995). Figure 5 shows an example from a group model building workshop focusing on care of dementia suffers in an area of the U.K. The *load on community care* is a comparison (ratio?) of the number of dementia clients in community care and the capacity of the community care services to deal with them. Participants in the workshop were asked what would happen if that load became too great. Three obvious feedback loops immediately result: increasing capacity, increasing transfers to palliative care, and decreasing the admission of dementia clients to community care (and there may be more, reaching further through the system). The group then talked in detail about what those aggregate feedback loops actually represented in the system.

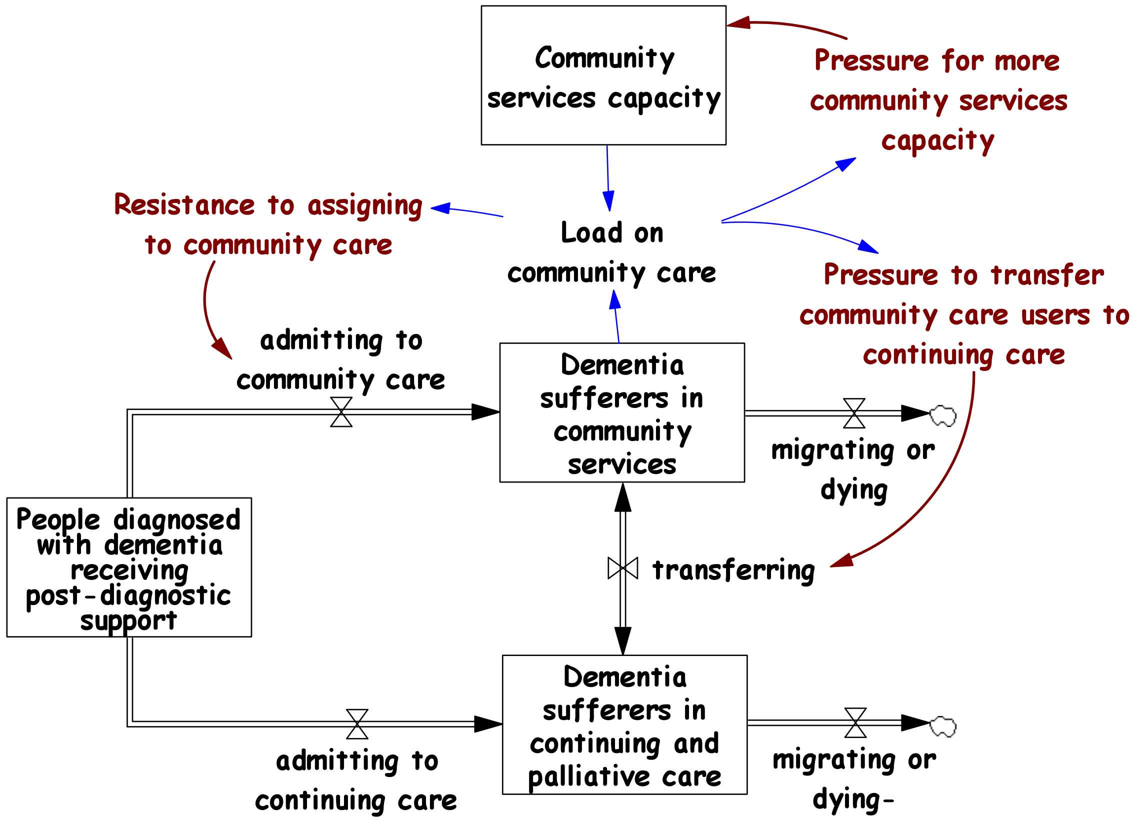


Figure 5: A portion of a stock-and-flow map illustrating a group model building script in which the Load on Community Care generates pressures that close feedback loops participants can articulate.

Model formulation, testing, and refinement: Ownership
Much of the system structure necessary to build a formal, quantified system dynamics model is developed in scripts such as these by the participants in group model building sessions, aided by the facilitator, the modeler/reflector, and the model building team. Some of the equations that would appear in a formal model are clear and explicit in the maps the group generates in this guided process. Most of the necessary data is elicited from the group (in other scripts not discussed here). But details always remain that are best handled by professional modelers offline.

At this point a central concern is group ownership of the model, its structure and behavior, and its implications for policy and decision making. The group knows the maps produced in the group model building sessions came from the group itself, with help from the modeling team. Now the group must come to own the formal model the modeling team produces from all that rich work.

A key in the process of extending group ownership from the maps they generated to the resulting formal model is *maintaining diagrammatic consistency*. The formal model must look like the maps drawn by the group. The most recognizable features, the stocks and flows, must appear in the formal model just as they do in the maps developed by the group. There will be more detail, more equations and some refinements necessary to support the thinking of the group and principles of good model building, but the formal model must look very familiar to the group. The process of transferring ownership to the formal model involves careful comparison the structure of the earlier maps with the structure of the formal model, with the facilitator gaining the group's advice and consent at every step.

The process of model testing, evaluation and refinement can also be carried out with very large groups communicating as a virtual group. See Vennix and Gubbels 1990 and Vennix 1996 for details and examples.

Simulation

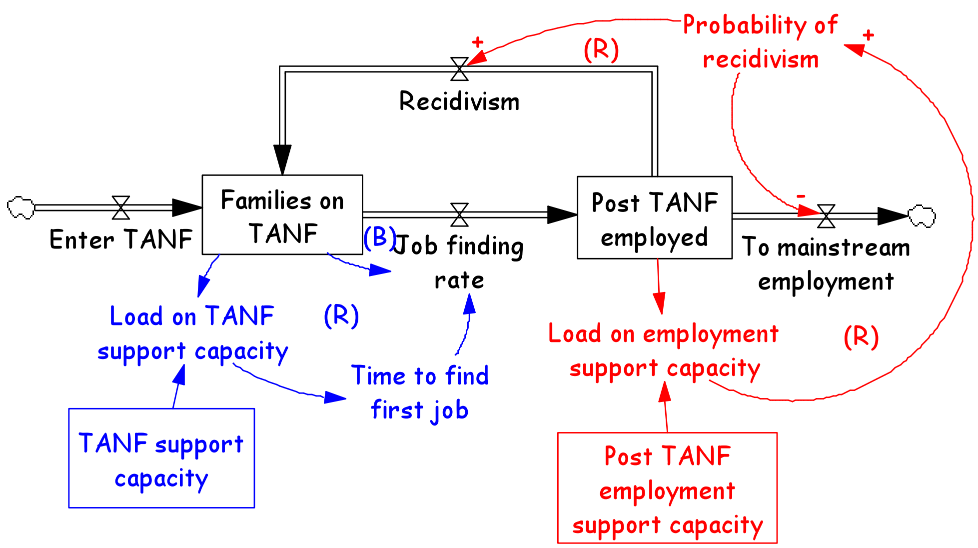
Ownership of the formal model also grows from simulation experiments participants propose. The robust, nonlinear structure of good system dynamics models means that they should behave plausibly under virtually any scenario one might propose (Forrester 1961). Group model building projects make use of that robustness by offering the formal model to the group to propose any set of parameter changes designed to test possible policies to implement, or to try to "break" the model. The richer the set of simulation experiments, the more the group can come to have confidence in the model it has developed (Forrester and Senge 1980, Richardson and Pugh 1981, Sterman 2000; see also Hujala and Kurttila in this volume).

It may take more than one group meeting, with intervening work by the group and the modeling team, but eventually the group will have explored the dynamic implications of their thinking and will have developed confidence in the policies and decisions they want to make to influence the future course of events (see generating new options in Ackermann and Eden, idea evaluation in Lewis, and convergence in Vogel and Coombes, all in this volume).

At this point the model developed by the group and the group model building team is likely to be large and detailed. Client understandings of the details of why the model behaves as it does come partly from their understandings of the formal model they helped to create, but also from their deep knowledge of the real system they are dealing with. A well developed formal model will do what it does for the same reasons the real world does what it would do under the same circumstances, so explanations grounded in real world understandings transfer to the model and vice versa.

Understanding surprising simulation results is often facilitated by building a small model to capture an insight embedded in the much larger complex system model. Figure 6 shows an example that emerged from group model building work on welfare reform (see Figure 2 and 3), which resulted in a structurally and dynamically complex model of more than 400 equations.

The large model tended to show that policies designed to improve welfare by accelerating the rate of job placement for Families on TANF (the major measured goal of then current national welfare reform policy) were less effective than those that focused on the "edges" of the system (such as policies aimed at stemming recidivism or moving former TANF clients from supported employment to mainstream employment) (Zagonel et al. 2004). Paradoxically, policies focused strictly on job finding tended to make the system worse in some respects. The tiny model shown in Figure 6, and the graphs over time it produces, reproduce this result in a surprising way, and provide the beginnings of an explanation for the behavior of the larger model.



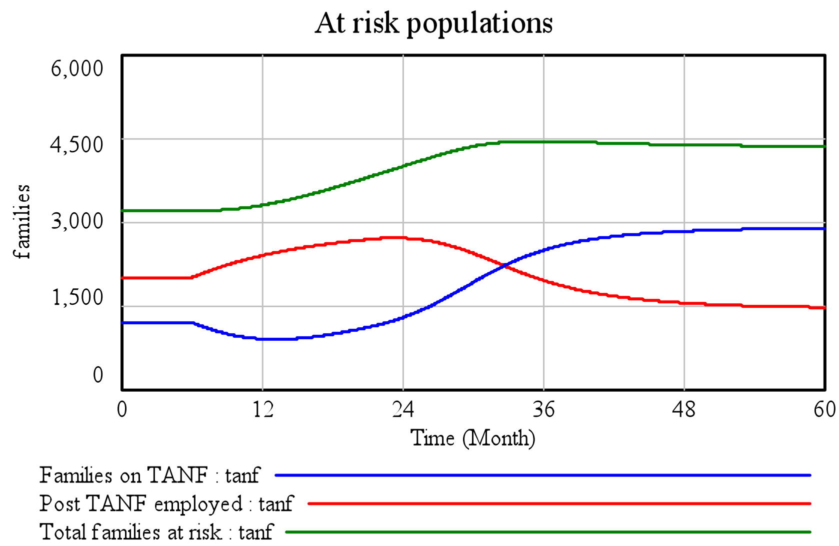


Figure 6: Structure and behavior of a surprising simulation insight

The tiny model shows that adding capacity upstream in the welfare system can speed the flow of families downstream, swamp downstream resources, and significantly increase recidivism, resulting eventually over time in *more* families on TANF and more total families at risk. Thus, a well-intentioned policy designed to improve the situation for families on temporary assistance shows the classic "better-before-worse" behavior in which the system overall is eventually made worse.

Discussion

Group model-building using system mapping and modeling is effective because it joins the minds of managers and policy makers in an emergent dialogue that relies on formal modeling to integrate data, other empirical insights, and mental models into strategy and policy processes (Rouwette 2003). Strategic policy making begins with the pre-existing mental models and policy stories that managers bring with them into the room. Strategic policy consensus and direction emerge from a process that combines social facilitation with technical modeling and analysis (Hujala and Kurttila in this volume). The method blends dialogue with data. It begins with an emergent discussion and ends with an analytic framework that moves from "what is" baseline knowledge to informed "what if" insights about future policy directions.

The key to the success of all these interventions is a formal computer simulation model that reflects a negotiated, consensual view of the "shared mental models" (Senge 1990) of the managers in the room (Ackermann and Eden in this volume). The final simulation models that emerge from this process are crossbreeds, sharing much in common with data-based social scientific research while at the same time being comparable to the rough-and-ready intuitive analyses emerging from backroom conversations.

In sum, we believe that a number of the process features related to building these models contribute to their appeal for front line managers:

- **Engagement**. Key managers are in the room as the model is evolving, and their own expertise and insights drive all aspect of the analysis.

- **Mental models**. The model building process uses the language and concepts that managers bring to the room with them, making explicit the assumptions and causal mental models managers use to make their decisions.

- **Complexity.** The resulting nonlinear simulation models lead to insights about how system structure influences system behavior, revealing understandable but initially counterintuitive tendencies like policy resistance or "worse before better" behavior.

- **Alignment**. The modeling process benefits from diverse, sometimes competing points of view as stakeholders have a chance to wrestle with causal assumptions in a group context. Often these discussions realign thinking and are among the most valuable portions of the overall group modeling effort.

- **Refutability**. The resulting formal model yields testable propositions, enabling managers to see how well their implicit theories match available data about overall system performance.

- **Empowerment**. Using the model managers can see how actions under their control can change the future of the system.

Group modeling merges managers' causal and structural thinking with the available data, drawing upon expert judgment to fill in the gaps concerning possible futures. The resulting simulation models provide powerful tools for strategy and policy development.

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