Annotated Bibliography

Modeling Psycho-Social Dynamics

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Contents

A - Overview

The references in this annotated bibliography are the result of a literature review. We group the references in categories relevant for the workshop. Although some references could fall into multiple ones, each appears in one category.

B - Key References

We find the following selected references to be particular useful in understanding the use of psychological and sociological variables in system dynamics models. Most are easily accessible to society members. Read these first.

1. **Batchelder, A. W. and D. Lounsbury (2015). Simulating Syndemic Risk: Using System Dynamics Modeling to Understand Psycho-Social Challenges Facing Women Living with and At-Risk for HIV (in press). Handbook of Applied Systems Science. Z. P. Neal. New York, Routledge.**

   Best practices in system dynamics model development call for application of a multi-stepped, iterative procedure involving problem identification, system conceptualization, model formulation, model simulation, and model evaluation. This procedure unfolds differently for each model-building project, with some steps requiring more investment than others depending on the problem of focus, the availability of supportive data and information, and the targeted audience or 'users' of the model. In this chapter we describe how we built and validated a system dynamics model of syndemic risk among women living with and at-risk for HIV in a low-resource, urban environment. We explain how we applied three sources of evidence to the model-building process, underscoring key decision-points we encountered along the way. We use the model to illustrate divergent patterns of syndemic risk using simulated profiles. These profiles generated important insights and implications for designing clinical, community, and public health interventions for this vulnerable population, including providing a deeper understanding of the dynamics of syndemic risk. Specifically, our model emphasized the need for individualized multi-aimed psychosocial interventions, prioritizing safety planning and substance abuse treatment, while addressing unmet psychosocial challenges and maximizing resilience. Finally, we reflect on how every system dynamics model-building project is informed by a process of careful deliberation by the modelers and their participating stakeholders, with the desired outcome of a deeper understanding of the problem and ways to effectively address it.

2. **Doyle, J., K. Saeed and J. Skorinko (2009). Personal versus Situational Dynamics: Implications of Barry Richmond's Models of Classic Experiments in Social Psychology Proceedings of the 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, System Dynamics Society.**

   There is a long-standing debate in the field of social psychology as to which is the primary determinant of behavior, the situation or system in which people act or the personalities of the role players. Psychologists have long studied this problem with controlled experiments on human subjects, and have now come to a general resolution of the debate. However, the field of psychology still lacks an efficient method for teasing apart the relative contributions of personal and situational variables in applied domains. An alternative to human subjects experiments is to employ system dynamics models of role systems, as was demonstrated by Barry Richmond when he attempted to model two classic experiments in social psychology: the Milgram and Stanford Prison experiments. In this paper, we replicate and discuss Barry Richmond's models to present them to a new audience. In addition, we use the models as a springboard to explore the relationship between social psychology and system dynamics and the potential for useful collaboration between the two fields.

3. **Hayward, J., R. A. Jeffs, L. Howells and K. S. Evans (2014). Model Building with Soft Variables: A Case Study on Riots. Proceedings of the 32th International Conference of the System Dynamics Society. Delft, System Dynamics Society.**

   A methodology for incorporating soft variables into system dynamics models is proposed. Building on previous research, the methodology uses a systematic assessment to identify soft variables, and concepts from software engineering to implement them. Data hiding is used to separate the units and scale of a soft variable from its effect on other model elements. By encapsulating the soft variable in a module with well<defined inputs and outputs, it can be used from a knowledge of its parameters alone, and not its internal construction, that is it is referentially transparent. The methodology is applied to an existing population model on riot growth, extending it to include soft variables whose scales are limited. The effects of the different soft variables on the populations are combined together using cognitive algebra. The extended model is compared to historical data and found to give a richer

explanation of the riot dynamics than the original model. The paper is exploratory and intended to inspire further research.

4. **Gambardella, P. J., Polk, D. E., Lounsbury, D. W., & Levine, R. L. (2017). A co-flow structure for goal-directed internal change. System Dynamics Review, 33(1), 34-58.**

   We describe a co-flow structure that models internal, goal-directed changes to an attribute (e.g., employee loyalty) of fundamental material (e.g., employees). This co-flow accommodates problems not adequately modeled with an existing, generic structure. Our structure builds on the co-flow proposed by Hines, which uses an information delay to model external change to an attribute. We use a first-order information delay to model both external changes to the attribute from the material stock and internal changes from an internal goal for the attribute. We provide an exact, dynamic solution for this co-flow enabling us to precisely describe its equilibrium and non-equilibrium behavior. Several examples are provided and discussed, including a situation where a management program is designed to increase average employee loyalty. In addition, we review applications of traditional and Hines co-flow structures to provide background and to describe our evolutionary path towards design of the new co-flow.

5. **Hirsch, G. B., R. Levine and R. L. Miller (2007). "Using system dynamics modeling to understand the impact of social change initiatives." American Journal of Community Psychology 39(3-4): 239-253.**

   Community psychologists have a long history of interest in understanding social systems and how to bring about enduring positive change in these systems. However, the methods that community psychologists use to anticipate and evaluate the changes that result from system change efforts are less well developed. In the current paper, we introduce readers to system dynamics modeling, an action research approach to studying complex systems and the consequences of system change. We illustrate this approach by describing a system dynamics model of educational reform. We provide readers with an introduction to system dynamics modeling, as well as describe the strengths and limitations of the approach for application to community psychology.

6. **Hopkins, P. L. (1992). "Simulating Hamlet in the Classroom." System Dynamics Review 8(1): 91-100.**

   During a STELLA workshop sponsored by the Catalina Foothills School District in Tucson, Arizona, a group of teachers working with Steve Peterson developed a STELLA model that analyzes the motivation of Shakespeare's Hamlet to avenge the death of his father.' Plot events lead Hamlet to believe that his uncle, Claudius, has become king by murdering Hamlet's father and marrying his mother, thereby depriving Hamlet of family and throne. The model is designed to expose the effect that plot events have on Hamlet's willingness to kill Claudius. It permits the examination of the impact of each event as it occurs and as Hamlet continues to contemplate the situation. This note describes the model and its use in high school classes and suggests further directions for simulation to support instruction in literature.

7. **Jacobsen, C. and R. Bronson (1987). "Defining sociological concepts as variables for system dynamics modeling." System Dynamics Review 3(1): 1-7.**

   Social structures and processes are generally described and analyzed in terms of verbal concepts. To simulate such phenomena in system dynamics models, the concepts must first be transformed into quantifiable variables. Useful intermediate steps in this process are specific but transferable nominal definitions, based on meaning analysis of the concepts. For modeling purposes, a well-defined variable should be reliable and realistic, and have face validity. The relevance and importance of these criteria, long recognized in sociological research, are documented and illustrated with examples drawn from recently published work on a model of normative systems in industrialized societies.

8. **Jacobsen, C. and R. Bronson (1997). Computer Simulated Tests of Social Theory: Lessons from 15 Years' Experience. Simulating Social Phenomena. R. Conte, R. Hegselmann and P. Terna. Berlin ; New York, Springer.**

9. **Jacobsen, C. and H. Law-Yone (1983). Sociology and System Dynamics. Proceedings of the 1983 International System Dynamics Conference. Chestnut Hill, MA. 2: 766-777.**

   The most basic problem of sociology as an empirical science is the difficulty of replicating studies within reasonable time limits and in genuinely comparable conditions. Sociologists aspire to make correct predictions based on verifiable statements about causal relationships, but cannot, the nature of macro-social phenomena precluding experimental designs with adequate controls. System Dynamics promises a way out of this dilemma. Four things need to be done. (1) Formulate the sociological theory as a causal loop diagram, making all causal reasoning explicit. (2) State what variables are involved in the functioning of the system. Calibrate the model until it is internally consistent. (3) Refine and adjust the constants until the model can reproduce a known time-series of relevant data. Repeat this on number of data-sets. (4) Systematically vary each constant in turn while controlling for the others. This is, in fact, the quasi-experimental procedure for testing the conditions under which the theory will stand or fall, and why. An illustrative example of the proposed strategy is presented, with encouraging results.

10. **Levine, R. L. (1983). The Paradigms of Psychology and System Dynamics. Proceeedings of the 1983 International System Dynamics Conference. Chestnut Hill, MA: 325-338.**

    This paper compares and contrasts the philosophical and methodological paradigms used by psychologists and system dynamicists. Currently, psychologists collect huge amounts of data, use open loop methods of experimental design, and think that classical statistical models, such as analysis of variance and regression analysis, provide the most useful methods for studying social phenomena. Behavioral approaches to psychology differ sharply with the system dynamicists concerning the relative importance of external vs. internal sources of influence on behavior. The behaviorists focus on controlling the external environment, even denying the existence or importance of internal states. The problems of using external control are illustrate by contrasting two simple attitude change models; one which modifies attitudes solely through outside influences and another which makes the change in attitudes a function of the state variables. System dynamicists attempt to understand the dynamics of social processes through the study and analysis of dynamic loop structure. These techniques would be extremely useful for those psychologists using correlational analysis and causal modeling methods, where the implications of dynamic structure are not always fully understood.

11. **Levine, R. L. (2000). System Dynamics Applied To Psychological And Social Problems. Proceedings of the 18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 126.**

    Originally, system dynamics dealt with problems in manufacturing, management, resource use, and in urban problems. With notable exceptions, there are very few applications of system dynamics to psychological problems, per se, or the use of psychological variables in models which focus on management problems. Some psychologists have influenced the system dynamics, but their contribution has focused upon studying the process of systems thinking, cognitive maps, and the limitations of people dealing with feedback processes. Unfortunately, one rarely finds psychologists who are interested in and are competent in system dynamics. This paper suggests ways to include the use of psychological and social variables in specifying the structure of one's model. It examines the underlying assumptions of system dynamics, such as the use of the bathtub metaphor. For modeling problems of attitudes, it is argued that the bathtub metaphor, which assumes potential conservation of material, may not be appropriate. On the other hand, emotional variables, such as anger, do display properties that are analogous to a draining process. I also suggest overt behavior (such as fighting) should be represented differently from inner psychological states. Thus, you can be angry without showing it. Also, I note the potential incompatibility between the trajectories of the SD model and the empirical time series, if the data (such as self-esteem level or level of depression) were measured on an interval scale. Finally, the paper will integrate personality and individual difference psychology into a system dynamics framework.

12. **Levine, R. L. (2003). Models of Attitude and Belief Change from the Perspective of System Dynamics. <u>Proceedings of the 21st International Conference of the System Dynamics Society</u>. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.**

    This paper describes models of attitude change from several theoretical perspectives. Current research in persuasion, argumentation, and attitude change emphasize cognitive, emotional, or behavioral factors, which determine how people change their attitudes. The paper reviews the pioneer mathematical work of John E. Hunter and his colleagues and then assesses his models for its loop structural characteristics. Simulation output as well as the structural characteristics of these models indicates that behavioral approaches, such as imitation and conditioning, are problematic in controlling attitudes. Cognitive dissonance and information processing models appear to be more effective in controlling attitudes. Finally, the paper concludes with an embellishment of these models to show how cognitive searching processes can give time to think about counterarguments and thus be used as a coping mechanism to resist persuasive messages.

Notes: The file is named "177.pdf" in the conference proceedings.

13. **Levine, R. L. and J. K. Doyle (2002). Modeling Generic Structures and Patterns in Social Psychology. Proceedings of the 20th International Conference of the System Dynamics Society. Palermo, Italy, The System Dynamics Society.**

    System dynamics has been enriched from many disciplines. This paper describes our effort to discover generic structures in the field of social psychology. Social psychologists have accumulated a body of empirical studies and theories that are reproducible and apply to a variety of social situations. Our task was to start modeling a few pivotal dynamic effects found in the social psychology literature. We present models of the dynamics of an important social process, namely, the "self-fulfilling prophecy." The structure underlying this process is associated with the drifting goals archetype. Next we model the dynamic effects of contact between groups. Finally, we develop a set of models that represent a key process in social psychology, namely the "fundamental attribution error." We hope that the approach to modeling generic structures in social psychology will enrich future system dynamics models by including relevant biases and distortions in perception discovered by social psychologists.

14. **Levine, R. L. and W. A. Lodwick (1992). Psychological Scaling and Filtering of Errors in Empirical Systems. Analysis Of Dynamic Psychological Systems: Methods and Applications. R. L. Levine and H. E. Fitzgerald. New York, Plenum Press. 2: 87-117.**

    Notes: There is a discussion on the reasons to use ratio scales, when possible, in system dynamics models.

15. **Levine, R. L. and H. Nguyen (2000). Coflow Structures: Some Problems And Solutions In Representing Psychological Characteristics And Processes. Proceedings of the 18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 125-126.**

    The coflow structure is useful when changes in one level simultaneously drive another set of changes in a second level. Coflow structures can represent how psychological variables, such as average attitudes, are carried over as a group of people change status or designation. In modeling a problem of an agency, we had difficulties using the classic form of the coflow process to represent average attitudes towards the organization. Total Attitude, which is defined as a state variable, is hard to interpret. This is particularly true when attitudes are also influenced by organizational experience and may erode over time. This paper compares an isolated coflow structure with the coflow structure combined with an eroding process. Adding an eroding process to the classical coflow structure generated interesting behavior modes, such as logarithmic decline to a minimum and growth toward a higher equilibrium point. We suggest directly using Attitude as a stock rather than using Total Attitude as the level. Changes in (Group) Attitude would depended on the influence of those coming in from the previous stage, experiences happening at that stage, and perhaps upon a naturally occurring eroding process. The influence of new people coming into the group affected Attitude in proportion to their numbers. If only a few entered the organization, their attitudes would have little effect on the group's Attitude. We suggest two alternatives to the classical coflow formulation. We also show how each formulation behaves when we allow attitudes to erode.

16. **Lounsbury, D. W. and R. L. Levine (2002). Understanding the Psychosocial Dynamics of HIV/AIDS Prevention and Care in the Community : Base Case Model Findings and Implications. Proceedings of the 20th International Conference of the System Dynamics Society. Palermo, Italy, The System Dynamics Society.**

    A system dynamics model was built for the purpose of fostering a greater understanding about the psychosocial dynamics of HIV/AIDS prevention and care in the community over a twenty year time horizon, from the epidemic's inception (circa 1981) to the present. In particular, the psychosocial dynamics of perceived stigma, complacency, and [dis]empowerment were studied in relation to the epidemiology of HIV/AIDS in Michigan. The study was informed by the results of an extensive qualitative research project that explored the current and emerging needs of persons living with HIV/AIDS (PLWHA) and by the insight and knowledge of a group of ten core informants from Michigan's HIV community. The underlying dynamics of the problem focus in the study were expressed in a set of five key causal processes. Initial feedback from members of Michigan's HIV community affirmed that the base case model has provided deeper insight into the phenomena of HIV/AIDS prevention and care.

17. **Nuthmann, C. F. (1994). "Using Human Judgement in System Dynamics Models of Social Systems." <u>System Dynamics Review</u> 10(1): 1-27.**

    This article addresses concerns about the validity of system dynamics models that rely on the quantification of human judgment. It reviews epistemological and semantic problems associated with scientific discourse, summarizes properties of four levels of scientific discourse (nominal, ordinal, interval, and ratio), and describes the judgmental conditions that must obtain when high level (interval and ratio) mathematics are applied to human judgment. Two simple system dynamics models employing continuous and discrete limens are used to illustrate the dynamic consequences of inappropriate uses of human judgment in system dynamics models. The author concludes that unless we have specific evidence that the judgmental phenomena we are modeling behave according to additive, multiplicative, or averaging models, we cannot assume we are dealing with anything other than ordinal phenomena.

18. **Roy, S. and P. K. J. Mohapatra (2003). Methodological Problems in the Formulation and Validation of System Dynamics Models Incorporating Soft Variables. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.**

    While formulating and then analyzing a system dynamics model that incorporates soft, qualitative variables, problems are encountered. First most of the variables of this kind are measured using a quasi-quantitative framework. The question of reliability and validity of such measurement needs to be addressed. Second, the causal relationships among the variables would have to be ascertained in a way that takes into consideration such a measurement approach. Further, there is the critical question of validating such a system dynamics model. The paper attempts to probe into the problems of developing system dynamics models that incorporate soft variables, and critically examines the model validation exercise in system dynamics in this context. It argues for enriching the methodology of system dynamics by establishing an interface with the methodology of structural equation modelling that would help address the issues of reliability and validity of the measures and the formulation and subsequent validity of the system dynamics model.

19. **Warren, K. (2008). Strategic management dynamics. Chichester, West Sussex, England; Hoboken, NJ, J. Wiley & Sons.**

    Notes: See Chapter 9 - Intangible Resources.

C - Additional Major References

The following references are also relevant to understanding the use of psychological and sociological variables in system dynamics models.

Section 1 – Psychological and Sociological Variables

These references cover methods and issues in using psychological or sociological variables with models.

1. **Chichakly, K. (2014) Dynamic Modeling I**
   This is the third on-line course in the six-course series from isee systems inc: "Systems Thinking to Dynamic Modeling." The third of four lectures is on Intangibles: "Not everything we wish to model is tangible. We often need to include soft variables, such as Morale, Reputation, and Loyalty, in our models. This class explains how to include soft variables in your model and covers some deeper details about graphical functions, which are necessarily part of modeling intangibles."

2. **Coyle, R. G. (2000). "Qualitative and Quantitative Modelling in System Dynamics : Some Research Questions." System Dynamics Review 16(3): 225-144.**

The tradition, one might call it the orthodoxy, in system dynamics is that a problem can only be analysed, and policy guidance given, through the aegis of a fully quantified model. In the last 15 years, however, a number of purely qualitative models have been described, and have been criticised, in the literature. This article briefly reviews that debate and then discusses some of the problems and risks sometimes involved in quantification. Those problems are exemplified by an analysis of a particular model, which turns out to bear little relation to the real problem it purported to analyse. Some qualitative models are then reviewed to show that they can, indeed, lead to policy insights and five roles for qualitative models are identified. Finally, a research agenda is proposed to determine the wise balance between qualitative and quantitative models.

3. **Coyle, R. G. (2001). "Rejoinder to Homer and Oliva." System Dynamics Review 17(4): 357-363.**

   This rejoinder clarifies that there is significant agreement between my position and that of Homer and Oliva as elaborated in their response. Where we differ is largely to the extent that quantification offers worthwhile benefit over and above analysis from qualitative analysis (diagrams and discourse) alone. Quantification may indeed offer potential value in many cases, though even here it may not actually represent "value for money". However, even more concerning is that in other cases the risks associated with attempting to quantify multiple and poorly understood soft relationships are likely to outweigh whatever potential benefit there might be. To support these propositions I add further citations to published work that recount effective qualitative-only based studies, and I offer a further real-world example where any attempts to quantify "multiple softness" could have led to confusion rather than enlightenment. My proposition remains that this is an issue that deserves real research to test the positions of Homer and Oliva, myself, and no doubt others, which are at this stage largely based on personal experiences and anecdotal evidence.

4. **Gaynor, A. K. (1987). "Simulating violators by Chanoch Jacobsen and Richard Bronson Operations Research Society of America, 1985." System Dynamics Review 3(1): 74-79.**

   Notes: This is a book review.

5. **Homer, J. B. and R. Oliva (2001). "Maps and Models in System Dynamics : A Response to Coyle." System Dynamics Review 17(4): 347-355.**

   Geoff Coyle has recently posed the question as to whether or not there may be situations in which computer simulation adds no value beyond that gained from qualitative causal-loop mapping. We argue that simulation nearly always adds value, even in the face of significant uncertainties about data and the formulation of soft variables. This value derives from the fact that simulation models are formally testable, making it possible to draw behavioral and policy inferences reliably through simulation in a way that is rarely possible with maps alone. Even in those cases in which the uncertainties are too great to reach firm conclusions from a model, simulation can provide value by indicating which pieces of information would be required in order to make firm conclusions possible. Though qualitative mapping is useful for describing a problem situation and its possible causes and solutions, the added value of simulation modeling suggests that it should be used for dynamic analysis whenever the stakes are significant and time and budget permit.

6. **Levine, R. L. (2002). Organizational Change at the Team Level : The Dynamics of High Performing Self-Directed Work Teams from a Learning Organizational Perspective. Proceedings of the 20th International Conference of the System Dynamics Society. Palermo, Italy, The System Dynamics Society.**

   This paper describes a model that explains the changes workers go through in formation and evolution of self-directed work teams (SDWT) over a six year period. The formation phase is characterized by major increases in worker commitment to the team concept. Upper management has to convince workers that the company will give them the freedom and resources to function as a SDWT. Once the team comes into existence, another set of processes dominate. The model describes the tradeoff between being empowered to set work intensity and worker accountability. High performing teams may seek external resources to raise the performance bar, through internal pressure to excel. Raising the bar generates burnout as an unintended consequence. However, high performing teams can be relatively immune to burnout. The model hypothesizes that loop processes, associated with team spirit and zeal for the job, appear late in the game to ameliorate the effects of burnout.

7. **Levine, R. L. and H. E. Fitzgerald (1992). Systems and System Analysis. Analysis Of Dynamic Psychological Systems: Methods and Applications. R. L. Levine and H. E. Fitzgerald. New York, Plenum Press. 2: 1-16.**

   Notes: Discusses the "family in crisis" example from the presentation slides in: Levine, R. L., Pearson, J. L., & Ialongo, N. (1988). Modeling the Dynamics of a Family in Crisis.

8. **McLucas, A. C. (2003). Incorporating Soft Variables Into System Dynamics Models : A Suggested Method and Basis for Ongoing Research. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.**

   How to determine the impact of soft variables, including intangibles or social variables, and combining them as necessary with hard variables in system dynamics models is a significant challenge. This paper identifies a weakness in system dynamics modelling practice, that is, in reliably incorporating soft variables into system dynamics models. A method for incorporating such variables and a basis for further research is offered. The method combines systems thinking, research into causality analysis, multiple criteria decision analysis (conjoint analysis) and system dynamics modelling, in an integrated approach.

9. **Richmond, B. (2001). Adding Texture to Your Compositions, Modeling "Soft" Variables. An Introduction to Systems Thinking, iThink, isee systems: 179-184.**

10. **Runge, D. (1975). Issues Underlying the Representation of Social Variables in System Dynamics Models. Proceedings of the Summer Computer Simulation Conferences. San Francisco, Simulation Councils, Inc.**

    Problems in the representation of the social variables of the dynamic model of the system.

    Notes: Also available as MIT System Dynamics Group Memo D-2167.

11. **Sterman, J. D. (2002). "All Models are Wrong: Reflections on Becoming a Systems Scientist." System Dynamics Review 18(4): 501-531.**

    Thoughtful leaders increasingly recognize that we are not only failing to solve the persistent problems we face, but are in fact causing them. System dynamics is designed to help avoid such policy resistance and identify high-leverage policies for sustained improvement. What does it take to be an effective systems thinker, and to teach system dynamics fruitfully? Understanding complex systems requires mastery of concepts such as feedback, stocks and flows, time delays, and nonlinearity. Research shows that these concepts are highly counterintuitive and poorly understood. It also shows how they can be taught and learned. Doing so requires the use of formal models and simulations to test our mental models and develop our intuition about complex systems. Yet, though essential, these concepts and tools are not sufficient. Becoming an effective systems thinker also requires the rigorous and disciplined use of scientific inquiry skills so that we can uncover our hidden assumptions and biases. It requires respect and empathy for others and other viewpoints. Most important, and most difficult to learn, systems thinking requires understanding that all models are wrong and humility about the limitations of our knowledge. Such humility is essential in creating an environment in which we can learn about the complex systems in which we are embedded and work effectively to create the world we truly desire. The paper is based on the talk the author delivered at the 2002 International System Dynamics Conference upon presentation of the Jay W. Forrester Award

    Notes: See the section "A hard look at soft variables" on pages 522-523.

Section 2 - Validating and Calibrating Psychological and Sociological Variables in Models

These references discuss model calibration and validation relevant to modeling with psychological and sociological variables.

1. **Eckerd, A., D. Landsbergen and A. Desai (2011). The Validity Tests Used by Social Scientists and Decision Makers. Proceedings of the 29th International Conference of the System Dynamics Society. J. M. Lyneis and G. P. Richardson. Washington, D. C., System Dynamics Society.**

    How can simulation be "sold" to policy decision makers? How can simulation be sold to other social scientists that do not accept simulation as a complement to "accepted" techniques" (Repenning, 2003)? Decision makers and social scientists use validation tests to determine how much confidence they should vest in a model (Forrester and Senge, 1980). And because these communities have different uses for models, they will employ different validation tests. If validation tests are not sufficiently clear, several problems could occur. A decision-maker may "dismiss" a simulation model using a particular validation test, unbeknownst to the modeler. This paper collects the validation tests in the various simulation and statistical / psychometric literatures into a comprehensive framework. Decision-makers are keenly interested in use as well as how "scientifically valid" that model is. Therefore, there are analytic, "consequential", and pragmatic validity tests. Decision-makers may rely on heuristics (Kahneman, Slovic and Tversky, 1982) as validity tests because they have difficulty understanding simulation (Cronin, Gonzalez, & Sterman, 2009). Decision-makers can teach modelers too – humans have used heuristics to become the dominant species in complex ecosystems. The long-term research objective is to use experiments (Sterman, 1987) to understand how decision-makers use both adaptive and dysfunctional heuristics.

2. **Levine, R. L. and W. A. Lodwick (1992). Parameter Estimation and Assessing the Fit of Dynamic Models. Analysis of Dynamic Psychological Systems: Methods and Applications. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 2: 119-150.**

   This chapter will cover those aspects of systems analysis that are more numerical in scope, dealing with ways to assess the relationship between dynamical models and empirical data. We shall describe techniques that have been found useful in estimating parameters of dynamic models. The chapter will also cover ways in which the modeler can assess how close the model predicts various quantitative and qualitative aspects of the real system under study. Finally we shall describe a method for pinpointing the exact nature of the model's specification errors in terms of various parts of the model.

3. **Levine, R. L. and W. A. Lodwick (1992). Sensitivity of Parameters and Loop Structures. Analysis Of Dynamic Psychological Systems: Methods and Applications. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 2: 43-86.**

   Sensitivity analysis, which can be performed even before embarking on an extensive empirical time series study, provides a powerful technique for assessing the impact of specific initial values of the state variables, table functions, and the impact of changing parameters of the model on the behavior of the system. The assessment of initial values and table functions has been described elsewhere, especially in Chapters 4 and 5 in Volume 1. The current chapter will emphasize assessing the sensitivity of parameter values that can serve as leverage points for changing policies. Indeed, once leverage points are found, the modeler will then know which parameters must be estimated with a great deal of precision, as opposed to other parameter values that have little effect on the behavior of the system and therefore may not require extensive time and effort in obtaining precise estimates. Note that performing a sensitivity analysis on the model provides information about how robust the system is to changes in policy. If a particular policy is found to positively affect the problem under study, one can use the Policy Parameter Sensitivity test to see the range of movement one has in making the change.

4. **Roy, S. and P. K. J. Mohapatra (2000). Causality And Validation Of System Dynamics Models Incorporating Soft Variables: Establishing An Interface With Structural Equation Modelling. Proceedings of the 18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 178-179.**

   Conventional methods and models are based on hard (quantitative, cardinally-measured) information. The problems are different in the analysis of soft, qualitative or categorically measured data. Social scientists have been more and more concerned with measuring qualities in order to grapple with complex configurations and the ambiguities inherent in human perceptions and behaviour. The authors had earlier attempted to model the work climate of an R&D laboratory using the system dynamics (SD) framework. Problems occur at two stages in developing such a system dynamics model incorporating soft variables. First most of the variables encountered in such systems are measure using a quasi-quantitative framework. The question of reliability and validity of such measurement would have to be addressed. Second, the causal relationships among the variables would have to be ascertained in a way that takes into consideration this quasi-quantitative measurement approach. Reliability refers to the stability of replicated measurements. Construct validity refers to whether the measure really measures what it is supposed to measure, as opposed to measuring some similar yet conceptually distinct variable. Causality or causal linkages are central to the paradigm of system dynamics. The causal relationships in the above-mentioned system dynamics model were largely derived from correlations, regression analysis, cluster analysis and multiple classification analysis. But in all these methods of analysis, causality cannot be inferred or verified. Further, there is the critical question of validating such a system dynamics model. Our approach towards soft systems modelling is quite apart from the methodological thrust of soft systems methodology (SSM) and other problem structure methodologies. For one, SD itself has moved away from the hard system paradigm, with the relativist/holistic philosophy of validation. Secondly, in SSM, the problem situation could be ill-structured and messy whereas the variables in the model need not be so. The central theme of structural equation modelling is the establishments of causal relationships among latent variables taking into consideration the reliability and validity of quasi-quantitative measurement of such variables. It is, therefore, argued that establishing an interface between system dynamics and structural equation modelling could be appropriate to address the problem of establishing causality in and validation of a system dynamics model incorporating soft variables. Data from a sample of 236 research units in the laboratories under the Council of Scientific and Industrial Research (CSIR), India have been used to develop two structural equation models. These models help in probing into the causal relationships among the factors of work climate and the measures of effectiveness of research units in CSIR laboratories.

Section 3 - Validating and Calibrating Models in General

These references discuss verifying, validating and calibrating system dynamics and social science models in general.

1. **Arthur, D. J. W. and G. W. Winch (1999). Extending Model Validity Concepts and Measurements in System Dynamics. Proceedings of the 17th International Conference of the System Dynamics Society and 5th Australian & New Zealand Systems Conference. Wellington, New Zealand, The System Dynamics Society: 16.**
System dynamics models are employed for a variety of purposes in socio-economic systems, including behavioural prediction, policy analysis, consensus building and for hypothesis testing about complex system behaviour. Models can be valid or effective in three ways: by precisely representing reality, through their potential to stimulate learning or by demonstrating utility by instigating organisational change. This paper proposes an overall framework for setting validity tests in the context of different modelling purposes, emphasising three main types of validity. A sequence is also proposed through which a validation process should move to be effective. Quantitative measures of validity and identification of different approaches to constructing prior consensus on validity are proposed. Validity profiles can characterise how model utility varies throughout a project. The validation framework affords explanatory power for the efficacy of different modes of modelling and can help to clarify model purpose.

2. **Back, G., G. Love and J. Falk (2000). The Doing Of Model Verification And Validation: Balancing Cost And Theory. Proceedings of the 18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 31.**

   Much of the model verification and validation (V&V) guidance and literature is useful for explaining the principles of V&V and how V&V is ideally integrated into the simulation model development life cycle. There is less information available, however, on how to execute V&V, especially, as is often the case, when the resource commitment for V&V is limited. There are few examples that illustrate concrete application of the available V&V techniques or discuss the tradeoffs between theory and cost that are often made. This paper describes the V&V approach used by Raytheon Company, C3I Systems and Project Performance Corporation in developing several low-resolution multi-purpose simulations of integrated industrial facilities and industrial sectors for a government customer. These projects were characterized by (i) the need to deploy each simulation model within a 60- or 120-day period; (ii) the need to utilize a commercial-off-the-shelf system dynamics software application; and (iii) heavy reliance on subject matter expert input to assess real-world fidelity. Furthermore, V&V had to be performed with little guidance at the outset as to what the acceptability criteria would be and V&V budgets of no more than 8 to 10 percent of the total project cost. Consequently, while the V&V efforts conducted for these projects were built upon the "what and why" guidance outlined in the customer's policies and in such documents as the Defense Modeling and Simulation Office's Verification, Validation, and Accreditation Recommended Practices Guide, tradeoffs had to be made in developing an efficient "how to" approach.

3. **Barlas, Y. (1994). Model Validation in System Dynamics. Proceedings of the 1994 International System Dynamics Conference Sterling, Scotland, System Dynamics**

Society. System Dynamics: Methodological and Technical Issues: 1.

Model validation constitutes an important step in system dynamics methodology. Validation is a prolonged and complicated process, involving both formal/quantitative tools and informal/qualitative ones. This paper first provides a summary of the philosophical issues involved in model validation. We then focus on the formal model validation. We offer a flowchart that describes the logical sequence in which various validations activities must be carried out. We give examples of specific validity tests used in the three major categories of model validations: Structural tests, structure-oriented behavior tests and behavior pattern tests. Finally, we focus specifically on the logic of the behavior pattern validation and illustrate it on a mutli-step validation procedure. Currently, we are in the process of implementing this multi-step procedure on micro-computers, embedded in a friendly user-interface.

4. **Barlas, Y. (1996). "Formal Aspects of Model Validity and Validation in System Dynamics." System Dynamics Review 12(3): 183-210.**

   Model validation constitutes a very important step in system dynamics. Yet, both published and informal evidence indicates that there has been little effort in system dynamics community explicitly devoted to model validation. Validation is a prolonged and complicated process, involving both formal/quantitative tools and informal/qualitative ones. This paper focuses on the formal aspects of validation and presents a taxonomy of various aspects and steps of formal model validation. First, there is a very brief discussion of the philosophical issues involved in model validation, followed by a flowchart that describes the logical sequence in which various validation activities must be carried out. The crucial nature of structure validity in system dynamics (causal-descriptive) models is emphasized. Then examples are given of specific validity tests used in each of the three major stages of model validation: Structural tests, structure-oriented behavior tests and behavior pattern tests. Also discussed is if and to what extent statistical significance tests can be used in model validation. Among the three validation stages, the special importance of structure-oriented behavior tests is emphasized. These are strong behavior tests that can provide information on potential structure flaws. Since structure-oriented behavior tests combine the strength of structural orientation with the advantage of being quantifiable, they seem to be the most promising direction for research on model validation.

5. **Coyle, R. G. and D. R. Exelby (2000). "The validation of commercial system dynamics models." System Dynamics Review 16(1): 27-41.**

   This paper discusses the need for formal criteria for the establishment of confidence in, or the "validation" of, system dynamics models constructed for fee-paying clients as opposed to for academic research purposes. The meaning of "validation" is first considered and the substantial differences between the consultancy and academic cases are discussed. That leads to a review of the system dynamics literature on tests of validity. Finally, there is a discussion of the process of consultancy in system dynamics. An outline of a set of formal tests is described.

6. **DiStefano, J. M. (1997). Credibility, Communication, and Conundrums: Facing the Realities of the Scientific Endeavor and the Limits of Knowledge. Proceedings of the 1997 International System Dynamics Conference: "Systems Approach to Learning and Education into the 21st Century". Y. Barlas, V. G. Diker and S. Polat. Istanbul, Turkey, Bogazici University Printing Office. 1: 117-120.**

   The System Dynamics community has an obligation to the public to teach the epistemological basis of System Dynamics models including an acknowledgment of the humanistic components of the scientific endeavor. Concern about scientific credibility has been expressed in recent articles in The System Dynamics Review. Barlas and Carpenter (1990) say: "No model can claim absolute objectivity, for every model carries in it the modeler's worldview" (p. 187). Lane (1994) comments on Habermas' argument that knowledge is never objective, but that "truth and rationality are phenomena of communication: knowledge arises from free discussion" (p. 113). And Vasquez, Liz, and Aracil (1996) make the case that Putnam's view of Internal Reality offers an alternative between "naïve realism and relativism" which offers SD a way to "clarify the strong interactive character of the modeling process" (p. 36). As Gerald Holton, Professor of Physics and History of Science at Harvard University said, "the scientific and humanistic aspects of our culture are complementary aspects of our humanity that co-exist," in the words of poet S.T. Coleridge, "in the balance or reconciliation of opposite or discordant qualities" (Holton, 1995, p. 38).

7. **Grcic, B. and A. M. Munitic (1996). System Dynamics Approach to Validation. Proceedings of the 1996 International System Dynamics Conference. G. P. Richardson and J. D. Sterman. Cambridge, Massachusetts, System Dynamics Society. 1: 186-189.**

   Model validation is a problem that both social and natural sciences have been facing with for many years. During the last decades it became particularly pressing in social sciences due to the development of contemporary complex tools for the modelling of real social systems. The systems dynamics methodology is one of these new tools. Although it has been developed through relatively long period of time, it was rather "closed" for critical opinions especially those referring to the validation of systems dynamics approach to models validation. It takes into consideration all relevant discussions about this matter, as well as some of the procedures and criteria used so far in the system dynamics models validation. Moreover, based on the evaluation of their advantages and disadvantages, certain formal criteria are provided aiming to strengthen the credibility of these models.

8. **Groesser, S. (2011). What Is a Validation Methodology? Analyzing and Synthesizing two Meanings Proceedings of the 29th International Conference of the System Dynamics Society. J. M. Lyneis and G. P. Richardson. Washington, D. C., System Dynamics Society.**

   In the domain of system dynamics and computational modeling, the assurance of model validity is a prominent challenge. A number of contributions concerning validation tests, processes, and their epistemological foundations have been developed. Considering the existing literature on validation, little has been said about a validation methodology for system dynamics models. This paper differentiates two meanings of methodology which are referred to as methodology I and methodology II. The first meaning refers to a body of methods. This understanding has almost exclusively been adopted in the field of system dynamics. The second meaning refers to a comprehensive understanding of elicitation, description, reflection, and evaluation of issues related to validation which are currently lacking. This paper's contribution is in analyzing the two meanings and synthesizing them in a conceptual model. The conceptual model is used to derive directions for future research as well as actions required bring the field forward. The paper ought to raise the attention of researchers for validation and commence a beneficial discussion.

Notes: Chapter in book: "Systemic Management for Intelligent Organizations: Concept, Model-Based Approaches, and Applications." Paper not available at conference site.

9. **Groesser, S. and M. Schwaninger (2009). A Validation Methodology for System Dynamics Models   Proceedings of the 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, System Dynamics Society.**

   Quality is a critically important issue in almost every discipline. The literature in the field of System Dynamics has bred a number of contributions concerning tests for the validation of simulation models and its epistemological foundations. To date, however, little has been said about a validation methodology for System Dynamics models, even for simulations in general. By validation methodology, we understand the systematic elicitation, description, and reflection of issues related to the subject of 'validation'. The paper's contribution is to initiate the development of a validation methodology. We explicitly address three topics: Complexity engineering through validation tests, integrated validation process, and finally the decision to cease validation efforts. The first defines validation tests according to their capability to ac-count for a certain level of model complexity; the second designs a validation process which addresses the domains of validation (structure, behavior, context validation) and the levels of resolution (micro, meso, macro) integratively and iteratively. And third, the 'cession decision' creates a heuristic method for the saturation of a System Dynamics model and conceptually defines when to cease with validation efforts. The paper concludes by providing further directions of research about a validation methodology.

   Notes: Just an abstract in the SDS conference proceedings.

10. **Groesser, S. N. and M. Schwaninger (2012). "Contributions to model validation: hierarchy, process, and cessation." System Dynamics Review 28(2): 157-181.**

    In the domain of dynamic modeling and simulation, the assurance of model validity is a prominent challenge. An extensive number of contributions concerning model tests, terminology, and the epistemological foundations of validation have been elaborated. These contributions, however, do not fully answer the questions for novice modelers, namely, which validation tests to choose, when and how to apply them, and at what point to cease

their formal validation efforts. Our intention here is to help close this gap by introducing a complexity hierarchy of validation tests, an integrative validation process, and a decision heuristic about when.

11. **Homer, J. (2014). "Levels of evidence in system dynamics modeling." System Dynamics Review 30(1-2): 75-80.**

12. **Homer, J. B. (2012). "Partial-model testing as a validation tool for system dynamics (1983)." System Dynamics Review 28(3): 281-294.**

    This paper discusses an approach to model refinement that involves testing the behavior of individual pieces of a model in response to empirical input data for comparison with empirical output data. Partial-model tests should be used for selecting formulations or estimating parameters only when appropriate case-specific or logical information is not available for this purpose. The smaller the model components used for partial-model testing, the more likely it is that the model will prove useful for anticipating events outside historical experience and the less likely it is that observed behavior will be incorrectly attributed to certain relationships or parameters. Thus, from the standpoint of structural validity, partial-model testing is an improvement over whole-model testing for the purpose of structural adjustment. The paper presents a detailed example of partial-model testing in the context of a generic model of the evolving use of a new medical technology. Specifically, the technique is used for adjusting and validating a model subsystem that can explain why the reporting of clinical information on cardiac pacemakers has been marked by regular oscillations over time. Originally published in 1983.

13. **Kleijnen, J. P. C. (1995). "Verification and Validation of Simulation Models." European Journal of Operational Research 82(1): 145-162.**

    This paper surveys verification and validation of models, especially simulation models in operations research. For verification it discusses 1) general good programming practice (such as modular programming), 2) checking intermediate simulation outputs through tracing and statistical testing per module, 3) statistical testing of final simulation outputs against analytical results, and 4) animation. For validation it discusses 1) obtaining real-world data, 2) comparing simulated and real data through simple tests such as graphical, Schruben-Turing, and t tests, 3) testing whether simulated and real responses are positively correlated and moreover have the same mean, using two new statistical procedures based on regression analysis, 4) sensitivity analysis based on design of experiments and regression analysis, and risk or uncertainty analysis based on Monte Carlo sampling, and 5) white versus black box simulation models. Both verification and validation require good documentation, and are crucial parts of assessment, credibility, and accreditation.

14. **Martis, M. S. (2006). "Validation of Simulation Based Models: A Theoretical Outlook " The Electronic Journal of Business Research Methods 4(1): 39-46.**

    Validation is the most incomprehensible part of developing a model. Nevertheless, no model

can be accepted unless it has passed the tests of validation, since the procedure of validation is vital to ascertain the credibility of the model. Validation procedures are usually framework based and dynamic, but a methodical procedure can be followed by a modeler (researcher) in order to authenticate the model. The paper starts with a discussion on the views and burning issues by various researchers on model validation and the foundational terminology involved. The paper later highlights on the methodology and the process of validation adopted. Reasons for the failure of the model have also been explored. The paper finally focuses on the widely approved validation schemes (both quantitative and qualitative) and techniques in practice, since no one test can determine the credibility and validity of a simulation model. Moreover, as the model passes more tests (both quantitative and qualitative) the confidence in the model increases correspondingly.

15. **Oliva, R. (1996). Empirical Validation of a Dynamic Hypothesis. Proceedings of the 1996 International System Dynamics Conference. G. P. Richardson and J. D. Sterman. Cambridge, Massachusetts, System Dynamics Society. 2: 405-408.**

    The purpose of this paper is to describe the methodological approach followed to validate a dynamic hypothesis of service delivery and explain its implications for service quality. For a full report on the application of the methodology and the substantial results obtained in the analysis see Oliva (1996)

16. **Oliva, R. (2003). "Model Calibration as a Testing Strategy for System Dynamics Models." European Journal of Operational Research 151(3): 525-568.**

    System dynamics models are becoming increasingly common in the analysis of policy and managerial issues. The usefulness of these models is predicated on their ability to link observable patterns of behavior to micro-level structure and decision-making processes. This paper posits that model calibration—the process of estimating the model parameters (structure) to obtain a match between observed and simulated structures and behaviors—is a stringent test of a hypothesis linking structure to behavior, and proposes a framework to use calibration as a form of model testing. It tackles the issue at three levels: theoretical, methodological, and technical. First, it explores the nature of model testing, and suggests that the modeling process be recast as an experimental approach to gain confidence in the hypothesis articulated in the model. At the methodological level, it proposes heuristics to guide the testing strategy, and to take advantage of the strengths of automated calibration algorithms. Finally, it presents a set of techniques to support the hypothesis testing process. The paper concludes with an example and a summary of the argument for the proposed approach.

Section 4 - Psychological and Sociological Variable Examples

These references contain examples of psychological and sociological variables within models.

1. **Caulfield, C. W. and S. P. Maj (2002). "A Case for System Dynamics." Global J. Engng. Educ. 6(1).**

Engineering education provides a thorough and systematic training in the design, development, maintenance and management of complex technical systems. While such education provides the necessary technical depth to graduates, many technical systems are best understood from the perspective of human and socio-economic relationships. A case in point may be Fred Brooks' law that states adding more developers to a late software engineering project will only make it even more behind schedule. Brooks' law is based on the understanding that additional, new software engineering staff will need time to come up to speed with the project and in doing so will divert the existing developers from their primary tasks. While Brooks' law is intuitively appealing, students and practicing software engineers really have no way of testing its efficacy in their particular situations. A tool to overcome this difficulty may be system dynamics. System dynamics is a systems thinking methodology for building quantitative and qualitative models of complex situations so that they can ultimately be better understood and managed. Accordingly, it can be argued, that system dynamics should be an essential part of the education of engineers from most, if not all, of the major disciplines.

Notes: The authors extend Brook's law through the use of soft variables.

2. **Cooke, D. L. (2003). Learning from Incidents. Proceedings of the 21st International Conference of the System Dynamics Society. New York City, System Dynamics Society.**

   Many disasters have occurred because organizations have ignored the warning signs of pre-cursor incidents or have failed to learn from the lessons of the past. Risk is inherent in many high technology systems, but society views the benefits of continuing to operate these systems as outweighing the cost of the occasional disaster. Must we continue to live with disasters? Normal accident theory sees accidents as the unwanted but inevitable output of complex systems, while high reliability theory sees accidents as preventable by certain characteristics of the organization. This paper proposes that an incident learning system can provide a bridge between these two theories. By learning from the incidents that inevitably occur in a complex system, an organization can reduce risk and minimize loss. Thus, an organization with an effective incident learning system sustains a process of continuous improvement that allows it to become a high reliability organization over time. Incident learning theory suggests that implementing a system to encourage reporting of more incidents will drive a cycle of continuous organizational improvement that will reduce incident severity and reduce risk of disaster.

3. **Cooke, D. L. (2003). "A System Dynamics Analysis of the Westray Mine Disaster." System Dynamics Review 19(2): 139-166.**

   This paper describes a system dynamics analysis of the 1992 Westray mine disaster in Nova Scotia, Canada. The paper examines the causal structure of the Westray system, including relationships that could have led to conditions that caused the fatal explosion at the mine. The value of simulation is its ability to capture a "mental model" of the safety system, which can stimulate discussion among safety experts as to the systemic causes of a disaster. By taking into account feedback loops and non-linear relationships, which is not possible with conventional root cause analysis, a dynamic model of the system provides insights into the complex web of causes that can lead to disaster and valuable lessons for organizational learning.

4. **Darling, T. A. and G. P. Richardson (1990). A Behavioral Simulation Model of Single and Iterative Negotiations. Proceedings of the 1990 International System Dynamics Conference. D. F. Anderson, G. P. Richardson and J. D. Sterman. Chestnut Hill, Mass., International System Dynamics Society: 14p.**

   A simple simulation model demonstrates that the outcome of a negotiation may critically be affected by (i) the structure of the negotiating problem -- the joint distribution of negotiators' evaluations of potential settlements; and (ii) the negotiators' tactical approach to the problem -- the decision rules that guide the choice of concessionary offers made during the bargaining process. Hampered by cognitive limits and faced with imperfect information about the other party's interests, negotiators may rely on simple heuristics in choosing among possible concessions during the negotiating process. The model of single negotiations is extended to examine how the outcome of one negotiation may impact future negotiations. Focusing on two negotiator interests -- concern for self and concern for fairness -- the model shows how adjustments in tactical decision rules from one negotiation to the next sometimes leads to an unwarranted deterioration in the parties' relationship.

5. **Denker, M. W., K. E. Achenbach and D. M. Keller (1986). "Computer simulation of Freud's counterwill theory: Extension to elementary social behavior." Behavioral Science 31(2): 103-141.**

   A model is presented describing decision processes of a living system at the level of the individual, together with its interpersonal relationship context (organism, subsystems, and suprasystem). The beginning point was the 1977 system dynamics model of Wegman, which was itself characterized by quantitative cross-level hypotheses concerning both physiological and psychological levels of functioning within the individual personality system. The extension process was accomplished by synthesizing concepts from many different theories in personality and social psychology into equations linking two multiple loop feedback systems to form a suprasystem. Each individual model was found to have several distinct operational modes, and the dyadic model had a number of interesting combinations of these modes which correlated with clinical descriptions of steady-state behavior and subjective experience in human marital dyads. For example, under certain conditions an individual operating in an unstable mode could achieve personal system stability within a dyadic relationship. In some cases, two unstable individuals could form a stable system. The process of extending the original model supports the utility of a synthetic approach to the construction of quantitative theories concerning small social systems. This process also suggests new approaches to planning future empirical research on small social systems using methods more appropriate to the study of complex, dynamic systems.

6. **Donnadieu, G. and M. Karsky (1990). The Dynamics of Behavior and Motivation.**

Proceedings of the 1990 International System Dynamics Conference D. F. Anderson, G. P. Richardson and J. D. Sterman. Chestnut Hill, Mass., International System Dynamics Society: 319.

MODERE (MOtivation, DEsire, REality), the model described in this paper, is the result of an international cooperation between a System Dynamicist and a specialist in applied Social Sciences. This model is based on several current theories of human behavior and motivation, some of which were developed several decades ago, others more recently, but all of which have proven in daily practice to be helpful in the analysis and understanding of human motivation and corresponding behavior in the context of real environment.

7. **Frost-Kumpf, L. and K. O'Neill (2000). The Sustainability Of Synthetic Policy Decision Groups. Proceedings of the18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 72-73.**

One major issue in group decision-making concerns the duration of a group as an effectively functioning entity. Many factors provide possible explanations for differences in the expected life span of a group versus its actual life span. We lack adequate knowledge about the dynamics and duration of "synthetic groups," that is, groups who would not otherwise form nor operate, unless and until they are brought together by external authorities and/or events, such as a crisis, to serve a specific purpose or address a particular issue. Using literature on groups and group model building, we model the dynamics of synthetic groups in crisis situations. We identify several factors to guide group behavior and development and serve as useful variables for construction of dynamic models or simulations. These variables include "group factors" such as: 1) number and types of agenda items, 2) number, intensity, and persistence of issue conflicts, 3) number, types, and quality of policy proposals, 4) sources, quality, and consistency of information available and used, 5) number, types, and frequency of official representation at meetings, 6) number, types, and influence of experts, 7) frequency and duration of meetings, 8) quality and acceptance of the group's decisions, and 9) expected versus actual duration of the group. Additionally, we consider the elements of argumentation (e.g., claims, evidence, warrants, and backings) taken from the work of Steven Toulmin, as a fundamental orientation for understanding group decision-making. We find that Toulmin's argumentation forms are applicable to group policy decisions, in general, and specifically to crisis policy decision-making by synthetic groups comprised of public officials operating in the public domain and for the presumed public interest. The model is tested for two cases. The first case is based on materials from Allison's study of the Cuban Missile Crisis, including recently de-classified documents involving White House recordings of group discussions held in the Office of the President. The other case involves intensive interactions between national, state, and local government officials who responded to a crisis with potentially serious health, economic, and political consequences in the local government arena. Data for this second case comes from extensive notes and transcripts of group meetings and follow-up, in-depth interviews with key participants.

8. **Gaynor, A. K. and J. Karl H. Clauset (1983). Implementing Effective School Improvement Policies: A System Dynamics Policy Analysis. Proceedings of the 1983**

International System Dynamics Conference. Chestnut Hill, MA: 307-314.

At the last System Dynamics research conference held in the United States, we presented a paper which described a computer simulation model of an elementary school. The purpose of the model was to examine the structural differences between schools which are effective and ineffective for what we have come to call "initially low-achieving children." In that paper (Clauset & Gaynor, 1981), in a subsequent paper (Clauset and Gaynor, 1982), and in a book manuscript (Clauset and Gaynor, in preparation), we have described in varying degrees of details tests which examined a number of school improvement policies. Policies testes included the following: Changing policies affection time allocations, Improving teacher skills, Encouraging teachers to place more emphasis on low achievers, Raising teacher expectations for low-achievers, Improving classroom of school-wide behavior, Changing class size, Changing the demographics of the student body (e.g., size low achievers).

9. **Gaynor, A. K. and J. Karl H. Clauset (1984). Improving School Effectiveness: The Dynamics of Implementation. Annual meeting of the American Educational Research Association. New Orleans.**

10. **Gaynor, A. K., J. Morrow and S. N. Georgiou (1991). "Aging, contraction, and cohesion in a religious order: a policy analysis." System Dynamics Review 7(1): 1-20.**

    The Order of the Servants of Mary traces its origins back to a group of young women gathered in Cuves, France, in 1840. It is a part of a larger Servite family, founded in Florence, Italy, in 1233. The Order established roots in the United States in 1893, some members migrating from England at that time. There are now 162 vowed sisters, active and retired. Servite communities exist throughout the United States, from Portland, Oregon, to Boston, Massachusetts. Servites are teachers, administrators, counselors, and librarians in elementary and secondary schools and in colleges. Sisters work in parishes, religious education, social work, hospital and hospice pastoral care, diocesan offices, and as consultants. They are also found in home missions in Appalachia and on the island of Jamaica. This diversity of work expresses the message of the Constitutions of the Servants of Mary: "Witnesses to the love that unites us in community, we put ourselves and our diverse gifts at the service of the Church's mission to foster love and unity among all people" (Constitutions, No. 6)

11. **Golüke, U., R. Landeen and D. L. Meadows, Eds. (1980). A Comprehensive Theory of the Pathogenesis of Alcoholism. The Biology of Alcoholism. New York, Plenum Press.**

12. **Golüke, U., R. Landeen and D. L. Meadows (1981). The Dynamics of Alcoholism. System Dynamics and the Analysis of Change. E. Paulre. Amsterdam, North-Holland: 215-231.**

13. **Golüke, U., R. Landeen and D. L. Meadows (1981). "A Simulation Model of Drinking Behavior." British J. of Addiction 76(3): 289-298.**

14. **Gottman, J. M., J. D. Murray, C. Swanson, K. R. Swanson and R. Tyson (2002). The Mathematics of Marriage: Dynamic Nonlinear Models. Cambridge, MIT Press: 500 p. ill**.

Annotation Divorce rates are at an all-time high. But without a theoretical understanding of the processes related to marital stability and dissolution, it is difficult to design and evaluate new marriage interventions. The Mathematics of Marriage provides the foundation for a scientific theory of marital relations. The book does not rely on metaphors, but develops and applies a mathematical model using difference equations. The work is the fulfillment of the goal to build a mathematical framework for the general system theory of families first suggested by Ludwig Von Bertalanffy in the 1960s. The book also presents a complete introduction to the mathematics involved in theory building and testing, and details the development of experiments and models. In one "marriage experiment," for example, the authors explored the effects of lowering or raising a couple's heart rates. Armed with their mathematical model, they were able to do real experiments to determine which processes were affected by their interventions. Applying ideas such as phase space, null clines, influence functions, inertia, and uninfluenced and influenced stable steady states (attractors), the authors show how other researchers can use the methods to weigh their own data with positive and negative weights. While the focus is on modeling marriage, the techniques can be applied to other types of psychological phenomena as well.

15. **Hall, L. M. and P. J. Gambardella (2012). Systemic Coaching: Coaching the Whole Person with Meta-Coaching. Clifton, Neuro-Semantics Publications.**

This book introduces a systematic approach to coaching. True coaching is systemic by nature and design. Yet most coaches today do not coach systemically, in fact, most have not been trained to think and work systemically and do not have systemic models to work with. Systemic Coaching enables a professional coach to discover what it means to think and work systemically. This book describes key variables in the human mind-body-emotion system, and how to distinguish the causes from symptoms, how to recognize the information in energy out loops. It includes transcripts of scores of coaching conversations by L. Michael Hall, Ph.D. and put into causal loop diagrams by Pascal Gambardella, Ph.D.

16. **Heinbokel, J. F. and P. J. Potash (2003). Modeling Human Behavior as a Factor in the Dynamics of an Outbreak of Pneumonic Plague. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA. The System Dynamics Society.**

We simulated three specific behaviors -- fleeing, seeking care, and isolating oneself -- on an outbreak of pneumonic plague in Surat, India, a city of 1.5 million inhabitants, in September 1994. We constructed an S-E-I-R model of pneumonic plague, using data from other 20th century outbreaks, to represent Surat. Use of antibiotics was inadequate to replicate the observations. Even incorporating flight by 30% of the population, the modeled disease failed to resolve as rapidly as observed. Only reducing person-to- person contacts by 70% allowed the model to fit the data. This latter factor was barely acknowledged by prior analyses of the

outbreak; without it, no reasonable combination of modeled parameters produced the observed dynamics. The human behaviors in this model were all applied exogenously. Current efforts focus on defining these behaviors as endogenously controlled dynamics within the boundaries of the simulated Surat outbreak.

17. **Heinbokel, J. F. and P. J. Potash (2005). Endogenous Human Behaviors in a Pneumonic Plague Simulation: Psychological and Behavioral Theories as Small "Generic" Models. Proceedings of the 23rd International Conference of the System Dynamics Society. Boston, The System Dynamics Society: 80.**

This report builds on a previous epidemiological model of a pneumonic plague outbreak that incorporated three behavioral responses as exogenous drivers and evaluated their importance in allowing us to replicate the actual outbreak (Heinbokel& Potash, ISDC-2003). The current paper describes our subsequent efforts to incorporate those critical and controlling behavioral dimensions into this model as critical feedback loops. We conceptually deconstructed the event into four segments: becoming aware of the outbreak, deciding to act in response, choosing a specific response, and returning to normal behavior. We utilized current psychological theories, such as the "Psychometric Paradigm" and "Brunswik's Lens Model," to build small, conceptually clear, transferable, and combinable behavioral submodels to simulate the first three segments involving information and social networks, social trust, and risk perceptions. We believe these modeling efforts comprise first steps in a critical process of translating current, frequently static, risk theories to dynamically responsive vehicles that can be flexibly and quantitatively applied to reliably aid in understanding and influencing responses to such public health threats, other extreme events, and other dynamic risk scenarios in general.

18. **Homer, J. B. (1985). "Worker burnout: a dynamic model with implication for prevention and control." System Dynamics Review 1(1): 42-62.**

This paper explores the dynamics of worker burnout, a process in which a hard-working individual becomes increasingly exhausted, frustrated, and unproductive. The author's own two-year experience with repeated cycles of burnout is qualitatively reproduced by a small system dynamics model that portrays the underlying psychology of workaholism. Model tests demonstrate that the limit cycle seen in the base run can be stabilized through techniques that diminish work-related stress or enhance relaxation. These stabilizing techniques also serve to raise overall productivity, since they support a higher level of energy and more working hours on the average. One important policy lever is the maximum workweek or work limit; an optimal work limit at which overall productivity is at its peak is shown to exist within a region of stability where burnout is avoided. The paper concludes with a strategy for preventing burnout, which emphasizes the individual's responsibility for understanding the self-inflicted nature of this problem and pursuing an effective course of stability.

Notes: This reference is also in the book "Models that Matter (2012)" by the author.

19. **Homer, J. B., J. Richard and W. Cotreau (1986). A Dynamic Model for Understanding**

Eating Disorders. Proceedings of the 1986 International System Dynamics Conference: System Dynamics: On the Move. J. Aracil, J. A. D. Machuca and M. Karsky. Sevilla, Spain, International Systems Dynamics Society: 201.

A system dynamics model is presented which integrates current knowledge on the various aspects of normal and abnormal weight control and which provides new insights into the mechanisms underlying certain eating disorders. Anorexia nervosa, in both its purging and non-purging variants, emerges from the model as a behavior pattern tied up with the fear of weight gain which serves to strengthen the individual's drive toward extreme slimness. Policy tests suggest that appetite-suppressing drugs may be helpful in reducing this fear and its negative physical consequences. The encouragement or discouragement of physical activity may also serve the goal of stabilizing the individual, depending on how different therapeutic objectives are weighted for the specific individual. Future research may take the form of model enhancement or of empirical studies guided by the model's structure and behavior.

20. **Jacobsen, C. and R. Bronson (1985). Simulating Violators, Operations Research Society of America.**

    Notes: This book uses System Dynamics to model how social norms are violated and new norms are created.

21. **Kapmeier, F., M. Schmalz and T. Ackbarow (2007). Happiness - Cracking the Equilibrium State of People's Well-Being Proceedings of the 2007 International Conference of the System Dynamics Society. Boston, MA, The System Dynamics Society.**

    Understanding the mechanisms producing happiness is not only crucial for individuals and psychological research but also for management science and political economy. In this paper, we develop a System Dynamics model to analyze mechanism creating happiness. It allows a better understanding of the formerly vaguely proposed connections between external life events and individual well-being. We propose that it can make a qualitative estimation of a person's happiness over time as a function of external events. It is widely accepted in positive psychology that good and bad events temporarily affect happiness. Yet, individuals quickly adapt back to hedonic neutrality. This is known as the hedonic treadmill (Brickman and Campbell, 1971), the dynamic equilibrium theory, or set point theory (Headey, 2005). We model a hedonic treadmill by assuming that people's expectations and aspiration levels adapt to the actual stock levels of happiness drivers, such as income, health, and social networks. Policy-designers learn how well-intended policies to increase happiness only succeed short-term.

22. **Kurstedt, H. (2003). Dyadic Dynamics in Interpersonal Cycles. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.**

    Dyadic dynamics studies interpersonal interactions in pairs of people--system dynamics of

dyads. The causal map for a vicious interpersonal cycle including four reinforcing loops is developed showing the system structure generating exponential growth in personal hard feelings and low regard, and interpersonal anxiety. A real-life interpersonal cycle example develops reinforcing loops, demonstrates the power of a systemic goal statement, and shows structural changes that lead to different system behavior and to a virtuous reinforcing cycle. A generalized dyadic system structure shows the effect of balancing loops and the role of corrective action. The marriage relationship is mapped to show the most intense dyadic relationship. Simple stocks and flows illustrate hard feelings as a state variable. Adjustment time for responding to behavior change is mapped. Extensions include triangular relationships, organizational dyads, archetypes, and other interpersonal issues such as trust.

Notes. Paper 261.pdf in SDS 2003 Conference

23. **Levine, R. L., A. Leholm and R. Vlasin (2001). Come Be a Leader in a Self-Directed Work Team : The Dynamics of the Transition from Being a Supervisor to a Team Leader. Proceedings of the 19th International Conference of the System Dynamics Society. Atlanta, Georgia, System Dynamics Society.**

    Although self-directed work teams (SDWT) have become popular since the mid-eighties, little modeling has been done on the dynamics of leadership in the formation, operation, and the sustainability of these groups. This paper describes preliminary efforts to model the dynamic problems of moving from a supervisor in a "command and control" environment to becoming a successful team leader in a supportive environment. In addition to modeling the leader's effect on the work or the service being done, this model portrays such subjective processes as role ambiguity, fear of the unknown, trust in and commitment to the team, and the leader's willingness to let go of traditional control functions. The model generates several qualitative patterns. It helps us to explore under what conditions newly formulated teams may be abandoned prematurely, and under what conditions supervisors can move to new productive roles when, at later stages, some important social loop processes dominate and performance grows.

24. **Levine, R. L., J. L. Pearson and N. Ialongo (1988). Modeling the Dynamics of a Family in Crisis. Proceedings of the 1988 International Conference of the Systems Dynamics Society. J. B. Homer and A. Ford. La Jolla, California, International System Dynamics Society: 259.**

    A model of the dynamics of a family problem was developed as a prototype of future work in family therapy. In this situation, a family was in crisis over the problem of managing the son's illness. The father refused to recognize the severity of the disease, while the mother begrudgedly took responsibility for the care of the child. The model describes the dynamics underlying the mutual anger between the parents, the guilt of the father, and the effects of therapeutic interventions on this family system. The output of the model was oscillatory in nature. The timing of these oscillations of the parents anger and the father's guilt matched the sequence of emotions actually observed by the clinical team when dealing with this family. The modeler, who was not in possession of all the facts, predicted a relapse of the father's behavior and a recycling of bouts of anger between parents after about six months following the termination of therapy. The therapists substantiated this prediction, giving confidence in the model.

25. Levine, R. L., M. V. Sel and B. Rubin (1985). A Model of Burnout in the Work Place. Proceedings of the 1985 International Conference of the Systems Dynamics Society. Keystone, Colorado, International System Dynamics Society: 487.

Burnout is a problem associated with work in social service organizations. It is characterized by loss of energy, negative attitudes, and decreased performance. This system dynamics model encompasses the literature on burnout and belongs to a general class of stress and motivational models which describe problems of alcoholism and sexual harassment in the work place, etc. The gap between performance and professional expectations generates physical and psychological fatigue, which decreases involvement and performance. Supervisors frequently ignore the workers' problems, but will initiate structure when quality is perceived to decrease. The gap between expectations and performance may account for burnout initially, but cannot account for maintaining burnout after expectations decrease. Learned helpless may be the mechanisms that sustains burnout.

26. Lopez, L. and R. Zuniga (2013). Burnout and Floating Goals in High-Contact Service Operations. Proceedings of the 31st International Conference of the System Dynamics Society. R. Eberlein and I. J. Martinez-Moyano. Cambridge, MA USA. System Dynamics Society.

This paper explores behavioral issues associated to the management of high- contact service operations. In this type of operations there is a tension between managerial target setting and the well-being of service agents. Target setting and monitoring to maintain overall efficiency, resource utilization, and output rate often leads to burnout and high attrition rates. This paper looks at how workloads and target performance metrics are adjusted in a service operation and explores the interaction of the mechanisms associated to the management of these goals with burnout and attrition. The paper finds that a simple linear relationship between resource utilization, burnout, and attrition is insufficient to explain observed data. The paper proposes that a feedback non- linear structure is better suited to explore those issues. The proposed feedback structure takes into account agent learning, resource utilization, human agent expectations, and target workload and performance goals. The article explores these issues in the context of a case study of a large high contact service operation

27. Lounsbury, D. and R. Levine (2010). Using Dynamics Modeling to Promote Effective Tobacco Treatment Practices in Community-Based Primary Care Settings Proceedings of the 28th International Conference of the System Dynamics Society. Seoul, Korea, System Dynamics Society.

This paper describes formative field research to develop and test the utility of a system dynamics modeling intervention intended to promote evidence-based tobacco treatment practices in community-based primary care settings. Brief counseling interventions by primary care providers have been shown to effectively promote tobacco cessation among patients who smoke, yet many physicians are inconsistent in the way they intervene with their patients. Too little time, poor training, lack of third-party reimbursement, competing clinical problems, and the belief that their patients are not able to change explain, in part, why some physicians do not adhere to evidence-based guidelines for treating tobacco use and dependence. Via a protocol for conducting on-site office visits to small primary care practices located in medically underserved urban communities, we tested the hypothesis that providers exposed to the simulation tool would demonstrate better understanding and progress towards full implementation of the US Public Health Service Guideline for Treating Tobacco Use and Dependence. Results indicate that simulated output that reflects the dynamics of providers' unique practice environment is associated with stronger behavioral intent than other forms of feedback information, such as patient chart reviews.

28. **Luna-Reyes, L. F., I. J. Martinez-Moyano, T. A. Pardo, A. M. Cresswell, D. F. Andersen and G. P. Richardson (2006). "Anatomy of a group model-building intervention: building dynamic theory from case study research." System Dynamics Review 22(4): 291-320.**

The system dynamics group at the Rockefeller College of the University at Albany has been developing techniques to create system dynamic models with groups of managers during the last 25 years. Building upon their tradition in decision conferencing, the group has developed a particular style that involves a facilitation team in which people play different roles. Throughout these years of experience, the group has also developed several "scripts" to elicit knowledge from experts based on small-groups research, and well-established practices in the development of system dynamics models. This paper constitutes a detailed documentation of a relatively small-scale modeling effort that took place in early 2001, offering a "soup to nuts" description of group model building at Albany. The paper describes in detail nine of the scripts that the group has developed, offering some reflections about their advantages and limitations. Copyright © 2006 John Wiley & Sons, Ltd.

Notes: Incorporates "trust" in the models.

29. **Pala, Ö., E. A. J. A. Rouwette and J. A. M. Vennix (2002). The Process Model of Problem-Solving Difficulty. Proceedings of the 20th International Conference of the System Dynamics Society. Palermo, Italy, The System Dynamics Society.**

Groups and organizations, or in general multi-actor decision-making groups, frequently come across complex problems in which neither the problem definition nor the interrelations of parts that make up the problem are well defined. Members of a decision-making group have disagreements on what the problem is and/or how it should be solved. The study reported in this paper represents a causal loop diagram which brings together different causes that lead the group members into disagreement. In this way features of individual and group decision-making can be integrated in a coherent framework. By analyzing the problem from a feedback point of view, we hope to clarify the self-perpetuating quality of these problems. The main feedback loops in this model were identified with the aim of pointing out key issues to keep in mind for interventions in complex problems. A small portion of this model was also quantified to show the possible creation of a sustained disagreement situation.

30. Pala, Ö. and J. A. M. Vennix (2001). Dynamics of Organizational Change. Proceedings of the 19th International Conference of the System Dynamics Society. Atlanta, Georgia, System Dynamics Society.

This paper discusses a model of organizational change as described in the punctuated equilibrium model. The model builds on two previous models in this area, i.e. the one by Frechette and Spital and the one by Sastry. After discussing shortcomings in both these models a new model is presented which is believed to be (a) a more valid representation of Tushman and Romanelli's theory of punctuated organizational change, and (b) an extension of both existing models incorporating new structure not represented so far. The paper discusses the structure of the new model and tests its validity by comparing dynamics from the model with those stated in the theory. Sensitivity analyses are conducted in order to further explore model behavior and find potential inconsistencies and areas for improvement. In a concluding section the limitations of our model are discussed and improvements for the future are proposed.

31. Pala, Ö. and J. A. M. Vennix (2003). A Causal Look at the Occurence of Biases in Strategic Change. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.

Information is important for organizations in making their decision to change. Hence, information processing is a fundamental task, which should be done effectively. However, the vast amount of available information coupled with the limited cognitive capabilities make such activities less effective than desired. To reduce mental effort required to collect and analyze information, organizations employ various biases and heuristics. Researchers, both in psychology and decision-making, point out the persistence of biases. Such literature streams, however, mostly pay attention to the occurrence of one bias at a time even though some biases are dependent on each other and occur simultaneously. The proposition of this paper is that the use of Information is important for organizations in making their decision to change. The importance of this proposition is shown with a system dynamics model by demonstrating that the isolated effects of two biases generate different results than their combined effect.

32. Park, B.-W. and J.-H. Ahn (2010). "Policy analysis for online game addiction problems." System Dynamics Review 26(2): 117-138.

With the worldwide popularity of online games, game addiction is a serious social issue. To address online game addiction problems and pursue the steady growth of the online gaming industry, we propose and evaluate two policies using a system dynamics approach: a self-regulation policy and a tax and rebate policy. Through our analysis, we demonstrate that the tax and rebate policy can be a very effective policy measure. Contrary to the concern of most game companies, by implementing the tax and rebate policy while the total revenue of the online gaming industry increases slightly, the social image of gaming improves and the number of addicted game users decreases. This clearly demonstrates that restricting excessive use of games actually benefits online game companies as well as society in general, and that the system can be more efficiently implemented by the tax and rebate policy.

33. **Radzicki, M. J. (1991). Dyadic Processes, Tempestuous Relationships, and System Dynamics. Proceedings of the 1991 International System Dynamics Conference: System Dynamics '91. Bangkok, International System Dynamics Society: 474.**

This paper describes two exercises that are useful in an introductory course in system dynamics. They are centered around two models of a couple engaged in a tempestuous relationship. Although the models are quite simple, the exercises can be used to introduce and practice a surprisingly large number of system dynamics skills.

34. **Roberts, E. B. and J. B. Homer (1982). "A Systems View of the Smoking Problem: Perspective and Limitations of the Role of Science in Decision-Making." International Journal of Bio-Medical Computing 13: 69-86.**

The complex issues and relationships surrounding the smoking problem indicate the desirability of a system dynamics computer simulation model for policy development and analysis. This paper describes an initial model-building effort, including reports of initial policy and sensitivity testing of the model. The lack of scientific research on most of the relationships and parameters required in such a model forced heavy reliance upon intuition in the model development. The sensitivity of simulated model outcomes to many of these assumptions demonstrates the need for a more concentrated multi-disciplinary research effort if forecasting and policy determination are to be carried out with confidence.

35. **Salthe, S. S. (1990). "Hierarchical non-equilibrium self-organization as the new post-cybernetic perspective." Communication & Cognition 23(2-3): 157-164.**

Natural systems are not well described by cybernetics, which is an equilibrium perspective on unchanging systems that are open only to knowable or stereotypical aspects of their environments. Natural systems are all dissipative forms, driven into existence by energy flows at the boundaries of other systems higher than them in scale. Once they succeed in emerging, they undergo a stereotypical development from immaturity to maturity, and are then recycled. During this time they traverse a series of stages described as a specification hierarchy. Open systems like this also evolve in the sense of being irreversibly marked by traces from encounters with perturbations from their environments. Cognition in such developing-evolving systems obviously cannot be well described cybernetically. The purpose of this paper will be to criticize existing cognitive simulations as being non-verisimilitudinous to natural systems.

36. **Sohn, T.-w. (1986). Motivation Dynamics: An Application of System Dynamics to Expectancy-Valence Theory, Rutgers University.**

37. **Zaini, R. M., D. E. Lyan and E. Rebentisch (2015). "Start-up research universities, high aspirations in a complex reality: a Russian start-up university case analysis using stakeholder value analysis and system dynamics modeling." Triple Helix 2(1): 1-31.**

There have been several initiatives by the governments in different parts of the world to establish world-class universities (WCUs). Such initiatives have been attempted only several times and yielded varied results. This article contributes to the existing body of research in architecting WCUs by presenting an operational strategic modeling framework that is grounded in the existing body of literature for developing WCUs (Salmi 2009) which can be used to test assumptions, reveal strategic levers, and analyze dynamic complexity inherent in a task of scaling a start-up university. We present a research study that leveraged stakeholder analysis and system dynamics modeling to architect and test a long-term strategic plan of scaling a newly created Skolkovo Institute of Science and Technology (SkolTech) in Moscow, Russia. We find that the existence of patient capital and favorable governance is conditional on university leadership's ability to effectively manage stakeholder expectations, maintain high-quality standards of its faculty and student population, and protect its brand of a world-class institution. We argue that the operational framework and findings derived from the case of SkolTech can be generalized and applied to other efforts in that area.

Notes: The model contains the variable "reputation."

Section 5 - Modeling in the Social Sciences

These references discuss modeling within system dynamics and the social sciences.

1. **Baird, J. C. and E. J. Noma (1978). Fundamentals of scaling and psychophysics. New York, Wiley.**

2. **Conte, R., R. Hegselmann and P. Terna (1997). Simulating social phenomena. Berlin ; New York, Springer.**

3. **de Sitter, U. (1974). "A System Theoretical Paradigm of Social Interaction: Toward a New Approach to Qualitative System Dynamics." Mens en Maatschappij 49(3): 260-296.**

4. **Eden, C. (1994). "Cognitive Mapping and Problem Structuring for System Dynamics Model Building." System Dynamics Review 10(2/3): 257-276.**

5. **Forrester, J. W. (1986). Lessons from System Dynamics Modeling. Proceedings of the 1986 International Conference of the System Dynamics Society: System Dynamics: On the Move. J. Aracil, J. A. D. Machuca and M. Karsky. Sevilla, Spain, International System Dynamics Society: 1.**

The power and utility of system dynamics depends on going beyond a model to implications and generalizations that can be drawn from the process of modeling. System dynamics papers too often stop with the description of a model. But to be effective, models should become part of a more persuasive communications process that interacts with people's mental models, creates new insights, and unifies knowledge. In doing so, modeling can make use of the full range of available information--the mental data base and the written data base, as well as the numerical data base. The last century has been devoted to exploring the frontier of physical science. During the next century the great frontier will be exploring the dynamic nature of social and economic systems.

Notes: Also available as Memo D-3904-1, M.I.T. System Dynamics Group

6. **Georgantzas, N. C. (1990). Cognitive Biases, Modeling and Performance: An Experimental Analysis. Proceedings of the 1990 International System Dynamics Conference: System Dynamics '90: . D. F. Anderson, G. P. Richardson and J. D. Sterman. Chestnut Hill, Mass., International System Dynamics Society: 410.**

   Producing (or constructing) strategic decision entails numerous cognitive and other bounds on human rationality, which often cause systematic errors and biases. Yet among the economic and management models used in strategic planning, few try to explain why decision makers remain so stubbornly and extravagantly irrational, ignoring logic, principle of optimization, and even postulated self-interest. One explanation may be the difficulty of extending methods used to study individual choice and decision-making behavior to dynamic group settings. This experimental analysis assessed the impact of cognitive simplification processes on the performance of 118 graduate business students who worked in a simulated strategic context. Randomly assigned to twenty-four teams, the subjects run international conglomerates with multiples actors, feedback loops, non-linearities and time lags and delays. The teams' interaction, expectations, choice and model selection produced results that systematically diverged over time. Within a crossed factorial design, these results support the hypothesis that cognitive biases interact with strategic management models to influence performance. Poor performers chose models that reinforced their cognitive limits and bounds. Conversely, good performers constructed models which helped them recognize and overcome the negative effects of cognitive simplification processes. They produced effective decisions, not by optimizing functions, but through searching for recognizable patterns when they received feedback.

7. **Gilbert, G. N. (2008). Agent-based models. Los Angeles, Sage Publications.**

   Notes: Mentions in Chapter 1 agent-based models on opinion dynamics and consumer behavior.

8. **Golüke, U. (1981). Behavioral Science and System Dynamics: The Prospect of a Symbiosis. Proceedings of the International System Dynamics Research Conference Rensselaerville, NY, International System Dynamics Society: 100.**

9. **Greenstein, T. N. (2006). How Do We Measure Concepts? Methods of family research. Thousand Oaks, Calif., Sage Publications: 51-61.**

10. **Habbema, J. D., T. J. Wilt, R. Etzioni, H. D. Nelson, C. B. Schechter, W. F. Lawrence, J. Melnikow, K. M. Kuntz, D. K. Owens and E. J. Feuer (2014). "Models in the development of clinical practice guidelines." Ann Intern Med 161(11): 812-818.**

    Clinical practice guidelines should be based on the best scientific evidence derived from systematic reviews of primary research. However, these studies often do not provide evidence needed by guideline development groups to evaluate the tradeoffs between benefits and harms. In this article, the authors identify 4 areas where models can bridge the gaps between published evidence and the information needed for guideline development applying new or updated information on disease risk, diagnostic test properties, and treatment efficacy; exploring a more complete array of alternative intervention strategies; assessing benefits and harms over a lifetime horizon; and projecting outcomes for the conditions for which the guideline is intended. The use of modeling as an approach to bridge these gaps (provided that the models are high-quality and adequately validated) is considered. Colorectal and breast cancer screening are used as examples to show the utility of models for these purposes. The authors propose that a modeling study is most useful when strong primary evidence is available to inform the model but critical gaps remain between the evidence and the questions that the guideline group must address. In these cases, model results have a place alongside the findings of systematic reviews to inform health care practice and policy.

11. **Hanneman, R. A. (1988). Computer-Assisted Theory Building: Modeling Dynamic Social Systems. Newbury Park, CA, SAGE Publications, Inc.**

12. **Hubbard, D. W. (2014). How to measure anything : finding the value of intangibles in business. Hoboken, New Jersey, John Wiley & Sons, Inc.**

13. **Kirkwood, C., W. (1998). System Dynamics Methods: A Quick Introduction. College of Business, Arizona State University.**

14. **Lane, D. C. and E. Husemann (2008). "Steering without Circe: attending to reinforcing loops in social systems." System Dynamics Review 24(1): 37-61.**

    Relating system dynamics to the broad systems movement, the key notion is that reinforcing loops deserve no less attention than balancing loops. Three specific propositions follow. First, since reinforcing loops arise in surprising places, investigations of complex systems must consider their possible existence and potential impact. Second, because the strength of reinforcing loops can be misinferred - we include an example from the field of servomechanisms - computer simulation can be essential. Be it project management, corporate growth or inventory oscillation, simulation helps to assess consequences of reinforcing loops and options for interventions. Third, in social systems the consequences of reinforcing loops are not inevitable. Examples concerning "globalization" illustrate how difficult it might be to challenge such assumptions. However, system dynamics and ideas from contemporary social theory help to show that even the most complex social systems are, in principle, subject to human influence. In conclusion, by employing these ideas, by attending to reinforcing as well as balancing loops, system dynamics work can improve the understanding of social systems and illuminate our choices when attempting to steer them.

Notes: 2007 Jay Wright Forrester Award address.

15. **Levine, R. L. (1992). Introduction to Qualitative Dynamics. Basic Approaches To General Systems, Dynamic Systems, and Cybernetics. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 1: 276-330.**

16. **Levine, R. L. and H. E. Fitzgerald (1990). Basic Approaches to General Systems, Dynamic Systems, and Cybernetics. New York, Plenum Publishing.**

17. **Levine, R. L. and H. E. Fitzgerald (1992). Analysis of Dynamic Psychological Systems: Basic Approaches to General Systems, Dynamic Systems, & Cybernetics. Cambridge, Mass. ; New York, N.Y., Perseus Publishing ; Plenum Press.**

18. **Levine, R. L. and H. E. Fitzgerald (1992). Analysis of Dynamic Psychological Systems: Methods & Applications. Cambridge, Mass., Perseus Publishing.**

19. **Levine, R. L., M. V. Sell and B. Rubin (1992). System Dynamics and the Analysis of Feedback Processes in Social and Behavioral Systems. Basic Approaches To General Systems, Dynamic Systems, and Cybernetics. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 1: 145-266.**

20. **Luna-Reyes, L. F. (2003). Model Conceptualization : A Critical Review. Proceedings of the 21st International Conference of the System Dynamics Society. R. L. Eberlein, V. G. Diker, R. S. Langer and J. I. Rowe. New York City, USA, The System Dynamics Society.**

Model Conceptualization is the most important activity in the development of a system dynamics model. Since Randers' classic paper 23 years ago, researchers in the field have worked in the development and refinement of tools and methods to improve the process. Although progress has been made, we still lack understanding of the process itself. The purpose of the paper is to review the progress in the model conceptualization area, and concludes with initial ideas for a research program.

21. **Luna-Reyes, L. F. and D. L. Andersen (2003). "Collecting and Analyzing Qualitative Data for System Dynamics : Methods and Models." System Dynamics Review 19(4): 271-296.**

22. **Martinez-Moyano, I. J. and G. P. Richardson (2013). "Best practices in system dynamics modeling." System Dynamics Review 29(2): 102-123.**

This research explores opinions about best practices in system dynamics modeling elicited from a distinguished group of experts in the field. We address three questions: What do practitioners believe is the best way to undertake system dynamics modeling? What specific core activities are essential for exemplary action during the different stages of the modeling process? What do experts believe are the most important practices during the different stages of the modeling process? The researchers used a multi-method approach involving interviews, virtual meetings using the Internet, statistical analysis of the generated data and, finally, a facilitated face-to-face meeting in which experts discussed the results of the study and their implications. The results of this research include 72 best practices grouped into six categories that reflect the stages of the system dynamics modeling process.

23. **Mclucas, A. (2000). To model or NOT to Model. International Conference on Systems Thinking in Management. 72.**

24. **McLucas, A. C. (2000). When To Use Qualitative Or Quantitative System Dynamics Techniques: Guidelines Derived From Analysis Of Recent Man-Made Catastrophes. Proceedings of the 18th International Conference of the System Dynamics Society. Bergen, Norway, System Dynamics Society: 143-144.**

    Events found by Boards of Inquiry, Royal Commissions and Inquests to have caused, or contributed to, a number of recent man-made catastrophes were analysed. The basic premise for this research was ... 'if, by studying historical events we can better equip ourselves to recognize symptoms and circumstances that were precursors to past catastrophes, we might learn to avert tragedy in the future'. Concept mapping techniques were used to analyse events and their complex interrelationships. This research not only provided valuable insights into how and why systemic failures occur, it revealed much about the nature of problems, problems comprising both detail complexity and dynamic complexity. Detail complexity describes myriad, interrelated factors or forces, just too many to be considered at any one time. Dynamic complexity describes something insidious and self-organising. The research reinforced the need to be able to identify and understand what underlies and produces spontaneous self-organisation, and the relationship between systemic structure and dynamic behaviour. The research also revealed recurring systemic structures. Except that in the catastrophes studied the sequences of events resulted in death, the precursor situations identified are strikingly similar to those characterising complex dynamic problems we face daily. Systems thinking and system dynamics modelling can help: this is widely acknowledged. Not so is when it is most appropriate to use qualitative versus quantitative techniques to aid our understanding and strategy development. This is addressed. Analysing what might have been reasonably known before each of these catastrophes occurred provided insights guiding the choice between qualitative and quantitative system dynamics techniques.

25. **McLucas, A. C. (2001). An Investigation Into the Integration of Qualitative and Quantitative Techniques for Addressing Systemic Complexity in the Context of Organisational Strategic Decision-Making, University of New South Wales.**

26. **Pelham, B. W. and H. Blanton (2007). Conducting research in psychology : measuring the weight of smoke. Australia ; Belmont, CA, Thomson Wadsworth.**

27. **Rahmandad, H. and J. Sterman (2012). "Reporting Guidelines for Simulation-based Research in Social Sciences." System Dynamics Review 28(4): 396-411.**

28. **Richardson, G. P. (1996). "Problems for the Future of System Dynamics." System Dynamics Review 12(2): 141-157.**

In this provocative article, the author sets out a personal list of "problems" that must be solved if the field of system dynamics is "...to advance beyond a craft, to approach the rigors of a science". The problems include issues in the enhancement of technical and interpretive aspects of modeling, and in the advancement and propogation of good practice. These identified problems are characterised as those that are through their difficulty, deserving of continuing attention, and at the same time are those that threaten the field if not resolved. The article carefully ends with an epilogue inviting response, rather than a conclusion.

29. **Richardson, G. P. (1999). Feedback Thought in Social Science and Systems Theory. Waltham, MA, Pegasus Communications.**

30. **Richardson, G. P. (2001). Mapping versus Modeling : THE Answer to the Debate. Proceedings of the 19th International Conference of the System Dynamics Society. Atlanta, Georgia, System Dynamics Society.**

Recent articles and listserve discussions have raised the level of argument about the relative merits and weaknesses of qualitative and quantitative modeling - "mapping" versus "modeling." The discussion traces to initiatives with causal-loop diagrams and influence diagrams at MIT and the University of Bradford in the 1970s. Because mapping is cheaper and quicker than modeling, the great hope is that one can generate and communicate real insights through mapping alone. The historical debate is whether maps by themselves are adequate to support insights about complex dynamic systems. The claim of some is that they are not, while others claim they can in some circumstances stand alone and be very helpful. With Coyle's recent paper (SDR 16,3), the argument has taken a new and striking twist: Coyle argues not only that maps by themselves can create and sustain insights useful in serious policy analysis, but that quantifying can lead to nonsense. The historical argument is turned on its head: mapping is, in some circumstances at least, more reliable, less potentially misleading, than quantitative modeling. This presentation reveals the answer to this debate. The one, great answer (!) The "answer" emerges from rephrasing the question to avoid the camps that have solidified around debating positions. There are smart people arguing with deep conviction, and great experience, on both sides of this issue. That suggests we have the question or the debating proposition ill-posed. Indeed, an investigation of the ways mapping and modeling have been used in serious consulting or policy settings suggests that the two approaches have very different purposes and generate different kinds of insights. This paper offers an analysis of these differences in an effort to clarify for the field what is really at

issue. And as we might expect, it comes down to model purpose...

Notes: Not in SDS conference proceedings.

31. **Richardson, G. P. (2006). Concept Models. Proceedings of the 24th International Conference of the System Dynamics Society. Nijmegen, The Netherlands, The System Dynamics Society: 106.**

Working with groups unfamiliar with system dynamics, modelers need a quick way to introduce the iconography of the approach and some of its framing assumptions. In the early exploratory days of group model building interventions at the University at Albany, we settled on the use of sequences of tiny models for this purpose, which we call "concept" models. 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. Previous papers have sketched in passing the notion of concept models as we have used them. Here we provide a number of illustrative examples and describe in detail the ways we use these little models, the assumptions behind them, some design principles that have matured over time as our experience has grown, and a discussion of possible problems with the approach.

32. **Richardson, G. P. (2011). "Reflections on the foundations of system dynamics." System Dynamics Review 27(3).**

Jay W. Forrester's original statement of the foundations of system dynamics emphasized four 'threads': computing technology, computer simulation, strategic decision making, and the role of feedback in complex systems. Subsequent work has expanded on these to expose the significance in the system dynamics approach of dynamic thinking, stock-and-flow thinking, operational thinking, and so on. But the foundation of systems thinking and system dynamics lies deeper than these and is often implicit or even ignored: it is the "endogenous point of view". The paper begins with historical background, clarifies the endogenous point of view, illustrates with examples, and argues that the endogenous point of view is the sine qua non of systems approaches. What expert systems teachers and practitioners have to offer their students and the world is a set of tools, habits of thought, and skills enabling the discovery and understanding of endogenous sources of complex system behavior. Copyright © 2011 System Dynamics Society.

33. **Richardson, G. P. (2013). "Concept models in group model building." System Dynamics Review 29(1): 42-55.**

Notes: Similar to paper in the 2006 SDS conference proceedings

34. **Richardson, G. P. (2014). ""Model" teaching II: Examples for the early stages." System Dynamics Review: n/a-n/a.**

35. **Richardson, G. P. (2014). ""Model" teaching." System Dynamics Review 30(1-2): 81-**

88.

36. Richardson, G. P. (2015). "" Model" teaching III: Examples for the later stages." System Dynamics Review: n/a-n/a.

37. Richardson, J. (2013). "The past is prologue: reflections on forty-plus years of system dynamics modeling practice." System Dynamics Review 29(3): 172-187.

What lessons might a body of work recognized for "Lifetime Achievements" offer to a new generation of system dynamics modelers? In what areas are future contributions of system dynamics most needed and likely to have the greatest impact? My life goals have been the design of effective public policy systems and the remediation of ineffective ones. Searching for a practice – an "engineering" or "curative" discipline that would facilitate the attainment of those goals led me to system dynamics modeling. A chronicling of three projects focusing, respectively, on global modeling, conflict–development linkages, and Singapore's improbable resilience, illustrate system dynamics modeling principles, applications, and lessons learned. China represents an important new frontier for system dynamics modeling and modelers to contribute to the survival and well-being of the human species.

38. Sterman, J. D. (2000). Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, Irwin/McGraw-Hill.

Notes: Chapters 13 (Modeling Decision Making), 14 (Formulating Nonlinear Relationships), and 15 (Modeling Human Begavior: Bounded Rationality or Rational Expectations?) are relevant to soft variables. Section 21.3.1 (Types of Data) includes an explicit discussion of soft and hard variables.

39. Trochim, W. M., D. A. Cabrera, B. Milstein, R. S. Gallagher and S. J. Leischow (2006). "Practical challenges of systems thinking and modeling in public health." Am J Public Health 96(3): 538-546.

OBJECTIVES: Awareness of and support for systems thinking and modeling in the public health field are growing, yet there are many practical challenges to implementation. We sought to identify and describe these challenges from the perspectives of practicing public health professionals. METHODS: A systems-based methodology, concept mapping, was used in a study of 133 participants from 2 systems-based public health initiatives (the Initiative for the Study and Implementation of Systems and the Syndemics Prevention Network). This method identified 100 key challenges to implementation of systems thinking and modeling in public health work. RESULTS: The project resulted in a map identifying 8 categories of challenges and the dynamic interactions among them. CONCLUSIONS: Implementation by public health professionals of the 8 simple rules we derived from the clusters in the map identified here will help to address challenges and improve the organization of systems that protect the public's health.

40. Wolstenholme, E. F. (1983). "System Dynamics: A System Methodology or a System

Modeling Technique." Dynamica 9(2): 84-90.

41. **Wolstenholme, E. F. (1985). A Methodology for Qualitative System Dynamics. Proceedings of the 1985 International System Dynamics Conference Keystone, Colorado, International System Dynamics Society. 2: 1049-1058.**

This paper is based on the premise that there is a need to formalise the procedures used in system dynamics. outside the area of computer simulation analysis, to create a stepwise procedure for systemic analysis. This need arises within the subject when applications encroach on areas where quantification is difficult or unacceptable or when a full qualified analysis is not an economic proposition or limited by time factors. The paper suggests that qualitative system dynamics should be propogated through the medium of a general framework for system enquiry. The need for general systemic methodologies is examined and the major elements of system dynamics are used to formulate the basis of such a methodology. This formulation presents a means for qualitative problem analysis in terms of the organisational structure and process control structure of systems using generally proven results developed from quantitative system dynamics models.

42. **Wolstenholme, E. F. (1998). Qualitative v. Quantitative Modelling: The Evolving Balance. Proceedings of the 16th International Conference of the System Dynamics Society Quebec '98. Quebec City, Canada, System Dynamics Society. 1: 9.**

This paper addresses the issue of what are the wise uses of qualitative mapping and what are the conditions that require formal quantitative modelling within System Dynamics. The background to the evolution of qualitative and quantitative system dynamics will be explored. This analysis will recognises that although the history of feedback thought repeatedly contains the assertion that formal, quantitative models are essential for understanding the dynamics of complex systems, the need for quantification is relative and depends on the purpose of analysis, which in turn is related to the methods used and the audience addressed. The central theme of the paper will be to examine the strengths and weaknesses of qualitative and quantitative system dynamics and to relate these to their respective tool sets. The paper will also focus on evidence from the author's extensive recent use of qualitative and quantitative system dynamics in education, training, research and consultancy studies of the way in which qualitative and quantitative system dynamics can be linked together to consolidate management learning, both in projects and in organisations. The paper concludes that both qualitative and quantitative system dynamics are important and related to the purpose of analysis. It is suggested that within studies the true power of system dynamics to address problem solving lies in a judicious blend and intertwining of both qualitative and quantitative ideas, aimed at addressing as broad an audience as possible whilst remaining sufficiently rigorous to be useful. Within organisations it is suggested that there is a need to cement together the use of qualitative system dynamics in management development and quantitative system dynamics modelling for strategic and operational learning in teams.

43. **Wolstenholme, E. F. (2004). "Using Generic System Archetypes." System Dynamics**

Review 20(4): 341-356.

This paper provides some context for my paper which won the 2004 Jay Wright Forrester award. It describes the system dynamics challenges I received from a number of people and my response to them, particularly to explore the issue of mismatch in organisations between process and boundary structure. It also describes how I have been using generic archetypes in practice since publication of the original work.

44. **Wolstenholme, E. F. and R. G. Coyle (1983). "The Development of System Dynamics as a Methodology for System Description and Qualitative Analysis." Journal of the Operational Research Society (UK) 34(7): 569-581.**

45. **Wolstenholme, E. F. and R. G. Coyle (1983). "Development of System Dynamics as a Rigorous Procedure for System Description." Journal of the Operational Research Society 34(9): 885-898.**

Section 6 - Psychological and Sociological Dynamics

These references may also be of interest in understanding the use of psychological and sociological variables in models.

1. **Adler, K. J. and R. L. Eberlein (1987). Depression, Perception and Cognition. Proceedings of the 1987 International Conference of the System Dynamics Society. Q. Wang and R. Eberlein. Shanghai, International System Dynamics Society: 1-14.**

2. **Black, L. and D. Greer (2009). You meant what? Socially constructing meaning with ongoing interactions Proceedings of the 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, System Dynamics Society.**

Begun as a consulting project to resolve disconnects within large aerospace programs, this research effort asserts that we can gain new perspectives on innovative knowledge-work through simulations that represent the causal relations suggested by George Meads foundational theory of how we create shared meaning. In Meads interactionism we find principles and assumptions that underlie comprehensive social theories of structuration and practice as well as many studies on knowledge work, cognition, sense-making, and decision-making. In earlier work, we produced a formal theory represented in a simulation model of what exacerbates and reduces disconnects among four organizations interdependent in their innovative work. Here we describe how we collected and analyzed qualitative data in which the model was grounded; identified constructs in the data and literature relevant to the presenting problem; and proceeded with model-building and analysis, particularly detailing how we traversed from rich, qualitative empirical data to themes and higher-level abstractions useful as constructs in a theoretically informed simulation model. We now carry theory-building a step further by revisiting sociological theories of meaning-creation and knowledge-construction to probe how they inform and re-form our understanding and provide new insights about managing knowledge-work.

3. **Bresson, F. (1973). "Some aspects of mathematization in psychology." Social Science Information 12(4): 51-65.**

4. **Di Stefano, J. M. (1995). From Control to Chaos: A System Dynamics Model of Interpersonal Communication. Proceedings of the 1995 International System Dynamics Conference. T. Shimada and K. Saeed. Tokyo, International System Dynamics Society. 2: 444-453.**

   The current interest in learning organizations makes clear the need for more open, more collaborative communication practices in the workplace. "To compete in today's fast moving business environment," says one corporate communication expert, "organization must create a culture of shared understanding" (Locke, 1992,245). However, a major obstacle to facilitating open communication and the generation of new ideas required in learning organizations is the inadequacy of traditional communication models. These models tend to use information for control in organizations; to see information as signals or bits separate from meaning; to see the brain as analogous to a computer; and to seek accurate transmission and replication of messages rather than creation of new information. The purpose of this paper is to show that the confluence model of negotiating differences in interpretation is better suited to understanding interpersonal communication than the traditional cybernetic and information theory models based on Wiener and Shannon and Weaver. Furthermore, it argues that information for control is an outdated model that binds us to old scripts, to replicating traditional patterns rather than creating new ones.

5. **Forrester, J. W. (1969). "A Deeper Knowledge of Social Systems." Technology Review 71(6): 2-11.**

   Notes: Also, System Dynamics Group Memo D-4076. Also cited as pp. 21-31

6. **Forrester, J. W. (1969). "Overlooked Reasons for Our Social Troubles." Fortune LXXX(7, December): 191-192.**

7. **Halpin, B. (1999). "Simulation in Sociology." American Behavioral Scientist 42(10): 1488-1508.**

8. **Hassan, J. and D. Wheat (2009). Capturing the Dynamics of a Psychiatric Illness Proceedings of the 27th International Conference of the System Dynamics Society. Albuquerque, New Mexico, System Dynamics Society.**

   The present study undertakes a partial system dynamics (SD) translation of the contemporary biological and psychological conceptualizations of panic disorder (PD). It makes explicit the dynamic processes implicit in the narrative presentations in the literature. It serves as a facilitator for the discussion about PD for it provides an easy-to-understand and illustrative language for commoners to understand, and researchers of different fields to critically examine, the biological, psychological, social and cognitive aspects of PD.

9. **Karsky, M., S. Copin and S. Pitrach (1996). The Implementation of a Large System Dynamics Model of Human Behavior. Proceedings of the 1996 International System Dynamics Conference. G. P. Richardson and J. D. Sterman. Cambridge, Massachusetts, System Dynamics Society. 1: 264-267.**

A large model describing the dynamics the dynamics of human motivation is currently being implemented as a Learning Environment. This implementation and the corresponding use of the model by young mangers of future managers generated interest but also problems. Some of he reactions to this novel approach are described in this paper.

10. **Levine, R. L. (1992). Introduction to Qualitative Dynamics. Basic Approaches To General Systems, Dynamic Systems, and Cybernetics. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 1: 276-330.**

11. **Levine, R. L. and H. E. Fitzgerald (1990). Basic Approaches to General Systems, Dynamic Systems, and Cybernetics. New York, Plenum Publishing.**

12. **Levine, R. L. and H. E. Fitzgerald (1992). Analysis of Dynamic Psychological Systems: Basic Approaches to General Systems, Dynamic Systems, & Cybernetics. Cambridge, Mass. ; New York, N.Y., Perseus Publishing ; Plenum Press.**

13. **Levine, R. L., M. V. Sell and B. Rubin (1992). System Dynamics and the Analysis of Feedback Processes in Social and Behavioral Systems. Basic Approaches To General Systems, Dynamic Systems, and Cybernetics. R. L. Levine and H. Fitzgerald. New York, Plenum Press. 1: 145-266.**

14. **Repenning, N. P. (2003). "Selling System Dynamics to (Other) Social Scientists." System Dynamics Review 19(4): 303-327.**

    In the last decade I have tried to use system dynamics to do research that is acceptable to scholars from other social science communities. In this paper I reflect upon this experience and outline several errors that reduced the accessibility of my work to those outside the system dynamics community. While some of these mistakes are likely unique to me, others are more common to research that uses system dynamics. Acknowledging these errors has several implications for the future organization of the field.

    Notes: Recipient of the 2003 Jay Wright Forrester Award

15. **Sprott, J. C. (2004). "Dynamical models of love." Nonlinear Dynamics Psychol Life Sci 8(3): 303-314.**

    Following a suggestion of Strogatz, this paper examines a sequence of dynamical models involving coupled ordinary differential equations describing the time-variation of the love or

hate displayed by individuals in a romantic relationship. The models start with a linear system of two individuals and advance to love triangles and finally to include the effect of nonlinearities, which are shown to produce chaos.

16. **Sushil and B. John (1990). System Dynamics Modeling of Group Behaviour: A Conceptual Framework. Proceedings of the 1990 International System Dynamics Conference: System Dynamics '90. D. F. Anderson, G. P. Richardson and J. D. Sterman. Chestnut Hill, Mass., International System Dynamics Society: 1117.**

    This paper attempts to highlight how system dynamics methodology is useful in modeling and testing the dynamics involved in group interaction process to explain its behavior over time. Out of the prominent group models, Gladstein's model of groups in context is taken as reference model. The SD model of group structure which is a system component consists of six modules; roles, goal clarity, specific work norms, task control, size and formal leadership. This paper deals in detail, the module of formal leadership, and studies how the interrelations and interdependence influence the system behavior.

17. **Wolpert, A. (1992). Application of System Dynamics to the Study of a Religious Experience. Proceedings of the 1992 International System Dynamics Conference J. A. M. Vennix, J. Faber, W. J. Scheper and C. A. T. Takkenberg. Utrecht, the Netherlands, The System Dynamics Society: 837-846.**

    This paper informs the scientific and religious communities about a breakthrough in the study of religion: System Dynamics is being used to model and simulate the experience of a mystic during the time when he traversed the dramatic road to mystical union. The paper briefly presents how his modelling task is being approached and some of the key insights being made by focusing on the dynamics of the important dark night of the soul phase which preceeds mystical union. This gives a synopsis of the essence of my book manuscript, A Meditation of Mystical Union.