Using Qualitative Methods in the Conceptualization and Assessment of System Dynamics Models

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Abstract

The field of system dynamics depends heavily upon the use of quantitative data to generate feedback models. This paper argues that qualitative data and their analysis do have a central role to play at all levels of the modeling process. Although the classic literature on system dynamics strongly supports this argument, the protocols to incorporate this information during the modeling process are not detailed by the most influential authors. Data gathering techniques such as interviews and focus groups, and qualitative data analysis techniques such as discourse analysis, grounded theory methodology, and ethnographic decision models, could all have a strong, critical role in rigorous system dynamics efforts. The paper describes some of the main qualitative techniques developed by social scientists and explores their suitability in the different stages of the modeling process. Additionally, the authors argue that the techniques described in the paper could contribute to the understanding of the modeling process, facilitate communication among modelers and clients, and set up a methodological framework to promote constructive discussion around the merits of qualitative versus quantitative modeling.

Introduction

System dynamics is a powerful tool in the creation of feedback theories. Since its beginnings, the founders of the field have developed a series of guidelines for the model building process (Randers, 1980; Richardson & Pugh, 1981; Roberts et al., 1983; Wolstenholme, 1990; Sterman, 2000) and a series of tests to build confidence in the models created (Forrester & Senge, 1980; Sterman, 2000). As depicted by the classical literature, the development of system dynamics models is an iterative process. Each

iteration results in a better and more robust model. Although system dynamics models are mathematical representations of problems and policy alternatives, it is recognized that most of the information available to the modeler is not numerical in nature, but qualitative. While describing the information sources for the model building process, Forrester (1994) suggested that this qualitative data resides in the actors' heads (mental database), and in the form of written text (written database). Moreover, he recognized that the most important source, both in quantity and significance for the modeler, is the mental database (Figure 1).

> As suggested by the figure, the amount of available information declines, probably by many orders of magnitude, in going from mental to written information and again by another similar large factor in going from written to numerical information. Furthermore, the character of information content changes as one moves from mental to written to numerical information. In moving down the diagram, there is a progressively smaller proportion of information about structure and policies. (72)

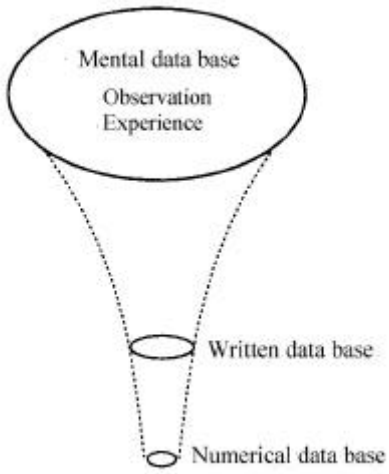

Figure 1. Mental database and decreasing content of written and numerical databases (Source: Forrester, 1994, 72).

Forrester identified qualitative data as a main source of information in the modeling process in several other papers (1975a, 1975b). Moreover, this perception is shared among mainstream authors in the field (Randers, 1980; Richardson & Pugh, 1981; Roberts et al., 1983; Wolstenholme, 1990; Sterman, 2000).

Although there is general agreement about the importance of qualitative data during the development of a system dynamics model, there is not a clear description about how or when to use it. The lack of an integrated set of procedures to obtain and analyze qualitative information creates, among several possible problems, a gap between the problem modeled and the model of the problem. That is to say, it is not always easy to understand the links between reality and the assumptions or formulations in the model. This gap is more noticeable especially when the model involves the use of soft variables, such as "customer satisfaction," "product quality," "pressure to decrease price," "engagement," or "perceived productivity." The quantification and formulation of this kind of variables have led some experts in the field to the conceptualization of a qualitative system dynamics practice (Wolstenholme, 1990). In some cases, the uncertainty associated with the quantification of qualitative variables has caused experts to believe that the results from ensuing simulations could be misleading, or at least, very fragile (Coyle, 2000).

On the other hand, social scientists have developed a series of research approaches oriented toward the collection and analysis of qualitative data. Counted among data-collecting methodologies are interviews, focus groups, Delphi studies, and participant-observer researcher. In the social science arena of data analysis are discourse analysis, grounded theory methodology, and ethnographic decision models (Bernard, 1999). These methodologies were created both to test theories as well as to build and generate new theories (Newman, 1998). These methodologies provide a powerful set of tools to promote formal inquiry and theory inference through the analysis of qualitative (mainly textual) data.

Purpose

This paper has two main purposes. First, after discussing some of the issues in system dynamics literature about qualitative data, it describes some of the main qualitative research methods, providing some illustrations of their use in the social sciences. Second, it explores and proposes some specific protocols for applying

qualitative research methods to build confidence in both the process of building and formulating a model, and in the model itself. We believe that the formal incorporation of these social sciences methods can both guide system dynamics practitioners during the modeling process, and provide a powerful way to uncover and contribute to the explanation of the modeling process.

System Dynamics and Qualitative Data

The question for system dynamics appears not to be whether to use qualitative data but a question of when to use it. What method should be used to gather data? From whom should they be gathered? At what stage in the modeling process might qualitative data be an appropriate, perhaps even a preferable information source? An interesting research question would be to ask how modelers make use of qualitative information, expert judgment, and group consensus.

When describing the modeling process, experts have organized the main modeler activities using different arrangements, varying from three to seven different stages (Table 1). On one extreme, Wolstenholme (1990) visualizes the process in three stages. On the other extreme, Richardson and Pugh (1981) conceptualize the modeling process as involving seven different steps. Randers (1980), Sterman (2000), and Roberts et al. (1983) have grouped the activities in four, five and six stages respectively.

Although the ways of grouping the activities vary in an important way among the different authors, the activities considered along the different stages remain fairly constant across them, allowing the building of a comparison like the one depicted in Table 1. For example, Randers' (1980) conceptualization stage or Wolstenholme's (1990) diagram construction and analysis consider activities that can be traced onto the problem definition and system conceptualization stages from Richardson and Pugh (1981) and Roberts et al. (1983). Sterman's (2000) dynamic hypothesis stage involves the same activities described in the system conceptualization stage of Richardson and Pugh (1981) and Roberts et al. (1983). Similarly, model behavior analysis and model

evaluation (Richardson & Pugh, 1981 and Roberts et al., 1983) include the same activities considered in the testing stage (Randers, 1980 and Sterman, 2000). Regardless of the differences in the ways of grouping the activities, all authors conceptualize them as parts of an iterative process in which the modeler will test a dynamic hypothesis that mirrors a piece of the real world, allowing the problem actors to learn about the situation, and design or redesign their guidance policies.

Table 1. The system dynamics modeling process across the classic literature

<table>
<tr><th>Randers (1980)</th><th>Richardson & Pugh (1981)</th><th>Roberts et al. (1983)</th><th>Wolstenholme (1990)</th><th>Sterman (2000)</th></tr>
<tr><td rowspan="2">Conceptualization</td><td>Problem Definition</td><td>Problem Definition</td><td rowspan="2">Diagram Construction and Analysis</td><td>Problem Articulation</td></tr>
<tr><td>System Conceptualization</td><td>System Conceptualization</td><td>Dynamic Hypothesis</td></tr>
<tr><td>Formulation</td><td>Model Formulation</td><td>Model Representation</td><td rowspan="3">Simulation Phase (stage 1)</td><td>Formulation</td></tr>
<tr><td rowspan="2">Testing</td><td>Analysis of Model Behavior</td><td rowspan="2">Model Behavior</td><td rowspan="2">Testing</td></tr>
<tr><td>Model Evaluation</td><td>Model Evaluation</td></tr>
<tr><td rowspan="2">Implementation</td><td>Policy Analysis</td><td rowspan="2">Policy Analysis and Model Use</td><td rowspan="2">Simulation Phase (stage 2)</td><td rowspan="2">Policy Formulation and Evaluation</td></tr>
<tr><td>Model Use</td></tr>
</table>

The conceptualization stage (problem definition and system conceptualization), in which the modeler focuses on a part of the real world—a "mental model," including "a verbal description of the feedback loops that are assumed to have caused the reference mode" (285), would seem to be a highly qualitative point in the modeling process. For example, Richardson and Pugh (1981) recognize that the behavior over time (reference mode) of several key variables could reside in some of the actors' mental databases.

> It does not require, as some might expect, that the modeler have access to explicit numerical data …. While data is very helpful, one is often faced with a dynamic problem in which a key variable is not traditionally quantified or tabulated. It is even more likely, however, that the modeler or the client knows the dynamic behavior of interest without referring to data (19).

Sterman (2000) also recognizes the need to access the client mental database, and the written database during the problem definition process. For example, he stresses the

use of both databases during the development of the initial characterization of the problem through the interaction of the modeler and the client.

> Usually the modeler develops the initial characterization of the problem through discussion with the client team, supplemented by archival research, data collection, interviews, and direct observation or participation (90).

Coyle stated that qualitative data had their place in the pre modeling stage, stopping short of the actual formulation stage at the point of "system description" (2000, 225, 233), going on to emphasize that "qualitative modelling can be useful in its own right and that quantification may be unwise if it is pushed beyond reasonable limits" (227). Wolstenholme (1990) shared this point of view by considering that the phase of diagram construction and analysis could be considered itself as a qualitative branch of system dynamics. There is room here for deciding how qualitative data collection and analysis would be a beneficial part of the formal modeling process.

The formulation stage, positing a detailed structure and selecting the parameter values, also can contain elements of qualitative data. In regards to the formulation of qualitative concepts, Richardson and Pugh suggest, "the modeler may wish to represent such a concept explicitly. To do so requires the invention of units and a measurement scale, and consistent treatment throughout the model" (1981, 160). The importance of the inclusion of this qualitative constructs in models is stressed by Sterman. "Omitting structures or variables known to be important because numerical data are unavailable is actually less scientific and less accurate than using your best judgment to estimate their values" (2000, 854). Nonetheless, this is the area in which system dynamics practitioners have questioned the use of qualitative variables. Nuthmann, for one, stated that there is a basic problem with modeling social judgment. He asked, "Can psychological variables be treated with the same mathematics as physical variables?" (1994, 1).

Richardson, in fact, devoted a section of his article on future problems in the field to the issue of qualitative mapping and formal modeling (1996, 148-150), using the term "qualitative systems thinking" (149). He presented a balanced set of arguments, looking at the positive and negative discussion and effects of using qualitative data approaches.

In the final analysis, however, Richardson provides a series of questions—future research issues, rather than a set of guidelines for the would-be systems modeler.

> What are the system conditions that suggest that a qualitative mapping approach can produce reliable inferences? What are the conditions under which a qualitative mapping may yield unreliable or false inferences? Are word-and-arrow maps showing explicit stocks and flows more reliable, although less accessible, for various practitioners or audiences? What are the implications of packaging systems insights in systems archetypes? Do archetypes limit or expand people's capabilities to reason in circular causal settings? Finally, is it possible to state conditions which require quantitative modeling? (150)

These questions appear to get at the heart of the matter for system dynamics. It is appropriate to use qualitative data for some aspects of the modeling process, but the formalization stage seems to be the area where there is greatest concern about its applicability.

The testing stage (model behavior and model evaluation). Forrester and Senge (1980) have gone into great detail in describing 17 tests at this stage of formal model development. For example, in the structure-verification test

> the model must not contradict knowledge about the structure of the real system. Structure verification may include review of model assumptions by persons highly knowledgeable about corresponding parts of the real system. Structure verification may also involve comparing model assumptions to description of decision making and organizational relationships found in relevant literature. In most instances, the structure verification test is first conducted on the basis of the model builder's personal knowledge and is then extend to include criticisms by others with direct experience from the real system" (416).

This particular test is not the only one in which Forrester and Senge make implicit or explicit references to qualitative data, but it serves here as an example of the sort of face validity issues that can be addressed at the testing phase.

Randers notably made a very strong statement about the use of qualitative data in the testing process.

> In judging how well a model meets the listed criteria, the modeler should not restrict himself to the small fraction of knowledge available in numerical form fit for statistical analysis. Most human knowledge takes a descriptive nonquantitative form, and is contained in the experience of those familiar with the

> system, in documentation of current conditions, in descriptions of historical performance, and in artifacts of the system. Model testing should draw upon all sources of available knowledge (1980, 295).

Randers described this testing process as asking if "the basic mechanisms actually create the reference mode" and if "the assumed relationships are reasonable" (285). These are areas that could profit from quantitative as well as qualitative knowledge of experts.

Besides the traditional testing techniques of a model, Sterman points out the "practical and political issues of modeling. There are no value-free theories and no value-free models." As a part of the testing process, "Model users must ask about the modelers' biases (and their own). How do these biases, especially those we were not aware of, color the assumptions, methods and results?" (2000, 851).

The implementation stage (policy analysis and use). Finally, the last step of the modeling process is implementation. Here the model or modeling team needs to transfer study insights to the users of the model. This is a process of describing the model to individuals who are not necessarily modelers themselves. It is necessarily a qualitative process, requiring discussion more than examination of parameter values and equation formulation. Furthermore, the interpretation and use of simulation results by policy makers pose several important challenges associated with our understanding of the many types of judgments needed during the model building process, and the judgments needed to assess and use the output of the model (Andersen & Rohrbaugh, 1992).

Thus, upon looking at Coyle, Richardson and Pugh, Andersen, Roberts et al., Randers, Wolstenshome, Sterman, and Forrester and Senge, it seems apparent that the question is not *if* to use qualitative data, but *when* to use it appropriately.[1] To that end, the following sections review the ways that social scientists and system dynamics practitioners could collect and analyze qualitative data to the benefit of their models and clients.

Models that Use Qualitative Information

Examples of models that use qualitative variables are profuse. Forrester's classic models considered some of these qualitative concepts. Quality of life in the world model, quality and attitude toward quality in the corporate growth model, or awareness of advertising in the advertising models constitute some of these examples.

However, the ways in which the qualitative data obtained from the mental and written databases are incorporated into model formulations is not always evident. Chapter 14 in Sterman (2000) presented an interesting way to use qualitative data in the formulation of nonlinear functions based both on observed qualitative data and interactivity with clients or client groups. As an illustration of the former case, Sterman presented the way in which Oliva (1996) "tested his model through a detailed field study of retail lending operations in a major UK bank. Through interviews, archival data collection, and participant observation, he gathered extensive data on the operations of the bank's major retail lending center" (569).

In a different example (chapter 13), Sterman described how Jones and Repenning (1997) formulated a decision policy as a nonlinear weighted average on the basis of their fieldwork at a major motorcycle-producing facility. The formulation is grounded to the results of interviews conducted with engineers in the organization, and illustrated with quotations from those interviews.

Perhaps the richest set of examples of modeling tools that deal with qualitative and judgmental data, and their incorporation in model formulations reside in the group model building literature (Reagan-Cirincione et al., 1991; Morecroft & Sterman, 1994; Vennix et al., 1992; Vennix, 1996; Vennix et al., 1997).

Social Science Research and Qualitative Data Collection

The following section reviews the basic categories of qualitative data collection in the social sciences. In particular, it looks at interviews, focus groups, Delphi groups,

observation, participant observation, and experimental approaches that lead to qualitative data. Content analysis presupposes that, in some instances, data already exist in the form of minutes, notes, newspaper news or memoranda. Content analysis appears in the data analysis section of this paper.

A suggested in Figure 2, the authors conceptualize the data collection strategies used by the social sciences as a set of "retrieval" tools whose aim is to "query" the mental database, storing the results in the written database. The modeler interacts with individual actors, as in the case of the interviews and oral history or with actor teams or groups, as in the case of observation, focus and Delphi groups.

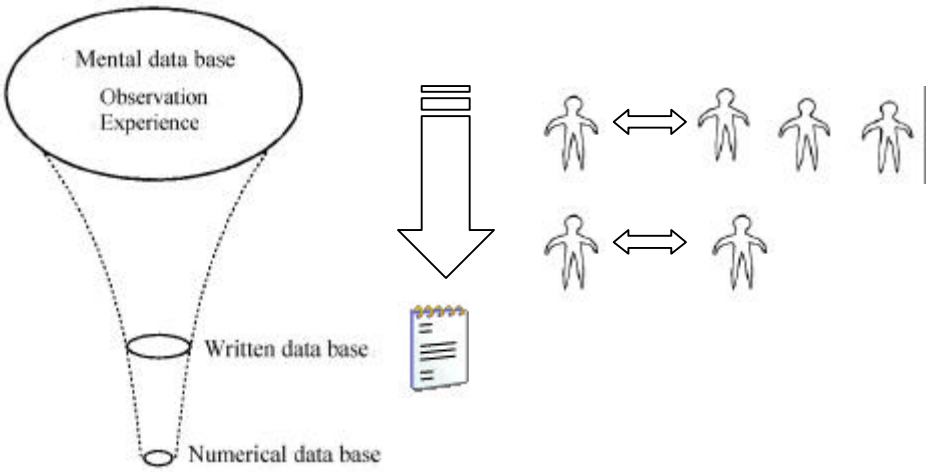

Figure 2. The use of qualitative data collection as a tool to "retrieve" the mental database into the written database.

Interviews. Interview research is a mainstay of social science qualitative data collection. The interview, either in person or over the telephone, allows for interaction between the researcher and the respondent. This interaction can be structured, driven by a carefully worded interview script that channels the topics of the interview. It can also be highly unstructured, allowing the respondent to tell stories, give examples, and often unearth issues that the interviewer finds novel or counterintuitive. Interviews allow for clarification of definitions, elaboration on topics, and collection of the respondent's own words or usage in a way not supported by questionnaires or surveys. The researcher

often asks permission to record the interview, and to quote the respondent anonymously in research reports. The strength of interviews is in the qualitative data that the researcher collects. The main role of the interviewer is to guide the dialog, clearing up any confusion before the interview is over, and remaining neutral so that the respondent's remarks are not biased by the behavior of the researcher (McCracken, 1988). After conducting a number of interviews, the researcher will analyze the data, looking for patterns, definitions, stories, and lessons that cut across the material elicited from all respondents.

Oral history. Thought of as a mainstay of historical research, oral history has some critical differences from interviews. Oral histories are interviews of individuals in which the researcher records the words of the respondent, guiding the direction of the discussion and looking for stories rich in detail and explanation. Upon returning to the office, the researcher transcribes the results of the interview, editing out repetitions and cleaning up the record in a print format. After this editing the researcher sends the oral history back to the individual to make sure that it is an accurate representation of the respondent's thoughts and stories. Oral histories become part of a public record and often part of volumes devoted to a particular point in history. They are rarely anonymous and often the end product of the researcher's work. (See the Department of History, University at Albany website, Talking History, Aural History Productions http://talkinghistory.org/ which includes oral history materials.)

Focus groups. While researchers conduct interviews and oral histories with one person at a time, the next several data collection techniques collect information from groups of respondents who interact with each other in the research environment. Focus groups, including group model building exercises, rely heavily upon respondents building off of each other's experiences and remarks. Eight to twelve individuals brought together for an hour are usually ideal. The role of the researcher is again that of guide, keeping the group focused and making sure that all respondents are heard while in particular guarding against one or two individuals taking the floor. Often the researcher is part of a team, with roles assigned for recording, leading, and analyzing the data that come out of the

focus group. The team will often meet after dismissing the focus group members, taking the time to analyze what has occurred, and what lessons or new concepts emerged from the data collection (Morgan, 1997).

Delphi groups. Delphi groups are an extension of focus groups, although they can also be used with survey or interview analysis. The researcher asks individuals, in whatever group format, to create a list of critical issues (e.g., policies, competencies, or causal factors). The researcher's initial job is to collect and collate this list (Babbie, 1992, p. 496, suggests that Delphi method requires anonymous input so that individuals of different ranks in an organization are on equal footing). Rohrbaugh has developed techniques to do this data collection asynchronously through listservs and online discussion lists (See Vennix et al., 1992 for a discussion of group model building techniques, and Martinez & Richardson, 2001 for an example of using online discussion lists in identifying the best practices in system dynamics). After collation, the researcher sends the materials back to the respondents, individually or in a second focus group, asking the respondents to rank order the list according to some standard set by the researcher. This could be most to least important, or, for example, into larger groups of "critical," "valuable," "nice but not necessary," or "unnecessary." Although full consensus of the group is not always possible, the researcher will arrive at a good understanding of the critical issues under discussion, both where there is consensus, and where there is disagreement among group members.

Observation. Observation is "fly on the wall" research. If done carefully, and ethically, if can produce a wealth of information about social structures, culture, process, and human interaction (Brewer & Hunter, 1989). Nonetheless, it is difficult for a researcher to watch and collected data for a long period of time without in some way affecting the environment he is watching. There is also the ethical issue of whether or not the researcher needs to announce his presence in the social situation. Sometimes it is enough to obtain the permission of a supervisor or upper level staff member, if the research is unobtrusive, and the means to an important end.

Participant observation. In order to avoid the ethical issues of strict observational data collection, participant-observer research assumes that the researcher will interact in a study situation. The researcher needs to be aware that his behavior could affect the results of the study. For both observation and participant observation, the standard data collection methods are notebook diaries and collections of documents, if any, produced by the group being studied. This method of data collection can be paired with interview collection in order to unearth individual motivations or behaviors that are not immediately obvious in a group setting. (Lofland & Lofland, 1984. See Brewer & Hunter, 1989, pp. 44ff. for a discussion of participant observation in particular, and field work in general.)

Experimental approaches. Data collection through experiments can take a wide variety of formats (Babbie, 1992, Chapter 9). For the purposes of this paper, we are particularly focused on data collection that will produce qualitative results. These data could be concerned with willingness scales before or after an intervention, with quality, satisfaction, or perceived productivity before and after training or instruction.

Qualitative Data Analysis

As described in the previous section, most of the qualitative data collection techniques are devoted to the elicitation of knowledge about a particular problem, enriching the written database to be used in the modeling process. Although some of these techniques involve some data processing, there is still the problem of how to translate the texts obtained through this process into a system dynamics model (Figure 3). The analysis techniques presented in this section constitute alternatives developed by social scientists that can help the modeler to ground the assumptions used in the model-building process with the textual information available to her, and to build a robust documentation of the model. Additionally, quotations from the texts can help the modeler to build "rich stories" containing the main insights from the process in order to communicate model results or to promote constructive dialog among the problem actors.

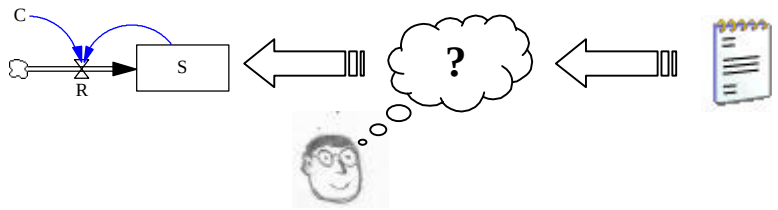

Figure 3. A pictorial representation of the gap in the incorporation of textual information into system dynamics models.

Hermeneutics. Derived from biblical exegesis, social scientists have applied the hermeneutic method to any kind of text, including conversations, images or videotapes. The main purpose of hermeneutic analysis is to find meanings and how they are connected to the expression of culture. Social scientists use this method to identify contextual explanations (in the same text or in the surrounding culture) of apparent contradictions found in textual data (Bernard, 1999). The spirit of hermeneutics is in many senses the same spirit discussed by Forrester (1975a) while he describes the use of observations and conversations with problem actors, "this material is sifted and compared. Cross-verification and contradictions are sought. Similarities begin to emerge between the new information and previous systems which are already understood." (161).

Discourse Analysis is a qualitative method used to study interactions among people in the context where they occur naturally. In this way, discourse analysis can be used any time that the modeler selects direct observation as a method to collect data. Once the observations are transcribed, the researcher selects the pieces of text related to the problem under study. In a similar way to other interpretive analysis techniques, the researcher transcribes chunks of text, followed by a commentary that extracts the wisdom and understanding that the specific passage adds to the research effort. Bernard (1999) describes how Waitzkin et al. (1994) used this method to understand how topics such as aging, work, gender roles and socioemotional problems are treated in encounters of older patients and primary care internists (442).

Grounded theory. Maybe one of the most interesting textual techniques for the modeler, grounded theory consists in a set of techniques to identify themes or concepts across

texts, and link them to generate meaningful theories. The texts used in grounded theory range from promotional ads to transcriptions of interviews, memoranda, meeting minutes or any kind of textual data. In one of the alternatives in the application of the technique, the researcher develops a set of categories or concepts that emerge across the texts. In the particular case of system dynamics, these themes can be variables, dynamic behaviors or policy-related topics. Every theme is "grounded" in a set of quotations or exemplars across the database of texts. The data associated with the categories identified are pulled out from the database in order to be compared and analyzed, in order to link them and build formal theories. The theories created must be iteratively contrasted and compared with the data, especially against negative or contradictory cases. The result of this kind of research is a model of a theory that is usually presented illustrated by exemplars from the text. Memoing is a widely used technique in the theory building process. The technique consists in writing down all the thoughts that emerge during the coding process, similar to the notes taken during an interview or a participant observation process. These notes are the basis of the model developed during the process (Strauss & Corbin, 1990). Although the identification of themes could be done with printouts of the texts and color markers, there exists specialized software to help the researcher during the process (NUD*IST and ATLAS/ti are two of the most widely used software tools).

Content analysis. Content analysis is a powerful technique that can be used in the identification of reference modes and parameter estimation from textual data. Content analysis is a deductive coding technique, in the sense that the researcher starts by defining the set of codes to be used in the process. Once the codes are defined, they are applied systematically to a set of texts. Researchers who use this technique are concerned about the reliability of the coding process, and have developed some statistical measures such as the Cohen's Kappa to test the level of agreement between coders. Codes obtained from texts are organized in a matrix of codes and texts according to the unit of analysis selected for the study (for example, a paragraph or a memo). The matrix can be analyzed using almost with any statistical method. As any quantitative approach, sample selection becomes an issue any time that the modeler is interested in statistical inference (Weber, 1990).

On the other hand, content analysis can be combined with grounded theory as a confirmatory analysis during the testing stage of the model building process.

Ethnographic decision models. One of the main challenges in the model building process is to understand the decision processes or policies that govern the rates of the system. Ethnographic decision models are qualitative analyses oriented to understand why a person makes a decision in a determined circumstance. The researcher interviews are oriented to a specific decision or policy in the system, for example why people decide to engage in an information technology initiative. After interviewing several actors, the modeler can build a decision tree (or dendrogram) describing the decision alternatives and processes. Although an ethnographic decision model can grow indefinitely, most social scientists test the predictive ability of the model, looking to account for at least 80% of the decisions with the smallest set of rules (Bernard, 1999).

The "bag" of qualitative analysis tools includes other methods like narrative analysis, componential analysis, analytic induction or taxonomic analysis. However, these methods are not described in this paper because of their limited applicability to the modeling process. However, they are potentially useful in the process of getting involved on a particular organizational culture. The interested reader can find a brief description of these methods on Bernard (1999).

Proposed Protocols and Uses of Qualitative Research Methods in System Dynamics

Since this paper presents what can be at best a work in progress, the result of our initial exploration could be conceptually pictured as a matrix in which we will map specific applications of qualitative data collection and analysis to the steps in model building and the tests for building confidence in system dynamics models (Table 2).

Table 2. Qualitative methods and their use during the modeling process

Steps in the modeling process		Qualitative methods potentially useful
Conceptualization	Problem Definition	Techniques that can be used for problem identification and elaboration of a dynamic hypothesis • Interviews • Oral history • Focus groups • Observation • Hermeneutics • Discourse analysis • Content analysis
	System Conceptualization	
Formulation	Model Formulation	• Interviews (elicitating policies and parameters with individuals) • Focus and Delphi groups (elicitating policies and estimating paramenters with groups) • Participant observation (observing policies and registering data to estimate parameters • Grounded theory (Creating model structure and documentation) • Content analysis (Estimating parameters) • Ethnographic decision models (Identifying policies)
Testing	Analysis of Model Behavior	Tools to obtain expert judgment about model structure and behavior • Interviews • Focus groups • Delphi groups • Experimental approaches • Grounded theory
	Model Evaluation	
Implementation	Policy Analysis	Tools to create insightful stories to communicate model results • Oral history • Grounded theory Tools to generate discussion among problem actors • Delphi groups • Focus groups Tools to test policies • Experimental approaches
	Model Use	

The literature described in this paper has already provided instances of the use of qualitative methodologies. An exploration of system dynamics articles will undoubtedly

lead to current practice in the field. Finally, live forums such as system dynamics conferences will allow for discussion and greater insights into how qualitative data could be effectively and validly used to create better models.

Future Research

The preliminary methodological framework described in this paper suggests at least three different, but related research threads.

As suggested in the previous section, an immediate research project could be oriented toward the analysis of a sample of papers involving system dynamics modeling in order to describe the current use of techniques by practitioners in different areas. This kind of meta-analysis would reveal the current and best practices in the use of textual data in the modeling process.

The second thread is related with the development and testing of formal protocols involving qualitative social research techniques to support the modeling process. The reflective application of these protocols in one or more case studies would lead to specific recommendations to enrich system dynamics practice.

Finally, experiments involving the use of some of these techniques with textual data across a variety of system dynamics modelers would help to look for similarities and differences of interpretation among them. The comparison of approaches followed by experienced modelers could potentially capture an understanding of the mental processes involved in the modeling process. This design is inspired by a discussion on the system dynamics list about how to build software to extract models from text (Richardson, 2002). The use of some of the tools described in this paper will help to make more transparent modeling processes by helping modelers to ground their feedback theories to the information gathered through the textual data presented in them. Making a more transparent process could promote constructive dialog among modelers with regards to

points of disagreement such as the quantification of soft variables and the suitability of the use of qualitative mapping versus simulation.

Note

[1] Forrester and Senge (1980, p. 218) unwittingly highlight a critical issue for this paper in their use of the passive voice. With such phrases as "…observed in a real system," "…are observed in the real economy," and "…have been observed" they highlight the need for specific research into who does the observing, who is the expert, and how this information is elicited from the observer.

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