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Plenary Session Papers

Mistakes Made During the First Years Teaching Students and Teachers to Create System Models

Diana M. Fisher
Franklin High School
5405 SE Woodward St.
Portland, OR
97206 USA

In a conversation with Dr. Jay Forrester, at the 1994 International System Dynamics Conference in Sterling, Scotland, the topic turned to how one could teach others to create models. Dr. Forrester felt it would be helpful for people to know the sequence of experiences, learning from the mistakes of a novice, while it was still fresh in the mind of the novice. At the time it was difficult to think of committing to paper a list of all the (more significant) mistakes made in such an experiment. But, as a promise was made at that time, this paper is an attempt to fulfill Dr. Forrester's request.

There are always mistakes committed when experimenting with new ideas, especially in an untested arena. Such was the case in two high schools in Portland, Oregon in the early 1990s when an attempt was made to teach high school students and teachers to create system models. The errors involved the type and sequencing of experiences used for instruction as well as mistakes made in anticipating acceptance by certain groups of students and teachers. With the help of some gifted teachers, over the past seven years, this experiment has expanded to many other pre-college classrooms, System Dynamics Magnet designations for the two original high schools, and workshops (stemming from the NSF CC-STADUS and CC-SUSTAIN Project grants) developed to train many high school and middle school teachers.

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Strategy Modeling for Top Management: Integrating "Silos Of Expertise" at Bell Canada

Alan K. Graham
Pugh-Roberts Associates
41 Wm. Linskey Way
Cambridge, MA, USA
GrahamAK@aol.com

Robert J. Walker
Bell Canada
105 Hotel de Ville,
Hull, Quebec, Canada

In 1997, Bell Canada faced two of the most significant challenges in its 117 year history. Beginning 1998, Bell would lose the last of its regulated monopolies, facing competition everywhere. Simultaneously, the global "sea change" in telecom technology accelerated. But Bell's internal organization and experience revolved around functional "silos," with little infrastructure for high-level cross-functional strategizing.

To prepare for these challenges, we implemented a large-scale simulation model of Bell and its business environment. After 4 months, when the Canadian regulatory authority defined "the new world order,"the model was ready to evaluate the strategic options. After 12 months, we had evaluated initiatives for a variety of stakeholders throughout the company.

The modeling context at Bell differed sharply from the situation more commonly described in the system dynamics literature, which involves participative modeling by midlevel managers on operational issues, seeking policy insights rather than high-leverage policy recommendations. So we constructed, validated, and used the model quite differently as well. The differences included:

1. Fast start. Bell needed a comprehensive model very quickly. So we started from a generic industry-wide telecom model, and used a small team of mostly modelers to customize it quickly.
2. Frequent delivery of results. To ensure that we could get results whenever executive schedules created an opportunity, we maintained 2 and even 3 parallel model development efforts.
3. Non-dynamic validation and buy-in. Executives validate in their own way, sometimes completely backwards from how modelers would. We used several non-traditional approaches to send executives the signals for "this is good work" to which they're accustomed.
4. Pull toward dynamically minor issues. In a regulated monopoly, there is a strong tradition of focus on single-silo, operational issues. Yet the model generally found few potential gains there. We still struggle to focus attention and resources on the high-leverage issues, which are generally cross-functional and have no executive owner.

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Design of Simulators to Enhance Learning: Examples from a Health Care Microworld

Gary B. Hirsch
Consultant
Creator of Learning Environments

C. Sherry Immediato
President
Heaven and Earth, Inc.

Thoughtful design of management simulators can help make them more effective learning environments and allow them to match a range of needs and learning styles. The authors illustrate these principles by drawing on their work in developing a "Microworld" learning environment for people in health care. The Microworld was designed to:

- provide insight on specific policy issues facing people in health care,
- increase capacity for thinking strategically and systemically in general, and
- help people learn to appreciate other points of view and have productive conversations.

Design features they will speak about include:

1. having a modular design with multiple entry points, topics, levels of detail, and different sized "bites" since various groups (Board vs. middle managers) will have different amounts of time, interests, etc. Modules build on each other by allowing learners to focus on one set of issues (health care delivery or health improvement) before combining both.
2. use of "preconfigured strategies" that introduce learners to the simulator and help them understand implications of different approaches before crafting their own strategies
3. encouraging people to discuss and set objectives before plunging into strategy development and then providing feedback relative to these objectives during simulations.
4. having multiple levels of information on results screens that get people to "drill down" and understand why strategies produced particular results.
5. supporting an iterative process of strategy development by making it easy to use strategies as basis for new strategies with incremental improvements.
6. distilling the model's causal structure to help users understand results (e.g., providing an overview screen with buttons leading to graphs that let learners follow causal links)
7. making archetypal structures embedded in the model explicit and providing ancillary materials to help learners apply these archetypes to their own "real world".
8. encouraging people to test strategies for robustness by giving them input screens for changing scenarios and key assumptions.

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Macro- and Micro-Modeling of Field Service Dynamics

Jack Homer
Homer Consulting
Voorhees, New Jersey 08043
JackBHomer@compuserve.com

Manufacturers of high-tech capital equipment typically offer their customers after-sales support in the form of repairs and preventive maintenance, as well as bug fixes and upgrades. These services require a field engineering workforce which tends to grow with the installed base of customer-owned equipment, but whose growth is also affected by other variables, such as equipment reliability and workforce experience. The company's ability to match field service capacity to demand affects customer satisfaction, and thus, future demand for its products and services.

A system dynamics model to investigate field service issues was developed for a major producer of diagnostic equipment for semiconductor manufacturing. This strategic model is broad in scope and treats variables in an aggregate and deterministic way that is typical for such models. This approach is adequate in most respects, but begs the key question of how service readiness (the adequacy of the workforce to handle service job volume and variety) is affected by the cross-training of workers on multiple product types. As a result, it proved useful to supplement the strategic "macro" model with a "micro" model that focuses on the daily queueing and assignment of service jobs. The micro model specifies the product-by-product skill levels of individual field engineers in a local service area and includes an optimization algorithm for job assignment. The micro model provides accurate information on expected service performance as a function of workload and extent of cross-training. This information is used for calibrating the strategic model and may also be used for making tactical manpower decisions at the local level.

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Impact of Individual Knowledge on the Increase of Sustainable Intellectual Capital of Organizations - A Systemic Approach

Ulli Koening
Mannheim University

Annabel Membrillo
The Strategic Decision Simulation Group

The old question about how individual knowledge affects company knowledge and how this affects company performance, has been considered from different points of view. We believe that system dynamics offers a richer approach for understanding this complex relationship than other methods because of its ability to incorporate soft variables into this type of analysis. This is especially true for companies whose main assets are intangible, such as business consulting. We base this paper on an internal project about a consulting firm.

The objective of this model was to gain deeper insight into the interaction between two structures, individual learning and the development of intellectual capital within the organizations, emphasizing how the first one leverages the second. The model includes several internal and external influences on the process of individual and organizational learning.

The main objective was to answer two questions: 1. "How do the individual abilities influence the creation of organizational knowledge?" and 2."How could the decision makers try to optimize the internal processes?".

The four sections of this paper include the background, the modeling process overview, how these two structures interact and our findings.

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Explaining Capacity Overshoot and Price Wars: Misperceptions of Feedback in Competitive Growth Markets

Paul A. Langley
McKinsey & Company
1 Jermyn Street
London SW1Y 4UH UK
Julius Thomsens Plads 10
DK-1925 Frederiksberg C,
Denmark

Mark Paich

John D. Sterman
MIT Sloan School of Management

Companies consistently get into trouble in rapid growth markets. Specifically, they grow too fast, overshoot when the market saturates, then get into price wars and suffer huge losses due to low prices and excess capacity.

The companies that grow most aggressively sometimes lose biggest, contrary to the new conventional wisdom that you have to be the biggest to benefit from increasing returns and scale effects, etc. How can the prevalence and persistence of this dynamic be explained? Is it just bad luck or is there something systematic going on, and if so, how can firms do better? To understand these issues further, we designed an experiment involving over 270 subjects (MBA and short course Executives). Subjects played the role of a management team for one player in a simulated duopoly market structure, with a rapidly growing demand for the new product and with an unknown market saturation volume and timing from product launch and an unknown replacement market volume. Subjects had to make quarterly capacity, pricing and marketing spend decisions over a simulated ten year period and performance was measured by cumulative net income over this period.

The results showed that subjects systematically made pricing decisions that were not only far from the "optimal" price, but were often in the opposite direction from the optimal change. Subject performance was very poor, compared to a benchmark performance computed using simple behavioral decision rules for the pricing and capacity decisions. Subjects did not substantially modify their policies under different market structures or different competitor strategies. Neither did they modify their policies over trials - little learning took place.

Furthermore, the poor performance is explained in terms of potential flaws in the subjects' mental models - their "misperceptions of feedback". Finally, the implications for improved senior management strategies in new product markets are discussed.

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Learning to Manage Growth: Lessons From a Management Game

James M. Lyneis
Senior Vice President
Pugh-Roberts Associates
41 William Linskey Way
Cambridge, MA 02142
Jim.Lyneis@PA-Consulting.com

Now that the downsizing of corporate America has nearly played itself out, there is a renewed emphasis on growth. But managing growth successfully is very difficult. Not only does it require identifying and managing the growth drivers (investments and other positive feedback loops), it also requires identifying and managing the growth constraints (bottlenecks, resource shortages, and competitive responses that manifest themselves in negative feedback loops). In a world of limited resources, where and when to invest for growth can often be a hit or miss proposition. How can we teach managers to better manage these dynamics?

This paper describes a management game which focuses on growth in a high-tech development and manufacturing business. Drawing on the results of hundreds of "plays" by management teams and business students, it develops key pitfalls and generic lessons, including:

* mistaking forecasts for reality
* failing to account for experience and skill dilution
* difficulties in maintaining functional balance
* failing to account for competitive responses
* failing to account for delays

The paper describes how teams learned these lessons during the course of the game and the debrief, and what policies distinguished the successful teams from the unsuccessful.

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The Use of System Dynamics Models In Forecasting:
A Case Study of the Commercial Jet Aircraft Industry

James M. Lyneis
Senior Vice President
Pugh-Roberts Associates
41 William Linskey Way
Cambridge, MA 02142
Jim.Lyneis@PA-Consulting.com

Forecasts of demand, revenues, profits, and other performance measures are a common input to managing a business. And while we intellectually appreciate the difficulties with forecasts, the use of assumptions about the future is inevitable and necessary. Since the forecasts that come from system dynamics models are likely to be better than those from other approaches, especially in the mid-term, we must educate our clients to make proper use them.

System dynamics models can be used to generate forecasts, and to assure that they are used properly in planning and decision-making, in several ways:

* to determine what buffers and contingencies are required to deal with forecast inaccuracies (e.g., inventories);
* as a means of scenario-based planning;
* to determine the direction and magnitude of policy changes and decisions; and
* as a part of an on-going learning system, in which discrepancies between the forecast and actual results leads to a review of model assumptions and structure.

This paper discusses the proper use of forecasts from system dynamics models, and illustrates that use with examples from a model of the commercial jet aircraft industry. It shows how the model was used to identify important structural changes in the industry (leasing companies as owner-operators of aircraft), to avoid unnecessary capacity expansion, and to identify strategies to best "bridge" a business downturn.

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Our Ten Years of Work on Transparent Box Business Simulation

José Antonio Domínguez Machuca, Jose Carlos Ruiz del Castillo,
Miguel Angel Domingo Carrillo, Maria del Mar González Zamora
G.I.D.E.A.O. (Grupo de Investigación en Dirección de Empresa Asistida por Ordenador)
Universidad de Sevilla
Facultad de Ciencias Económicas y Empresariales
Dpto. de Economía Financiera y Dirección de Operaciones
Avda. Ramón y Cajal, 1
41018 Sevilla
jmachuca@cica.es

Traditional business games are of the so-called black-box type (BBBS=Black box business simulator); that means that the internal structure which generates the results of the simulation after decision-making is not known. As a result, the player normally operates by trial and error and bases his decisions on the symptoms of the problem (the observed behaviours of the system's variables) and not on the real causes of the problem (the system's structure).

Since 1988 José A.D. Machuca has insisted that the business games based on System Dynamics models should be *Transparent-box business simulators* (TBBSs). That means that, during the game, the user has access to the structure of the underlying model and is able to relate it to the observed behaviours. The *hypothesis* is that such *transparency would facilitate causal reflection and favour systemic learning* of business problems.

In 1990, the G.I.D.E.A.O. Research Group took action on this idea and centered one of its lines of research on this matter with three main objectives:

* Creation of TBBSs.
* Introduction of TBBSs in Undergraduate and Graduate Management Courses as well as in Executive Training.
* Experimentation in controlled environments in order to test the hypothesis mentioned in the above paragraph.

This line of research has been and is being sponsored within different complementary frameworks: regional (Junta de Andalucia (Government of Southern Spain) as well as private and public companies), national (CICYT (Interministerial Commission of Science and Technology)) and European (COMETT and Leonardo Projects). Now, ten years after the birth of the idea, we would like to share the results obtained during that period. The results have been carefully validated by different statistical tests.

With the same design approach we are now working on a **Competitive multifunctional TBBS** which increases realism and adds the possibility of *distance learning*. We hope that the prototype of this simulator will be finished by July 98.

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Technology: A Crucial Success Factor in Manufacturing?
Some Insights from the Research Project: World Class Manufacturing

Frank H. Maier
Visiting Scholar from the University of Mannheim at Massachusetts Institute of Technology,
Sloan School of Management, System Dynamics Group, 30 Memorial Drive, E60 365, Cambridge, MA 02142, USA,
fmaier@mit.edu
Home address: Industrieseminar der Universität Mannheim, D-68131 Mannheim, Germany,
fmaier@is.bwl.uni-mannheim.de

Continuous technological change is often cited as a prerequisite for competitiveness and survivability of companies and whole economies alike. Although technology influences all activities in a company’s value chain, technology particularly affects a company’s competitiveness in the area of manufacturing. This paper falls within the scope of the international research project “World Class Manufacturing“. The project’s aims are to investigate the critical success factors in manufacturing, mainly on the basis of statistical analysis. A large subset of the project, and the main focus of this paper, is the field of technology. In a first step, the collected data are used to test hypotheses, about the effect of technology on several measures of performance. This part shows the typical approach of empirical analysis. However, this statistical analysis is insufficient to investigate the highly dynamic area of technology, and to show and explain the influences of technology on competitiveness. Therefore, in the second step some basic feedback structures of a System Dynamics model are presented. This structure is verified on the basis of data collected within the empirical survey. The model then can be used to investigate whether there are specific conditions under which technology strategies lead to a competitive advantage or are condemned to failure from the start. Additionally, it will be shown how system dynamics based modeling and empirical research can complement each other and aid the process of theory building.

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Using Games to Teach SD Principles Quickly

Dennis Meadows
Director, Institute for Policy and Social Science Research
University of New Hampshire
Thompson Hall #301
Durham, NH 03824
meadows@unh.edu
http://www.unh.edu/ipssr/index.html

We know how to teach mastery of SD to someone in a two-year, full time graduate program. But what can one really convey in a short workshop? Over the past 5 years I have been working to design and test a 3-4 day workshop on systems thinking, sustainable development, and team work. The workshop has been tested in 13 countries. Using very simple games, videos, and group assignments I am learning which concepts can be taught in 3-4 days and how to do it most efficiently.

The emphasis of my work has been on sustainable development, which is one mode of growth against a limit. Collapse is another. In this session I will show how a sequence of simple games has been used to build up a fairly sophisticated understanding of the dynamics of growth against a limit. I will indicate the strengths and the limitations of games as an educational tool. Included in the presentation will be a description of Group Juggle, a game I developed that provides more system dynamics insights in 15 minutes than the Beer Game does in 60-90 minutes. The session will involve all the audience, directly or vicariously, in a number simple games.

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Setting Public Policy Using System Dynamics and Causal Loop Diagramming:
A Case Study from a Competitive Public Electric Utility

Patrick Parker-Roach Senior Partner
PBT, Inc.
Consulting Member, Society of Organizational Learning
pparker-roach@PBT-Inc.com

Nagah Ramadan Commissioner of Cleveland Public Power

Our presentation describes work which we accomplished in redesigning Cleveland Public Power, a City-owned, competitive electric utility. In two years time, we managed to move CPP from a junk bond status to one of the highest ratings given by Moody's on Wall Street.

As part of the effort, we used a system dynamics approach to help understand the complexities facing a City-owned utility, struggling in a bitter competitive battle for its survival, with the uncertainty of deregulation looming on the horizon. Our paper has two distinct, but highly interrelated components.

The first component describes the techniques which one of us (Parker-Roach) used in guiding a diverse group of individuals (managers, design engineers, customer service representatives, service technicians, etc.) through a series of meetings and exercises which uncovered critical system variables and their interactions relative to CPP's competitive, city government environment. These understandings resulted in a preliminary 25 variable Causal Loop Diagram. The approach in generating the diagram was, for the most part, team-based, thorough and fast. The techniques for guiding groups of people unfamiliar with system dynamics concepts through the construction of a quality CLD should be of interest to other practitioners.

The second half of our presentation is by Nagah Ramadan, then Commissioner of Cleveland Public Power. In his talk, Nagah explains how he took the CLD and used it to formalize his strategy thinking for the utility and communicate it inside and outside (Mayor, Wall Street, etc.) the utility. He then generalized it into a policy model for competitive public institutions. His talk will cover the nature of the model and insights gained from experience.

A paper describing the overall two year reinvention effort of CPP will soon be published in Pegasus Communication's Innovations in Management Series. Formal descriptions of Nagah's public policy insights from the effort are documented in working papers in his Doctorate in International Business Management program at Case Western University.

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K-12/Collegiate Collaborations in Systems Education: The Powers in the Feedbacks

P. Jeffrey Potash
Waters Center for System Dynamics
Trinity College of Vermont
208 Colchester Ave.
Burlington, VT 05401
wat-cent@charity.trinityvt.edu

John Heinbokel
Waters Center for System Dynamics
Trinity College of Vermont
208 Colchester Ave.
Burlington, VT 05401
wat-cent@charity.trinityvt.edu

Will Costello
Champlain Valley Union High School
Hinesburg, VT

What traditionally passes as "collaboration" in education can more accurately be described, in systems terms, as a one-way flow of "answers." In this model, experts from the college or university bestow the "truth" upon a captive audience of k-12 educators. Each level in the educational system, however, has particular strengths and balancing shortcomings. Ignoring those complementary strengths leads to the repetitive cycles of educational fads, where innovations that match good theory with weak implementation seem to alternate regularly with wonderful pedagogy lacking fundamental content. If innovations which represent lasting improvements are to be made, then all the strengths of the various educational levels must be brought to bear in true collaboration. This requires not one-way flows of wisdom but feedback systems where the experiences of all the participants are accorded respect and the means to influence the development of the system.

Much of our progress at the Waters Center has come from consciously recognizing the developmental steps needed to move most people (students and faculty) toward an ability to creatively and productively utilize System Dynamics tools to meet their educational needs. Our early 'blitz" training programs, where we expected a quick training in model building would provide teachers with the necessary tools to transform their classrooms, are illustrative of an earlier mindset. For a few who might be characterized as "educational pioneers," that training is enough; for most, it skips too many steps in the developmental process.

We now base our training efforts and classroom applications on a recognition that people most naturally and comfortably develop high level system dynamics skills through a developmental progression. This paper proposes a model for understanding how people learn and utilize systems thinking. Critical elements include: 1) provision of "introductory" models which address "real world" issues, are easily manipulated within limits, and incorporate visual explanation for how each system works; 2) modeling products and exercises emphasizing the power and transferability of generic models while developing the essential mechanical skills for creating and extending models; and 3) major curricular innovation in the field of interdisciplinary education showing how insight from one discipline can effectively be used to inform another.

True, successful collaboration is a rich system of feedbacks. The theories, conjectures, and experiences of many players provide a means for designing and testing innovative approaches and for recognizing what truly is beneficial and what is not. It can be a slow and messy process, but it represents a powerful "learning curve" that will minimize the danger of System Dynamics being relegated to a status of "yesterday's fad."

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Resource Dependence in Product Development Improvement Efforts

Nelson Repenning
Robert N. Noyce Career Development Assistant Professor
Operations Management/System Dynamics Group
30 Wadsworth St, E53-339
Cambridge, MA 02139
nelsonr@mit.edu

Managers and scholars have increasingly come to recognize the central role that design and engineering play in the overall process of delivering products to the final customer. Give their critical role, it is not surprising that design and engineering processes have increasingly become the focus of improvement and redesign efforts. In this paper one hypothesis for the difficulty of making the transition between existing and new development processes is developed in the form of a simulation model. The starting point for the analysis is the observation that in an organization in which multiple products are being developed, scarce resources must be allocated between competing projects in *different* phases of the development process. The scarcity of resource creates interdependence; the performance of a given project is not independent of the outcomes of other projects. Resource dependence among projects leads to the two main ideas presented in the paper: First, the existence of resource dependence between projects, coupled with locally rational decision making leads to an undesirable allocation of resources between competing activities, and second, this error is self-reinforcing. Strategies for mitigating these undesirable dynamics are also considered.

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Constructing Reference mode

Khalid Saeed
Social Science and Policy Studies
Worcester Polytechnic Institute
Worcester, MA 01609, USA
saeed@wpi.edu

System dynamics models represents problems not systems *per se*. Therefore, the first step in the modeling process is to define the problem. This problem definition is named reference mode in Jargon. Reference mode is based on historical information and is often described in a graphical form, although there are many misconceptions about what is a reference mode. More often than not, reference mode is perceived to consist of historical data, although historical data may only be a starting point to construct a reference mode, which is an abstract concept that must be developed very carefully from the historical data and the inferred future trends it points towards. In fact, reference mode is a fabric of trends representing a complex pattern rather than a series of historical time series. It may contain concrete variables actually existing in historical information as well as abstract variables representing missing information. I shall attempt to describe in the proposed paper the process of constructing a reference mode from historical data, illustrating it with examples.

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Analyzing the research on self-reinforcing processes in organizations: Another approach to archetypes

Anjali Sastry
University of Michigan Business School
701 Tappan Street
Ann Arbor MI USA 48109-1234
masastry@umich.edu

A wide range of existing theoretical and empirical work explains how past decisions and actions are reinforced in organizations. A summary of the key ideas in five theories in organizational studies--imprinting, learning by doing, escalation of commitment, institutional isomorphism, and diffusion--sets the context. I show that the theories offer some two-dozen alternative processes or archetypes by which history shapes organizations over time. While the language and models used in this research differ greatly from the system dynamics approach, I find that mapping specific self-reinforcing mechanisms of history dependence highlights similarities and differences between the reinforcing processes. One result is an analytic framework useful in explaining the multiple ways in which organizations can be shaped by history. Broadly speaking, history- dependent processes represent potential solutions to two sets of problems all organizations face: increasing efficiency and maintaining control. Potential outcomes fall into two general categories of history dependence: persistence within an individual, group, or organization; and convergence among people or organizations. Considering the limits to each process suggests ways in which organizations break out from under the influence of the past, while considering the role of initial conditions suggests how organizations may be path-dependent. Finally--and perhaps most importantly for a system dynamics audience--the feedback loops and related bodies of research offer a ready-made list of ideas for modelers to draw on in trying to understand dynamics of real-world organizations. The resources offered here will be useful in developing links between system dynamics and other forms of research, as well as in making work in our field (and in others) more cumulative.

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Some Thoughts at the Boundaries of Classical System Dynamics

Peter M. Senge

Two boundary profile alternatives to classical system dynamics merit attention: (1) "structuration" and related views, which suggest processes for how the structure of social systems arises and (2) how "wholism," which illuminates the "enfolded" nature of reality, the whole present in all parts.

Classical system dynamics looks at the effects of structure on behavior, the way that operating policies interact with available information and with material flows to produce observable patterns of change. But, system dynamics says little about the genesis of the operating policies. Structuration argues that people, collectively, enact underlying structures into existence through their daily practices and suggests that reflection on those practices is a key to change.

System dynamics, along with other approaches to system analysis, focus on interrelationships. Such approaches are "extensive" insofar as they extend our awareness to focus on feedback interactions beyond the normal frame of the actors in a system. By contrast, wholism looks "intensively," to discover the deep, implicate patterns that

give rise to the diversity of manifest systems. Looking in this way might help us understand, for example, why there is a surprising degree of stabilty among the set of manifest systemic structures (a possible ontological argument for "generic structures").

Structuration and wholism are common in offering two different potential explanations for how particular system structures come into being. In so doing, they potentially address questions that have often been neglected in system dynamics, like: "How do human systems can evolve?" and "What is our theory of change?"

These ideas are tentative and offered in the hope of sparking reflection and debate. Of particular interest to the author is how these complementary perspectives to classical system dynamics may lead to better understanding of system dynamics' strengths and limitations and to more effective practical application of system dynamics.

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Case Study: Comparison of Spreadsheet and System Dynamic Techniques for a Government Funding Process

J. Chris White
Program Manager
Decision Dynamics, Inc.
4600 East West Hwy., Suite 410
Bethesda, MD 20814

This paper describes the results of a study to create a preliminary system dynamics model of a typical government funding process in which normal commercial labor and market pressures do not apply. The funding process controls how the direct hourly labor rate charged by a government agency is adjusted yearly to ensure break-even operation over the long term.

The purpose of the study was to determine if the system dynamics methodology was an appropriate tool for modeling the funding process which has traditionally been modeled with spreadsheets, and to facilitate a deeper understanding of the process and its complexities. This model offers insight into how the funding process might respond in the future based on different "what-if?" assumptions.

Results for the first few years of a ten-year simulation appear to track historic data well, which helps validate the model. However, the results indicate that the process is inherently unstable over the long term due to accounting delays. The accounting techniques seem logical on paper, but instead they lead to amplifying oscillations in the direct hourly labor rate charged by the agency, as well as the agency's annual costs and revenue. In year ten, results show radically different behavior than current projections based on historic data. Because of the inherent instability, management spends a great deal of time and effort keeping the process "under control" financially through various accounting methods, yet making many decisions without sufficient information or a full understanding of their longer term effects.

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Qualitative v. Quantitative Modelling: The Evolving Balance

Eric Wolstenholme
Professor of Business Learning, Leeds Business School
Director, COGNITUS

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 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 author¹s 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 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.

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Parallel Session Papers

The Application Of Systems Thinking and System Dynamics in the Strategic Transformation of Public Enterprises

Johan Ackerman
Principal Consultant, Bastion Consulting
ISCOR Ltd
P.O. Box 192
NEWLANDS
Pretoria, South Africa
johana@hq.iscorltd.co.za

This presentation can be described as a South African case study on the successful application of systems thinking and system dynamics within the public domain of the post apartheid period. The post-apartheid era initiated the need to integrate many state and parastatal entities into a coherent public management framework. Against this framework all Government departments and enterprises had to mobilize, design and create an overall transformation program to enable the realization of a new South Africa.

The author was involved in the design and creation of the transformation programs of such government entities. This presentation is based on the experience of applying systems thinking and dynamics approaches during the execution of strategic management processes and models within these entities.

The overall systems thinking approach utilized was primarily based on the Total Systems Intervention (TSI) approach as designed by R. Flood and M. Jackson from the University of Hull, UK.

The application of systems thinking approaches, and dynamic modeling tools, in environments never exposed to such logic, caused its own contextual challenges. Getting acceptance from the decision makers for the application of software in the modeling of thinking patterns and the prioritization of issues, strategies and policies was especially difficult.

The presentation will focus on the contextual environment of the case study; the approach that was applied, the tools utilized, the challenges experienced and the lessons learned.

The audience will leave with an insight into the nature of change management in public departments as practiced at the tip of Africa.

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Measurement of Consensus & Learning and Consensus & Learning on Measurement

Henk Akkermans
Eindhoven University of Technology

Erwin van Schaik
Origin Consulting

Group Model-Building has been highly instrumental in getting client teams in effective strategic decision-making, policy making and organizational change and learning. This has been confirmed by many clients and corporate success stories. At the same time, several attempts have been made to measure these effects more objectively, to be able to distinguish real benefits from the hype.

However, most of these attempts in the past decade have been unsuccessful. Do people learn from engaging in dynamic simulations containing feedback? Sterman and Bakken et al (1992) have shown that such learning from feedback and delays is often very limited, and learning from dynamic learning environments also. Another series of efforts has been focused not on just exploring a quantified simulation model, but also on the more qualitative group-model building process in which such models are developed (Verburgh, 1995; Vennix 1990; Akkermans, 1992). And again, little cognitive results could be objectively identified: not more complex mental maps. Also, subjective assessments of the amount of learning were very positive (Akkermans and Vennix 1997). This has led to an ongoing effort to refine measurement instruments, because if one does not find an effect, this may be due both to the measurement instrument as well as to the underlying phenomenon.

So perhaps it is getting time to start considering another theory: perhaps people *really* don't learn a great deal in the narrow, cognitive sense from group-model building and perhaps the benefit really are only the *subjective* ones, the feelings/attitudes of participants. (Faber and Scheper, 1998)

This paper presents yet another set of data that illustrates the discussed discrepancy between objective and subjective measurements of in particular consensus and learning from a case study in group-model building. This case study was a group-model-building activity in the aviation industry. Two types of measurements of learning and consensus were used. A subjective pre- and posttest as well as objective measurements were taken. These measurements yielded contradictory results. The measurement methods were somewhat crude but the findings fit the pattern shown above. The paper will then go on to present another theoretical insight of what group model-building may deliver, and how such an insight better fits the data that emerge from this case and earlier ones.

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Group Model Building to Support Welfare Reform Part II: Dutchess County

Robert Allers
Commissioner, Dept. of
Social Services, Dutchess County

Robert Johnson
Office of Temporary and Disability
Assistance, New York State

David F. Andersen, Tsuey Ping Lee, George P. Richardson, John W. Rohrbaugh, Aldo A. Zagonel-Santos
Nelson A. Rockefeller College of Public Affairs and Policy
University at Albany, State University of New York
300 Milne Hall, Albany, NY 12222 - USA

Increasingly, approaches to Systems Thinking are coming to rely on the practice of building a System Dynamics model directly with a group of managers, as a means to accelerate the teams' learning, and to align their mental-models. Researchers at the University at Albany, building on two decades of experience with decision conferences, are currently using Group Model Building to support the implementation of Welfare Reform in New York state. This paper continues the efforts to document how group model building takes place at Albany. It is a follow-up to last year's report presented in Istanbul.(1)

The product of this work is a 600-equation model elicited from groups of county managers responsible for implementing federal and state mandates regarding welfare reform. We will briefly present the structure of the model, some policy runs, and comment on their implications. Preliminary results suggest that the group model building (GMB) method is a valuable tool to overcome the complexity involved in the welfare system, to focus group discussions, and to provide an adequate setting for promoting interorganizational relationships (IORs) among the public and private agents involved in delivering social services.

This work is continuing. A management flight simulator interface is under development for the model. The model is regularly refined based upon on-going discussions with the management teams. Also, here at the Rockefeller College, three doctoral dissertations are underway based upon this work: (i) exploring the GMB method in terms of buiding IORs; (ii) investigating the financing of welfare reform; and (iii) on interface development, gaming, and learning environments.

(1) Rogers et. al. "Group Model Building to Support Welfare Reform in Cortland County." In the Proceedings of the 15th International System Dynamics Conference. Istanbul, Turkey: 1997.

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A System Dynamics Model to Analysing Population Risk in Case of a Voluntary Vaccination Program against Meningococcal Meningitis

Yolanda Álvarez Castaño, Martín Caicoya, Rafael María García Rodríguez , Begoña González-Busto
bbusto@hp845.econo.uniovi.es

Meningococcal meningitis outbreak is a complicated public health problem. Control measures include prompt treatment of cases, vaccination and contacts chemoprophylaxis. The treatment of an index case cuts the spread of bacteria, the treatment of contacts avoids the disease in those that might be infected and cuts the spread of the disease by carriers and the vaccination lowers the risk of disease. Vaccination has a limited value because it does not protect children under two years, only confers partial immunity against certain serogroups, the duration of immunity is short, it does not provide herd immunity and revaccination has conflicting results. When the incidence is high, mass inmunizaton is recommended. If the incidence is not high, in some situation where public pressure is high, an offer of voluntary vaccination has been done. We hypothesise that in this situation the risk of nonvaccinate might be increased. In effect, those that decide to be vaccinated will have the same risks and benefits than those that did so under massive vaccination. However, those that decide no to vaccinate might be an increased risk. This is so because vaccination has avoided the disease in those that would have become cases if no vaccination; but it does not avoid their infection: they will be spreading virulent bacteria, and as no treatment is imposed to cut their infection, they would do so as long as it lasts the natural history of this situation. Those contacts that are vaccinated are at low risk but non-vaccinated contacts are at high risk because they are not to benefit from chemoprophylaxis and they might be exposed for longer periods of times to the aborted index case. In this sense, a simulation model is built in order to analyse the hypothesis related to higher risks for those not vaccinated in case of a voluntary vaccination offer.

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Managing Skilled-Employee Productivity in Cyclical Markets

Edward G. Anderson Jr.
Asst. Professor
University of Texas at Austin
Dept. of Management
CBA 4.202
Austin, TX 78712
edanderson@mail.utexas.edu

Cyclicality is a well-known phenomenon in market economies. Less appreciated, however, are the implications of cyclicality on the long-term productivity of skilled employees. The aerospace industry is one such industry notorious for the intensity of the business cycles it faces. Adjusting capacity levels to match orders in this industry is hampered by the interaction of this volatility with the significant time required to train production employees. This forces firms to dynamically balance the cost of excess employees against almost-certain capacity shortfalls. This paper uses a system dynamics/control theory approach to develop a model which captures these effects and to design a robust and efficient employee management policy for machine tool firms. Analytic measures for equipment order volatility, employee volatility, and workforce shortfalls are also developed. Finally, a numerical example is provided to illustrate the efficacy of this approach under various levels of consumer demand volatility.

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Managing Software Implementers in the Information Services Industry:
An Example of the Impact of Market Growth on Knowledge Worker Productivity and Quality.

Edward G. Anderson Jr.
Asst. Professor
University of Texas at Austin
Dept. of Management
CBA 4.202
Austin, TX 78712
edanderson@mail.utexas.edu

Consultancy firms which customize "enterprise management systems" such as SAP or PeopleSoft for Fortune 500 customers have experienced both explosive growth and increasing headaches. Part of these problems may stem from the general inexperience of the consultants with the intricacies of each particular software package. To combat this inexperience, the consultancies have begun to develop knowledge bases which record their employees' combined experience for future use. This paper uses system dynamics/control theory techniques to model this productivity problem. The novelty of this formulation lies in accounting for both tacit knowledge resulting from the experience of individual knowledge workers PLUS the firm's aggregate learning curve resulting from knowledge database development.

Using both simulation and analytic techniques, a robust policy is developed to cope with this problem, an instance of managing knowledge workers under continuous demand growth. The paper will then examine some of the implications of this model for a typical consultancy. In particular, the paper will show that under many real-world operating conditions, the interaction of knowledge workers and market growth can drive firms to deliver lower levels of service at a higher cost. Finally, the paper puts this research into a framework with the experience-curve and technology supply-chain literature to outline possible directions for future research.

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Modelling Product Development Processes: A System Dynamics Approach

Bernhard Angerhofer Ddembe Williams Michael Kennedy
Information Management and Modelling Group
School of Computing, Information Systems and Mathematics
South Bank University
Borough Road, LONDON SE1 OAA
b-angerhofer@sbu.ac.uk; williadw@sbu.ac.uk

This paper describes the System Dynamics (SD) approach used and experiences gained while modelling a new products development process. The empirical study was carried out in collaboration with a leading international semiconductor company over a period of three months.

The aim of this project was to explore the potential of dynamic simulation to allow managers to test different policies in order to improve product development cycle-time and the overall time to market.

As global competition increases, corporate organisations have to find new ways to ensure quality and at the same time increase productivity while improving cost/time effectiveness of new products development processes.

Group interview techniques were used to capture and document the basic structure of the new products development process in order to facilitate the understanding and hence improvement of such processes through modelling.

The resulting SD model was validated using existing process data, thus allowing us to test different policies in order to achieve the company's strategic aim of decreasing time to market.

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A Phenomenon of RETARDED CATASTROPHE - Examples in Environmental Pollution and in Economic Crises - A System Dynamics Model and its Qualitative Analysis

Javier Aracil	***Michel Karsky***	***Bernard Paulre***
Etsii, Sevilla, Spain	Kbs, Paris, France	University Of Paris I, Paris, France

This paper has three parts :

1 - A System Dynamics model of environmental pollution, with some unexpected and surprising simulation results.

2 - A mathematical "Qualitative Analysis" of the model.

3 - Similar results in the field of economics.

A rather simple three population model can show a catastrophe-type behavior at quite unexpected moments. Such behavior can be explained mathematically and, in some cases, have been experienced in practice.

Beyond the conclusion that such behavior is always possible for certain class of systems, comes the idea that one should not always look for a direct cause of experienced catastrophes, but also search for hidden, long forgotten structural causes.

It is also shown that some very minute changes in the behavior of one protagonist of a system can completely perturb, at a much later time, even after the disappearance of that same protagonist, the behavior of the remaining system.

The validity of such behavior is shown mathematically by means of a Qualitative Analysis, after which a second example of such Retarded Catastrophe is shown in the area of Economics.

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Dynamic Analysis of the Effects of Alternative Policies on the University Entrance Bottleneck in Turkey

Andac Arikan
New York University, Stern School of Business
44 West 4th Street, Room 7-150 New York, NY 10012-1126
aarikan@stern.nyu.edu
aa329@is8.nyu.edu

Yaman Barlas
Bogazici University, Department of Industrial Engineering
Bebek, Istanbul TURKEY 80815
ybarlas@boun.edu.tr

The study focuses on the imbalance between the limited university capacities and the huge demand for higher education in Turkey and aims to analyze the future consequences of the current two-step university elimination/placement system. A system dynamics simulation model of the university entrance dynamics was

constructed in order to analyze the causes of the bottleneck and test alternative strategies proposed by policy makers. The demand pressure created by retrying candidates (i.e. the candidates who take the entrance exams more than once) was addressed. The model is a macro level representation of the university entrance process that starts with ÖSS (the screening exam) applications and ends with placement after ÖYS (the placement exam). All major high school types, university types and branches were included in the model. The structure of the model had to be developed at a macro level, so as to create "group behavior" similar to the real system's aggregate behavior, without having to model the exam performance of each individual (over a million of them). The results generated by the model after the standard verification and validation test were very much alike the real data indicating the increasing demand pressure of "retrying" candidates on fresh secondary school graduates. Various widely-discussed policies about the problem were tested using the model. While individual application of these policies proved to be ineffective, simultaneous application of several policies yielded some noticeable results. A combination of channeling students from vocational and general high schools to 2-year vocational colleges, forbidding the retrying of already admitted/enrolled students and increasing the 2-year vocational college capacities resulted in important improvements.

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Formalization of the Biological-Productive Process of a Typical Agricultural Exploitation in Castilla-León

M.R. Arranz, J.J. Garcillán, M.P. Pérez and M.D. Soto
Facultad de Ciencias Económicas y Empresariales (Universidad de Valladolid)
Avda. Valle Esgueva, 6, 47011 Valladolid, SPAIN
juanjo@esgueva.eco.uva.es

In this work we develop the Forrester diagram associated with the biological-productive process of a representative agricultural exploitation from the Spanish region of Castilla-León full devoted to barley cultivation in dry land. The work factor is contributed by one sole qualified person who has a concrete machinery, buys seed for the sowing and sells the product after the harvest. He plans the sow in two different moments. If the weather conditions are favorable, half of the earthly is sowed in the autumn and, always, the rest in the winter.

Five dependent sequential stages by year are considered in the process, from the sowing until the harvest. We suppose a random behavior of the weather conditions in the formalization, that is adjusted to the real data observed in previous years. The effect of the weather conditions over the cultivation in each one of the stages is valued. For this, we have taken as reference the data on rain and temperatures given for the "Centro Meteorológico Territorial de Castilla-León", the statistics of the productions in the zone in the last years, and the opinion from experts. The results in each stage affect to the following stages. The final production will be resulted of the evolution of the cultivation in the different phases.

The results are simulated departing of different initial conditions of technology (available machinery, type of seed, fertilizer, quality of the land, etc.), and compared with real available data in order to determine the consistency of the modelization.

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The Virginia Timber Dynamics Learning Environment

Samuel H. Austin
State Forest Hydrologist,
Virginia Department of Forestry
P.O. Box 3758
Charlottesville, Virginia, 22903

A system dynamics model is presented that identifies causal links, dynamics, and environmental effects associated with timber harvesting in Virginia from 1940 through 2020. The “Virginia Timber Dynamics Learning Environment on CD-ROM” identifies the impacts of accelerating rates of forest clearcutting and information delays associated with forest inventory methods on land use policy, stream water quality, stream water quantity, forest type, forest distribution, timber supply, timber availability, and wood processing capacity. Indices identifying available habitat for key wildlife species are also included. Harvesting rates from 1940 through 1997 are accurately predicted. The companion paper, *The Long Term Dynamics of Timber Supply in Virginia*, describes trends in timber supply, timber availability, and wood processing capacity identified by the model, and the projected, sometimes counter-intuitive, future consequences of several management alternatives.

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A System Dynamics Model of Group Productivity Factors on Generative TaskPerformance

Diana Azevedo-Carns
Computing & Information Technology
University of Massachusetts Dartmouth
285 Old Westport Road, North Dartmouth, MA USA 02747-2300
dcarns@umassd.edu

Increasing applications of group modeling and team learning have heightened the need for understanding interrelated causal factors in group task performance. While there is considerable research from several fields, there is little common theoretical basis for the variables studied or methods used. What is missing from the literature is a multi-disciplinary theoretical framework for investigating how key variables and feedback mechanisms are dynamically interrelated in terms of specific performance tasks.

This research builds on previous research (Azevedo-Carns, 1996) presented at ISDC '97 on enhancing generative task performance. The current research presents a System Dynamics model based on a synthesis of selected research from Social Psychology, Management Science, Group Performance Support Systems, and Communications theory. Although there are many specific tasks involved in group modeling or interaction, they can be considered in two broad categories: a) generative tasks for generating new information, alternatives, or plans and b) evaluative tasks (Vennix, 1996). Generative tasks are the primary focus of the present model.

This research goes beyond the simple question driving a majority of early research in group performance literature: Which perform better, groups or individuals? Instead, it asks the question: Under what conditions will certain types of interaction and related variables enhance specific task performance? Research findings may be of practical value to managers seeking to improve group performance on generative tasks using groupware or computer-mediated tools.

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A Role for Response Surface Based Optimization in System Dynamics Studies

Reid Bailey, Bert Bras and Janet K. Allen
Systems Realization Laboratory
G.W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, GA 30332 USA
gt4986e@prism.gatech.edu, bert.bras@me.gatech.edu, janet.allen@me.gatech.edu

Traditional system dynamics studies rely heavily upon heuristics and experience. Notwithstanding, mathematical optimization techniques have been introduced as important elements for a successful study. Different views abound regarding the relevance of qualitative heuristics compared to mathematically rigorous optimization tools. We argue that the role of optimization in system dynamics studies is not to replace experience-based knowledge, but instead to augment, facilitate and expand the heuristic exploration of a model. Accordingly, our approach involves narrowing the design space (using response surfaces) and the subsequent direct investigation of the simulation model (using heuristics).

Response surfaces received considerable attention in optimization due to their capability to replace complex models with analytic equations, thereby increasing computational efficiency. However, doubts exist as to whether these simple equations can adequately capture a simulation model's behavior. Our approach is developed through causal loop analysis of an existing response surface concept exploration technique. We demonstrate the usefulness of response surfaces in system dynamics studies with a case study involving a high-level model of an industrial ecosystem; our intent in using response surfaces is not to replace the simulation models with analytic equations, but instead to direct attention to regions within the design space with the most desirable performance. Recommended changes to a system are based directly on the simulation model, not on response surfaces, averting the added level of approximation inherent in response surfaces. Additionally, final results are composed of ranges of values for parameters, not single, point values (allowing for added flexibility in policy setting).

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Lessons from Electric Utility Restructuring in California

Ellen Banaghan
Senior Analyst, Tabors, Caramanis, and Associates
9289 Shadow Brook Place
Granite Bay, CA 95746
ellen@tca-us.com

California is undertaking wide-spread electric utility restructuring, including the establishment of a Power Exchange to set energy prices for regulated utilities, an Independent System Operator to control the grid and schedule power for exiting utilities and new entrants, and retail customers offered direct access to alternate energy suppliers. Originally slated to go into effect January 1 of this year, the complexities and vast changes in business operation have resulted in a slip of the ambitious implementation schedule. One of the contributing factors in this delay is a lack of understanding and readiness of new market participants to operate with such vastly different underlying systems.

Studies of electric utility restructuring in the U.K. have shown that there is a volatile period of transition between traditional markets and implementation of steady-state restructured markets. During this period there are many dynamic forces in action. For example, short term prices are not in balance with long-term capital stocks of generation; companies are divesting, new players are entering markets and new alliances are forming; and policy makers are developing rules to compensate for market inefficiencies, which may lead to further market distortions.

This paper reflects upon efforts by new market participants to do business in this changing environment and the lessons that can be learned from the underlying relationships. It describes the real-life application of such characteristics to the restructuring that is going on in California and suggests strategies for participants in the marketplace. Finally, it provides guidance for both policy makers trying to smooth the transition in California, as well as those establishing new market structures in other areas."

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System Dynamics Modelling in the Australian Water Industry

John Barton
Department of Management, Monash University
Room N 7.39
PO Box 197
Caulfield East, Victoria, Australia, 3145.

This paper provides an account of the application of system dynamics to the exploration of regulatory options in the Australian water industry. The work was undertaken on behalf of the Water Services Association of Australia, the industry association of the major urban water authorities.

While the initial aim of the project was to explore the sensitivity of asset management policies to a productivity measure known as data envelopment analysis (DEA), the project was broadened to consider price regulation and to test the suitability of system dynamics as a learning framework for policy development.

A demonstration model was developed of a typical sewerage business, based around a reference mode characterised by frequent short term instability superimposed on long-term cycles of capital spending. Average factor prices (market determined), regulated sewerage service charges to customers, and inherited asset profiles were treated as exogenous and the sensitivity of levels of service and productivity to changes in these exogenous variables studied.

Simulation results indicate that the system is particularly sensitive to service charges and support the hypothesis that if service charges are reduced below critical levels, capital funding becomes highly unstable as funds are diverted to meet short term maintenance contingencies linked to the cyclic nature of inherited asset profiles. This results in quite dramatic reductions in levels of service as measured by the percentage of properties sewered. However, productivity as measured by the DEA score is little affected.

This result reinforces industry perceptions that subject to meeting service level and efficiency criteria, regulators need to ensure that the liquidity of utilities is strongly maintained.

One outcome of this work has been the development of a proposal for a regulatory regime based on measuring technical efficiency using DEA and using system dynamics modelling of individual companies to assist in setting individual price paths which reward meeting and exceeding industry determined efficiency goals. This structure overcomes the circularity associated with rate of return type regulation which keeps appearing under various guises.

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Methods Chosen to Identify Dominant Feedback Loops that Explain Software Project Cost

G.A.Bell and J.O.Jenkins
City University
School of Informatics
Northampton Square
London EC1V OHB
G.A.Bell@city.ac.uk; J.O.Jenkins@city.ac.uk

The aim of this paper is to briefly describe methods which have been selected to assist in identifying dominant feedback loops within an embedded software development process. A justification for this approach to explaining software project cost is provided. These methods are essentially outlined in a hierarchical order to address specific issues and some originate from disciplines other than software engineering. We believe that this research can be viewed as an interdisciplinary systems approach to software project cost explanation. Finally, verification and validation issues that affect the explanatory cost model are discussed.

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A Theoretical Justification for an Interdisciplinary Systems Model to Explain Project Cost

G.A.Bell and J.O.Jenkins
City University
School of Informatics
Northampton Square
London EC1V OHB
G.A.Bell@city.ac.uk; J.O.Jenkins@city.ac.uk

This paper proposes an interdisciplinary systems model to explain software project cost. We have reviewed literature from the software engineering discipline, systems dynamics discipline and systems movement to find support for our claims. We have developed a conceptual framework to explain how algorithmic cost models can be developed and applied to estimate the cost of future software projects. Furthermore, we have derived a one-dimensional scheme based on Burrell and Morgan's work to clarify the meta-theoretical assumptions that underpin cost models for software projects

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Profitability Cycles, Delay Structures and Industrial Dynamics

Peter Berends
University of Maastricht
Faculty of Economics and Business Administration
Dpt. Management Science
PB. 616
6200 MD Maastricht, The Netherlands
p.berends@mw.unimaas.nl

Capital intensive industries generally seem to suffer from profitability cycles, often leading to dramatic re-organizations and both societal and personal disasters. The scenario of increasing concentration has long been standard advice for companies in these kinds of industry. This paper proposes that up and down movements in profitability arise from the dynamic interaction between a) concentration and b) time delays between the investment decisions and actual changes in production capacity. Data from the paper producing industry show that concentration has been rising but, unfortunately, the cyclical behavior did not dampen out.

This study employs a system dynamics perspective, built on the well known 'archetypal' models as developed for example by Meadows (1970). Data of the European paper industry over de last 25 years are used to calibrate and validate the model. The results suggest that even in a situation of total concentration the delay structure of the paper industry still results in cyclical behavior and outcomes. The causes of this counter intuitive result are also discussed.

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Eroding Goals: A Look at Criminal Justice Policy

Dan Bernstein
Rockefeller College
University at Albany, State University of New York
135 Western Avenue
Albany, New York 12222
U.S.A.

Crime has been a hot political topic in the United States since the Reagan years. The presumed drift to low levels of performance by the criminal justice system, and the perceived increase in crime has made this a popular issue with American politicians. In fact reported crime has been stable or dropping since 1990. In spite of this jail populations have continued to grow.

Can the generic structure of eroding goals explain this phenomenon? Did a rising crime rate flood the system causing the system to drift to low levels of performance, and did this continue even after crime rates went down? What about changes in standards mandated by the courts, did this create a situation where scarce resources were more difficult to obtain? Was this enough of a reason to cause the apparent demise or drop in effectiveness? To what extent was the system eroded by pressures exerted from within the system? Work by Shaffer and McCold has suggested that apparent changes in performance of the system might be due to a tendency of the criminal justice system to magnify small changes in crime rates.

Was the public call for more punitiveness in the criminal justice system a reaction to the lowering of standards? Can it be shown that the system was giving less punishment for the same crimes? Did the American public respond by demanding new legislation to force a return to the what was the perceived standard?, or is the public shifting towards a more punitive response to crime?

I will explore these issues within the context of eroding goals. This structure was developed with the private sector in mind. How relevant is this structure in the multi-goal and multi-constituency government environment? Is this simple structure adequate for complicated public policy issues which have many constituencies and many objectives?

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The Business Plan as a Learning-Oriented Tool for Small/Medium Enterprises: A Business Simulation Approach

Carmine Bianchi	***Graham Winch***	***Colin Grey***
Assistant Professor	Research Professor	Research Assistant
of Business Management	in Business Analysis	Computer-aided Visioning
University of Palermo (ITALY)	University of Plymouth (UK)	University of Plymouth (UK)
bianchi@unipa.it	Graham.Winch@pbs.plym.ac.uk	CGrey50@aol.com

The philosophies and policies put in place during the early stages of a new business venture will have a lasting influence on the future growth of the firm. In recent times there has been a growing trend of small firms utilizing formal business plans, particularly in start-up and growth phases. A major reason for this phenomenon is likely to be that such documents are pre-requisite to receiving state financial grants or as part of commercial loan applications. Quite often, however, entrepreneurs have viewed writing their business plans as a bureaucratic constraint (i.e. as a duty to be fulfilled), rather than as a learning tool which may help them to be aware of the business formula that is going to be adopted within their firms. The outcome of such a mechanistic perspective is a static and non-systemic document emerging from the aggregation of disparate data that does not assist entrepreneurs in understanding the dynamic system the firm will comprise.

This paper identifies the main issues of a joint research project whose focus is on opening up to the new entrepreneur the process of developing and using a business plan as a learning tool, adopting a system dynamics perspective. This will help make their business ideas more explicit and facilitate their operationalization. Preliminary results of a first fieldwork stage are summarized in this paper, and initial conclusions suggest that there is a need to support planning/learning in this way, and from this an emerging full research program is thus identified.

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Managing Fleet Dynamics in a Car Rental Enterprise

Carmine Bianchi
Assistant Professor of
Business Management
University of Palermo (Italy)
bianchi@unipa.it

Domingo Andria
Master Phil. Candidate in System Dynamics, Bergen
Doctoral Candidate in Financial Sciences
University of Palermo (Italy)
andria@unipa.it

The goal of this paper is to demonstrate how a System Dynamics based model can support decision makers to figure out the effects that a given set of financial policies is likely to produce on key physical resources and, through them, on business performance, feeding back to financial resources availability.

The research domain is the car rental industry and the company studied is *Italy-by-car*, a sole-licensee for Italy of the American *Thrifty Car rental*. *Italy-by-car* market share is about 2%; although such a percentage might appear quite immaterial, it is significant under two main perspectives:

*the high *industry concentration* in Italy (i.e. more than 50% of market share is hold by four bigcompanies);

* the relatively small size of *Italy-by-car*, which is a family-owned enterprise ranked as the tenth firm in its industry.

During the '80s and the early '90s, the company experienced a growth behaviour in sales revenues and investments. In spite of such a growth trend, since the second half of the '90s, it suffered some financial shortages which acted as a *limit to the fleet growth*. The resulting sharp reduction in sales revenues and the concurrent rise of interest costs (due to a high "debts-to-equity" ratio) led the business owners to take into consideration the opportunity to look for external equity investors.

In order to evaluate pros and cons of different scenarios related to such a policy, a system dynamics model has been sketched, aiming at supporting - through simulation - a *business plan* drawing-up.

Modelling financial and physical processes, based on both company accounting reports and information from external sources, as well as entrepreneur's *mental database*, allowed us to relate system dynamics to the "shifting the burden" and "limits to growth" archetypes, as two main feedback loop structures.

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The application of System Dynamics to the management of a small firm?
A Case of Study of the wine industry: "Cantine Settesoli"

Enzo Bivona
Master student in System Dynamics
University of Bergen, Norway
enzo.bivona@ifi.uib.no

The purpose of this paper is to analyse a winery company, with respect to the design of a growth strategy with emphasis on sustainability. Cantine Settesoli is an Italian co-operative that produces red and white wines of different qualities. Its challenge is to increase the market share in Europe, and to penetrate markets in U.S.A and China. Unfortunately, some factors limit the growth of the company. In fact, the land that the partners assign to the production of red and white wine and the actual quality produced do not match market demand. The size of the company and the environment in which it is located may allow management to search for a product mix that better meets the market demand.

The wine sector has some characteristics that forces it to take a long range view for possible outcomes. The 15 years life time of the grape plants, the gradual improvement of quality, and the expensive marketing strategies in a very competitive environment are some of these characteristics. These characteristics call for a system dynamics approach. This paper describes a model consisting of four sectors:

1. The land sector describes how the total land available is being assigned to the production of wine.
2. The production describes the supply of raw products, their transformation and the bottling processes.
3. The market describes the effectiveness of the salesmen in obtaining new distributors so as to produce new orders.
4. The financial describes the effects of the various strategies on the company revenue.

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Milestone Timing: Improving Process in New Product Development

Laura Black
Doctoral Candidate
System Dynamics Group
Sloan School of Management, MIT
lblack@mit.edu

This paper develops a simple model of one manufacturing company's product development process and explores intervention points for increasing throughput in new products launched, focusing specifically on the timing of certain milestones and "gates" in the product development process. Developed from individual project cases as well as aggregate data, it seeks to represent trade-offs between short-term and long-term improvements in both gross throughput and quality. Policies regarding stage-gate timing, resource investment, documentation requirements, and workload balancing (at various stages of development) are tested and discussed. Building on previous system dynamics work that suggests that productivity in the product development "factory" falls off nonlinearly when capacity is exceeded, I focus on indicators that might signal when the product development organization nears its capacity throughput and discuss strategies of transition for implementing process improvements.

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Diversity Dynamics Modeling

William Bonnell
US&C Consulting Services
Eastman Kodak Company

The issue: Reaching corporate global performance expectations by building and managing a truly diverse corporation.

Building Diversity: In ten years, Kodak's work force representation in its management ranks will reflect the demographics of the global markets we serve and will be at parity in the U.S. with the availability of women and minorities. Specific and meaningful goals also will be established for all regions of the world.

Our objective is to achieve a mixture that reflects the customers that we serve and the communities in which we reside.

The Policy Committee of the company will be accountable to ensure that specific plans are developed and interim goals are established and met. Progress will be monitored on a regular basis. Achieving diversity goals will be a key measure for future management incentive plans." (Extract from Management Communications Bulletin Board)

The model purpose: To understand work force dynamics in terms of age, sex, and race under different hiring and attrition policies, and to verify that goals are reasonable, specific, and meaningful.

The approach: Develop a system dynamics model of the corporate population, looking at the company as a whole and also at individual divisions. Analyze historical data for hiring and attrition patterns. Establish initial conditions. Use the model to ensure that short-term actions result in long-term goals and that long-term goals are realistic.

The result: The model facilitates communication and provides a roadmap to track annual progress in order to reach the desired future state.

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The MIT Guided Study Program in System Dynamics: An Experiment in Distance Learning

Lucia Breierova, Leslie A. Martin, Manas Ratha, Helen Zhu with Nan Lux
System Dynamics in Education Project
MIT System Dynamics Group
lucia@mit.edu, lamartin@mit.edu, manas@mit.edu, helenzhu@mit.edu, nlux@mit.edu
http://sysdyn.mit.edu

During the summer of 1997, Professor Jay W. Forrester discussed with the System Dynamics in Education Project (SDEP) the idea of offering a tutoring class in system dynamics to a few members of the public. The tutoring,to begin that Fall, would be accomplished electronically by email, fax transmissions and web site downloads. The class content would be centered around the Road Maps series, a self study guide for learning system dynamics, which is the ongoing writing project of the SDEP.

The Guided Study Program (GSP) was announced by email to two system dynamics mailing lists and many people responded with interest. In September of 1997, about a dozen people** began this experimental program taught in English. The GSP participants for this year were from the United States, Spain, and the Netherlands. The authors of this paper were the tutors of this electronic classroom. Participants were given reading assignments from Road Maps and classic system dynamics literature each week, along with questions based on the readings. The participants sent

back their answers and then received model solutions and general individual suggestions from the tutors. As the GSP supervisor, Professor Forrester approved the assignments and solutions before they were sent to each participant.

In this paper, we will discuss the system principles covered, the system dynamics skills developed by the participants, and extra independent model-building lessons that are not included in the Road Maps series.

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Recognising The Importance Of Design Complexity in System Dynamics Projects: A Practitioner's Perspective

Roderick D Brown
MA MBA DipM
Managing Consultant
HVR Consulting Services Ltd.,
Alton, UK

David Exelby
BSc PhD MSc
Senior Consultant
HVR Consulting Services Ltd
Alton, UK

Understanding all issues relating to model development at the outset of a project is important for success in terms of timely and to budget delivery as well as analytical efficacy. This paper considers an analogy between successful new product development and successful SD model development drawing on recent research in the former and experience from consulting projects in the latter. It goes on to explore the complexities inherent in the modelling task, highlighting the importance of early stages in model development and challenging any tendency to adopt a single or universal methodology as best practice. It contends that each project will need a unique combination of resources and skills, both technical and managerial.

In noting a trend to large scale models with the proliferation of computing power, the paper considers the modeller's response comparing Ashby's "Law of Requisite Variety" which states the variety of response be equal or greater than the variety of the problem. It goes on to consider that success in modelling relies not necessarily in matching response to task but in understanding the level of actual (rather than perceived) complexity at the outset. Complexity for the modeller derives not only from the number of components and relationships in a system but also from 1) time frame; 2) Skill level of participants; 3) Number and proximity of participants; 4) organisational and national culture(s). The paper thus investigates factors that modellers might consider when embarking on a project in order to assess probability of success.

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Industrial Policy Design Based on Supply and Demand Sides Case: Indonesia's Manufacture of Products of Plastic (ISIC 356)

Andi Cakravastia and Lucia Diawati
Laboratory of Industrial System Planning and Optimization
Department of Industrial Engineering
Bandung Institute of Technology – Indonesia

The objective of this study is to develop a system dynamic model that can be used as a tool for industrial policy design. The model developed consists of eight sectors a – production sector, capital sector, labor sector, raw material sector, financial sector, house hold sector, government sector, and international trade sector which are categorized into supply and demand sides. The simulation results suggest that integration of supply and demand sides' factors into the design of industrial policy enables the industrial sector to maintain production growth. On one side, the demand side policy tends to be effective in short-term maintaining market demand. On the other side, the supply side policy is needed to strengthen the industrial capabilities to keep industrial competitiveness in the long run. Strengthening the supporting industries to ensure supply of materials to the main industry demands a serious attention from the government. Otherwise, high growth of the industry may drive high increase in import of materials that may result in negative trade balance.

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Microworlds for Training Electricity Traders

L. Camargo, , C.M. Henao, C.J. Franco, L. Bedoya, S. Montoya, R. Smith, E. Larsen, and I. Dyner
Interconexion Electrica SA, Universidad Nacional de Colombia
and University of Bologna

As liberalisation of energy markets are rapidly taking place around the globe, little time has been allowed for institutional preparation to confront the current industry conditions. The new market set-up requires that companies

undertake major structural transformation, including changes in corporate mission and operation, management culture, decision support tools and information support systems.

In this newly engineered market, with hundreds of awkward rules which are difficult to understand not only to newcomers but also to incumbent companies, the application of new management development tools may be an effective strategy. With such tools, companies will gain competitive advantage as performance will depend greatly on discovering new opportunities as well as on defending from competitors.

ISA, which aims to promote electricity markets, has decided to design training programs for electricity trading, supported by MICROWORLDS. The objective of these programmes is to prepare a new generation of executives as well as re-educating the existing ones. This papers presents the rational behind the flight simulator and the initial model specified to support such training programs.

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Using Systems Thinking Concepts To Relate Outputs To Outcomes For The New Zealand Customs Service

Robert Y. Cavana
School of Business and Public Management
Victoria University of Wellington
PO Box 600, Wellington
New Zealand
bob.cavana@vuw.ac.nz

Leslie V. Clifford
Risk Policy Manager
New Zealand Customs Service
PO Box 2218, Wellington
New Zealand

Recently a Working Group of government officials from the New Zealand Customs Service (NZCS), Treasury and State Services Commission has been engaged in a Baseline Review of Customs activities. As part of this Review, the Working Group commissioned Victoria University of Wellington, to undertake a pilot study to investigate the suitability of strategic modelling to determine the desired purchase mix for the Customs Service. Given the large number and complexity of output-outcome interactions, and the preference to capture both soft issues and hard data, it was considered that the traditional analytical techniques might be of limited use. Hence this pilot study, using the system dynamics methodology, was an exploration into the suitability of strategic modelling as an approach to examining these complex interrelationships.

The pilot study was performed on the "Search & Surveillance" Output Class, from the Purchase Agreement between the Minister of Customs and the Chief Executive of NZ Customs Service. However, the focus of the study was on the Search for Drugs. This paper summarises the work undertaken for the pilot study. This includes a qualitative analysis of a range of sector, influence and stock flow diagrams showing the interrelationships between the inputs, outputs and outcomes associated with the search activity. A brief discussion is also provided regarding the availability of relevant output and outcome data for the development of a system dynamics model and the implications of the limited amount of relevant strategic statistical work that has been previously undertaken at Customs to relate outputs to outcomes. In addition a qualitative analysis is provided of the influence diagrams related to other Customs output / outcome relationships.

Although we had intended to undertake a full pilot strategic modelling study, we found that because of the severe time constraints for the project, and the lack of suitable data and appropriate outcome measurements, we concentrated on the systems thinking (qualitative system dynamics) aspects of the project. In this respect the project was highly successful, as it has given the NZ Customs Service a "way of thinking that should enable more objective discussions between the NZCS and its Minister on purchase mix decisions". It has also provided a framework for the strategic analysis of Customs input/output/outcome relationships.

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Evolutionary Scenarios in Power Generation. Modeling Competitive Effects in the Italian Electricity Market

Massimo Chindemi(1), Sabina Manca(2), Giampiero Marcello(2), Raffaella Turatto(1), Nazareno Ventola(1)
1EniTecnologie S.p.A., Via Maritano 26, 20097 S. Donato Mil. (MI), Italy
2Eni S.p.A., P.zzle E. Mattei 1, 00144 Rome, Italy

The Italian electricity market is undergoing a process of change under the effect of three major forces: the deregulation process at EU level, the technological development in power generation with special attention to gas-fired technologies, the environmental policy at national and European level, seen in many cases as a source of business opportunity. The mutual interaction of those forces is likely to give shape to a market whose characteristics will be different from the past. How it will be different will depend on many factors, such as the degree and timing of market deregulation, the electricity demand growth rate, the trend in fossil fuel prices and the relative importance of the environmental issue. In this paper, a System Dynamics approach to the problem is presented, modeling the power generation system and showing the investment decision in generation capacity is strongly interrelated with how the electricity market evolves. A set of scenarios is therefore presented, with particular attention to the evolutionary nature of the competition between different power generation technologies.

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Dynamic Approach for the Effectiveness of Congestion Toll System

Nam-Hee Choi and Min-ki Hong
Chongju National College
Department of Computerized Public Administration
Chongju city, South Korea
drnhchoi@cjcnet.chongjunc.ac.kr

Transportation economists favorite remedy for traffic congestion is road pricing. Not only is road pricing based on sound economical principles, but also current technology it could be implemented at reasonable cost and in a flexible and sophisticated manner. But there are serious obstacles to the widespread adoption of road pricing. There are some main problems of phase-in: does really road pricing system reduce traffic demand and change behaviour of drivers to get into the central business district?

Recently a 2,000-won(about 2.5 $) congestion toll, the first of its kind in the nation, is levied on every private passenger car carrying less than three people which passes through the tunnels, which cut across the center of seoul, from nov.11, 1996. After one week into the implementation of a controversial congestion toll system, a report released by the Seoul Metropolitan Government indicated the hefty congestion toll played a role in curbing the overall number of vehicles using the tunnels 24percent far greater than the initial target of 13 percent and increasing to a relatively brisk 43kmph from the previous snail-like pace of 18 kmph. But there are growing concerns on whether the system would achieve "sustained results" in the future. About this the metropolitan report showed the average vehicle velocity in the tunnels dropped from a peak of 43kmph to 40kmph and 35kmph during the third and the fourth week. The decrease backs the fact that many commuters have resorted to their previous habit of driving their private cars to work.

Why the implementation of congestion toll system showed like this result? One of the reason about this is that the traffic demand is more income elastic than price elastic. In this paper, we make a system dynamic model for analyze the dynamic behavior and simulate long-term effectiveness of implementing of congestion toll system. The key elements of this model are traffic volume and velocity of pricing tunnel, traffic volume and velocity of non-pricing detour road, toll price, supply of public transportation, driver's income. Developing and running the congestion toll model, we find that this model demonstrates the noneffectiveness of implementing of congestion toll system longtermly as means to reduce the traffic demand.

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A Dynamic Approach to Evaluate Information System Using System Dynamics Model: A Case of Developing Waste Recycling Market

Ik Jae Chung
Department of Public Administration
Seoul National Polytechnic University
Seoul, Korea
chungij@cnsvax.albany.edu

As more organizational resources are expanded in designing and developing management information systems, it becomes increasingly important to assess the benefits actually derived from the systems. The information provided by the system is a resource available to an organization or decision-makers. Like other resources, it has cost and value. This means that the introduction of an information system should be justified on a cost-saving ground. However, it is difficult to measure the benefits of information system or to quantify the value of information. Although several approaches for evaluating information system have been suggested, they show significant difficulties in applying to complex and dynamic organizational environments. In this study, a systems approach to information evaluation is explored. A System Dynamics model is used as a laboratory setting to evaluate information system by examining the relative merits of a set of information attributes for their influences on the overall system performance. As well, the systems approach explains the behavioral changes in terms of the impact which the structure of information system have on decision-making process and system control. The System Dynamics model displays a hypothesized information feedback system and decision-making structure of waste recycling market in New York state. The information attributes of availability, accuracy, and timeliness are reviewed. The system performance is discussed with three different aspects; expansion of waste recycling rate, stability of waste recycling capacity, and efficiency of capacity utilization.

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A System Dynamics Model of Information Feedback and Activity Coordination in an Agricultural Value Chain

L. Martin Cloutier
Graduate Research Assistant
Food and Agribusiness Management Program
University of Illinois at Urbana-Champaign, USA

Steven T. Sonka
Director, National Soybean Research Laboratory
University of Illinois at Urbana-Champaign, USA

For the past decade agricultural hog production has become more downstream coordinated with the emergence of new market forms in a US pork meat market of $30 billion and prospects for growth in international demand. Hog producers, as suppliers of raw material to packers, receive economic incentives to become food ingredient suppliers and issues of conformance quality have become key to economic value creation.

The dynamic hypothesis examined in this work posits that information scarcity characterized by longer price transmission delays within a hog production and packing system results (a) in misalignment in the coordination mechanism in the short-run due to amplified oscillations, and (b) in the non-availability of resources required to enhance organizational design of function coordination in the long-run.

Developed with the input of industry participants, the hog production and packing value chain captures physical, economic and conformance feedback interactions in the execution of activities over time. The system dynamic model presented in this paper considers dynamic interactions across commodity price, component price and information feedback, presented as alternative coordination mechanisms towards system improvement. The research effort makes two important contributions. First, it focuses on endogenous information feedback at the interface between production and packing activities within a value chain. Second, the value chain subsectors receive market feedback from the business environment subsector. The business environment subsector is based on an amended and updated version of the Dynamic Commodity Model (Meadows, 1970; 1974). The paper includes detailed influence diagrams of alternative coordination mechanisms and computer-based simulation results.

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Blurring the Teacher-Student Boundaries: Teaching System Dynamic Groups

Will Costello
Champlain Valley Union High School
Hinesburg, VT

John Heinbokel
Waters Center for System Dynamics
Trinity College of Vermont
208 Colchester Ave.
Burlington, VT 05401
wat-cent@charity.trinityvt.edu

P. Jeffrey Potash
Waters Center for System Dynamics
Trinity College of Vermont
208 Colchester Ave.
Burlington, VT 05401
wat-cent@charity.trinityvt.edu

Providing conceptual, as well as technical, training in the field of system dynamics within the educational community, has proven to be a more challenging pursuit than we originally envisaged. Typically, "teachers" acquire such training in formal workshops or courses, often receiving graduate credit in recognition of their efforts. "Students" acquire their systems training in classes, focused specifically on system dynamics, computer modeling or a content area for which system dynamics is a significant exploratory tool, under the guidance of a "teacher."

We have, on four occasions, explored an alternative training scenario, in which K-12 teachers and their students were integrated into a class which worked through the training protocols in conjunction with content-area material. . Our first experience was a one week intense modeling workshop for a K-12 private school: teachers from elementary through secondary levels were joined by two students. Our second experience mixed 9 Vermont secondary teachers with 4 of their "advanced placement" students in a course that developed system dynamics as a fundamental tool in exploring the underlying course focus of exploring the impact of epidemic disease on the course of human history. Our third and fourth efforts focused (in the case of the third) on a semester long general introduction to system dynamics; each individual was responsible for applying the core lessons to his/her own educational interests and obligations and (in the case of the most recent effort) upon developing the "Structures of Revolution" course, which explores prominent political, industrial, and technological events of the last three and one half centuries from a systems perspective.

In all four cases, the mixing of "teachers" and "students" into single groups of "learners' paid significant beneficial dividends. Student enthusiasm and facility with the computer aspects of the activities were evident and infectious. Teacher maturity and significant "life experiences" were stabilizing and enriching. Perhaps most importantly, both groups, working together as equivalent "learners" began to model and experience an approach to education in which traditional school categories of "teacher" and "student" were significantly blurred; the individuals became collaborators engaged together in an educational process in which both groups had substantive contributions to make.

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The Development and Use of the Production Learning Environment Simulation at Ford Motor Company

Shelia Covert-Weiss
Ford Motor Company
scovertw@ford.com

Gregory J. Clark
Ford Motor Company
gclark@ford.com

Phil Odence
High Performance Systems, Inc.
podence@hps-inc.com

Ford Motor Company is in the midst of dramatically restructuring every element of the way it conducts business. The umbrella term for this restructuring, "Ford 2000", includes reengineering the manufacturing process. This reengineering returns Ford to it roots in lean manufacturing including standard ways of doing business, measurement, and training around the globe. Additionally, the effort has included experimentation in the application of Systems Thinking and System Dynamics to the change process in the plants.

This paper focuses on the experimentation in the application of Systems Thinking and System Dynamics to Ford's implementation of lean manufacturing. Specifically, the development and use of a System Dynamics flight simulator at Ford, as well as the basic structure of the simulator, is described. This simulator, the Production Learning Environment, is encased in a manufacturing theme and provides a practice field for teams to think about business practices and strategies. Results, mostly in story form, tell of the success of using System Dynamics in a "regular business setting."

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System Dynamic Modeling as a Central Part of Modeling Complex Societal Problems

Dorien J. DeTombe
Delft University of Technology
School of System Engineering, Policy Making and Management
P.O.Box 5015
2600 Ga Delft, The Netherlands
detombe@sepa.tudelft.nl
http://www.sepa.tudelft.nl/webstaf/detombe/index.htm

Modeling complex societal problems give the handlers of the problems the possibility to analyze the relations between the phenomena and between the actors of the problem. Modeling the problem enlarges the insight in the problem. The method Compram uses a seven layer modeling scheme that models the problem in different ways using different languages in such a way that one layer compensate the weak points of an other. In the seventh layer a simulation model of the problem is constructed. This system dynamic simulation model is the result of the insights in the problem developed by modeling the previous layers. In this way it is a central part of the modeling scheme of the method. In making this model communication tools such as interview techniques and brainstorming by groupware are used. Modeling enhances the communication about the problem. Communication is needed because these problems are handled by a group of people. Several groups of people of different fields, interests and backgrounds analyze the problem. First by experts with knowledge of the different fields of the problem, than by the different actors involved in the problem and than by a group of representatives of the groups involved. This makes it clear that there is a enormous demand for clear communication. The different models ease each in their own way the communication between the problem analyzers. The problem handling process of complex societal problems has a knowledge, power and emotional component. All these components should be handled carefully in the support of the process. The seven layer model emphasizes the knowledge component of the problem. The paper will focus on the creation and the use of the system dynamic model in relation to the handling of complex societal problem.

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International Aid Projects: Help or Handicap for Domestic Development Projects?

Amadou Diallo
Professor, Ecole des Sciences de la Gestion
University of Quebec at Montreal
315 Ste Catherine E
Montreal
H3C 4R2
diallo.amadou@uqam.ca

The World Bank, the American US-AID, the Canadian CIDA, the European EDF, the German GTZ to name a few, are some of the giant structures set up throughout the developed world to help the so called developing countries in their effort to the improve the quality of life of their populations. After almost half a century of effort, few if any of these countries have succeeded to get rid of the developing status and join the developed circle.

Many reasons has been pointed out to explain such a poor result : The developed countries are developing faster, the poor countries are politically unstable, their leaders are corrupt, there are cultural obstacles, etc¼ Here we explore the possibility of a dynamic poor performance of aid and domestic development policy. This could be verified in some countries and in some sectors. System Dynamics is the best approach for uncovering potential (and real) bad surprise from well intended policies. We use it in this research as a tool for conception, illustration and communication.

A system dynamic model is built using many sources of information including: Information gathered while we were managing a CIDA project, information received while participating in the implementation of an IRDC project. Both projects are in Higher education in Guinea. Three situations are modeled : domestic project alone ; international project alone and a mix of both types of project. While the first two situations are unrealistic, we will see that a poor combination may be far more disastrous.

On the field experience and model simulation help explore many ways of making the best out of local policy and international aid in higher education in Guinea. A tentative extention of the analysis to other sectors and other countries is also presented.

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SUCH-WWW: A Web Based Dynamic Interactive Simulator For Introducing The Basic Concepts Of Supply Chain Management

Vedat G. Diker
Bogazici University
Endustri Muh. Bol.,
Bebek 80815 Istanbul,
TURKEY
diker@boun.edu.tr

Fusun Ulengin
Istanbul Tech. University

Y. Ilker Topcu
Istanbul Tech. University

This paper introduces a multi-party dynamic interactive simulator hosted on a WWW server and can be used over Internet. SUCH (Supply Chain Management Simulator) is a four-party, dynamic interactive simulator designed to be used as a management gaming platform that introduces the basic concepts of Supply Chain Management. The underlying model is based on a 'spreadsheet model' introduced by Bowersox (1986) and developed on Vensim modeling software.

The two main outcomes of the project that lies behind this paper are i) constructing a multi-party 'management flight simulator' to a wide audience virtually all around the world, thus providing a medium of interaction and collaboration among scholars and students working on issues pertaining to a certain subject area (supply chain management, in this case), and ii) providing an extensive, well-structured and easily accessible data-base for researchers that work on issues such as decision procedures, nature of dynamic decisions, cognition, etc.

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Integrating Systems Thinking/System Dynamics Into Public Policy Evaluation

Anne M. Dowling
Director, Information Services
Institute for Traffic Safety Management and Research
University at Albany
80 Wolf Road Suite 607
Albany, New York 12205

The theory and practice of good public policy analysis is a challenging task on both a conceptual and practical basis. Traditionally, analysts and evaluators have used a variety of social science research designs and techniques to evaluate public programs and policies, ranging from the descriptive approach of case studies to the more sophisticated quasi-experimental approach of time series analysis to randomized control experiments. To compensate for the limitations associated with these designs, analysts and evaluators rely on a broad range of statistical techniques, which have their own set of limitations. With a goal toward enhancing existing traditional methods for public policy analysis, this study explores a strategy of integrating traditional analytic techniques and systems thinking into public policy evaluation. The study is based on the hypothesis that systems thinking, built on the concepts of feedback and circular causality, is a conceptual tool that offers analysts and evaluators an opportunity to do what they need to do better.

The evaluation literature and our own synthetic data experiments show that despite the growing recognition among researchers and analysts of the role feedback plays in social systems, the concepts of feedback mechanisms are generally not being incorporated into the research designs assessing public policies and social programs. The goal of this research effort is to develop grounded theory about integrating systems thinking/system dynamics into public policy evaluation through the use of a test case. The test case for this study measures the impact of New York State's prompt license suspension law on recidivist drunk driving. The research method for the study follows a multi-stage process that involves the use of two panels, one that focuses on a traditional analytic thread and one that focuses on a systems

thinking thread. A third thread, a reflective thread, is used to capture both the process and the conceptual work undertaken by the two panels.

Preliminary findings suggest that the integration of systems thinking/system dynamics into public policy evaluation may need to begin at the "front end" of the research design process. The study suggests that the principles of systems thinking and the techniques of system dynamics modeling can be used to improve the development of traditional analytic research designs by generating insights on which to build theory-based hypotheses. Preliminary findings further suggest that the successful integration of the two approaches depends more on sociological factors than on technical factors. Key factors or variables that appear to affect integration include: 1) the ability of system dynamists to attain a common understanding of the problem being addressed and the levels of communication and participation among themselves, 2) the background, experience, and open mindedness of the individuals involved, irrespective of the approach they represent, and 3) the trust and respect among the individuals involved. From the "traditional" perspective, understanding the technical aspects of system dynamics modeling does not appear to be as important in integrating the two approaches as does understanding the language associated with the systems approach, especially with regard to the notions of feedback and circular causality.

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A Bachelor of Science Degree Program in System Dynamics at WPI

James K. Doyle, Matthew W. Grabowski, Amy H. Kao, Michael J. Radzicki, and Khalid Saeed
Department of Social Science and Policy Studies
Worcester Polytechnic Institute

In the Fall of 1998 Worcester Polytechnic Institute, the third oldest private college of science and engineering in the United States, will begin offering the world's first Bachelor of Science degree in system dynamics. The purpose of this paper is to describe the rationale for, and design of, this new program and to solicit feedback from the system dynamics community before the program is implemented later this year.

We believe that the creation of an undergraduate major is important for the future development of the field of system dynamics. Although system dynamics is taught at more than 200 high schools in the United States and dozens of graduate schools throughout the world, there is currently no place for interested students to study system dynamics at the college level beyond a couple of courses. This interruption in the flow of students from high school to graduate schools and careers in system dynamics is probably at least partly responsible for the current low supply of highly trained modelers (relative to demand) and the increasing tendency for companies to hire people who have had little formal SD training to do system dynamics work. This in turn reduces the average quality of system dynamics work, lowering the reputation of system dynamics and hindering the growth of the field. The proposed program is designed to bridge this gap between high school and system dynamics careers, to increase the supply of highly trained modelers, and to encourage the development of similar programs at other universities.

The program will train students in system dynamics modeling and related topics and prepare them for jobs as modelers, consultants, or policy analysts in either government or industry or for graduate work in system dynamics. The instructional format of the program will be based on Kolb's model of experiential learning and will emphasize modeling craftsmanship. Apprenticeship will be a key learning mode in the program. This apprenticeship component is made possible by WPI's unique undergraduate projects program, in which each student works closely with faculty advisors to complete 2 extended research projects, often in collaboration with industry or government at off-campus project centers.

The following program elements will be described and discussed:

1. A 4-course sequence of courses in system dynamics modeling.
2. Required courses in cognitive psychology, decision making, and group model building.
3. An 8-course sequence in mathematics and computer science.
4. Additional courses in social science and management.
5. Modeling application areas in management, public policy, infrastructure planning, etc.
6. The Major Qualifying Project, a senior-thesis research project required of all WPI students.

Plans for the marketing and future development of the program will also be discussed.

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Measuring Changes in Mental Models of Dynamic Systems: An Exploratory Study

James K. Doyle, Michael J. Radzicki, W. Scott Trees
Department of Social Science and Policy StudiesDepartment of Economics
Worcester Polytechnic InstituteSiena College
100 Institute Rd.515 Loudon Rd.
Worcester, MA 01609Loudonville, New York 12211.

Measuring change in the mental models of the participants in systems thinking and system dynamics interventions is unavoidable if the relative effectiveness of different interventions in promoting learning is to be assessed. However, existing methods for organizing, representing, eliciting, and mapping mental models are

designed primarily to facilitate change in mental models, rather than to measure change, and so new methodologies for measuring change in mental models are needed. The purpose of the present paper is to define the necessary features of any methodology that aims to rigorously measure change in mental models of dynamic systems; to describe the development and implementation of one specific new methodology designed to fulfill these criteria; and to present the results of an exploratory application of the method to a systems thinking intervention designed to change mental models of the causes of the economic long wave, or Kondratiev cycle.

Sixty-four undergraduates enrolled in an introductory social science course at Worcester Polytechnic Institute participated in the experiment. Subjects participated in a 5-day systems thinking intervention which included a single play of the Kondratiev game developed by Sterman and Meadows (1985) and an extensive debriefing session. Mental models of the causes of the economic long wave were measured by administering identical survey instruments before and after the intervention. The narrative data from these instruments were coded into cognitive maps based on Schank's (1972, 1975) conceptual dependency theory of causal relationships in natural language. Several quantitative features of these maps were then subjected to statistical analysis.

Results indicated that the intervention produced statistically reliable changes in the content and size of subjects' mental models, as well as the degree of feedback thinking that they contained. However, there was no evidence that the intervention increased either the detail complexity or dynamic complexity of subjects' mental models, and the post-test models were still extremely simplified and nonspecific compared with the expert model of the economic long wave.

The experiment demonstrated the ability of the new method to capture even subtle changes in mental models due to interventions, and it can be widely applied to answer important questions about the cognitive effects of alternate interventions. Priorities for future research include: applying the method to stronger, more realistic interventions; correlating measured changes in mental model with behavioral changes; and assessing the stability of measured changes over time.

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Modelling for Policy Support in the Colombian Electricity Market

Isaac Dyner, Ricardo Smith, Santiago Montoya, Leonardo Bodoya and Antonio Quintero
Universidad Nacional de Colombia

As competition turns vigorous in the Colombian power supply industry, companies seek to develop tools and models for policy support. In this new industry environment, similar to the British one (although primarily hydroelectric with little regulation capacity), a number of minor capital-intensive opportunities have emerged, including gas-based and micro hydropower stations.

As revenues forecasting exhibits greater uncertainties, because of system restrictions and plant dispatch merit order criteria, companies need close evaluation of investment and trading strategies. This paper describes in broad terms a System Dynamics based model especially developed for assessing company policies in the Colombian electricity market. Typical simulation results are exhibited.

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Modelling to Assess Policies on Gas Penetration in the Colombian Energy Sector

Isaac Dyner, Ricardo Smith, Yris Olaya, Antonio Quintero and Santiago Arango
Universidad Nacional de Colombia

As the Colombian gas industry rapidly captures a larger share of the energy market, it is difficult to assess the extent of its effect both within the gas sector as in connection with its substitutes. For years politicians and experts have argued in favour of an extensive gas plan for Colombia, yet little has been done in terms of valuing negative impacts. Gas benefits have been partly evaluated as a substitute in the household and commerce sectors for cooking and water heating as well as in the power supply industry for electricity generation - in this sense progress has been made.

However little is known in relation to its availability (reserves and transport) and use for large scale urban transport (taxis and buses). Many questions still remain unanswered, such as supply reliability, market penetration and environmental impacts. This papers exhibits a model as support tool to address some of these questions, particularly with respect to the sustainability and discovery issues. Results are exhibited.

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An Adaptive Telecommunications Network Microworld Simulator
Comprising an SD Customer Behavioural Model Linked with Non-SD Network Simulators

Derek J. Edwards
British Telecommunications plc
Building B81 140, BT Laboratories,
Martlesham Heath,
Ipswich, Suffolk, IP5 7RE
United Kingdom

This short paper discusses the interactive linking of two competing telecommunications network (technology) simulators together with a System Dynamics model of customer behaviour. The whole forms a "complete" competitive microworld which can be examined and manipulated in a variety of ways.

Typically System Dynamics models of this type are self-contained, are the principal focus of attention and require users to apply various hypotheses. Similarly, the network simulators were designed for manual manipulation of call loadings and network failures in order to observe probable consequences and the required improvement to adaptation algorithms.

Key to this work is an intermediary application which has been developed to process and pass data between the models as well as control various aspects of the overall simulation. This also enables long time-frame (many months) cumulative simulations to take place, whilst each of the models can have short sample times (hours, seconds, milliseconds).

Data from the network simulators comprises call performance data which is processed and passed automatically to the SD customer model. This influences customer migration from one network to the other. Related call patterns are then synthesised and passed automatically to the network simulators, completing the loop. Various results can be displayed and data collected as the simulation progresses. This enables post processing of the data using the same environment or other applications for visualisation and statistical analysis.

Early results indicate that the combination of interacting simulation models can provide very useful insights into the overall problem area and can also accelerate the analysis process.

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Bayern Online: A whole State Goes Online!

Jörn W. Ewaldt, Peter Maybaum
Brandenburg Technical University of Cottbus
Department of Mechanical, Electrical and Industrial Engineering
03013 Cottbus / Germany
j.ewaldt@tu-cottbus.de, maybaum@tu-cottbus.de
http://www.wiwi.tu-cottbus.de/controlling

To gain advantages in the competition of locations a high-developed and high efficient technology is necessary. This paper examines how a governmental investment program can speed up the corresponding diffusion process to increase the access and use of such a technology - the Internet. An overview of the underlaying system dynamics model is presented. The simulation is based on a real case - the initiative "Bayern Online", in which the Bavarian Government invests several hundred millions of Deutsch Marks with different focuses. The final analysis extracts some critical factors on the way to realize such advantages.

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A Feedback-Rich Climate-Economy Model

Thomas S. Fiddaman
Ventana Systems
Tom@Vensim.com

More than 20 energy-economy models have been developed to address different climate policy questions. While these integrated models are quite varied, most draw heavily on the energy-economy models of the 70s and 80s, which were motivated by energy security issues and explored the potential impacts of increasing energy prices on economic growth. They typically employ exogenous rates of technological improvement and backstop energy prices. Factor allocation is optimal. The impact of a carbon tax on the energy system at a given time can often be reduced to an instantaneous tradeoff between abatement costs and emissions.

System dynamics models of energy-economy interactions focus instead on disequilibrium dynamics and feedback complexity, with behavioral decision rules and explicit stocks and flows of capital, labor, and money. This research uses elements of earlier system dynamics work to create a model that tests the implications of feedback processes that have not been explored in the climate change context. Among these are endogenous technological change

and boundedly rational decision making. Energy requirements are embodied in capital, and energy production capacity depends on explicit capital stocks. The search for optimal policies is decoupled from other decisions, and uses intertemporally fair criteria.

Experiments with the model indicate that depletion of oil and gas resources has critical interactions with climate policy. The inclusion of learning-by-doing and other path-dependent mechanisms suggests that abatement efforts will be more effective and should be more stringent than models with exogenous technology forecasts indicate. Inclusion of delays and biases from structural and behavioral features of the energy system reveals higher long-run emissions reduction potential but imposes substantial constraints that prevent rapid reductions. Fair discounting and consideration of intangible damages substantially raise the indicated abatement effort.

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A Set Of Lessons for Teaching a First Course in System Dynamics Modeling to High School Students

Diana M. Fisher
Franklin High School
5405 SE Woodward St.
Portland, OR
97206 USA

Since 1992, a System Dynamics Modeling Course has been taught at Franklin High School in Portland, Oregon, to high school students. In the early years, the course was offered only to upper level students (those who were currently taking second year algebra or a higher level math course). This past year the course was open to any student, including freshmen (ages 13-14) who had completed first year algebra with a grade above average (A or B). Most of the freshmen students are doing exceptionally well in the course.

Over the past six years a sequence of exercises for a full year course for high school students has been developed. The exercises draw upon materials designed by Fisher, Guthrie, Gallaher, Piper, and Hamilton and are adapted for use specifically by students in the 12 to 19 age group. The materials have been tested extensively at Franklin High School by three different modeling teachers and are now being made available to other interested persons. There is a student book of lessons and a teacher's book with suggested answers along with a disk containing the models for the lessons. The hope is that these two books will stimulate others to generate additional published materials for the middle school and high school level. Without published materials significant progress cannot be made in establishing a "systems study" foothold in a large number of pre-college schools.

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A Behavioral Approach to Feedback Loop Dominance Analysis

David N. Ford
Associate Professor, System Dynamics Program
Department of Information Science
University of Bergen
5020 Bergen
Norway

Feedback loop dominance is a critical tool in explaining how structure drives behavior. Current analytic tools for loop dominance analysis are tacit, not codified, unable to accurately identify dominant loops or inapplicable to most models. Most loop dominance analysis tools focus on model structure to link structure and behavior. We use a behavioral perspective to define dominance, improve descriptions of behavior patterns and identify two important and incompletely developed areas of feedback analysis: simultaneous dominance by multiple loops and shadow loop structures. An analytic procedure is presented, illustrated and compared to an alternative analysis method. An evaluation of the behavioral approach is the basis for identifying new issues and future research opportunities.

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Operationalising the Resource-Based View of the Firm

David N. Ford
University of Bergen

Laurent A. Mahieu
Telenor Research & Development
Telenor FoU, Postboks 6701 St. Olavs plass,0130 Oslo (Norway)
laurent.mahieu@s.fou.telenor.no

Over the last decade academics and practitioners have grown increasingly dissatisfied with traditional strategic management tools as a framework for creating and sustaining competitive advantage. One response has been the development of the Resource-Based View (RBV) of the firm into a general theory. According to the RBV the firms which perform better are those that hold valuable assets with certain characteristics. Researchers often mention, but have rarely addressed questions related to the operationalisation of the RBV. Operationalisation means a formalisation of the theory's ideas and concepts into applicable models, facilitating all stages of strategy formulation and decision making processes. One cause of the failure to operationalise the RBV is its high level of abstraction.

We initially describe prerequisites for operationalisation and demonstrate the need for RBV operationalisation. This becomes the basis for determining the content and domain of validity of resource-based operative models and an original method for operationalising RBV.

The application of this method is illustrated with the example of an incumbent network operator's strategy design when facing national market liberalisation. We emphasise the resource selection process based on insights revealed by the resource-based framework. We use our simulation model to explain resource accumulation dynamic and the consequences of different policies. Model behaviours show that classic incumbent responses to market liberalisation are ineffective because the incumbent resources management policy design includes mis-perceptions of resource accumulation processes that feed back onto the operator productivity. This in turns decreases the ability to compete against more agile entrants.

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System Dynamics as a Strategy for Learning to Learn

David N. Ford
Associate Professor, System Dynamics Program
Department of Information Science
University of Bergen
5020 Bergen
Norway

Many problems faced by managers today have no specific or exact solutions orspecific or exact procedures for finding those solutions and are too complex for complete understanding by any single expert. To sucessfully address these problems managers require the ability to develop new knowledge about specific complex systems. Policy development in which managers must learn how different policy levers impact system behavior prior to designing a successful policy is an example of a problem which requires managers to develop new knowledge. Traditional educational approaches focus on teaching facts and problem solving procedures but not on how to learn about complex issues and systems. Successful education for these managers must include helping them learn how to learn.

Learning to learn is difficult because it is more abstract than learning facts or procedures, is harder to verify whether it is occurring and therefore facilitate, is more dependent on conditions which support learning such as safe learning spaces and because goals and questions are often unclear. We use a simple iterative model of learning as a foundation for using system dynamics to teach students how to learn. The successful implementation of our strategy requires that students develop competence in four fundamental learning activities and the ability to manage an iterative learning process. We describe specific system dynamics tools used to develop each learning activity and the apprenticeship model used to develop student's ability to manage iterative learning. Specific barriers to learning to learn are identified and methods for overcoming these barriers described.

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Eruption, Impact, and Marine Regression: A Dynamic Model of the End-Cretaceous Mass Extinctions

Tom Lum Forest
tforest@cordada.com

The diversity of life on Earth has generally increased since its inception over 3 billion years ago. But there have been a handful of abrupt reversals in that time. The best known reversal, or mass extinction, occurred 65 million

years ago at the end of the Cretaceous period at a point called by paleontologists the K/T boundary. Several causal chains have been cited over the years. Currently, the most popular ultimate causes among paleontologists are:

Volcanic eruptions in India -- the Deccan traps -- causing extended darkness, cooling, and wildfire.

Bolide impact in the Yucatan, also causing extended darkness, cooling, and wildfire but in a much shorter time.

Sea level changes, with attendant changes in habitats and the distribution of land & water surfaces.

This paper examines the geography of Late Cretaceous Earth, the factors responsible for its biodiversity potential, and how continental topology affected that diversity. The response of biodiversity to slow and rapid changes in energy availability, sea level, and continental distribution are simulated, individually and in combination.

The author draws primarily from J. David Archibald, Dinosaur Extinction and the End of an Era -- What the Fossils Say, 1996. This paper also builds on the research I presented at ISDC '97 in a paper entitled "Sustaining Life: The Origin, Diversity, and Extinction of Species?. It differs from that work by focusing on the K/T boundary, 65 million years ago, and by more closely examining through simulation the plausibility of competing scenarios of extinctions at that time.

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The Perilous Frontier: East Asian Cultural Ecology and Two Millennia of Chinese Dynastic Succession

Tom Lum Forest
tforest@cordada.com

The majority of Chinese have lived within a unitary state for most of the last 2,000 years. Yet those states have been ruled by a number of dynasties diverse in origin, strength, and policies. There have been native dynasties, frontier dynasties, and even a nomadic (Mongol) dynasty. Throughout most of Chinese history, there have been distinct entities in the Yellow & Yangtze River valleys; the Northeast (Manchuria); and the steppes (Mongolia). Despite the advent of firearms and sophisticated artillery in the 18th century, this cycle continues today.

The author examines the characteristics of Han China, Manchuria, and the steppes as they relate to this succession of rulers: their economic wealth, their military power, and their internal strength. It also examines the characteristic appeasement policies of the Han and the confrontational policies of the Northeastern dynasties with respect to the peoples of the steppes, and how they affected their position with respect to each other. The unique conquest of Han China and the Northeast by the steppes under the Mongols is considered

This paper draws primarily from Thomas Barfield (The Perilous Frontier, p. x), who applies "anthropological models of tribal and state development to the available historical data on the tribes who bordered China's northern frontier." This paper also builds on the research the author presented at ISDC '95 in a paper entitled "Sustainable Civilization: Cohesion, Capacity, and External Contacts," and ISDC '97 titled "Byzantine, Bulgarian, and Ottoman: The Dynamics of Empire at the Crossroads of Europe and Asia." It differs from those previous works in that it discusses a different geographical setting (China, Manchuria, and Mongolia), and that it treats in detail the different policies of confrontation vs. cooperation of Han and Manchu dynasties towards the nomad states.

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System Dynamics, Alternative Futures, and Scenario Planning

Jay Forrest
The Strategic Decision Simulation Group (SDSG, L.L.C.)
11606 Highgrove Drive
Houston, Texas 77077
jayf@sdsg.com
http://www.sdsg.com

System dynamics models are typically built around perceptions of the past and key assumptions about the future. Alternative structures and assumptions may be considered and explored, but typical projects focus on one model reflecting the consensus of the modeling participants. By concisely documenting the predominant paradigms of the participants, the system dynamics model serves as a powerful window for exploring alternative futures and for scenario planning.

For this context, alternative futures or scenarios does not reflect variation of model parameters (which should be considered as sensitivity analysis), but rather structural and exogenous uncertainties which impair the viability of the existing model. The exploration of alternatives generated by these uncertainties provides a powerful approach for expanding awareness and readiness for action among the participants.

Using system dynamics models for this purpose involves considering a number of factors:

- the boundaries of the model (the exogenous variables)
- the bases of the model (particularly with respect to structures and mechanisms)
- the "probable" (anticipated or implied) future on which the model is based
- the range of possible futures (and the trends and discontinuities which create deviation from the probable future)

Experience indicates that blending system dynamics with futures studies and scenario planning generates broader and deeper understanding of the system under investigation. Concepts from futures studies and scenario planning are introduced and explored to reinforce the methods and insights of this approach.

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The Creation of a Paradox: The Development of Shared Mental Models and Groupthink

Sheldon Friedman
Lally School of Management and Technology
Rensselaer at Hartford
275 Windsor St.
Hartford, CT 06120

James K. Doyle
Department of Social Science and Policy Studies
Worcester Polytechnic Institute
Worcester, MA 01609

As organizations increase the use of systems thinking and other knowledge management techniques which enable them to improve their competitive advantage, a paradox could be evolving to which little attention has thus far been paid. Namely, when management teams try to build shared visions in the workplace and instill the use of shared mental models, are they simultaneously increasing the chance of groupthink, that is, the chance of a reduction in decision quality due to in-group pressures?

This paradox came to light during a recent session with executives at a large manufacturing company, while attempting to elicit group knowledge about their system. Regardless of attempts to remove politics from the process, it seemed to continually raise its ugly head, either in the form of experts being valued more for their opinions or because status effects of one kind or another led to premature group consensus and frustration on the part of those who disagreed.

To assess this potential paradox, this paper will review the classic work on groupthink by Irving Janis as well as the latest empirical research on the topic, in order to identify the factors that are known to promote and prevent groupthink in decision making teams. Then, several established systems thinking techniques for knowledge elicitation and model building, including Interactive Planning (Ackoff), Strategic Assumption Surfacing and Testing (Mason), Soft Systems Methodology (Checkland), the Strategic Options Workshop (Eden), the Strategic Forum (Richmond), and the Group Model Building approach (Vennix), will be reviewed and their susceptibility to the promotion of groupthink examined.

Finally, recommendations will be made for improving existing techniques to decrease the likelihood of groupthink. Suggestions for empirical research to verify these recommendations will also be discussed.

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SyM Bowl: Origins and Progress Report

Edward J. Gallaher
Associate Professor
Departments of Physiology - Pharmacology and Behavioral Neuroscience
Oregon Health Sciences University
Portland, OR 97201

SyM Bowl was started in 1996 to provide high school students with an opportunity to present original System Dynamics modeling work. Teams are judged based on a written report, a morning poster presentation, and an afternoon oral presentation. Criteria included defining the problem, building and explaining the model, parameter estimation, sensitivity analysis, simulations, and conclusions. We have now conducted SyM Bowl for three consecutive years with a dramatic increase in the number of teams and the quality of the modeling projects. We look forward to additional regional SyM Bowls, and a National SyM Bowl, in the foreseeable future.

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Formalizing and Extending Existing Theories of Corporate Diversification with System Dynamics Models

Shayne Gary
London Business School
Sussex Place; Regent's Park
London NW1 4SA, United Kingdom
email: sgary@lbs.ac.uk

One of the most widely researched topics in corporate strategy over the past three decades has been diversification. Widespread global adoption of the multi-divisional corporate form (M-form) means that there are now

an abundance of diversified firms to study throughout the world, and the wide variance in performance of those firms continues to make for both a relevant and important research topic. After all these years of academic research on this topic, there are still many unanswered questions about what distinguishes successful diversification strategies from those that fail. There are four different schools of thought, or theories, regarding how diversification can lead to sustained competitive advantage:

1) Product/Market relatedness (Singh and Montgomery, 1987),
2) Dominant logic similarities (Prahalad and Bettis, 1986),
3) Administrative adaptation (Penrose, 1959), and
4) Competence transfer (Prahalad and Hamel, 1990; Markides and Williamson, 1994).

It is important to note that the first two theories listed above are fundamentally static perspectives. In contrast, the last two theories listed above are dynamic theories. Although it is becoming widely accepted that dynamic theories are more powerful and hold more promise for gaining understanding about strategy issues than their static counterparts, there have been very few attempts to formalize the dynamic theories using approaches suited to investigate dynamic problems. This paper focuses on formalizing and extending the administrative adaptation and competence transfer theories of diversification in two separate system dynamics simulation models.

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Developing a System Dynamics Model of the Health Care Industry

Peter J. Genta
President CEO
The Magellan Group
124 Mt. Auburn St. 200N.
Cambridge, MA, 02138, USA
pgenta@magellan-group.com

Madhu Nott
Manger
Arthur Anderson
One Financial Center
Boston, MA, 02110, USA
madhu@alum.mit.edu

Lindsey Gannon
Associate
The Magellan Group
PO Box 720
Hanover, NH 03755, USA
lgannon@connriver.net

The health care industry accounts for nearly 15% of the US economy, or $1 trillion. While the hospital segment is struggling to stay afloat, other segments such as HMO's and managed physician practices are growing rapidly and adding tremendous value for their shareholders. Value is no longer created by acquiring traditional assets but is created through building a network of suppliers and customers. Learn how a group at Arthur Andersen is using systems thinking to understand this fundamental change to the healthcare industry and the impact to their clients.

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The Alberta Gas Game, Having Fun with Strategy

Peter J. Genta
President CEO
The Magellan Group
124 Mt. Auburn St. 200N.
Cambridge, MA, 02138, USA
pgenta@magellan-group.com

Lynn Sveinson
Senior Advisor Business Planning
Nova Corporation
801 7th Ave. S.W.
Calgary, AB, T2P 2N6, Canada
Lynn.Sveinson@nova.pipe.ca

Malcom Turner
Sr. Business Analyst
Nova Corporation
801 7th Ave. S.W.
Calgary, AB, T2P 2N6, Canada
MalcolmTurner@nova.pipe.ca

In 1996, NOVA Gas Transmission partnered with Amoco Canada to develop a strategic model of gas supply and the pipeline system in western Canada. This project allowed both groups to gain a different perspective of the gas industry which resulted in a stronger, more robust system dynamics model. The use of subsequent versions of the model strongly influenced Nova's response to competitive threats and reinforced their choice of strategic direction. This session will tell the story of this project and explore the roles that the academics, consultants and industry play in helping to build an industry wide learning community.

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Assessing the Cost of Managed Behavioral Care

Nicholas C. Georgantzas, Matthew Sever, and Frederick Stell
Management Systems ¥ GBA
Fordham University at Lincoln Center
113 West 60th Street ¥ Suite LL617-D
New York, NY 10023-7471, USA

Assessing the role of feedback in managed care is crucial because its aggressiveness determines the financial performance of health care programs. Our policy study emphasizes the role of feedback in the case of a managed mental health and substance abuse program. This program not only reimburses for treatment, but also guides the treatment plan of each patient and determines how much treatment will be paid for. The program is funded by the flat capitation rate it receives from its members and its expenses depend on the treatment authorized. In turn, the authorized treatment depends on the aggressiveness of case management, which is relative to the severity of illness. Our system dynamics modeling process aimed at evaluating exactly how the aggressiveness of managed care affects the total cost of the program. The objective of case management is to authorize the least sessions while keeping the treatment effective.

Given that inpatient care is more expensive than outpatient care, intuitively, it seems more cost effective to case managers to move patients into outpatient care as soon as possible. When the inpatient care is cut too short, however, patients that have not had enough time to recover are re- admitted into the hospital and, consequently, the total cost of the program rises despite the intend. Our model depicts the relationships among program enrollment, case management, behavioral care treatment, and cash flow. Because case management affects all other sectors, we assess performance variables in each sector by varying the aggressiveness of managed behavioral care.

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Rezulin: Effective and Efficient Drug for Diabetes?

Nicholas C. Georgantzas, Kelley Trilling, and Yun Chou
Management Systems ¥ GBA
Fordham University at Lincoln Center
113 West 60th Street ¥ Suite LL617-D
New York, NY 10023-7471, USA

System dynamics simulation is used to assess the dynamic effects of using the new drug Rezulin for the intensive treatment of diabetes, a most prevalent disease among patients of the Veterans Integrated Service Network (VISN 3) in the New York City metropolitan area. According to the Brooklyn VA Medical Center data, one in five of its outpatient visits is associated with diabetes and approximately 10,000 of the VISN 3 veterans are diabetic. Although the effects of diabetes on the development and progression of long-term complications have been established, about 90 percent of the VISN 3 diabetic veterans do not seek treatment and thereby create a tremendous cost because of complications. These are mostly type 2 diabetes patients who prefer to defer insulin injection therapy for as long as possible because of the inconvenience, the cost, and the pain of constant blood monitoring and insulin injections. Those who seek treatment, diet, exercise, and use oral drugs or insulin therapy, generally have less costly complications but there is still a high cost associated with their treatment and, more importantly, they can also become resistant to insulin. Because Rezulin directly treats insulin resistance, and can lower the HbA1c level of patients (a clinical marker of severity of disease via a blood test), this new drug is expected to increase the life of diabetics by 1.5 times. Our model incorporates real life policy parameters and NIH statistics to assess the potential monetary benefits of switching from insulin to Rezulin oral treatment.

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A System Dynamics Based Planning Solution for Integrated Environmental Management and Policy: The IDeaMaP™ Toolbox

Roderic Gill
Leader, New England Ecological Economics Group
Centre for Water Policy Research
University of New England Armidale
NSW 2351, Australia
rgill@metz.une.edu.au

This paper is an account of the accumulated experiences and learning of a group of system dynamics/ecological economics researchers and consultants dedicated to the cause of progressing a more integrated or transdisciplinary and consultative approach to environmental policy development and resource management. It represents an account of the New England Ecological Economics Group's attempts to integrate insights from the system dynamics, learning organisation and ecological economics communities towards a unified, practical process to underpin public decision making in the environmental area. The discussion encompasses an account of the theoretical constitution of the resultant planning process as well as an account of its practical track record to date. Essentially, the Integrative Decision Making and Planning (IDeaMaP™) process combines a very basic form of conceptual mapping with system dynamics group modelling, all set within the integrated economic, ecological and sociocultural sustainability ambitions of the recent, and increasingly influential territory of ecological economics. The aim has been to create a process that is practical as well as pragmatic. It is a response to convert public sector rhetoric with regard to the need for more integrated and total sustainability orientated approaches to decision making into planning reality.

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Structural Transparency as an Element of Business Simulators

Andreas Größler
Industrieseminar der Universität Mannheim
D - 68131 Mannheim, Germany
agroe@is.bwl.uni-mannheim.de

Pre-fabricated simulation tools like business simulators for individuals or computerized planning games for groups usually offer a user friendly interface. This allows inexperienced users a fast access to the simulation since they do not have to posses specific knowledge about simulation techniques. Furthermore, a learning process can be supported by various additional material like source material, external data, or instructional information creating complete, computerized interactive learning environments. Thus, giving simulation models an easy-to-use interface increases the acceptance of the simulation tool and draws attention to it. But, in addition to that, the presence of an user interface and of additional information certainly also influences the effectiveness of a computer simulation tool to support learning.

Adding features to provide structural information about the underlying model could be a means to combine the advantages of user friendly simulators with the power of model building and analysis tools, which are supposed to give structural insight. Learners are not only able to examine the results of their decisions but the causes of these results using powerful system dynamics diagramming techniques. This introduces transparency to the former black-boxes, producing so called transparent-box business simulators.

The paper reports on an experiment evaluating the relevance and effects of structural transparency. This experimental design can also be used to examine other variations of business simulators. Some hypotheses regarding the effectiveness of transparency were tested. Results show the necessity for further research and collaboration.

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Teaching a Conventional Class (Global Studies) in an Unconventional Manner using STELLA

Scott Guthrie and Megs Patton
CC-SUSTAIN Project
1151 SW Vermont
Portland, OR 97219 USA
sguthrie@teleport.com

Recent successes in teaching students system dynamics using STELLA in our high school and interest expressed by fellow teachers in using "systems" in other classrooms has led to a "reversed" introduction to system dynamics: teaching a global studies class using STELLA as a tool to generate and focus student ideas and discussion.

This class is co-taught (with funding for the second teacher provided by the Waters Foundation) by Scott Guthrie (science) and Megs Patton (social studies), both with experience in using STELLA. The class uses STELLA as a way to get the students to "ask the better question" and get beyond a rhetorical, anecdotal, "common sense" based look at the world and see what the situation really is and what the important issues really are.

Work on the curriculum was first started in the summer, with input from Jeff Potash and John Heinbokel (at the Waters Center for System Dynamics). We decided that the most interesting ("common sense" laden) subject for the students to examine first would be "Why Revolutions Happen." After that, U.S. immigration and U.S. immigration policy would finish out the first semester.

During the second semester, the students are studying world population and its growth with an emphasis on natural resource distribution and use, distribution of wealth, pollution, land use and sustainability issues which will hopefully lead students to reflect back on the work of the first semester.

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Local Rules: The Theory, the Application and the Chances of Success.

Tim Haslett
linchpin@surf.net.au

This paper report on results for a simulation of the "local rules" used by managers in a manufacturing setting. Local rules are similar to what Forrester termed implicit decisions which are the "unavoidable result of the state of the system". The theory of local rules is developed further using the work of Kauffman and Holland on fitness landscapes.

Local rules are those rules that are repeatedly used by individuals or agents to increase the "payoff" for them in a given situation, this equates to Kauffman's "fitness peak". In this case, the payoff was to deflect senior management criticism of potential stockouts in the system. A second rule' used by individual operators to ensure that they did not run out of the parts that they used was also modelled.

The simulation model is of a Kanban, or Just-in-Time system, in a linked assembly and manufacturing system. The operation of the system and the effect of the local rules interventions are modelled, individually and separately.

The success of the managers' rule is reported and the relative failure of the operators rule is also reported. Some tentative generalizations about the effectiveness of local rules are advanced.

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The Development, Illustration, and Evaluation of a Method for AnalyzingPolicy Development in Social Systems

Sylvelin Hauge, Paal Davidsen, and Michael Spector
University of Bergen
N-5020 Bergen
Norway
Sylvelin.Hauge@ifi.uib.no

We will develop, illustrate its use, and evaluate a method for the application of synthetic data experiments to analyze policy development in social systems. We believe that policy development is affected by the discrepancies in dynamic complexity between a real world system and the mental models used to govern such a system. Policy development results in modifications of the mental models themselves through adaptations and double loop learning. The rules for adaptations and structural modifications in the form of double loop learning, that is the learning policies, are embedded in the mental models as well, and may thus be subject to an indefinite number of modifications themselves. We will, however, adopt and test a finite number of learning policies experimentally.

We have chosen to illustrate our method by using a project and a company as examples of social systems. We will evaluate our methodology be investing if it fulfills our three evaluation criteria. First, we want the method to be useful for evaluating whether or not it is important to model decision processes explicitly when policy developments in social systems are analyzed. Second, we want the method to support comparisons between actual and potential outcomes of policy development in social systems; and finally, we want the method to be general.

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The Missing Link: Incentives and Energy Deregulation in Denmark.

Christian Haxholdt
Dept. of Management Science and Statistics
Copenhagen Business School
Julius Thomsens Plads 10
DK-1925 Frederiksberg C,
Denmark

Jeanette Bodi
Dept. of Management Science and Statistics
Copenhagen Business School
Julius Thomsens Plads 10
DK-1925 Frederiksberg C,
Denmark

Erik R. Larsen
Dept. of Management

University of Bologna
Piazza Scaravilli,1
I-40126 Bologna, Italy

The Danish electricity industry has evolved a culture based on co-operation, consultation, and informality with close connections between the companies in the sector, the government and consumers. There has been consensus around issues such as demand side management, energy-environment policies, renewable energy resources and combined heat and power generation This "energy network" will now because of de-regulation in Denmark and the European Union come under pressure for dramatic changes.

In this paper we focus on how the incentives in the electricity industry need to change because of deregulation and competition. Using a system dynamics model, we explore the consequence of the current "non-profit" requirement for Danish electricity companies. We discuss and simulate what other incentive structures might be possible in the municipality and consumer owned Danish electricity industry.

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ATO Test Case Program for Tax Law Clarification - Practical SD Modelling to Prevent Budget Overrun.

Mark Heffernan
Director International System Dynamics

Bob Tomkins
First Assistant Commissioner
Tax Law Services Australian Taxation

Government departments and instrumentalities are coming under increasing public pressure and scrutiny to spend public moneys wisely and efficiently including careful consideration of long term consequences.

This is sometimes at odds with the political system, with Governments elected for limited terms and funds allocated in annual Budgets.

It is widely recognised that many policy initiatives have long gestation periods and may take years to come to final delivery. In some cases the bulk of the expenditure attributable to these programs comes with progressive delivery of high cost capital items eg defence acquisitions, in others, initial decisions may set in train a sequence of events that lead to significant expense sometime in the future. In all cases a budget overrun can bring an otherwise beneficial program into disrepute.

This paper deals with the use of a relatively simple system dynamics model to make explicit the time delays, attrition rates and ultimate costs involved in prosecuting a suitable number of Tax law test cases. The model forms the basis for limiting the initial and subsequent selection of test cases (a relatively inexpensive process) to avoid an inexorable cost blow out in the program in subsequent years due to the high cost of running these cases before courts. The model justifies the decision for an initial underspend to achieve a program of tax law clarification which is sustainable in the long term.

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Monetary Model of Entrainment between Economic Cycles

Juan Hernández-Guerra
Universidad de Las Palmas de Gran Canaria
C/Saulo Torón s/n, 35017 Las Palmas, Spain
Juanh@empresariales.ulpgc.es

Entrainment between economic cycles has been a source of modeling since the first studies of Sterman and Mosekilde (1993). This initial model has been successively extended incorporating more sectors and substitution between productive factors (Kampmann 1996). Money is an essential asset not introduced in last studies yet. This work incorporates the role of monetary factors in the multi-sector model using some classical Tobin hypotheses. The introduction of money carries on the possibility to simulate some new economic facts. The expectations hypothesis and the neutrality of money are tested in this paper, obtaining in general results according to the economic theory.

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Overcoming Organizational Resistance with System Dynamics

Jim Hines — LeapTec/Ventana
Cindy Luca — NOVA Chemicals Ltd.

Pronouncing a new policy is easy. Bridging organizational resistance, however, may be difficult. A cultural divide separated top-most corporate executives from senior operating managers at Nova Chemicals. The divide came into focus when the company appeared to resist a top-level corporate directive to manage by a new concept, cash flow cycle time (CFCT). This presentation describes how NOVA Chemicals Ltd. used a system dynamics process to understand and resolve the cultural and hierarchical issues that impeded CFCT performance improvements.

Presentation topics include (i) a discussion of how the issue was brought to light during a System Dynamics workshop focused on managing CFCT within the context of NOVA Chemical's overall business; (ii) a description of the group process used to generate a causal loop diagram of the cultural issues around CFCT as well as comments on the effectiveness of the process; (iii) an explanation of the cultural and hierarchical issues that were illuminated by the workshop; (iv) a description of how the identification of leverage points was translated into action and result.

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A Model of Educational Innovation

Gary B. Hirsch
Consultant
Creator of Learning Environments

A model of educational innovation has been developed to help school Board members, administrators, teachers, parents, students, and other community members understand the process of innovation and explore reasons why innovations often produce results other than the ones that are desired. The model was developed under the auspices of the Gordon Brown Fund, with the assistance of a group of educators who identified critical factors affecting innovation and the interactions among those factors. Impacts of innovations on students' capacity to learn, trust between the community and school, and teacher motivation and feedbacks from these variables to a school's ability to innovate are at the core of the model.

The model enables its users to consider multiple types of innovations including major changes in curriculum, teacher-initiated curriculum projects, changes in how students are evaluated, and structural changes (e.g., more flexible scheduling systems). The model can help users examine how these types of innovations interact with each others and

how some innovations create a foundation that other types of innovations require to succeed. A dynamic model such as this one also helps its users understand the hazards of moving too quickly or initiating overly ambitious innovations or, on the other hand, moving too slowly once the community's expectations have been raised.

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An SD Model to Evaluate Complex Naval Command Systems

John Holt

The aim of the project was to develop an SD approach to compare the performance of large, complex Naval command and control (C2) systems. In the high technology environment of modern warfare, warships are dependent on complex computer systems to control the weapons and sensors as well as providing support for the various operator decision making and command processes. C2 ship systems are complex. They are difficult to evaluate because of the difficulty of taking into account human decision making . Furthermore it is difficult to ass the implications of system performance over the over a wide range of scenarios.

To address these issues, a mix-methodology approach was adopted, incorporating a soft operational research method, Mission Orientated Analysis (MOA) with the SD model. MOA utilises expert judgement to assess the impact of various levels of performance on parameters of interest. SD can be used for assessing the rate of output of a system and for evaluating whether it is efficient (e.g. whether outputs are produced without undue delay). MOA can be used to address the issue of whether the output of a system will lead to a system being effective (e.g. how the output of a system will contribute to organisational goals being achieved), for example linking system reaction time and error to the goal of providing an effective naval blockade in a peacekeeping operation

A further important innovation was the modelling of human decision making in the system. This was represented by modelling processing rate and error rate for key decision making tasks.

The assessment of system effectiveness and the modelling human factors aspects described in this paper represents a significant enhancement of the capability of SD modelling in the assessment and selection of complex information systems.

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Attention Cycles of Environmental Policies

Min-Gi Hong
Chung-Ju Junior Colledge
Dept. of Computerizing Public Administration

Moon-Hee Lee
Choong-Nam Junior Colledge
Dept. of Regional Development

Dong-Hwan Kim
Chung-Ang University
Dept. of Public Administration
456-756
SAN, 40-1, Ne-Ri, Dedug-Myun
Ansung-Kun, Kyungki-Do, Korea
sddhkim@cau.ac.kr

An attention cycle in public policy issues is characterized by sudden rising and fall in the public concern on the policy issues. We have observed the attention cycle in the environmental policy of local government in Korea. Attention cycles in environmental policy lead to fluctuation of budget allocations in environment development programs. In this paper, we build a system dynamics model for explaining why and how the attention cycle in environmental policy continues. Our simulation model produce similar behavior of historical fluctuation of environmental budget allocation in local government in Korea. By experimenting our model, we proposed some remedies for smoothing the attention cycle and thus sustaining public investment in environment development programs.

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Infrastructure Planning in an Agricultural Dualist Economy: A Search for a Policy Framework

Xu Honggang
Human Settlement Planning Division
Asian Institute of Technology
Thailand

Khalid Saeed
Social Science and Policy Study Department
Worcester Polytechnic Institute
USA

Provision of adequate infrastructure has been a major responsibility of the state in many developing countries in the course of their development. A sample of developing countries shows that infrastructure typically represents

about 40 to 60 percent of public investment [World Bank 1994]. However, various case studies indicate that infrastructure policies are not effective in many developing countries. Infrastructure has become a major bottleneck for economic development. Distributive effect through public infrastructure also failed. The poor have been subsiding the rich in the public infrastructure delivery.

A main reason for the failure of infrastructure polices is due to the lack of the understanding of the dynamic consequences of the infrastructure decision making within its economic context. Analytic techniques for infrastructure policies are very much crippled. Traditional economic analysis is usually silent in this area because its ideal economic model is too far away from the actual infrastructure decision making. Conventional engineering standards have dominated in this area. Planning for infrastructure almost always begins with preliminary plans for specific projects formulated by functional specialists.

A system dynamics model is built based on Saeed's income distribution model attempting to catch the actual infrastructure decision making in the dualist agricultural system. The model replicates the historical behavior of infrastructure performance in many developing countries. Operational policies which are designed to improve the effectiveness of infrastructure delivery in the dualist agricultural economy are explored through the experiment of the model.

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Using System Dynamics to Explore the Role of Disruption and Delay in the Cost of Compressing Large Projects

Susan Howick and Colin Eden
Department of Management Science
University of Strathclyde
Glasgow, UK
susan@mansci.strath.ac.uk

As projects in the field of aerospace, transport and civil engineering get bigger the demands by clients for earlier delivery after the project has started are increasing. This paper discusses the use of System Dynamics modelling to investigate the consequences of the contractor accepting these demands. The System Dynamics model used for the exploration is unusual because it is based upon a successful and large claim for disruption and delay in relation to a UK based mega-project. The model constructed for the claim, constructed over 18 months and validated by the real data, has been generalized so that it properly reflects transport and aerospace projects across the organization. The generalized System Dynamics model enables the impact of disruption and delay resulting from the holistic and dynamic impact of a compressed delivery date to be assessed in relation to a number of specific and typical options. Use of the model suggests that disruption and delay are usually greater than normally expected and that the costs of project compression will usually be in excess of typical bonuses for early completion.

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Dynamic Strategy Building

Ruey-Lin Hsiao
Doctoral Researcher,
Warwick Business School
University of Warwick
Coventry CV4 7AL, UK
R.L.Hsiao@warwick.ac.uk

Bernhard Angerhofer
Doctoral Researcher,
School of Computing, Information Systems & Mathematics
South Bank University,
Borough Road, London SE1 0AA
b-angerhofer@sbu.ac.uk

The barrier of applying system dynamics in corporate intervention lies largely on the inability to discern the nature of strategy building. The research seeks to explore this issue by examining two modes of strategy building: the linear and the dynamic approach. The purpose is to investigate the fundamental characteristics of these two approaches and to explain the differences of the linear (goal-seeking) and dynamic (leverage-searching, based on the application of system dynamics methods) approach. By so doing, the paper explicates why system dynamics finds itself difficult to permeate into corporations and how practitioners can overcome these difficulties in order to exploit the benefits offered by system dynamics.

The research conducts a scenario-based interview with a group of middle managers. By comparing a linear-based and a system-dynamics-based strategic planning exercise, it explores the underlying understanding of managers' strategy building process. The aim is to identify the basic entities of the two strategy building approaches (goal-seeking and leverage-searching) and suggest potential areas within which practitioners may employ system dynamics.

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Adoption and Diffusion of Data Warehousing Technology: A System Dynamics Approach

Arunee Intrapairot and Mohammed Quaddus
The Graduate School of Business
Curtin University of Technology
GPO Box U 1987, Perth, Western Australia 6845
intrapairota@cbs.curtin.edu.au , Quaddusm@gsb.curtin.edu.au

This study initially employs multiple criteria decision making (MCDM) to evaluate and prioritise technological alternatives that can fulfil the vision and objectives of one of the largest banks in Thailand (i.e. the Siam Commercial Bank, Pcl.). The study results revealed that the most predominant technology is data warehousing. Subsequently, system dynamics (SD) approach is employed to elaborate the diffusion model of data warehousing.

Banks are under pressure to adopt new technologies and make changes in existing technologies to seek more lucrative opportunities, keep up with an accelerated business growth, fulfil organisational needs, facilitate operational activities, and generally improve services. When new technologies are adopted, bank managers have to put in a great effort to diffuse them quickly enterprise-wide or throughout customers to avoid prohibitive costs due to high obsolescence.

A data warehouse (DW) is a subject-oriented, integrated, time-variant, and non-volatile collection of data in support of management's decision-making process. Based on the subject orientation, customer-based process management is being tried to improve internal banking processes, minimise costs and time, and increase sales through mass customisation.

Although data warehousing is a hot information technology, the success in gaining potential benefits from DW projects is still lower and takes longer than expected. Many projects fail even before the first phase is completed. Therefore, a diffusion model based on a SD approach is developed in a group environment via an interaction with high executive level staff in order to identify the present state and constraints of this technology. Then, strategic policies are proposed and tested to detect the ones that can diffuse the technology most fruitfully and productively.

The conceptual model being developed based on the qualitative system dynamics approach, indicates that diffusing data warehousing should emphasise initially endogenous factors (e.g. staff and organisational environments) because it is internally used for decision support and management purposes. Additionally, the direct customers of this technology are bank staff rather than bank customers.

The model detects four main factors that drive the diffusion rate; training as an instrument in creating knowledge workers, the co-operation between IS departments and key users, top management support, and technological support from vendors. Once bank staff is enabled to comprehend and utilise this technology productively, the information and knowledge gained will impact directly on customers and economic gains, respectively.

In ongoing research, the qualitative conceptual model will be simulated and quantified to enhance strategic and holistic insights, promote understanding about the effectiveness of different policies, and build confidence before proceeding to real implementation or continuous investment.

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Problems of Food Scarcity and Renewable Natural Resource Utilization in Sub-Saharan Africa: An Archetype-based Conceptualization

Omer H. Jirdeh
Rockefeller College of Public Affairs and Policy
University at Albany - SUNY, Albany, NY 12222

Sub-Saharan Africa has experienced recurrent droughts and famines during the last four decades, which led to chronic food shortages and massive rural migrations. Two thirds of all countries suffering food insecurity are in Africa and of the 44 countries listed as facing poor or critical food security by the United Nations Food and Agricultural Organization, 33 are in Sub-Saharan Africa. Despite the tremendous efforts by the African governments and the international community to improve the food production through investments in massive agricultural projects and rural development programs, per capita food production has been declining. Rural-to-urban migration eroded the production potential of the agricultural sector and exacerbated the living conditions in the urban sector.

Attempts to understand the problems causing the deterioration of food production and natural resource utilization in Sub-Saharan Africa in the past have focused on the urgency of the situation and sought quick remedies. Sector-based development policies failed to capture the interactions among the sectors that might undermine policies designed to improve the conditions of a particular sector. This paper presents a system dynamics approach to conceptualize and understand the problems inherent in the food production and natural resource utilization in Sub-Saharan Africa. It draws from the accumulated knowledge and insights from system dynamics modeling and systems thinking to identify the structures responsible for the observed problematic behavior. Three main system archetypes and their interactions are identified to be the major sources of the observed food problems in Sub-Saharan Africa. A more elaborated model is formulated based upon the initial archetype-based conceptualization. This exercise illuminates the problem of food scarcity in Sub-Saharan Africa and demonstrates that system archetypes are very powerful tools for model conceptualization.

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Prerequisite Skills for Modeling Dynamical Systems in Science

Sarah Johnson and Mary Ellen Verona
Maryland Virtual High School of Science and Mathematics
Blair Magnet Program, 313 Wayne Avenue, Silver Spring, 20910
http://mvhs1.mbhs.edu/mvhs.html
mverona@mvhs1.mbhs.

A unit in system dynamics has been included in the 9th grade introductory computer science course at the Montgomery Blair Science, Mathematics and Technology Magnet Program since 1985. Concurrently, these students take science and technology classes so that an interdisciplinary emphasis is fostered. The students are gifted, but have a varied background in computer science, some having no previous experience, while others have had classes in LOGO and BASIC. They are enrolled in mathematics classes that range from Geometry to Calculus. All have received a B or better in Algebra I.

Previous research into the prerequisite skills needed for success in system dynamics at this level has been very limited. Four classes of ninth graders, including an advanced class of students who had been successful in past computer science instruction, were included in the current research. Students were given a pretest, received six weeks of instruction in system dynamics including modeling physical systems using STELLA, and took a posttest which included both paper and pencil questions and a section on modifying a computer model. The pretest included several questions in six areas such as graph interpretation and deductive reasoning.

Correlation of pretest and posttest results was analyzed as a whole, and separated by advanced versus regular computer classes. Some analysis by mathematics class was also completed. The pretest as a whole was significant at the 95% or 99% level in most cases. Significance of item types varied according to the how the student groups were classified. Different item types were significant for the advanced computer science students and the regular students. When students were grouped by mathematics class, particular item types were not significant, except for the geometry class, although the test as a whole was significant.

Further research based on revision of the pretest is warrented, as well as the collection of data based on use in other environments.

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Passion and Patience: Infusing a High School with System Dynamics

Timothy Joy
La Salle High School
Milwaukie, Oregon 97222 USA
tjoy@pps.k12.or.us
lasalle4@lasalle.pvt.k12.or.us

System dynamics came to La Salle High School in September 1993 inside the heads of three teachers. Initial models in Physics and Literature, developed by our teachers in the CC-STADUS 1993 Summer Institute, yielded delightful surprises in the classroom: interest was high, perceptions deep, even though we occasionally stumbled in the delivery. These tentative moves lead to other models within our disciplines; eventually, we sought broader curricular ambitions. Two of us, then, began planning how to systematically infuse system dynamics throughout our small parochial school of 600 students and about 35 teachers.

We started with a simple goal: students would see system dynamics twice each year, over their four-year career, each time in a different discipline. A few willing, risk-taking teachers responded to our ideas. Since then, students have seen STELLA models in Chemistry, Mathematics, Physics, Biology, Health, Literature, Government, Economics and even Religious Studies. Staff interest and enthusiasm continues to spread to new hires, including our attendance secretary.

Successes notwithstanding, what we presumed to be a simple and reachable goal ran headlong into the complex, highly adaptive system called ³a traditional Catholic college preparatory high school.² Some early problems are surmountable: pedagogy had to adapt, but CC-STADUS offered excellent support; a software shortage dogged us for two years. Some problems are systemic: our school is very good because it has experienced teachers, and experienced teachers resist change; traditional departmental boundaries remain sacred; a faculty is in flux‹continuously.

Still, progress has come. Our initial passion for system dynamics, though slightly dampened, has found a compatriot virtue in patience. Bringing system dynamics into our small Catholic high school‹with its traditional college prep curricula‹has been humbling, exciting, problematic, and‹not surprisingly‹political. At the National K-12 Networking Conference in June 1995, Jay Forrester challenged a roomful of teachers : “Be prepared to commit your life to it”. We are now sensing the depth of that prophecy.

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System Dynamics: An Umbrella for Integrated Problem Solving

Andreas Kaempf and Panos Ninios
McKinsey & Company, London Office
Andreas_Kaempf@McKinsey.com

System Dynamics is an effective tool for solving a broad range of problems. Its unique power comes from its ability to capture feedback, time dependencies, non-linearities, and behavioural aspects. Nevertheless, it lacks the capabilities of other solution paradigms such as game theory, option pricing theory, iterative algorithms, and agent-based simulation, to name a few.

The present paper discusses recent work at McKinsey & Company, in which we have incorporated elements of these alternative problem solving approaches into system dynamics models.

More specifically we present cases where we have used optimisation alogorithms, micro-economic cost curve analysis, game theory and option pricing theory within the context of System Dynamics models. The benefits and technical characteristics of this integrative approach are discussed, within the framework of projects in the electricity industry, an environment which is characterized by technical complexity that challenges the traditional system dynamics approach.

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The Service Dilemma: A System Dynamics Analysis of the Effects of After Sales Service Reorganizations on Overall Business Performance in Capital Goods Companies

Robert Kallenberg
Aachen University of Technology,
Aachen, Germany
kal@fir.rwth-aachen.de

Klaus Schalm
Krupp Kunststofftechnik GmbH,
Essen, Germany
schalm.kkt@krupp-ag.e-mail.com

Strong interdependencies between sales of new goods and after sales services are a well-known phenomenon in capital goods industries. Quality and cost of after sales services have a significant impact on sales of new machines which in turn determine future revenues from after sales services.

Studies show the increasing strategic importance of after sales services for differentiation in capital goods industries. To meet these changes many companies are reorganizing their after sales departments. While the possible alternatives are well documented the effects of implementing them on overall business performance are not. This poses a difficult situation for decision makers as business practice shows that many reorganization projects of after sales service departments end up as long-term failures despite initial success.

As learning from trial and error in the real world is not an option in this situation due to the long time delays involved, this study uses the system dynamics approach to explain the interactions between after sales service performance and sales of new goods. Building on established existing system dynamics models the modified and extended model is able to reproduce much of the behavior observed in the real world. The factors most influencing the interactions between after sales services and sales of new goods are sought from this model using sensitivity analysis.

The study then proceeds to assessing alternatives for successful reorganization of after sales service organizations. The development of a management simulator is suggested in order to disseminate the results to industrial decision makers.

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Teaching Social Psychology through System Dynamics

Amy H. Kao, Matthew W. Grabowski, and James K. Doyle
Department of Social Science and Policy Studies
Worcester Polytechnic Institute

In 1997 the Department of Social Science and Policy Studies at WPI, sponsored by the Davis Educational Foundation, began a long-term project to revise its existing course in social psychology to incorporate system dynamics and cooperative learning. The project has two primary goals:

(1) To create effective system dynamics teaching materials for classic topics in social psychology. A literature review has shown that there are few existing system dynamics models of social psychological problems. To fill this gap, models were built for teaching purposes covering the following topics: (a) Milgram's experiment on obedience (based on the model described in Richmond's (1977) paper); (b) change in prejudice over time during 4 years at an ethnically diverse college; and (c) the effect of intrinsic and extrinsic variables on student motivation.

(2) To design and implement a rigorous assessment program to measure the effect of the new course on student learning, motivation, and behavior. Although system dynamics has been widely applied in education at all levels, the effectiveness of these efforts has never been rigorously documented. The current assessment design incorporates three versions of the course: a control course taught in the current lecture-based format and two system dynamics based courses (one in which students complete homework assignments individually and one in which they work together in cooperative learning teams). Changes in mental models brought about by the courses will be measured using the techniques developed by Doyle et al. (1998).

The control course was taught in the Fall of 1997 and the two new experimental courses will be taught in the Fall of 1998. Thus, the results of the experiment will not be known for another year. This paper will therefore focus on describing the goals of the project, the rationale for the design of the new courses and the assessment program, and the new system dynamics teaching materials that were developed for the project.

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"Everything You Ever Wanted to Know about Developing a System Dynamics Model, But Were Afraid to Ask"

Elizabeth K. Keating
MIT Sloan School of Management

Over the past forty years, system dynamicists have developed techniques to aid in the design, development and testing of system dynamics models. This paper proposes a general System Dynamics Model Development Life Cycle (SDMDLC) that weds the existing system dynamics model techniques to a system development life cycle process. The framework is designed to provide a methodology to be followed when developing a model. The framework builds upon the "standard method" proposed by Randers (1980), Richardson and Pugh (1981), and Roberts et al. (1983). Within each modeling phase, the framework provides a list of issues to consider; the modeler can then select the issues that are appropriate for that model and modeling engagement. In addition, the framework can serve as a guide for students to assist them in analyzing and critiquing system dynamic models.

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The Effects of a Group Model Building Intervention on Information Choices for Sustainable Development Decision Making

Kristine L. Kelly
Project Research Manager
NYS Center for Technology in Government
UAlbany
kkelly@ctg.albany.edu

This presentation discusses findings from a study conducted to examine how a change in the way people conceptualize decision-making problems, in this case, economic development decisions, affects how they choose information to support decision making. Specifically, the study evaluates the impact of a group model building intervention on the choice and perceived level of importance of information for sustainable development decision making.

The study was designed to test a systems approach to the identification of information for sustainable development in the New York State Adirondack Park. More specifically, the study's experimental design tested three propositions: (1) a systems thinking intervention will result in new issues being identified, (2) changes will result in the perceived importance of issues and measures, and (3) there will be an increase in the alignment among decision makers as measured by variability in the importance ascribed to the issues and measures.

Identifying, implementing, and evaluating sustainable development strategies requires the integration of information about environmental, economic, and social factors. Most efforts toward the identification of decisive information for sustainable development have focused on the development of indicators of progress toward sustainability and preliminary work has been done to identify linkages among indicators to support their integration into decision making. These efforts however, fail to account for important feedback effects and nonlinearities and are therefore likely to result in ineffective or contrary policies and decisions. An alternative systems approach is suggested as a way to incorporate such effects into decision making and policy analysis.

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Issues in System Dynamics Model Building to Support Monitoring and Managing Quality in Higher Education

Michael Kennedy
Information Management and Modelling Group

School of Computing, Information Systems and Mathematics
South Bank University
Borough Road, LONDON SE1 OAA, UK
kennedms@sbu.ac.uk

This paper examines issues in monitoring , assessing and managing quality in Higher Education. It discusses factors that should be incorporated in a system dynamics (SD) model, designed to assist in policy analysis regarding quality issues. A pilot study is described in a companion paper.

Quality has been an issue for many organisations attempting to gain competitive advantage. In the UK various peer review structures have been established to attempt to assess the quality of both research output and teaching. Most institutions have created internal monitoring and review procedures. Many issues remain controversial however: how can we define "quality"?; how can we measure it?; are output measures sufficient or should we compute "value added"?; what are the relationships between research and teaching quality?; what is the impact of changing resource levels?; what is the impact of various management styles?

The paper assesses the potential usefulness of SD in exploring quality issues and linked resource problems. A conceptual model of 'Quality Management Process' in higher education settings is produced. The potential value of SD for quality management is in accommodating non-linear and iterative views, hard and soft issues, strategic objectives, and changes in educational processes. This project attempts to integrate "fuzzy" concepts into the SD model.

The model should help management to investigate the impact of specific policies before implementing them. This paper shows the potential role of SD in coping with the ever-reducing resources available, and increasing quality standards demanded in the UK.

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A Pilot System Dynamics model to Capture and Monitor Quality Issues in Higher Education Institutions: Experiences Gained

Michael Kennedy
Information Management and Modelling Group
School of Computing, Information Systems and Mathematics
South Bank University
Borough Road, LONDON SE1 OAA, UK
kennedms@sbu.ac.uk

This paper describes and reports on a system dynamics (SD) model, developed as a pilot study in order to assess the feasibility of modelling the complex, interdependent set of variables concerned with the various aspects of managing quality in higher education.

The quality of higher education delivered is a major concern for students, institutions and government departments, particularly as the "unit of resource" continues to decline. Quality issues impinge on all aspects of an institution's planning, students' and staff performance, administration and finance.

The initial set of influences were based on relationships identified by researchers in the field of maintaining quality standards in higher education. This initial structure was validated and calibrated for this School by incorporating academic and research staff perceptions. These were captured through a survey, subjected to statistical analysis, and were incorporated in the model. Currently, the model contains over 100 variables. A number of runs were made at an average of 25 seconds per run on a Pentium 266 MMX with 126 MB RAM in a Windows NT environment. The model is simulated over an eight year period.

From the results of the pilot study, it would appear that Higher Education departments may obtain useful insights into the likely impact of educational policies on the attainment of quality related objectives, through the use of such a model. Further work to expand the scope, (including incorporating student perceptions), and to improve the calibration of the model, is planned.

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Construction of the Modified Problem Behavior Graphs for Dynamic Modeling of Group Problem-Solving Processes

Leon Khaimovich
Learning R&D Center
University of Pittsburgh
LKHAIM@pitt.edu

The presentation will cover a small part of the project that is ultimately directed on elaborating the theory of organizational behavior that can be traced to the writings of Max Weber on bureaucratic rationality (Weber 1968/24) and was elaborated in works of Barnard (1938), and March and Simon (1958). The ways to employ dynamic modeling for building theories of nonlinear multivariate processes like organizational problem solving and decision making will be discussed.

The current study focuses on developing the modified Problem Behavior Graphs (Newell and Simon 1972) that are capable to describe both emotional and cognitive behaviors in face-to-face groups. The graphs provide a flexible means for representing problem-solving processes in the form suitable for modeling by the methods of system dynamics (Forrester 1961). Examples of Problem Behavior Graphs will be presented together with the methods for developing them.

Problem-solving behavior for the study was videorecorded during a Business Process Re-engineering workshop convened in one of the divisions of a large international company. The task was to design a process for timely and error-free resolution of problems with customized software systems installed at customer sites for control of technological processes. The data from videotapes of the workshop is complemented by a gamut of materials collected during the 1.5-month long fieldwork.

Additionally to preparing the methodology for developing the Problem Behavior Graphs and creating the substantive input for modeling, the study has generated several insights about usability of the Root Cause Analysis methods for group model building of business processes.

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A System Dynamics Approach to Decision Making on Outsourcing from Suppliers with Different Innovation Capabilities

Bowon Kim
Assistant Professor
Graduate School of Management
Korea Advanced Institute of Science and Technology (KAIST)
207-43 Cheongryangri Dongdaemoon-Ku
Seoul, 130-012 KOREA
bwkim@cais.kaist.ac.kr

In this paper, we develop an economic insight into a dynamic outsourcing decision when a firm can use multiple suppliers with different innovation capabilities. Many firms focus primarily on current cost structures when they choose their suppliers or make a plant location decision. We show that focusing on the present cost structures might lead to a short-term solution with possible long-term sub-optimality. In order to achieve long-term effectiveness, the firm must take into account the dynamic evolution of cost structures, which is often carried out by the suppliers' innovating activities. The setting can be handily extended to a global market, where an individual supplier can be analogized with a pool of suppliers in a particular country. To support our propositions, we employ an optimal control theory modeling and its numerical examples derived from system dynamics simulation.

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Learning Labs for Unlearning

Doa-Hoon Kim
Public Administration Department
Sookmyung Woman's University
Chungpa dong 2 ga 53-12,
Yongsan Ku,
Seoul, Korea (South)

Dong-Hwan Kim
Chung-Ang University
Dept. of Public Administration
456-756
SAN, 40-1, Ne-Ri, Dedug-Myun
Ansung-Kun, Kyungki-Do, Korea
sddhkim@cau.ac.kr

Simulation based learning games are widely accepted as promising environments for learning system thinking. However, the effects of learning labs on the pre-learning stage of students have received little attention. When we introduce system thinking or system dynamics to our students, we must struggle with their way of thinking shaped for more than ten years. Before students learn system thinking, they must give up their rigid belief in the linear relationship, open loop thinking, and static thinking. In this paper we explore the "unlearning process" and essential requirements of "unlearning labs (UL)" against old way of thinking rather than learning labs (LL) for system thinking.

In this paper, we emphasize that unlearning the old way of thinking do not means learning system thinking. The unlearning process can be characterized by transient states. Belief systems of students in learning labs oscillate between their previous thinking and system thinking. Secondly, we design and test our scheme of unlearning labs, where students are expected to give up their old belief in the effectiveness of penalty increase on the crime rate. In order to focus on the unlearning process of students, we must design user-interface of unlearning labs (UL) from the perspective of wrong belief system, which is contrasted to the traditional scheme of learning labs (LL). Last part of this paper is devoted on identifying research areas for using unlearning labs for learning purpose.

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Feedback Loop Gains in Action

Dong-Hwan Kim
Chung-Ang University, Dept. of Public Administration
456-756
SAN, 40-1, Ne-Ri, Dedug-Myun
Ansung-Kun, Kyungki-Do, Korea
sddhkim@cau.ac.kr

Although a feedback loop gain is a rather simple concept, its dynamics nature in complex systems has defied our understanding as well as exploiting it. Previous methods for analyzing feedback loop gains require lots of efforts. As a result, system dynamicists tend to give up using the concept of feedback loop gains in explaining and controlling system behaviors. In this paper, a simplified method for tracing feedback loop gains, called as a shadow loop method, is proposed. A shadow loop is a loop mirroring the original loop. Feedback loop gains are calculated by comparing values of the shadow loop and those of the original loop. One can easily build a shadow loop in most system dynamics softwares that provide array variables. Several examples for analyzing feedback loop gains with the shadow loop method is explained in the STELLA environment. These examples show how to put the concept of feedback loop gains into action. Last part of this paper is devoted on the role of feedback loop gains in discovering candidate variables for leverage points.

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Linking Pins between Policy Leverages and Feedback Loops

Dong-Hwan Kim
Chung-Ang University
Dept. of Public Administration
456-756
SAN, 40-1, Ne-Ri, Dedug-Myun
Ansung-Kun, Kyungki-Do, Korea
sddhkim@cau.ac.kr

Won-Gyu Ha
Electronic & Telecommunications
Research Institute, Korea

One of the most powerful concepts in system dynamics is a policy leverage. It tells policy makers where he can achieve significant and enduring improvements with small well-focused actions. Although most system dynamicists are accustomed to the usage of policy leverages in complex systems, the concept of policy leverage remains ambiguous and unorganized. For beginners in system dynamics, policy leverage is a well-understood concept but a hard-to-apply tool in real systems. In this paper, we present our classification scheme of policy leverages. We find that most policy leverages in the literatures of system dynamics can be classified as problems of adaptation, bottle-neck, and critical mass. Adaptation problems arise when there are information or material delay in feedback loops linking input and output rate variables. Bottle-neck phenomena take place when output rate variables are in inefficient states. Critical mass problems represent situations where an input rate variable cannot be triggered because of a low state of a level variable. Our conceptual scheme of policy leverages allows us to link policy leverages to the feedback loop strucutre.

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Evaluation of Policies to Reduce Automobile CO2 Emissions by Modal Shift

Satoru Kobayakawa, Yoshio Hanzawa, Kunimichi Takada, Atsushi Fukuda
Transportation Engineering
College of Science and Technology
Nihon Univerisity
kobaya@trpt.cst.nihon-u.ac.jp

This study aims at examining how to attain a modal shift in transportation from automobiles to mass transit in order to reduce the total CO2 emissions from automobiles. At the third meeting of the Conference of the Partics to the Framework Convention on Climate Change held in Kyoto, Japan in December 1997, Japan set the target of cutting greenhouse gases to 6% below 1990 levels.

In order to attain this target, it is necessary to drastically reduce CO2 emissions from transport, especially automobiles. To that end, among many problems to be addressed under the status quo, one of the biggest issues is diminishment of the automobile use.

It seems difficult in reality to regulate possession or driving of automobiles to lessen their use because it will give a great impact on industrial activities. In contrast, the policy to promote the modal shift from automobiles to mass transit such as railways is more practical, and discussions have been held to shape specific plans about it.

In the study, first, system dynamics was utilized to prepare a model to project macroscopic transportation demand by means on the basis of the relation between automobiles and mass transit in their use in Japan.

Next, with this model, simulation was made to estimate how the modal shift would make progress if various taxation systems and transportation demand management policies to promote the use of mass transit were applied. At the same time, CO2 emissions were projected for each case to make a comprehensive evaluation of the policy.

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A System Dynamics View on Knowledge Acquisition and Knowledge Diffusion in Organisations

Ulli H. Koenig
Industrieseminar der Universitaet Mannheim
D - 68131 Mannheim, Germany
ukoenig@is.bwl.uni-mannheim.de

The classical combination of organisational or group learning and simulation is designing a simulation model to support learning. This paper deals with a different possibility, an approach to simulate the way individuals (in organisations) acquire knowledge and how this knowledge diffuses through the organisation.

Based on the concept of an cybernetic approach to learning, several small system-structures are presented, simulated and discussed. The view on the individual learning process is very abstract. There are no differentiation made between the various types of knowledge. One of the main spots is the process of "unlearning" or "inactivation of knowledge".

After this view on individual knowledge acquisition the multiple dimensions of the organisations are implemented. The view on the organisation is realised by two different structures. One with a main focus on the departments and not the individuals. It is a causal-model and will not be simulated. The second one is more detailed and deals with the process of knowledge diffusion, based on a Bass-diffusion-model. It deals with soft variables like ability and will to learn.

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Risk Analysis in Dynamic Simulation Based Financial Planning

Vitaliy Kovalenko
Complex Adaptive Systems Laboratory,
Central European University,
Budapest V, H 1245, Hungary
vitkov@hotmail.com

Despite importance of financial planning methods used for decision making in this area are often static and not interactive. Traditional risk estimation approaches are based mainly on consideration of alternative assets returns,e.g. investigation of assets different from the very beginning projects, instead of exploration of dynamics of the same project. However, it is quite reasonable to investigate dynamic risks having different scenarios of the project development.

Simulation software like STELLA/iTHINK offers great opportunities to undertake actions which are actually branches of decision trees. That means, for example, use of messages from a simulation system under given conditions of dynamics of specific elements of financial ratios. Moreover, simulation delays due to system messages are also suitable for changes in uncertainty conditions by re-definition of random elements in flow units.

In general it means combination of the approaches of the management flight simulators and expert support blocks. The last one contains sets of advice on actions, use of which in risk-free simulation environment produces different risk estimations to be compared for decision making.

However the structure of a simulated financial plan could also be changed, mostly because of involvement of participants from all related management units. Such improvements mean new communication possibilities with cognitive visualisation in planning models built in STELLA or Vensim, being very important in, for example, foreign direct investments in the new emerging markets where both interested sides have different ways of thinking.

In the paper there is a presentation of how to use combination of approaches of a management flight simulator and experts' defined rules base to obtain dynamic risk estimations for practical use in financial planning.

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Transport Forecast and System Dynamics

Karsten Kuchenbecker and Werner Rothengatter
Institute for Economic Policy and Research
University of Karlsruhe, Germany

Transport forecast is usually done by standard four-stage transport models. The necessary socio-economic data is hereby exogenously given. Nevertheless, the improvement of infrastructure nets changes the regional socio-economic structure which leads to a changed traffic situation. Such feedback mechanisms are usually neglected in standard transport planning.

To improve the ability of transport modelling we applied the System Dynamics (SD) approach to our socio-economic, environmental and transport models. First, we extracted so-called key functions from these models to design a SD master model. Then our external models were directly lonked to the master model. The iTHINK equation set is translated by a new cross-compiler to a UNIX program that communicates through defined interfaces with the other models.

The resulting disaggregated SD model then runs in continuos time while the external models are started at specific situations (violation of constraints, evident indicator changes). They are receiving inputs from the SD model and feed back the refined information into the dynamic process.

The combination of the SD approach with standard transport models allows for linking together the possibilities of global feedback modelling with disaggregated net-based models. The degree of detailedness which is a distinguishing feature of such models can be improved by the higher degree of functional interrelations in the SD approach.

Results of a long-term master model derived from the ASTRA research project for the European Commission will be presented as well as first outcomes from our disaggregated combined system dynamics/transport model for the German state Baden-Wuerttemberg.

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Office Market Cycles: Combining Econometric, Institutional Economics, and System Dynamics Methods to Solve an Economic Problem

Max Kummerow and Mohammed Quaddus
Curtin University of Technology
GPO Box U 1987, Perth, Western Australia 6845
KummerowM@cbs.curtin.edu.au, Quaddusm@gsb.curtin.edu.au

This paper proposes system dynamics arising from faulty system information structures and policies in conjunction with demand growth and construction lags as a universal process explaining office oversupply cycles. Office oversupply is seen as a system design problem. Office markets are not usually managed as systems, instead individual entrepreneurs and capital sources make strategic decisions based on expectations of other stakeholder's behaviour. But office markets could be managed as systems through institutional changes or by means of aggregated effects of changes on individual behaviour.

The ubiquitous nature of the office oversupply problem suggests a fundamental causal mechanism beyond particular local tax policies, regulatory institutions, or market conditions. A system dynamics model of office markets allows experimentation with information feedback structures and decision policies controlling office supply responses.

Results of a simple model simulating office markets suggest that it is easy to design policies that would perform better than real world office market decision makers. The model indicates that system dynamics (lag and control structures) rather than random shocks contribute most to generating office market cycles--that is, instability and departures from equilibrium leading to less efficient outcomes and financial losses. This leads to suggestions for system redesign to reduce the severity of cycles. The keys are reducing lags through better demand forecasting, reducing planning delays, and smoothing commencements.

Forecasting may be aided by a combination of simulation and econometric methods. Principle/agent conflicts and prisoners' dilemma games also contribute to office oversupply. Therefore, changes in institutional design of office market systems would be required to improve market efficiency. Changes to implement system re-design might include better alignment of interests between investors and agents through contractual allocation of risks. The prisoner's dilemma problem could be addressed by "collective action" (Olson, 1971), that is, institutional changes to prevent collectively irrational outcomes of individually rational decisions. Solving the problem of office oversupply requires the synergy of institutional economics, system dynamics re-design, and forecasting methods. A combination of methods goes farther towards understanding and mitigating the office market oversupply problem than the sum of the individual methods.

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Looking in the Wrong Place for Healthcare Improvements: A System Dynamics Study of an Accident and Emergency Department

DC Lane C Monefeldt JV Rosenhead
The London School of Economics and Political Science

Accident and Emergency units provide a route for patients seeking urgent admission to acute hospitals. Public concern over long waiting times for admissions motivated this study, whose aim was to explore the factors which contribute to such delays. In collaboration with a major London teaching hospital, a system dynamics model of the

interaction of demand pattern, A&E resource deployment, other hospital processes and bed numbers was developed. The paper discusses the formulation of this model; the calibration of a Base Case simulation; and the outputs of policy analysis runs of the model which vary a number of the key parameters. Two significant findings appear to have policy implications. One is that while some delays to patients are unavoidable, reductions can be achieved by selective augmentation of resources within, and relating to, the A&E unit. The second is that while reductions in bed numbers increase waiting times for emergency admissions, their principal effect is to increase sharply the number of cancellations of admissions for elective surgery. This suggests that basing A&E policy solely on any single criterion will succeed in transferring the effects of a resource deficit to a different patient group.

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A System Dynamic Model For Food Security

Miguel Lechuga
Industrial Engineer Dpt. Chairman
TEC De Monterrey, Mexico
mlechuga@campus.ccm.itesm.mx

Olga Lopez
Demography Dpt. Chairman
Health National Institute, Mexico
olopez@insp3.insp.mx

The vague notion that we have about sustainable development, and the lack of a complete methodology relating to the dynamics of the interactions of the three phenomena, population, development and environment, thereafter abbreviated PDE, force to undertake new approaches to elucidate characteristics of those relations that apply in a general context and those that apply only under specific conditions.

On this essay we analyze the relations between several factors of population and food production.

We use classical statistics methods, and a new approach to construct an example of PDE relations (restricted to food production and population indicators) using dynamics models by means of the ITHINK software.

We establish different scenarios to study the possibility of Mexico to access food security, ours models go until 2030, they give a good appreciation of the potentiality of system dynamic models to handle a food security problem.

They show that the development model followed in the past has proved its inefficiency and impose to adopt new strategies toward a best distribution of resources and food production strategies.

This essay is on the base of a project who attempts to identify critical PDE problems toward the elaboration of a comprehensive methodology which in a specific setting, shows us the particularities of the interrelationship of the three phenomena toward to establish sustainable development strategies.

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A Judgment Approach to Estimating Parameters in Group Model-Building Sessions: A Case Study of Social Welfare Reform at Dutchess County

Tsuey-Ping Lee, David F. Andersen, George P. Richardson, John Rohrbaugh, Aldo Zagonel
State University of New York at Albany
TL7134@cnsvax.albany.edu

Building models directly with client groups has become increasingly common in the field of system dynamics. For the past ten years, the modeling group at the University at Albany has been experimenting with techniques handling the complex modeling and facilitation processes involved in group work. This article extends the previous work of scripted techniques by discussing parameter estimation techniques in group model building.

The discussion is divided into four sections : The first section states the purpose of the study and reviews the literature of the past efforts on estimating parameters in group model building. It is followed by an overview of the approach for group parameter estimation designed by Albany modeling team. It elucidates the problems addressed by each elicitation step and the solutions for solving them. The script for data calibration is shown as following:

1. Getting familiar with the major structure of the model.
2. Clarify the definition of important variables.
3. Elicitation of key parameters
   3.1 Clarifying parameter definition and location
   3.2 Estimating parameters by individual judgment
   3.3 Tuning numerical value of parameters by group judgment
4. Elicitation of key table functions
   4.1 Rank-Ordering the effect by individual judgment
   4.2 Selecting more important effect for estimation
   4.3 Estimating table function by group judgment

The case study following the script overview is a description of the data calibration conference at Department of Social Service, Dutchess County. It presents how the Albany modeling team applied the designed scripts supporting parameterization in a conference. Strengths and weaknesses of the application are discussed. The last section of this article contains suggestions for future work on estimating parameters in group model building.

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A System Dynamics Based Analysis Of The Economic Effects Of Material Flow Cycles In The Branch Of Production

Frank Lehmann
Industrieseminar der Universitaet Mannheim
D - 68131 Mannheim, Germany
fl@is.bwl.uni-mannheim.de

It seems, that one of the biggest problems of "green production" is the time gap between investments and the ROI. Together with a hard competition, this makes it a difficult decision to rise costs now for uncertain revenues in some years.

A simulation model based analysis of the interdependence between recycling technologies, market structures and recycling structures allows a better understanding about how material flow cycles are helpful for a sustainable development of companies and why some of the possible recycling technologies and organization structures are used and some are not.

The presentation discusses a Vensim model, which is part of an ongoing PhD study at Mannheim University. The main sections of the model are the material and financial flows in the production area of a single company, a diffusion market model and the after sales phase including the recycling-flows. To get results regarding the short term, the simulation period is monthly. Concerning the long term effects caused by the life cycle problem, the simulation time goes up to several years. Effects on the conditions of a sustainable development and the short term living ability of companies are the main fields of research of the PhD study and they are also the guidelines of the presentation.

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Squeezed Between Two Masters: The Dynamics of an Organization which Interfaces Both Community and the Academy

Ralph L. Levine, Peter Hovmand, and David Lounsbury
Department of Psychology
Michigan State University
East Lansing, MI 48824
leviner@pilot.msu.edu

Academic institutions are venturing into the urban environment to provide help in economic and community development and other outreach services. This paper describes a group modeling effort to characterize the dynamics of an organization, Michigan State University's Center for Urban Affairs, which has had a long history of outreach activities and projects aimed at solving community problems. However, recently the Center has come under greater pressure its higher administration to conform to a more traditional academic role, which puts emphasis on publications, applied faculty research, and evaluation studies. On the other hand, the communities in which the Center had painfully established a reputation in solving economic and social problems have more interest in concrete results than being included in university research projects. The citizens in those communities have very little interest and even may distrust being the subject of published books and reports in obscure academic journals. The Center has to please both parties, and therefore has to deal with conflicting goals.

A system dynamic model was generated by using a series of focus groups composed of the staff, faculty and a large number of graduate students employees of the Center who principally went out into the community to work in neighborhoods and agencies on funded projects. Most efforts at building the foundation of a learning organization have been associated with a relatively stable base of employees who might have a long term stake in the organization's future. Unfortunately, our modeling group had to take into consideration the transient nature of the students who did the majority of work for the Center. The average length of employment at the Center was approximate a year and one half to two years. This paper will describe some of the details of the system dynamic model which captures the dynamics of the Center's conflict between academic goals and the wishes of the community. In addition, it will deal with how to work effectively with groups that initially are relatively unmotivated to embrace a long term perspective.

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Urban Modeling Revisited: Psychological and Social Dynamics of a City which Has to Adjust To a Large Number Of Plant Closings

Ralph L. Levine, Peter Hovmand, and David Lounsbury
Department of Psychology
Michigan State University
East Lansing, MI 48824
leviner@pilot.msu.edu

This paper describes an extension of the Forrester urban dynamic model to include many of psychological and social processes which are associated with a downturn in the local economy. The loop structure was based on information gathered from approximately 700 citizens, organized into small focus groups. The psychological processes studied were alienation, political apathy, conflict among political leaders, family stress, and erosion of skills in a changing job market. Of interest in this model are the dynamics of those workers who remain in the area who go down the economic ladder from a single relatively high paying job in manufacturing to multiple, low paying jobs in service industries. Twenty years ago, this urban center was a world class leader in automobile parts manufacturing. Then most if not all plants were closed down, leaving all the land occupied with these business structures alone and vacant. Today, these business structures remain in limbo because of pollution or lack of interest from outside companies which are not attracted to the area. In addition to looking at psychological processes associated with an economic downturn, the model attempts to account for the dynamics of migration and attraction of businesses to the city, when ample land has been allocated for business structures.

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Defence Preparedness and Economic Rationalists - A System Dynamics Framework for Resource Allocation

Keith Linard
Senior Lecturer
University College, University of New South Wales
Australian Defence Force Academy
k-linard@adfa.oz.au

In 1996 the Australian National Audit Office delivered a critical report to Government on the Defence Department's preparedness methodology: It noted that preparedness objectives did not adequately comprehend the interaction between Army, Navy and Air Force activities; competing resource implications were not adequately addressed; and performance management information systems for preparedness planning were inadequate to enable decision makers judge between competing proposals in a resource constrained environment.

The National Audit Office recommended that the solution address the interaction between budgetary resourcing and the (interrelated) operational, logistical and training interactions. This paper presents the system dynamics framework, developed at the Australian Defence Force Academy, which is seen by senior defence managers as the basis for responding to the Audit Office requirements. The modelling takes the doctrinal assessments regarding the necessary force structure (quantum of equipment and skilled personnel) as given. 'Template models' of the various force element groups are being developed in Powersim which address the interrelationships between personnel, training and equipment. In turn, the inter-relationships between the force element groups are modelled. The modelling tools are being integrated into a 'virtual' learning laboratory via Lotus Notes groupware.

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Reducing Traffic Safety Deaths: A System Dynamics Perspective

Roderick H. MacDonald
Rockefeller College of Public Affairs and Policy
University at Albany, 100 Milne Hall, Albany New York
73243.432@Compuserve.com

Traffic safety deaths on American highways have been decreasing since the early 1970's. The decreases in highway fatalities have been attributed to safety improvements in vehicles and advances in highway engineering. With the introduction of dual airbags as standard features on all vehicles in the mid 1990s traffic safety experts believe that future vehicle safety improvements will have a negligible impact on reducing traffic deaths. Furthermore, improvements in highway design will continue, but those areas with higher than normal accidents levels were identified early, funds were allocated, and engineering improvements were made. Thus, the marginal impact of additional spending on highway improvements will not have the same influence on reducing traffic vehicle deaths as dollars spent in earlier years.

While it is believed that the factors that have historically had the largest impact on reducing traffic safety deaths have reached a plateau, it is feared that increases in the number of vehicles on the road, the number of miles driven, and an increase in older drivers are creating pressures that will increase traffic safety deaths. Therefore, in order to reduce traffic safety deaths further, programs and policies aimed at changing driver behavior must be emphasized.

Working with a multi-disciplined group made up of individuals in administrative and policy positions from New York State, the Institute for Traffic Safety Management and Research is developing a system dynamic model to examine the tradeoffs between programs that emphasis education and enforcement. There are two goals for this project. The first goal is to get key traffic safety decision makers in New York State involved in developing and using a system dynamics model to examine new ways of reducing traffic safety deaths in New York State. Second, the model will be used to examine the effect of different resource allocation measures between education and enforcement measures.

The presentation will focus on the findings of the model as well as how the model is being used to influence policy, resource allocation, and thinking about traffic safety in New York State.

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Organizational Reengineering Using Intelligent and Real Time System Dynamics Based Models

Julio Macedo
Institut Stratégies Industrielles
229 Forest, Pincourt, P. Q., J7V 8E8, Canada
k26400@er.uqam.ca

Reengineeering the organization of a manufacturing system consists of integrating the productive resources and management practices so that the products made in series satisfy the managerial attributes desired by the target market (delivery delay, reject rate, production cost). A new CAD system for reengineering manufacturing systems that utilizes system dynamics models in different forms is presented. This CAD system works as follows: First, a shop floor controller is connected to the analyzed manufacturing system and used to measure its current state on line; second, these measurements are expressed in scales 0 to 1 and introduced in an intelligent system that identifies the organizational improvements by allocating binary values to the control variables of the analyzed manufacturing system; third, these binary values are displayed with implementation examples across the industry in order to support the design of the suggested improvements; fourth, the shop floor controller is deconnected from the real manufacturing system and used to optimize the intensities of the found organizational improvements; fifth, the organizational improvements are introduced in the real manufacturing system; sixth, the shop floor controller is reconnected to the real manufacturing system to follow-up the behavior of the manufacturing system and to check if the expected behaviors are achieved. At this point note that the intelligent system above uses system dynamics models with fuzzy cognitive map structure trained with data across the industry. In addition, the shop floor controller above is a system dynamics model that measures on line the performance of the analyzed manufacturing system. The CAD system suggested in this paper is applied to reengineer the organization of a laboratory that makes biotechnology products.

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Hybrid Modeling : System Dynamics combined with Multicriteria Analysis
An application to Urban Mobility

Cathy Macharis
Researcher, Center for Statistics and Operational Research,
Vrije Universiteit Brussel, Pleinlaan 2, B1050 Brussels, Belgium
Cathy.Macharis@vub.ac.be

This paper proposes a methodological frame for blending System Dynamics (SD) modelling with Multicriteria Decision Aid (MCDA) on two levels. The aim is to design and to implement policies of long-term benefit to complex socio-economic systems. The first level deals with the explicit incorporation of multicriteria analysis in the model itself. This will be illustrated by an application in urban mobility. The model is developed to understand and control the mobility problem faced by many cities. The growing traffic jams is the main problem in focus here. On a second level, policies are suggested to deal with this problem. These policies are evaluated on several criteria in order to find the most appropriate one. The choice of the policy to be implemented is the result of collective decision-making using available MCDA tools. The PROMETHEE-GAIA methodology, based on outranking techniques, has been used.

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A Simple and Useful Model of Global Scale Pollution

Robert M MacKay
Clark College Meteorology Department
1800 E McLoughlin Blvd.
Vancouver, WA, 98660, USA

A Stella II model is presented that relates the time dependent global burden of a chemical species to the emission strength, emission growth rate, and atmospheric lifetime of the species. Pedagogical examples will be given to show how this simple model is used in a learner centered laboratory to help students better understand the dynamic behavior of global scale pollutants. Specific examples of the application of this model to current problems in global change science will be explored. These examples are: 1) the evaluation of the potential accumulation of carbon dioxide in the atmosphere and its consequences for global warming, and 2) an estimation of the future dynamic behavior of the atmospheric concentrations of the primary chloroflourocarbons and their relation to the expected future recovery of the stratospheric ozone hole. The overall success of using this model in a learner centered learning environment is summarized. Finally, the possible use of this model by policy makers is also described.

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Learning Laboratories, Dashboards and Learning Environments
Are they all the same?

Conrado Garcia Madrid
Strategic Decision Simulation Group
cong@sdsg.com

As people work and live in their immediate environment, they grow their experience, knowledge and intuition about life in that environment. Their understanding of the environment is implicit in the mental model which they carry with them. When they leave the environment, all of their understanding leaves with them. How can we capture and transfer this implicit knowledge to non-experts, while letting them test their understanding in a risk-free environment?

Many tools such as learning laboratories, dashboards and learning environments capture the essence of their understanding in a system dynamics model and provide a user-friendly interface with which the non-expert learns from the model. But are these tools all the same?

This paper explains how these tools provide significantly different results for the customer, both in their elaboration and final use. Examples are given based on a case study developed at the Mexican Light and Power Company. Finally, the advantages and disadvantages of each are discussed.

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A Taxonomy for Computer Simulations to Support Learning about Socio-Economic Systems

Frank H. Maier ***Andreas Größler***
Industrieseminar der Universität Mannheim
D - 68131 Mannheim, Germany
fmaier@is.bwl.uni-mannheim.defmaier@is.bwl.uni-mannheim.de, agroe@is.bwl.uni-mannheim.de

In literature as well as in discussions among scientists or practitioners one can find some confusion when computer-based simulation tools to support learning processes are under consideration. Besides the unsolved question of their efficacy, this confusion often is caused—or at least increased—by problems connected with terminology: many words are in use that symbolize the same object, or a single word is used for different objects. “Microworld”, “management flight simulator”, “business simulator”, “business game”, “management simulation”, “learning environment”, can sometimes be found to describe the same simulation tool. But sometimes two instruments both called “management simulator” are quite different. Some authors distinguish between “business games” and “business simulators”, some do not.

For scientific research a clear, unambiguous terminology seems more than important: it is the basis of understanding other people's work and gives the opportunity to criticize it. Furthermore, this will help analyzing the effects of different types of these simulation tools and building a bridge between the many involved fields of science (e. g., management science, psychology, instructional design, computer science).

The confusion is caused by various reasons: different academic backgrounds of the people involved, marketing aspects, and a not reflected adoption of terms originally used with other intended meanings. In order to clarify these issues, in a first step this paper presents and criticizes commonly used terms for learning instruments. Then a list of possible characteristics is given and applied to some well known tools. Finally, our suggestions for a coherent terminology are shown.

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Virtual Interaction and Learning Management of Systems-based Mircoworlds

Mahendran Maliapen
Information Technology Consultant and Doctorate Student
Curtin University of Technology
Perth, Australia
Mahendran.Maliapen@optum.com.au

The opportunity to develop smart ideas and learning through dynamic interaction of network enabled computer simulation models called 'microworlds' provides a fertile platform for imagineerng and policy experimentation for business managers. In this paper, we discuss the application of systems dynamics and soft systems methodologies in the development of such microworlds over the Internet.

Together these developments allow modellers to create computer-based collobrative learning environments which allows policymakers 'to experiment' their knowledge of business and social systems and to debate policy and strategy change. The differences in the application of these development methodologies are studied and evaluated and their strengths are combined to evolve a more 'satisfied' decision model of the business problem under scrunity. It also requires the exchange of ideas and suggestions amongst the participants through the model development process.

The paper also discusses the strategies for managing knowledge assets in such learner-centred environments virtually over the Internet. Explicit business knowledge of the mechanisms of business policies, processes, decisions and their rewarding outcomes are the key enablers of successive and repeatable business goals. Valuable knowledge assets that are transacted between business organisations need to be carefully controlled, managed, stored in such a manner that would give corporate leverage because of the humanware's readiness and availability to respond to environmental variables and changing product life cycles.

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Strategic Planning for a Management Institute

Ali N. Mashayekhi
Department of Industrial Engineering,
Sharif University of Technology,Azadi Avenue
Tehran

An Industrial Management Institute (IMI) was established more than 30 years ago to carry out management training, research, and consulting as three interrelated functions. However, the three functions have not grown as interwoven activities. While training has expanded from operation management subjects to include strategic issues, consulting mostly is focused on the level of operation and research activities are not considerable and those little researches that are done are usually around socio-economic issues and not related to corporate management. The lack of relationship between above three functions and also inadequate consulting capabilities at the strategic level are major concerns at the institute. A system dynamics model is developed to portray the historical behavior of the institute and analyze its strategic choices for future development.

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Seizing Business Opportunities & Understanding the Economic Risks of New Products in a Multi-Faceted Market

Ann Matthews, Jo Osborne and Michael Lyons
BT Laboratories, Martlesham Heath
Ipswich, IP5 3RE, England
mattheal@boat.bt.com

As we move into the next millenium, exciting leading-edge technologies will offer businesses unparalleled opportunities to seize rich new markets. However, the prospect of enormous new revenues must not be allowed to

blinker the vision of strategic business planners. They must understand the risks as well as the opportunities. Furthermore, the complex interactions between their multiple resource options and a multi-faceted customer market must be understood. Frequently, it will be important to mine through the web of opportunities to target resources at those products for which the customer market will offer the greatest return on investment and the lowest risk.

A Systems Dynamics modelling technique, used to explore the futuristic market opportunities available to telecommunications companies, will be presented. Its prime objective is to identify how to seize market share by prioritising resources at particular products through understanding the multi-faceted customer base.

The technique for breaking down the complex problem space into small, manageable and testable units which can be modelled as reusable modules will be discussed. These modules can be subsequently bolted together to form a large, seamless, elaborate and powerful model, for the analysis of "What-if" business scenarios. Customer takeup of new products (or services), service usage, costs, revenues and profit will be discussed with respect to the business opportunities available and, most importantly, it will be demonstrated that this technique, for telecommunications, can be reapplied to any business market.

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Impacts of Dynamic Decision Making and Policy Development Modes on the Causal Understanding of Management Flight Simulators

Dalton E.M. McCormack and David N. Ford
System Dynamics Program,
Department of Information Science,
University of Bergen,
Norway
Daltonm@ifi.uib.no

System dynamics contends that understanding the causal structure of systems is required to successfully manage their behavior. However the best means of improving causal understanding is not well understood. Management Flight Simulators (MFS) have been used for many years for learning, performance and transfer of learning. These tools have been used almost exclusively to simulate dynamic decision making environments. However recent research by Langley and Morecroft(1996) suggests that policy development MFS environments can improve causal understanding better than dynamic decision making environments. We use an experiment to test this hypothesis by having subjects manage a version of the Kaibab Plateau model in either a dynamic decision or policy development mode. We quantitatively measure causal understanding with two measures: performance and the results of an on-line questionaire about the causal relationships in the managed system. Initial results indicate that the process of policy development has a larger impact on causal understanding than dynamic decision making.

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Practical Application of SD Modelling to Ensure Governments Get More Bang for their Defence Dollar

John M. McLuckie	***Sqn Ldr John W. Kearney***	***Major Robert***
Director	Visting Military Fellow	USAF Exchange Officer
International System Dynamics	Australian Defence Force	Directorate of Logistics
Pty Ltd	Academy	Development RAAF

Governments around the world spend vast sums of money procuring defence assets. In times of changing global circumstances and tight fiscal policies, getting more for less is the ongoing challenge. A need has been identified for systems that minimise the risk of over or under procuring particular defence assets. This has to be balanced with the level of logistical support that is to be provided.

If an asset is under procured, or lacks the appropriate level of logistical support, it may fail to provide the capability or level of deterrent required and thereby be of little or no value. If an asset is over procured, or has a greater level of logistical support than is required, then funds that could have been utilised by Governments in other areas are trapped in fixed assets and ongoing support expenditure.

This paper deals with how systems based on the practical application of SD modelling can help improve defence capability and efficiency. It outlines case studies where SD modelling has been used to improve the performance of fleets of army helicopters and strike reconnaissance aircraft and determine logistical support requirements. It also outlines how this modelling can be extended to give a “whole of system” perspective.

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**Cost Effectiveness of National Investment for Prevention of HIV:
Evaluation Of Canada's Investment Using A Simulation Modeling Approach**

Meagher NL, Hanvelt RA, Schneider DG, Copley TT, Marion S

Background: Cost effectiveness analyses are increasingly being used for policy and program planning. While the rationale for prevention of HIV is strong due to the enormous human and economic costs of infection, there is still a need to determine the return on investment in prevention for allocation decisions. Evaluation of prevention in the spread of HIV is problematic: it implies counting something that doesn't happen, and it runs the danger of excluding benefits such as the multiplier effect of averting or delaying infections. This paper seeks to evaluate prevention in Canada on a macro level through simulation modeling.

Methods: A system dynamics approach to evaluation is taken. Two simulation models are integrated: one on the epidemiology of the infection in diverse populations, and the other on behaviour change from prevention interventions. The latter model has investment fueling prevention activity, which is a two stage process. National, provincial and municipal spending onprevention was considered for the years 1985-1995. Other data

on the impact of prevention was gathered through a classification of existing evaluations in the literature. Weekly iterations were used to estimate the period 1970-1999. The simulation was run both with and without investment dollars, with the difference in cumulative incidence being the number of cases averted.

Results: Early simulations indicate that approximately 9200 cases of HIV were averted through prevention investment. With $759 million (1996 Can. $) invested, this implies that to date $82,500 has been spent for every case averted. The effect compounds on itself, implying increasing returns to scale for prevention. Note these are the results from simulation analysis, not from field studies.

Conclusion: With direct medical costs alone estimated to be approximately $150,000 (1996 Can. $) for an episode of HIV, national spending of an estimated $82,500 per case of HIV averted is clearly cost saving. As prevention demonstrates a multiplier effect through avoidance of secondary or tertiary infections, the total number of cases averted will continue to rise. Cost savings in the case of prevention of infectious disease is an increasing function of time. This exercise has used simple cost minimization for comparison. Evidently, moving towards a more comprehensive analysis that accounts for more than direct medical costs will add strength to the case for prevention.

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Modeling the impact of prevention in the spread of HIV for the purposes of economic evaluation
Meagher NL, Marion S, Hanvelt RA, Schneider DG, Copley TT

Background: Evaluation of prevention investment is an important step for policy formation. Given the complexity of prevention of HIV, modeling is considered to be a valuable method for pursuit of evaluation. Ex-isting work in prevention modeling often takes prevention as given exogenously. While this has provided in-sights, modeling of prevention as a policy variable for purposes of evaluation requires more detail on the cost, impact and process of prevention. As more precise modeling of the epidemiology was useful for insights on the importance of viral load and transmission rates, more precise modeling of prevention holds promise for our understanding of interventions in the spread of infectious disease. The objective of this study is to explicitly model the process of prevention in the spread of HIV with particular attention to economics.

Methods: Two semi-autonomous deterministic simulation models were developed: prevention and the epidemiology of HIV/AIDS. Prevention is based on the stages of change behavioural theory. Prevention ac-tivities were divided into those that seek to (1) change knowledge or attitudes, and (2) change behaviour through education or testing/counseling. It was assumed that someone would have to experience (1) before (2) would have any impact. Impact, or outcomes of an intervention are an increasing function of its resource use intensity, which depend on the type of intervention. The amount of prevention activity available is reliant on investment dollars allocated to a given population grouping. Other details included in the prevention model include time delays between the policy decision to allocate funds and the time funds are available, an overhead cost of "building capacity", and funding that is generalized or targeted. Examining prevention in such detail required development of an epidemiological model that contains detail that relates to risk groups and their interactions, transmission routes, disease staging, and behavioural characteristics of both the susceptible and infected populations.

Results: Both models were developed using the simulation software Stella.

Conclusion: Such an explicit treatment of prevention in the spread of HIV is useful for economic evaluation purposes. Using this model one can pose policy questions that relate not only to the timing or intensity of intervention, but also to their type and implementation in diverse populations. Both average and marginal costs can be examined. Some applications of this model could be to consider the effect of a less than perfect vaccine, the impact of lower viral load due to drug therapy, or the effect of targeted versus generalized prevention interventions.

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Modeling a Start Up Business

Keith K. Millheim and Thomas Gäbler
Department of Drilling, Petroleum Production and Economics
Mining University
Leoben, Austria

Almost every action in our business life is somehow measured, recorded, and somewhere stored on files. Useful utilization of this enormous amount of data, most of the time buried in organization's "family tombs", was the

core idea of a large governmental research institution's software project. The commercialization of the software package was expected to take three years from the start of the project.

Soon it turned out that for a successful market introduction two critical parameters have to be taken into account. (1) The vicious cycle of: the more trained engineers are working with the software package, the more active customers will be generated, which in return will need more trained engineers. (2) Whereas the costs of the software development are carried by the government, the project management is faced with substantial high market introduction costs, which have to be generated without governmental subsidies.

Although both major issues of concern were recognized early in the project's development, the project management decided to initiate a system dynamics study to guide the commerzialization of this product, by exploring the system-immanent dependencies on headcount, costs, customer generation, interest rates, etc., testing the sensitivities on the overall project's success. To accomplish these goals a system dynamics study was commissioned.

In the undertaken system study, where the business situation was modeled and several scenarios defined, the authors could prove the value of a system investigation to isolate critical variables (especially those, which take some time to kick in), as well as the useful application of a system model as a computer-based decision tool.

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The Transition to New Generations of Technology

Peter M. Milling
Industrieseminar der Universität Mannheim
D-68131 Mannheim, Germany
pmilling@is.bwl.uni-mannheim.de

In nearly all its aspects, innovation management is a highly dynamic, complex, and risky business. The most difficult decisions, however, deal with the shift from one cycle of technology to a new, more sophisticated one. When the technology in use approaches the end of its life cycle, future gains and achievements get smaller and smaller (decreasing marginal utility). Management has to decide, whether and when it leaves the track of the proven and accustomed technology and switches to the new one with a high potential for further developments but no advance experience. This transition is in the focus of an integrated decision support model presented in this paper.

A core aspect of the investigation is the competition between different firms on one side and different cycles of technology with substitution processes between them on the other. Special attention is given to the interrelationship between the firm’s markets and research & development activities.

R&D is modeled as an evolutionary process in which the available knowledge is expanded by stochastic variation and effectiveness determined selection. It is a C-written algorithm based on concepts from biological evolution theory. The market module comprises internal and external processes associated with production and marketing of products. It represents both, a specific firm under investigation and its competitors. It generates the typical life cycle of a particular product and the sequence of cycles for generations of products within one technology generation. The module reflects the fact, that the development and diffusion of innovations over time is influenced by factors like price, product quality, and market entry time.

The integration of both modules leads to a simulation model, that satisfies the requirements of a Decision Support System. It is used to analyze the dynamic consequences of different strategies on research and development, production and marketing, the timeliness of market entry and the resulting competitive advantages. The focus on a comprehensive perspective of a single product and its successors allows to investigate the effectiveness resource allocation decisions.

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The Art and Science of Constructing System Stories

Mohammad Mojtahedzadeh, David Andersen, George Richardson
Rockefeller College of Public Affairs and Policy
State University of New York at Albany
Albany, NY 12222, USA

One view of a simulation model is that it is a way to tell a system level story about how the structure of the system gives rise to system behavior over time. Simulation models tell these stories about system structure and system behavior in a manner that is often mysterious and silent but mathematically precise and never failing. Simulations reveal the behavior over time of a set of interrelationships --structure-- but fail to specially delineate how the system's structure generates its over-time behavior. As a result, the task of constructing system stories that on the one hand reveal the connection between structure and behavior, and on the other hand link to the mangers mental models has remained within the domain of experienced modelers' intuition and judgement.

This paper presents a hierarchy of key issues and questions that arise when one attempts to construct system stories. It illustrates how pathway participation metrics can facilitate the use of the concepts of loop polarity, loop dominance and shifts in dominant polarity as an adequate language for telling insightful system stories from simulation models.

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System Dynamics to Interpret Theories in Strategy Literature: Intra-Organisational Ecological Theory of Strategy Making

Edoardo Mollona
System Dynamics Group
London Business School
Sussex Place, Regent's Park
NW1 4SA London, UK
emollona@lbs.lon.ac.uk

In the strategy field, the ex-post test of external validity of theories is well supported by a wide range of statistical tools for the rigorous analysis of time series.

On the other hand, not many tools for the ex-ante test of internal validity and logical coherency of theories have been developed. In this light, System Dynamics could provide an effective tool for rigorous representation and testing of verbal theories.

In this paper the process is reported with which Burgelman's intra-organisational ecological theory of strategy making has been represented and transformed into a System Dynamics model. Burgelman's work provides a promising theoretical framework to illuminate such themes as firm change, adaptation and conditions for long-term survival. Firms' strategic behaviour is explained by the structure of inter-connected processes of variation, selection and retention of strategic initiatives in the corporate.

The paper illustrates how:

1) System Dynamics conceptual tools supported the translation of the verbal theory into the simulation model.
2) The use of simulation tests was used to generate surprise behaviours and to identify potential areas for further enquiries.
3) The feedback lenses sustained the investigation of the link between decision-making structure and emerging strategic behaviour.

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Developing Core Thinking Skills for System Dynamics

John Morecroft
London Business School
Sussex Place, Regent's Park
London NW1 4SA UK
jmorecroft@lbs.ac.uk

An important and continuing challenge for system dynamics is to develop people with in-depth skills in modelling and simulation. Such skills, though sought-after in the job market, cannot be acquired through a single introductory course. Traditionally PhD programmes have filled this development need and will continue to do so in the future. But increasingly masters and undergraduate programmes have the flexibility to accommodate serious modelling. The specialist masters programme in system dynamics at the University of Bergen is a good example. This paper looks at the opportunities for disseminating system dynamics in an international MBA programme such as offered by London Business School.

In a business school/MBA environment, modelling can often be misperceived (by students and faculty alike) as a narrow technical subject relative to the broad backdrop of general management. Yet this bias need not persist. There are many non-technical ways for system dynamics to complement a general management education. The paper explores seven core thinking skills relevant to system dynamics including time-based thinking, feedback systems thinking, stock/flow thinking and algebraic thinking. There are frequent opportunities in an MBA programme to develop these core skills with materials that fit seamlessly with general management education such as model-supported case studies, scenario planning and strategy. The paper examines four degree courses now offered at London Business School that awaken and develop core system dynamics skills. There is a brief review of the content and scope of the courses, how they reinforce each other and how they fit with other MBA courses to provide "thinking skills for a complex world".

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Hydrosystem Operation in Competitive Market: A System Dynamics Approach

M. Morozowski and C.M.Cardozo
UFSC - Federal University of Santa Catarina - Brazil
marciano@gpse.ufsc.br

A hydroelectric generation plant is a device that converts the potential energy of water streams into electricity. Its dynamics is determined partly by the streamflows and partly by the electricity demand. Physical feedback loops exist between storage head, outflow and production characteristics of hydro plants. The operation planning of hydroelectric systems is usually done with the support of simulation models, some of which are aggregate, whereas other are detailed, representations of the hydrosystem. All simulation models share the following objectives: They seek the optimum operation of the hydrosystem; They don't take into account the managerial aspects of the production process. The last aspect is getting increasingly important in Brazil and many other countries with high hydro participation, due to privatization and unbundling of electricity utilities. In this new market structure, potential conflicts between the optimum operation of the overall hydrosystem (as determined by an independent system operator) and the commercial targets of the individual plants (as defined by the plant manager) may emerge, whenever the plants in a hydro basin belong to different generation companies. As a consequence, a need exists now for simulation models able to consider, simultaneously, the physical and managerial aspects of the hydropower production process.

In this context, this paper presents a SD based, detailed simulation model aimed at determining the hydro operation policies that reconcile the global and local interests in hydropower production. It does so by creating a feedback loop between the production process and the manager's decisions.

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Planning Hydrothermal System Operation by a Dynamic of Systems View

Marciano Morozowski, FilhoJéferson Meneguin
UFSC - Federal University of Santa Catarina - Brazil
marciano@gpse.ufsc.br

Due to those hydroelectric plant in the Brazilian systems are considerably low fall (variable liquid fall), the relation between the available hydro power and fall could be highly nonlinear, and their exactly representation would be problematical with the Linear Programme model as well as with the Dynamics Programme Models.

As the hydro generation plants within the brazilian systems have been preponderant historically and more powerfull, thermal units have been operated to produce energy and treated as being carried on base. However, when the proportion of the thermal capacity increases, the need to evaluate the convergence of the load during both the expansion and operational planning will increase specially during the periods where the levels of the reservoir are low and the capacity of generating hydroelectric plant will be reduced.

In the long-term, the high use of thermal generation will lead to more attention which concerns aspects such as minimum time of input and output, taxes of load's ramp ups and, possibly, factors of minimum load which are the results of the take-or-pay contracts associated with natural gas and coal plants.

As a result this paper presents a simulated model based on the Dynamic Systems technique which allows how to establish the generation capacity of a hydrothermal system which is compound firstly, by a gas thermal and hydrogeneration network, taking in account the operational limitation of the hidro plants (operation of reservoir and minimum streamflow) as well as the thermal network (tax of load's ramp ups and minimal limitation of generation).

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Systemic Insights To Established Principles

Prof. A. O. Moscardini, Dr. K.Lawler and M.Loutfi
University Of Sunderland, U.K

This paper investigates the philosophical implications generated by applications of the Systems Dynamics methodology to established economic principles. Typical of such principles considered are: the state of equilibrium and disequilibrium within the classic flow income/expenditure model; unsuitable or 'razor' edge growth in an economy subject to random exogenous or endogenous shocks and the quality behavior of a macroeconomic system experiencing dynamic upswings and downswings. These well-established principles are contexualized within the framework of the Egyptian Economy in the 1990's.

Egypt, as a developing economy teeters between classic Neo-Keynesian under-employment equilibrium and Harrodian 'razor' edge growth. Hence, the possibility of chaotic 'cobwebs' developing due to switches in government policy or tiny exogenous or endogenous shocks, provides an excellent backdrop for the application of System Dynamics to tease out critical casual links. Periodic macroeconomic instabilities are usually analysed by economists applying Keynesian or Neoclassical methodologies, because the mathematical implications become intractable. Moreover, stabilized macroeconomic principles primarily target advanced economies, where financial intermediation and governments countervail chaotic swings in markets

This paper examines the qualitative macroeconomic behavior of the Egyptian economy in periods of dynamic change and shows that without effective government policy initiatives, cobweb style movements in Egyptian labor/goods and money models are likely. A detailed study of qualitative behavior of the Egyptian economy shows the power of System Dynamics in recommending optimal intervention criteria. The models in the paper are implemented in Powersim.

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European transport policy in the light of resource and energy consumption:
A material-input-based system-dynamics approach

Andreas Mündl, Andrea Scharnagl
Wuppertal Institute for Climate, Environment, Energy
Doeppersberg 19, D-42115 Wuppertal, Germany
andreas_muendl@wupperinst.org, andrea_scharnagl@wupperinst.org

This paper will take a look at the options for a future 'sustainable' transport policy for the European Union 15. It will be based on results of the ongoing work on a multi-sectoral, physical-oriented simulation model (developed in Powersim) which combines the idea of Embodied Energy Accounting with the concept of Material Input Analysis aiming to simulate possible economic development potentials and dematerialisation options under different, sector specific and economy-wide assumptions.

After an introduction into the concept of embodied energy main model structures and feed-back mechanisms are outlined. Then, the integration of material flows - as an input-oriented concept to assess the environmental impact potential - into this system dynamic model is given attention to.

Different transport policy strategies will be analysed according to their effect on main economic indicators (such as growth or dependence on oil imports) and their material and energy intensity. Policies range from modal split to transport avoidance strategies affecting passenger transport as well as freight deliveries for manufacturing enterprises. The multi-sectoral approach allows a simulation of policies affecting all sectors' variables. This is of particular importance for transport policy analysis since transport activity is almost entirely derived demand. Consequently, apart from passenger transport demand, the environmental impact caused by induced freight transport and possible counter-strategies within a dematerialisation concept is given special attention to.

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Heuristics for Data-Driven Model Calibration

Rogelio Oliva
Harvard Business School
Baker Library 174
Boston, MA 02163
roliva@hbs.edu

SD interventions normally start with the articulation of a dynamic hypothesis -- a proposed explanation of how structure is causing the observed behavior. Because of our limited ability to infer dynamic behavior, a set of equations and parameters that captures the system structure (a model) is build to test the dynamic hypothesis. Guidelines for model conceptualization within the SD tradition ensure that equations and parameters have a real-world equivalence. Model *calibration* is the process of estimating the model parameters to obtain a match between observed and simulated distributions of a dependent variable.

The increasing availability of statistically-based estimation/calibration routines in SD software makes it possible to perform 'automated' calibrations of system parameters. Although system-wide automated calibrations are possible -- given an error function that includes all available data and a complete set of parameters to tune -- this estimation strategy does not make optimal use of the data available. Furthermore, system-wide calibrations are not capable of identifying structural deficiencies in the model.

This paper develops a set of guidelines to make better use of the data available through partial model calibration and a comprehensive set tools to analyze and diagnose fit and residuals. Partial model calibration normally requires an iterative process of structure formulation, parameter estimation, analysis of fit and residuals, and model re-formulation. The process is repeated until arriving to a structure that adheres to current knowledge about the real system and that is capable of explaining the observed behavior. Although it is impossible to *verify* a dynamic hypothesis, partial model calibration augments our confidence in the theory to the extent that the proposed formulations are capable of capturing the micro-behavior observed in the real world. Since the model formalizes the hypothesized relationships between variables, thus creating a refutable cause model with multiple 'points of testing,' the calibration exercise constitutes a test (in the Popperian sense) for the dynamic hypothesis. A final set of tests is suggested at the system level to ensure system-wide adherence to the data.

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Experiencing Simulation through 3D/VR Interface

Denny Park
Simulator Solutions Group
Powersim Corporation
1700 Montgomery Street, Suite 111
San Francisco, California 94111
denpa@powersim.com

Bradley Swift
Project Manger
Sense8 Corporation
100 Shoreline Highway, Suite 282
Mill Valley, California 94941
E-mail: brad@sense8.com

Communicating ideas and tasks using simulation, results in higher comprehension than traditional presentations. By allowing users to "experience" a situation through simulation, they become more aware of their actions and corresponding consequences. If you combine with simulation a graphic 3D/VR (Virtual Reality) user interface you can heighten the simulation experience. Simulations with graphic 3D/VR user interfaces can provide users with a broad range of clues and hints from the obvious to the sublime, similar to what one would experience in real-life situations. With recent advances in computing technology, the hardware cost of near real-time interactivity with a simulation through a graphic 3D/VR interface is below $10,000. Combining system dynamics models with graphic 3D/VR user interfaces presents the simulation community with an enormous challenge and opportunity to reach users as never before.

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System Dynamics in Human Resource Management and Team Building

Janecke Pemmer
Paradigm Business Simulators AS
C.Sundtsgt.4
N-5004 Bergen
NORWAY

Jan Folkman Wright
Det Norske Veritas A/S

This paper describes how System Dynamics simulation models may be used to analyze problems within the field of Human Resource Management. Identified problems are related to the composition of optimal teams for each phase of a project or work process in order to increase the probability for success. A system structure is proposed and a simulation model is being built. Basic assumptions include the facts that people have different professional and human qualifications. Hence they will differ in their capability to excel at various project stages. Undervaluing the importance of these qualifications when teams are composed could cause people to be misplaced and feel uncomfortable. This could cause lack of compatibility and communication within the team, organizational conflicts, and reduced performance and motivation.

System Dynamics, Team Role, Personality Theory, Learning Psychology, and Action Science are theories and approaches that are combined to provide a learning environment for supporting initial design, development, and maintenance of project teams, management groups, and other groups of professionals, where high performance is essential for success.

Simulation of projects and team roles facilitates a better understanding of the dynamic behavior of a team throughout a project. Each team member will gain insight into his/her own strengths and weaknesses based on their team role profile. This insight should promote group communication, and acceptance of necessary changes in team leadership and key roles.

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Public Decision Making For Land-Use and Transportation Planning.

John Peschon, Leif Isaksen and Laszlo Hajdu
adriennep@jps.net

The often contentious debate of the US 101 corridor through Marin and Sonoma counties starting at San Francisco's Golden Gate Bridge provided the incentive to write this paper and to refine a decision structure that is suitable for addressing large publicly financed transportation projects with significant long-term socio-economic and ecological impacts upon a region. This decision structure goes beyond the traditional cost benefit (or with and without) analyses. It defines the system state that today's informed public would like to see two generations from now. This "horizon" state comprises a number of interrelated variables pertaining not only to transportation, but also to land-use and demography which in turn affects socio-economic and ecological outcomes. The first goal of this search for a desirable horizon state is to avoid the kind of major mistakes involving large-scale public systems that were made in good faith during the past two generations, for example, water developments in the Southwestern U.S. A related goal is to identify new paradigms which constitute elegant and sustainable solutions, mainly a network of towns that are relatively compact and have a match of demography and the local economy, and thus eliminate the need for freeway

expansion. Actual regional examples of the new paradigm are described and the techniques of visual preference and *charrettes* to inform and persuade the public are presented.

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Model Quality: Determinants and Consequences

David W. Peterson ***Robert L. Eberlein***
60 Jacob Gates Road Ventana Systems Inc.
Harvard, MA 01451 USA Belmont, MA 02178 USA
dwp@world.std.com vensim@world.std.com

In instances where more than one model address the same problem, evidence shows that some models are considerably better than others. Model quality can be measured in two dimensions. First, there is technical quality -- the ability of a model to correctly compute what it represents, often a prediction of policy implications. The second dimension of quality has to do with a model's contribution to communicating and compelling people to act; this second dimension might be called persuasive quality. This paper argues that both types of quality are usually maximized by the simplest possible model that conforms to the available knowledge of the system. The knowledge comes in several forms, three of which are indispensible: model fragments (potential equation forms), thought experiments (mental simulation, often at limiting conditions), and numerical data. Adherence to the basic definition of quality yields models which usually, but not always, conform to the features typical of system dynamics models, such as nonlinearity, feedback, and stock-and-flow structure. Examples illustrate and support the concept, and show that unusual and innovative model structures sometimes arise from the direct pursuit of model quality.

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Organizational Creativity With and Without Models

David W. Peterson
60 Jacob Gates Road
Harvard, MA 01451 USA
dwp@world.std.com

System Dynamics models are sometimes offered as improved replacements for the mental models currently used by decision-makers. However, the common presumption that decision-makers use mental models conceals a paradox. The experimental and historical evidence shows that mental models are so inept as to be of little help in managing any complex system. Nevertheless, many complex systems have been successfully managed without the help of system dynamics models. How can organizations achieve anything with such poor models? This paper shows how systems can be managed without any models at all, by means of a form of organizational evolution. Numerical simulations of such quasi-evolutionary systems reveal the conditions under which model-free management prospers. The results offer some new and disturbing insights for the implementation of system dynamics models, but suggest that the eventual impact of system dynamics will be vastly greater than currently observed.

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System Dynamics Modelling: The Case of a Temp Agency

María del Pilar Pérez González
Departamento de Economía Aplicada (Matemáticas)
Facultad de Ciencias Económicas y Empresariales, Universidad de Valladolid
Avda. Valle Esgueva, 6, 47011 Valladolid, SPAIN
mpperez@esgueva.eco.uva.es

The business turnover of the temp agencies in Spain has pasted of 35.000 millions of pesetas in 1994 to 165.000 millions in 1997 and it's expected to arrive to 500.000 millions in 2003. There are 429 temp enterprises in Spain, but only five of them have the 60% of the business turnover of the sector. A good management is fundamental in this hard war for to keep and to improve his situation in the market.

The role of the temp agencies is fundamental in the conduct of the employ. They are obligated to spend the 1,25% of their total wages bill on formation. In this way, they have influence in the hiring of temp workers.

The aim of this paper is to construct a simulation model about the activity of a temp agency in Spain, in order to plain, to understand and to analyse the consequences of the decisions made.

Financial and social variables have been considered in the construction of the model. The overhead costs are influenced by the index of retail prices. The interest rate in the market is very important in order to evaluate the time given to the businessman between the payment to the workers and the charge to him. On the other hand, the effect of the unemployment rate is considered.

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Dynamic Approach for Incorporating Intellectual Capital in the Strategic Development of a Consulting Firm

Luz Maria Puente, Hal Rabbino, Annabel Membrillo
SDSG,LLC The Strategic Decision Simulation Group
11915 Stone Hollow Road #1527
Austin, Texas 78758
halr@sdsg.com
http://www.sdsg.com

This paper focuses on applying system dynamics to the concepts of intellectual capital. Important new ground has been made in establishing a formalized methodology for including the intangible worth of a company in terms of intellectual capital. Because this creates the potential to change the very foundation of current accounting practices for all company valuation across all industries, we believe it is imperative to understand how these new elements of valuation may affect leadership.

To gain deeper insight into the intellectual capital concepts of structural capital, human capital and customer capital, how they interrelate and how they affect company leadership, we integrated these concepts into the company-level, system dynamics intellectual capital model of a consulting firm. We believe that the effective management of intellectual capital is the key driver of success for service industry firms such as consulting.

Our goal was to capture these critical elements of success and place them in a dynamic model for simulation of various hypotheses for managing intellectual capital. The first section of the paper outlines the modeling process, the second part discusses the alternative hypotheses and the third section describes the findings.

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The HIV/AIDS Sector in THRESHOLD 21 Malawi

Weishuang Qu, Douglas Symalla, Gerald O. Barney
MILLENNIUM INSTITUTE

In mid 1997, supported by UNDP/Malawi, the National Economic Council of Malawi decided to use THRESHOLD 21 as a tool for national and sectoral planning. As Malawi has one of the highest HIV/AIDS prevalence rates in the world, it was decided that the health care sector in THRESHOLD 21 was inadequate to capture the AIDS epidemic in Malawi, and a new HIV/AIDS sector was developed to explore the demographic, economic, and social impacts of the epidemic, and to design strategy to deal with them. This paper introduced major assumptions used in the HIV/AIDS sector, the structure of the sector, and initial applications of the sector in doing what-if analysis.

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Production Functions in THRESHOLD 21 and their Preliminary Applications to Italy, Benin, and Cambodia

Weishuang Qu, Gerald O. Barney, Philip Bogdonoff
MILLENNIUM INSTITUTE

The production functions used in THRESHOLD 21, a national sustainable development simulation model, are Cobb-Douglas and have been developed separately for three sectors: industry, services, and agriculture. Factors of production for industry and services include labor, capital, technology, energy, and education and training. Factors for agricultural production are land, capital, technology, energy, soil quality, and water availability.

Italy, Benin, and Cambodia are representative of three different types of countries: Italy is following a "normal" development path. Benin is not "normal" in the sense that during the ’70s and ’80s, its labor productivity (per worker real output) decreased. The reason, according to two Benin nationals, was the Russian-style economic system used in Benin during 1972 - 89. Cambodia’s development is not "normal" due to decades of war.

With no modification for Italy, and slight modifications to the production functions for Benin and Cambodia, THRESHOLD 21 was applied to all three countries and used to generated simulations for the period 1965 - 1997 which fit historical data reasonably well. The models were then used to explore a variety of policy scenarios for possible future development paths in each country.

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System Dynamics Modelling of Information and Communication Technologies: Policy Studies in the Banking Industry in Thailand

Mohammed Quaddus and Arunee Intrapairot
The Graduate School of Business
Curtin University of Technology
GPO Box U 1987, Perth, Western Australia 6845
Quaddusm@gsb.curtin.edu.au , intrapairota@cbs.curtin.edu.au

This study aims to develop a holistic, system dynamics model for information and communication technologies (ICT) in a major bank in Thailand in order to identify various policy variables affecting the adoption and diffusion of ICTs.

Thailand's economy is currently confronted with a major crisis originating in the property and financial sectors. A financial institution's ability to adopt and diffuse ICT may be a key to financial control mechanisms necessary to prevent repetition of such damaging outcomes in the future.

Initially, the study explores the current usage of ICT of the bank. The resulting information reveals critical problems that the bank had to confront (e.g. rapid obsolescence, high costs of technologies, low productive usage of adopted technology, lack of capable employees, and low acceptance from staff and customers).

The model divides organisation boundaries into five sub-sectors, i.e. the bank- technology group as a change agent, bank staff, customers, vendors, and external environments. It emphasises four resources, i.e. technology, profit, staff, and customers, and captures main feedback loops, positive and negative, of the system.

Subsequently, the qualitative conceptual model is simulated using the Ithink software by adding each feedback until the whole system is complete. This additional technique contributes to enhance understanding regarding the impacts of each feedback loop, detecting errors and tracing the logical concepts.

The simulation model reveals these following issues. First, training is a vital factor for the success of technology diffusion. Second, the backlog of problems from technology diffusion decreases relative advantages and sales dramatically. Third, technology cannot bring many customers as many as the bank expects, although it can be successfully diffused, due to the constraint of market potential. Fourth, excessive investment in new technology can be detrimental to the bank. Therefore, the bank has to determine the desired investment in new technology. Fifth, technological support from vendors can bridge the skilled staff gap leading to an increase in technology diffusion. Sixth, if technology is directly employed to satisfy customers, marketing is an important factor to enhance customer satisfaction. Finally, the bank cannot harvest economic gains from investment in new technology without substantial investment.

This ICT model enables bank officials to understand the present state and constraints of technology adoption and diffusion. This can then be used for policy analysis and forward planning to mitigate the constraints and re-design the system behaviours. Additionally, since existing and potential banking technologies are abundant, the model can be initially used to gain holistic understanding before applying to any particular technologies or tailoring for specific organisations.

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Modelling The Dynamics Of Process Reengineering : A Research Proposal

Qudrat-Ullah
qudratu@ifi.uib.no
Department of Information Science
University of Bergen
Norway

Competitive pressures, changing regulation, and influx of technological innovations require businesses to reengineer the ways they do business. The effective management of the changes associated with the process redesign requires a modelling technique. The traditional modelling techniques such as dataflow diagrams, action workflow and wall-graphs emphasize much upon what of a business process. These techniques fail to express why of the process i.e., the behavioural aspect. They fail to capture the motives and rational behind a process, rendering process reengineering a less effective endeavour. Also, the existing process improvement models are often based on a static analysis of the individual processes. Here, the analysis is often made without an understanding of the dynamic behaviour when the processes interact and are dependent upon each other. The focus of this research, therefore, is to develop a methodological frame work, useful for modelling and analysis of the processes, processes-interactions and their impact on business performance. This study proposes a System Dynamics model based Process Reengineering Laboratory as a potential solution to the problem. The research will first present review of the existing modelling techniques. Then the proposed modelling framework for better understanding of the dynamics of process reengineering will be developed and presented. Finally, implementation of the modelling framework will be explained by applying it to some real world cases across the business domains.

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Applying the Principles of Co-opetition With System Dynamics Tools

Hal Rabbino
SDSG,LLC The Strategic Decision Simulation Group
11915 Stone Hollow Road #1527
Austin, Texas 78758
halr@sdsg.com
http://www.sdsg.com

Business, like war, is a win-lose proposition. This is the traditional training and mindset that has shaped management's view of their role and responsibilities towards their shareholders, clients, customers and suppliers. This approach focuses on gaining a bigger piece of the existing pie, which forces leaders to consider every transaction as a battle, and is by necessity confrontational. This approach is now being challenged.

In their book, *Co-opetition*, Brandenburger and Nalebluff introduce a framework for applying game theory principles into management practice. The message is that competition and cooperation can, and should, co-exist. Their concern is with growing the pie itself rather than gaining a bigger share of what is already there. However, they do not provide a means for managers to test their understanding of these ideas without committing the company resources.

With the help of system dynamics modeling tools, managers can approach the concepts of co-opetition more richly and more effectively. Through an in-house example from a consulting firm, this paper explains how to consider co-opetition alternatives for running a business in a dynamic framework.

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The Costs and Benefits of Needle Exchange Programs: A System Dynamics Approach

Julie E. Radzicki, Michael J. Radzicki

Public officials in many US cities are currently wrestling with the question of whether to institute needle exchange programs for illegal intravenous drug users. Government run needle exchange programs supply CLEAN needles, free of charge, to illegal intravenous drug users. Proponents of these programs argue that they reduce the need for addicts, who are often poor and unable to work, to share needles with other addicts. This reduces the spread blood-born diseases such as AIDS and hepatitus, and ends-up saving the government money because it does not have to pay to treat addicts who have contracted serious diseases.

Opponents of needle exchange programs argue that, although clean needles can certainly reduce the spread of blood-born diseases, they must be used by addicts EVERY TIME they receive a dose of an illegal intravenous drug. Just one dose from a dirty needle can defeat 100 doses obtained via clean needles. They further argue that free needles actually ENCOURAGE the use of illegal intravenous drugs (i.e., they lead to more users and more uses by the same users) and put the government in the inenviable position of pro-actively contributing to the spread of the illegal drug culture.

This paper presents a system dynamics model of a needle exchange program that incorporates the various factors described above. Simulation runs examine the costs and benefits associated with the introduction of a needle exchange program in a city in terms of dollars and cents, and in terms of the number of people who contract blood-born diseases.

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An Essay on The Ratification of The Amsterdam Treaty – The Interaction between Management Styles and Economics of Convergence in EU-countries

Stig Rée
Copenhagen Business School
Institute of Management, Politics and Philosophy
Denmark
reemanag@inet.uni-c.dk

The Ratification of The Amsterdam Treaty is characterised as a wicked mess with both high dynamic and high behavioural complexity. It is therefore analysed not only with traditional economic variables, but also with management dimensions and styles as seen in foreign policy and private business. Focus is on the interaction between economic and behavioural systems, and the inherent system dynamics. EU economics is characterized by very high unemployment levels and low labor market flexibility, existing together with high rates of productivity in selected industries and geografical areas. European politics is centered around the discussion of sustainability of the welfare state, and the Western Europeans role as followers in relation to US foreign policy.

Different EU-countries are segmentated on their macroeconomic structural and dynamic elements, and by their different styles of management and leadership. The economic analysis will build on OECD norms and standards, the management analysis on behavioral theory on mental styles in foreign policy and private business.(Among others Kissingers foreign policy styles). It is discussed, how the political most significant elements of The Amsterdam Treaty:

environmental protection, criminal investigation integration, and not the least, the EU-expansion with some of the former Eastblock-countries can trigger off both constructive and destructive development patterns. The analysis will be done with an adapted ex ante OADI sequence.

The result of the analysis are system dynamics caused demands for EUinstitutional change in voting rights for different countries, and in the rules for interaction among the Commission, the Counsil of Ministers and the European Parliament, and a comparison to demands put forward by other decision criteria such as more openness, more influence for national parliaments, more regional development etc.

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Getting Quality the Old-Fashioned Way: Self-Confirming Attributions in the Dynamics of Process Improvement

Nelson Repenning and John Sterman
MIT Sloan School of Management

Managers, consultants, and scholars have increasingly recognized the value of considering an organization's activities in terms of processes rather than functions. Process oriented techniques for improving quality and productivity have proven to be powerful tools in many organizations. However, while suggesting new and valuable improvement opportunities, process-focused improvement techniques often fail, many times despite initial success. Existing theory does not explain many of these failures in part because process improvement involves interactions among physical structures and decision making processes in the firm while existing frameworks tend to address one at the expense of the other. Operations research and management science focus on the physical aspects of process improvement while organization theorists focus on the behavioral side. In this paper the beginnings of an integrated, interdisciplinary theory are developed. Drawing on the results of two in-depth case studies of process improvement efforts within a major US corporation, we develop a model that integrates the physical structure of process improvement with established theories on human cognition, learning, and organizational behavior to explain the dynamics of process improvement efforts. We show how these interactions can lead to self-confirming attributions which thwart improvement efforts. We consider implications for practitioners and future research.

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Limits to Groupware-Facilitated Organizational Learning in a Consulting Firm

Eliot Rich
Department of Management Science and Information Systems
School of Business BA 310
University at Albany
Albany, NY 12222
rich@acm.org

Consulting firms and other knowledge-intensive organizations leverage a single asset: the collective learning and knowledge of its staff. They collect, retain and disseminate skills, best practices, and project histories as they market and deliver servi ces to clients. In the past these activities were performed through a combination of written documents and formal and informal relationships among the staff over time. Over the last five years many firms adopted groupware tools which combine the connectivity of electronic mail with the storage and indexing facilities of text databases. Groupware provides the technology platform needed to grow repositories of corporate experience and encourage new information sharing relationships.

This paper presents a model of the relationships between individual experience, organizational knowledge, and the dynamics of information sharing. The major hypothesis is that the introduction of groupware increases the volume of information available for sharing and opens up new channels for sharing, but that other forces (e.g., individual time constraints, lack of information management), ultimately reduce the transfer of individual knowledge to the organizational knowledge base.

I also discuss how groupware systems generate incidental data, such as system logs, that may be used in concert with other research methods to develop the model. When completed, the model will provide new perspectives on the use of groupware to support organizational learning and the policy options available to firms attempting to increase the return on its technology investments.

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Outcomes from an Evaluation of a Group Model Building Intervention for Public Sector System Change

George Richardson, David Andersen, Steve Huz, Roger Boothroyd, and Roberta Spencer

Over the past four years, researchers at the State University of New York at Albany and the New York State Office of Mental Health have been conducting a study of the impact of a group model building intervention on groups

working on a public policy issue. The major goal of this project was to determine the extent to which a group model building intervention could enhance the coordination and integration of local vocational rehabilitation and mental health services for persons with severe mental illness.

To test the effectiveness of the group model building intervention the design of the project called for the three comparative conditions. These conditions were:

(1) two teams of policy makers from sites which received explicit mandates to examine this policy issue and who participated in a group model building intervention;

(2) two teams of policy makers from sites who did not receive explicit mandates to examine this policy issue and who participated in a group model building intervention; and

(3) two teams of policy makers from sites which received explicit mandates to examine this policy issue and who **did not** participate in a group model building intervention.

Data were collected pre- and post-intervention on group member characteristics, attitudes and beliefs about the importance of integrating services, organizational networks, and perceptions of the value and effectiveness of the intervention. This presentation will provide an overview of findings from this study.

Preliminary analyses of the data on the attitudes and beliefs of participants show that sites where group model building (Conditions 1 and 2) occurred made greater progress in agreeing on the means to achieving an integrated system and believed that those means were more a part of the agenda in their service system than prior to the intervention than did a similar group of policy makers and providers in sites in which there was no group model building (condition 3). No differences were detected between mandated sites and non-mandated sites (conditions 1 and 2) on means for achieving an integrated system.

Initial analyses of data from questionnaires measuring shifts in goal importance showed no differences between any of the study conditions. On measures of the group's impression of their progress toward improving their team functioning (goal clarity, team cohesion, internal fragmentation, openness of group process) to achieve their goal of integration, individuals from sites which experienced group model building (conditions 1 and 2) reported significant improvements, while individuals from sites where no group model building occurred reported no shift.

On a second measure of group functioning which focused more directly on the team's system integration work, groups experiencing the group model building intervention reported significant gains in their understanding of the problem, the importance of the problem and the degree to which members became more aligned around the group's proposed solutions to the problem. Subjects from sites where no intervention reported no shifts in these areas.

When assessing the overall value of the group model building process group members from counties which had an explicit mandate (condition 1) rated the experience more favorably than group members from non-SIP counties (condition 2) suggesting perhaps a greater initial motivation to solve the problem when the model building team arrived.

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Systemic Leverage: Finding Leverage in Complex Systems in the Real World

James L. Ritchie-Dunham
President, SDSG,LLC The Strategic Decision Simulation Group
11915 Stone Hollow Road #1527
Austin, Texas 78758
jimrd@sdsg.com
http://www.sdsg.com

Leverage has allowed people for thousands of years to exert more force indirectly in moving things than they could directly, giving us the pyramids, grain mills, see-saws, pulleys, and gears. In social systems, decision makers use leverage to move larger-than-self bodies (i.e. public opinion and employee motivation) skillfully in the desired direction. Machiavelli identified several such leverage points in complex systems over 500 years ago in The Prince. He developed those insights over a lifetime of counseling royalty and ambassadors. Modern day decision makers deal with equally challenging social systems, yet have less time to understand the intricacies to implementing change.

Authors in SD and resource economics emphasize the importance of leveraging resources. This paper provides a framework for defining different types of leverage and how they work together and a proven tool set for identifying and utilizing these leverages.

Three forces act in systemic structures to significantly affect behavior: mechanical advantage, momentum and goal alignment. Systemic leverage utilizes three distinct forms of leverage to move these systemic forces: direct, dynamic and structural. On their own direct and dynamic leverage each create short-term leverage, and on its own structural leverage creates mid-term leverage, but combined these three forces create very strong, sustainable leverage. This is systemic leverage.

The paper shows how some popular management trends (i.e., balanced scorecard, levers of control, core competencies) focus on one or two of the leverages and could be strengthened by the addition of the other leverages.

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Strategic Fixed-Points: The one-to-many relationship between practices and performance

Scott F. Rockart
Sloan School of Management, MIT, 50 Memorial Drive
Cambridge, MA 02142
srockart@mit.edu

Four sources of performance differences dominate the strategy literature; environmental factors, practice differences, resources, and positive feedback in systems. It is my belief that the system nature of firms, of which positive feedback is one aspect, is a promising and underdeveloped area of exploration to understand performance differences across firms. The theory explored here is that firm differences may arise not because of different practices across firms, but because any one system of managerial practices may produce more than one locally-stable performance equilibrium.

These performance outcomes are characterized by an internally consistent set of firm attributes that are interlinked and self-supporting. Some of these outcomes will be unstable, and firms will quickly be knocked out of such performance states by even minute real world forces. Other equilibria will be locally stable - resistant to small shocks or managerial actions - allowing us to observe firms in those different outcomes for time spans of practical significance. Stable performance states need not be the polar extremes common in positive feedback literature. The interplay of positive and negative feedback may create equilibria that are vanishingly close together. The general point is that structurally identical firms, firms which are the same on all key practices, may exhibit different performance levels.

This paper explores sufficient and realistic conditions for multiple locally-stable equilibrium performance outcomes at the firm level. It proposes examples of where such equilibria may be occurring in real firms, and establishes several normative insights of this theory for managerial practice.

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A Regulatory Paradox: How a Governmental Attempt to Stabilize Hospital Finances Led to More Uninsured, Restricted Health Benefits, Reduced Hospitalizations, and Weakened Hospitals

John W. Rodat
President, Signalhealth
373 Wellington Rd.
Delmar, New York 12054
jwr@signalhealth.com

This paper describes a model and analysis exploring the relationships between:

1. Different types of health insurance coverage in New York State where, like the rest of the U.S., coverage is neither mandatory nor universal;
2. Hospital service utilization;
3. Hospital prices and payments, which for nearly three decades, were regulated by State government;
4. State mandated cross-subsidies of services for uninsured people through increased prices for those insured;
5. Insurance premiums; and,
6. Regulatory policies.

The model takes a relatively long view and is focused on hospital services in New York State. Analyses resulting from building and using this model formed the conceptual basis for abandoning price regulation.

A second model will also be described. It shares a common core structure with the model described above, but is focused on a single region over a shorter period, and is extended to include additional medical services. Among other things, it is used by service providers to evaluate pricing strategies.

Among others, key observations include:

1. The insurance relationship masks, delays, weakens, and aggregates price/demand dynamics in health care systems, but it does not eliminate them. Because there is not a direct economic relationship between seller and buyer, the effects of pricing policies emerge in ways not understood by those in the system.
2. Price regulatory systems that do not also effectively control volume create economic and political distortions; and
3. Institutional subsidies to offset the costs of hospital bad debt and charity care exacerbate the problem.

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An Example about how System Dynamics Can Improve the New Product Development Process: A Matrix Structure

Rafael María García Rodríguez and Yolanda Álvarez Castaño
University of Oviedo, Spain
Departamento de Administración de Empresas y Contabilidad
Facultad de Ciencias Económicas y Empresariales
Avenida del Cristo s/n, 33071 OVIEDO, SPAIN
rgarcia@hp845.econo.uniovi.es, yalvarez@hp845.econo.univoi.es

The new product development process is a risky and tricky activity that requires an integrated effort of a multifuncional team, and a unified method of planning and control. This method allows to enough flexibility in order to incorporate the new information about technology and change in the market, which is constantly arising.

The application of System Dynamics in the planning and the control of the research and development projects, improves the management of this processes, and at the time, allows the participation of all the people who will do the work, in the planning of the work. This provides two principal benefits: (1) Since the owners participants are involved in the planning of the work, this nurture their commitment which the plans and objectives of the project. (2) Much of the information about system structure of the new product development process resides in the mental models of process participants. By building a system dynamics model is necessary to elicit and articulate of knowledge held in the mental models of the people, which allows transferring of lessons from past projects to future projects.

In order to illustrate these points, a simulation model using a system dynamics approach was building, this model show as a matrix structure is not a adequate one for getting quickly a new product of great quality and low cost.

A later sensitivity analysis of the most important parameters defends the need for a structural change in the system.

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A System Dynamics Model to Analysing Waiting Lists in Public Hospitals in Spain

Rafael María García Rodríguez and Begoña González-Busto Múgica
University of Oviedo, Spain
Departamento de Administración de Empresas y Contabilidad
Facultad de Ciencias Económicas y Empresariales
Avenida del Cristo s/n, 33071 OVIEDO, SPAIN
rgarcia@hp845.econo.uniovi.es, bbusto@hp845.econo.uniovi.es

This work analyses waiting lists in public hospitals in Spain using a dynamics perspective. The relevance of this research lies in the political and social concern about the long periods of time patients have to wait in order to receive sanitary service. In this sense, it is necessary to firstly analyse the organisational characteristics of public hospitals, particularly their bureaucratic behaviour, human resources management and the incentive schemes usually employed.

This theoretical framework is extended with qualitative information obtained from interviews with key managers and sanitary personnel of the Spanish National Health Service. A simulation model using a system dynamics approach is derived from the application of all this information.

This model, after being statistically calibrated, is used to develop a sensitivity analysis of the most important parameters, enabling the detection of its leverage points. These can be used as a tool for improving the system's behaviour. Furthermore, the model allows us to analyse the short and long term outcomes of the policies currently being implemented in order to improve the evolution of waiting lists and to define new alternative policies which reduce the growth trend observed. The results obtained from the simulation support the main hypothesis which defends the need for a structural change in the system and criticises the employment of isolated initiatives whose effect is exclusively limited to the short term.

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The Puzzle of Unemployment: Retrospecting Kaldor, Lipsey and Phillips on Wage, Employment and Profitability

Alexander V. Ryzhenkov
Industrieseminar der Universität Mannheim
Schloß D-68131 Mannheim Germany
AlexR@is.bwl.uni-mannheim.de
Institute for Economics and Organisation of Industrial Production
Siberian Branch of Russian Academy of Sciences
17 Academician Lavrentiev Avenue Novosibirsk 630090 Russia
Ryzhenko@ieie.nsc.ru

As the number of jobless in the European Union mounts, the classical controversy on employment and growth gains momentum again. Phillips (1958) argued, first, the growth rate of real wage is proportional to the excess of the employment ratio over its equilibrium; second, the higher the growth rate of employment, the higher is the rate of change of money wages, other things being equal. Challenging Phillips' view, Lipsey (1960) has found out that times of falling unemployment were associated with lower rates of change of money wage rates than times of rising unemployment.

Computer simulations based on the model of long wave (Ryzhenkov 1995, 1997) are in agreement with the first Phillips conjuncture. Still there is a distinct tendency for the rate of change of real wage to be above the average when unemployment is growing and to be below the average when unemployment is decreasing.

Neither Phillips nor Lipsey included a profit rate as a factor of the wage rate in their models. Kaldor (1959) advised to relate wage increases to the increase in profitability. Simulations of a profit-wage spiral demonstrate that Kaldor's assertion may be only partially true since the rate of change of real wage can decline simultaneously with an increase in the profit rate, and vice versa.

This paper makes certain recommendations on employment policy. It stresses the impact of technological change on economic development and job creation.

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Consequences of Growth in Management Consulting Industry

Francesco Sacco
Business Policy Department
Bocconi University School Of Management
Via Bocconi 8
20136 Milan, Italy
francesco.sacco@uni-bocconi.it

The management consulting industry is fast growing and there is an expected growth in the global market of 16% per year until the end of the century. The management consulting industry is not just growing, but is also changing and demanding different competencies (IT, implementation, the ability to bundle strategies and technologies).

However, the only limited resource in the industry is people so, because of the long and strong expansion, the cost and the average quality of human resources could change.

A learning environment has been built to explain the consequences of this dynamics looking in perspective to the end of this growth period. The consequences of this shift between growth and decline are explored on the firm’s side and the effects are studied on financial indicators, on quality and on productivity.

The learning environment is aimed to show the use of system dynamics as a tool for policy making in an industry with structural changes.

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A Dynamic Simulation Model for Long Term Comprehensive Environmental Analysis of Gap

Ali Kerem Saysel and Yaman Barlas
Bogaziçi University
80815 Bebek, Istanbul, Turkey
saysel@boun.edu.tr

Southeastern Anatolian Project (GAP) is an integrated regional development project based on water resources development and large irrigation schemes and includes rural and urban infrastructural facilities as well. It covers 8 provinces, about 8 million hectares of land, 22 dams and 17 hydroelectricity plants. By the end of the project 1.7 million hectares of land is planned to be irrigated and an hydroelectricity capacity of 7500 MW is targeted. The overall idea is the economic integration of the so called "underdeveloped" region to national and global economy through economic activation which will be initiated by a regional increase in material resources supply, i.e. food, feed, fibre and oil crops and animal husbandry products.

But, big water shemes have many well reported adverse effects on environment, most of them related with agricultural modernisation practices such as chemical contamination, salinisation, deforestration, range lands destruction and land erosion which are also related with socio - economic conditions under which the farmers's strategies of production are determined.

In this model, the production strategies of the farmers, i.e. farm systems and agricultural input use are determined strongly by economic forces. The situation of competing goods such as food, feed, fibre, oil and animal products in the market promotes certain farmer strategies while it subsides others. But, different farm systems i.e. mixed, monoculture, polyculture and different crop rotations elevate different environmental impacts i.e. salinisation, pesticide contamination, nitrate pollution, overgrazing of rangelands and erosion, and in turn, those environmental impacts affect farmer strategies by affecting the fertility of land resources. Hence, a dynamic feedback analysis of farmer strategies under environmental and market pressures is performed for long term assessment of environmental problems in GAP.

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System Dynamics in K-12 Education: Across The United States

Mary Scheetz
255 SW Harrison, Apt. 6B
Portland, OR 97201

Joan Yates
645 W. Orange Grove Road, #1080
Tucson, AZ 85704
jyates@fc.cfsd.k12.az.us

For the past ten years, students in a small but growing number of K-12 classrooms across the United States have been using the concepts and tools of system dynamics to better understand the systems they study and in which they live. As staff members in approximately twenty school districts have learned principles and mechanics of system dynamics, they have helped students create and/or use system dynamics models, as well as non-computerized system dynamics tools. Students and staff use SD tools to help them answer questions intrinsic to system dynamics such as, "How have the important accumulations within this system changed over time?" and "What are the factors and dynamics within the system, particularly feedback, that have changed the system over time and how have they done that?"

Educators across the U.S. who work with K-12 students using system dynamics as part of their learning experience have been sharing ideas on how and when to use system dynamics in classrooms as well as models and other system dynamics applications created by students and staff. Presenters Mary Scheetz and Joan Yates began working with students and other educators using system dynamics 10 years ago as a middle school principal and classroom teacher, respectively, and have subsequently worked with fellow K-12 educators using system dynamics throughout the U.S. They will share examples of the products and thinking generated by students and educators who have used system dynamics to reach a deeper understanding of the systems they study and in which they live.

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Demand Forecasting and Strategic Planning in Electricity Distribution Companies:
A System Dynamics Approach

B. Schuch and M. Morozowski
UFSC - Federal University of Santa Catarina - Brazil
marciano@gpse.ufsc.br

Up to 1995, the Brazilian electricity market structure was a regulated monopoly. From 1995 on, government initiated reforms have been changing the market structure through privatization. The new energy market structure, the traditional times series and econometric models traditionally applied by forecasters shall be complemented by new models, able to take into account price feedback, consumer preferences in terms of price/ quality of energy supply, as well as the strategic options of alternative suppliers.

This rather complex problem was conceptualized in a system dynamics framework and the result is a new model to forecast the electricity demand of a distribution company, taking into account the feedback characteristics of the problem. The model is structured as follows:

- a technical module that projects the demand for each consumers category (industrial, residential,commercial, among others);
- a managerial module that defines the price and investment policies of the distribution/ retail company to keep (or enhance) its consumer base and market share.
- a feedback loop that links the two modules: the impacts of the investment and price policies (as determined by the managerial module) on the company goals (as measured by the technical module) are feedback to the managerial module, that reformulates the policies to cope with consumer behavior and/or competitor reactions, whenever a gap between company goals and policy results develops.

This model is being developed as part of a research project at the University. It is aimed at helping distribution companies to learn about competitive environments and at enhancing the curricula of the Electric Engineering courses at the University.

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Model Building and Validation: Contributions of the Taguchi Method

Markus Schwaninger
University of St. Gallen, St. Gallen, Switzerland

Andreas Hadjis
Technikum Vorarlberg, Dornbirn, Austria

Ascertaining the sensitivity of model behavior to parameter changes is a critical step in model building, simulation, and, in particular validation. In addition, knowledge about impact differentials between action variables ('policy variables', 'strategy variables') can contribute substantially to the robustness of a policy or strategy.

Traditional methods of sensitivity analysis, which are essentially based on varying the values of parameters one by one, are usually too costly and time-consuming in the case of complex models.

The objective of this paper is to outline the potentialities of the Taguchi Method to enhance efficiency in building and validating complex System Dynamics models. This is a method coming from engineering, where it is used to improve product design by calculating the relationships between signal, noise and output measures. Used in the context of model design and validation, it enables for a quantification and comparison of the sensitivities of multiple parameters, at a low cost. Therewith, insights into aspects of 'dominant structure' (Richardson) can be gained. This is not only helpful to direct attention of model builders to priorities. It is also of great value to ascertain areas of concern and priorities for parameter optimization.

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Dynamic Modeling for "Internet Telephony" Management

Habib Sedehi
HELP S.p.A. Auditing Informatico
Coopers & Lybrand
sedehi@help.it

Nicolò Vaccaro
Università degli Studi di Palermo
Facoltà di Economia e Commercio
Viale delle Scienze 90128 Palermo
(TALY
nvaccaro@tin.it

Internet Telephony (IT), i.e. the possibility to dispatch "voice" through Internet, constitutes a serious menace to the consolidated national Telecommunication company business. Indeed the possibility to dispatch an international telephone call paying the price of a local call incites private and business users to use more and more IT, shrinking present profit margins. The complexity of the problem and the opportunity to understand and analyse it from a systemic point of view, is a stimulating challenge.

The aim of this work is to provide TELECOM ITALIA, Italian national Telecommunication Company, with a tool, which supports management strategic decisions in transforming IT from a menace to a new business opportunity. In particular it consists in developing a System Dynamics simulation model, which can run in two different decision moments:

Firstly: in estimating in general the IT business economic effects, supposing that the company adopts a No Intervention strategy. The model, estimates the erosion effect on corporate profit margins, caused by IT, in order to determine the size of menace and, as a consequence, to calibrate corrective actions.

Secondly: the model evaluates the scenarios turned up from alternative strategies. This in order to esteem every strategy in absolute terms and to evaluate the most positive alternative strategies in relative terms.

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A Wine Production System Dynamics Model

Habib Sedehi and Christopher Barker
HELP S.p.A. Auditing Informatico
Coopers & Lybrand
sedehi@help.it, cphbarker@aol.com

System Dynamics (SD) is a principal methodology in a large European Commission financed research project called DAMAS (DAshboard MAnager System). The objective of the project, which involves a number of companies, is to assist European wine producers to make better operational and strategic decisions by understanding the dynamics of their processes.

This paper will concentrate on one of the main areas in which SD has so far contributed in the project: that of the wine production process. It will introduce the modeling of various stages of wine production in a medium-sized winery, and the understanding that can be created by a dynamic model of such a manufacturing process. After detailing some novel uses of SD in modeling allocation problems in production process, the paper will conclude with some indicative simulation results and observations on the limitations of the approach.

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Systems Coherence: A Method for Evolving Relationships and Measuring System Change

Raymond J. Seigfried
Senior Vice President
Christiana Care Health System

Systems and Systems Thinking are very much a paradigm change, a revolution in our own world view transforming the way we participate with the universe we live in. This mental revolution is sustainable because we consciously and deliberately choose to evolve our world view through several fundamental changes. The transformation I refer to includes three major introspective changes which are as follows. First, a change from fragmentation to wholeness. Secondly, a shift in our understanding to the root of the phenomena experienced and thirdly a change from the episodic time space view of events and problems towards seeing a timeless dimension of relationships.

To see the world systematically means to see the relationship in the phenomena we experience. The systems view is not just another way of improving an object or a process or even services in and of themselves as so many have stated. Nor should systems and systems thinking be seen as a method that is focused only on the concept of "quality." The traditional quality measurement tools like histograms, pareto charts, and even process control chart may work in a quality universe but are ineffective in the system universe. I am suggesting that the intrinsic value of systems thinking is in the movement of relationships and not in the process of improving objects or services. The purpose of this article will be to share this fundamental meaning of systems and systems thinking through a movement called "Systems Coherence."

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Microworld to Support Decision Making and Organizational Learning in a Department of a Colombian University

Jorge Eduardo Bez Serrano, Ricardo Sotaquir Gutirrez, Guillermo Rueda Rueda Jos, Daniel Cabrera Cruz
Universidad Aut¢noma de Bucaramanga
Computer Science Department
Bucaramanga, Santander. Colombia
jcabrer@bumanga.unab.edu.co
jbaez@bumanga.unab.edu.co

The purpose of this research project is to build a microworld based on a model of System Dynamics about the Computer Science Department of the Universidad Aut¢noma de Bucaramanga (UNAB) which can allow to members of the organization (Dean, area coordinators, professors and secretaries) to evaluate the incidence of policies and decisions, and support the design of organizational strategies which enable the improvement of certain situations whose symptoms have been occurring over the last years. The intention is the creation of a space for the learning since the microworld creates the conditions which make possible to the members of the Department to gain understanding about the organizational situations in which they are involved, when they have participated in the building of the mathematical model. The main problematical aspects that have been taken into consideration in this research are linked with, firts, the decrease in the number of applicants for the undergraduate program offered by the Department and second the evaluation of the incidence of changes made to the curriculum of the undergraduate program of Computer Science with regard to the thesis. The mathematical model, before built, allows to observe the effect of the different alternatives of action on some indicators of the academical management in the Department.

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The Effect Of Tank Size on the Average Throughput for a Continuous Flow Line Model with Two Unreliable Machines and an Interstage Finitebuffer

F Shooshtarian
Department of Mathematics and Statistics
University of Luton
Luton, LU1 3JU, UK

In this paper we propose to discuss such aspects as the size of the tanks and, the initial level of fluid in the tanks for production system of a continuous flow line model. Many typical industrial plants are very complex in nature. They tend to consists of processing stages (or units) together with buffer stocks (or tanks) with many or all of the units being subject to failure. Thus, it appears that any attempts at modelling individual plants are likely to falter if we seek to include all aspects of the particular plant involved. We therefore have set up simplified models which aim to reflect the essential features to be found in typical plant configurations. The model under consideration is made up of two processing stages and an interstage finite buffer stocks where the stages are subject to random breakdown. We present a novel computer-based method which uses a systems dynamic modelling and simulation approach. Systems dynamic software POWERSIM (Copyright + 1994 - ModellData AS) is used as a supportive tool in the modelling and simulation. POWERSIM is well suited to problems of this type as it provides ample facilities for the manipulation sets as well as processing a clock routine for automatic time advance from event to event.

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Modeling Resource Management in Instructional Systems Development Projects

Alexei V. Sioutine, Paal I. Davidsen, J. Michel Spector
University of Bergen

This paper describes the modeling of project development and management in the field of instructional systems development (ISD), specifically in accordance with a recent ISD model (ISD^4 or Fourth Generation ISD) which takes into account the dynamic aspects of instructional planning and development (Tennyson, 1993). Instructional systems development is a reasonably structured and well-established process for developing education and training. Today instruction often involves technology-based learning materials and environments, often referred to as courseware systems. These systems involve significant and expensive software development and typically represent a level of complexity not encountered in more typical business-oriented software development projects. Large-scale courseware development projects often run behind schedule and over or beyond allocated budgets. They frequently use a lot of resources in terms of manpower, especially expertise that is already in scarce supply.

In ISD^4 these projects are described as involving phases (Analysis - Design - Production - Implementation - Maintenance). The first two phases are often the most crucial for a project in terms of ending up within time and budget constraints. Therefore, our modeling process has concentrated around the analysis and design phases, and specifically on the most common ways in which activities in these two ways are interrelated. The model consists of four basic sectors that describe key aspects of the structure of the project: (1) human resource management; (2) control; (3) plans; and, (4) development. Typical complexities of ISD^4 projects, such as lack of transparency and delays in progress reporting, task processing failures and feedback, requirement for and allocation of experts and novices and their interaction, etc. as represented in the model.

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System Dynamics Simulation to Redefine Adversarial Supplier/Customer Relationships

Steven T. Sonka
Director, National Soybean Research Laboratory
University of Illinois at Urbana-Champaign, USA
s-sonka@uiuc.edu

R. Christopher Schroeder
Partner, AEC/Centrec
Savoy, Illinois, USA

Market relationships between farmers and food processors historically have been economically adversarial, following the model of perfect competition for commodity markets. In this model, suppliers (farmers) strive to deliver output that just attains minimal quality standards and processors compete by paying the lowest price possible. Although this market relationship has functioned well, final consumers (both domestically and internationally) are demanding higher quality food products that are difficult to deliver through commodity markets.

Midwestern family farmers are concerned that competition from alternative marketing channels, which often are vertically integrated so as to be more responsive to the quality demands of final consumers, will capture significant market share. Processors are concerned that a less viable family farming community will weaken their competitiveness. The Illinois Soybean Checkoff Board (ISCB), an organization of soybean producers, is collaborating with Cargill, a large processor of soybeans, to identify and evaluate alternative marketing relationships. The goal of this effort is to create alternative marketing systems that are more responsive to final consumer needs, yet retain key elements of independence important to family farmers.

Through development of a specialized system dynamics model, AEC/Centrec, an agribusiness management consulting firm, is assisting ISCB and Cargill evaluate alternative marketing relationships. This paper will describe the PowerSim-based model being used with these parties. Further, the paper will identify how systems modeling has proven useful in allowing participants in this adversarial relationship to understand the underlying sources of that adversity and how mechanisms that might alleviate these sources would perform in the future.

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System Dynamics to Operationalize a Strategic Framework for the Evolution of Information Technologies

Steven T. Sonka
Director, National Soybean Research Laboratory
University of Illinois at Urbana-Champaign, USA

L. Martin Cloutier
Graduate Research Assistant
Food and Agribusiness Management Program
University of Illinois at Urbana-Champaign, USA

Albert Lejeune
Professor
Center for Research in Management
University of Quebec at Montreal, Canada

Over the last decade, information technology (IT) has transformed resource use, business practices, and market competitiveness in numerous industries in the economy. To better understand IT's evolution and influence, we have developed a four stage strategic management framework that describes the dynamic processes by which IT applications enable functional or activity integration within firms as well as how it affects cooperation between firms. These four stages are identified as automation, representation, interaction, and integration. This framework extends several strategic management concepts to explicitly distinguish the roles of IT in the existing marketplace versus the potential marketspace. The marketspace concept recognizes the potential for electronic communications to destroy existing geographically defined marketplace dimensions.

Although a powerful framework, implementation of the framework by itself is less than satisfactory because the full implications of the dynamic elements within and across stages cannot be adequately described with words alone. In this paper we describe how system modeling concepts have been employed to dynamically operationalize the framework. This paper will describe the proposed framework and provide conceptual support for its development. Use of influence diagrams to document the dynamics of information technology adoption in two very different applications: the Canadian financial services industry and the US agribusiness sector, will be illustrated. In addition, prototype PowerSim-based models of these processes will be described.

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Does Success Mean Lack of Failure?

Stoyanova-Sice P, Moscardini A.O. and Lawler K.
University of Sunderland, UK

This paper is the third in a trilogy of papers that address the problems of how to create an organisational structure that encourages personal initiatives to flourish (with the attendant risk of failure) within the constraints and boundaries inherent in a competitive manufacturing company. The first paper described the innovative structure of a Danish hearing-aid manufacturer called Oticon and suggested some inherent causal relationships. The second paper designed a causal loop diagram and discussed a possible System Dynamic model of how Oticon managed Quality. This paper develops the model in the light of subsequent discussions with Oticon. It focuses on exploring the 'success-failure' dynamics in a project driven organisation.

The two crucial success factors identified by Oticon, i.e. the success rate of the projects and customer satisfaction are interpreted in a generic System Dynamic's model to investigate the effect of freedom and 'intrapreneurship' *(meaning intra company i.e. within company entrepreneurship)* on a company's performance in terms of the co-existence of failure and success in meeting customer expectation. The model shows that the eventual state of the company can exhibit success or failure through chaotic transients. This could have implications on risk assessment. The model was run using Powersim with fourth order Runge Kutta integration.

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Strategic Enrollment Management and Policy Planning at a Public Research University: A System Dynamics Approach

Bruce Szelest
Associate for Institutional Research
SUNY Albany Ad 240
1400 Washington Ave
Albany, NY 12222
bps23@albany.edu

As higher education institutions come increasingly under financial duress and their survival becomes ever more dependent on student generated tuition and fee revenue, understanding the dynamics of student enrollment will become a managerial imperative. Campus leaders will increasingly need to take stock of their external environment, reassess how their institutions operate, and adapt to changing conditions. The system dynamics approach to strategic thinking is a means of demonstrating the interconnectedness of seemingly separate objectives and processes. This approach

shows university decision-makers how their institutions are, and could be, poised to respond to varying stimuli and operating conditions.

Past system dynamics forays into the higher education arena have focused mainly upon exogenous factors such as demographic trends of the college going population and economic conditions as they relate to enrollment demand at the university system level. This paper describes the formulation and insights gained from examining feedback driven decision structures at the State University of New York at Albany, a public research university. The issues that a growing research university face, such as the perceived tension between undergraduate education and graduate research activity, the need to diversify revenue streams, and the establishment of outcomes based performance indicators are investigated by examining the causal relationships that exist between budgeting and funding mechanisms, the graduate and undergraduate student mix, faculty and instructional resources, physical facilities, and indices of faculty research productivity.

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Modeling the Department of Energy's Legacy Waste Flow

Greg Szwartz, Kevin Rapier
Project Performance Corporation
20251 Century Fourth Floor
Germantown, MD 20874

As part of an ongoing long-range planning effort, the Department of Energy's Office of Environmental Management (EM) is currently finalizing a set of flowcharts called "Disposition Maps" which depict the life cycle of transuranic radioactive waste management from generation through disposal.

Using the Disposition Maps and annual waste flow data, a systems dynamic model was built using an off-the-shelf software package (iThink), allowing EM to examine "What If?" scenarios regarding treatment, storage, and disposal facility operations and start dates, and other future uncertainty. This presentation reports results from a few "What If?" Scenarios along with some policy implications of the results.

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Modeling the Transition to Sustainable Materials Management: The Case of Paper

Hank Taylor

The municipal solid waste management industry has entered a new era of change. Disposal based waste management is shifting to a system of sustainable materials management, where recycling and waste prevention play larger roles. The effects of this shift are only now becoming evident, and will become more significant in the future. To understand the changes that are occurring in waste management, the industry can no longer can be thought of as the loose association of waste disposal industries it once was; on the contrary, the waste management system is now better thought of as the economy-wide materials management system.

The paper presents a very general conceptual representation of commodity material flow interconnections in the materials management system of the macroeconomy. In this representation, virgin materials (trees, bauxite, iron ore) are extracted from their points of origin and flow to primary producers. Primary producers transform the virgin materials into primary commodities (pulp, alumina, pig iron) which are sold to secondary producers. Secondary producers add value by "finishing" the material: transforming it into the commodity products that are directly consumed in the economy (paper, aluminum, steel). After consumption, these products are either discarded (landfilled or burned in a waste-to-energy facility) or recovered (via material recovery facilities, scrapyards) and reprocessed into material inputs (recycled pulp, recycled aluminum, recycled steel) which re-enter the system at the secondary processing stage.

Most previous work in the areas of waste management focuses on a single portion of the materials management system (moreover, most of the focus is on the disposal end of the system). These studies lose the ability to see whole system effects. Because waste management policies are rarely considered outside the context of disposal they are limited in the range of policies which can be considered and the types of effects observed. Given the linkages within the economy, waste management should be recast as materials management and the decision/policy bounds appropriately adjusted. Implicit are myriad material and information flow links between the sectors, as well as internal nonlinear constraints within each sector (such as factor stocks, inventories, and embodied production technology) that introduce high dynamic complexity to the materials management problem. A large amount of prior research has shown that decision-makers, confronted with dynamically complex tasks, generate rather consistent, significant, and costly errors. In fact, the multi-stage production and distribution structure is widely known for its unstable character and the difficulty that managers and policy makers find in controlling it. To transcend the limitations of managerial abilities, the author has built a model of the system - one which portrays the interactions between all parts of the system in a parsimonious but realistic way that allows policy analysis to demonstrate the tradeoffs associated with the different types of interventions proposed or in use.

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Group Model Building Assessment Studies: Order Out of Chaos

Jac A.M. Vennix, Etiënne A.J.A. Rouwette
University of Nijmegen

Over the last decades system dynamicists have experimented with approaches to achieve more involvement of clients in the model building process. These approaches are described in the literature under such names as group model building and systems thinking interventions. In many cases these interventions are the subject of more or less controlled assessment studies, in which researchers attempt to establish the effectiveness of the intervention. Unfortunately however, assessment studies differ widely with regard to research questions, research designs, data gathering techniques etc. This not only prevents mutual comparison, it also hampers accumulation of research results, a prerequisite if a research program is to be taken seriously.

Although the current situation is understandable since systems thinking interventions and studies to assess their effectiveness are a recent phenomenon, in order to make substantial progress in the field, the time has come to develop a research program and more or less rigorous standards to conduct empirical assessment studies. A logical first step in this process would be to review existing assessment studies and indicate similarities and differences as well as the most robust findings. This is the primary topic of this paper. Assessment studies in the area of group model building and systems thinking interventions are systematically reviewed. The paper discusses the similarities and differences between these studies, compares results and makes a first attempt at formulating points of departure for a rigorous research agenda.

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Preliminary Findings: Information Technology in a Learning Organization: Case Study and Causal Diagramming

Warren W. Tignor
TRW Systems and Information Technology

Recently, volunteers compared business case studies as case briefs to System Dynamics' causal diagrams. Although the number of volunteers is small, the preliminary findings indicate a collaborative relationship. The study examined three business cases. The Harvard Business School published the original business case studies. The author of this study briefed the cases and prepared causal diagrams for the analysis. The study provided, via the Internet, volunteer analysts criteria to compare the case briefs and causal diagrams. Lastly, the study presents a compilation of learning organization attributes gathered from the literature. The volunteers compared the learning organization attributes to the case brief and causal diagram results.

The hypothesis tested assumes that case briefs and causal diagrams identify different unique insights to business cases. Collaboratively, the two approaches may be more beneficial to business analysis than used separately. If the analysis of business case studies from a retrospective point of view supports the hypothesis, then the approach will have merit for business analysis going forward.

Competition requires businesses to leverage capabilities at every opportunity. Businesses use information technology as a strategic asset to improve their competitive positions. Case study provides a low technology method to learn about business experiences. Historically, case study produced insights that help businesses leverage or avoid situations similar to those documented in cases. The primary nature of a case brief is a list of information in a linear form that structurally moves from facts to problem statement, decision, and reasoning.

System Dynamics's causal diagrams offer a convenient way to represent the dynamic structure and behavior of systems composed of interacting feedback loops. Causal diagrams identify the principal feedback loops without distinguishing the nature of the interconnected variables. Unique attributes of a case brief are identifiable by causal diagrams that are not normally part of a case brief, e.g., feedback loops, amplification factors, and delays.

Businesses will actively use techniques and tools that improve competitiveness. Comparison of case brief and causal diagram results offers an opportunity to identify unique contributions that each may make to improve competitiveness.

If the analysis of business case studies from a retrospective point of view supports the hypothesis, then the approach may have merit for business analysis going forward. The study examines whether the possible contributions are unique, overlap, and are collaborative.

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Cooperative and Non-Cooperative Conducts in Conflict Resolution

Imrana Ahmed Umar
Senior Consultant
Powersim Corporation
1175 Herndon Parkway, Suite 600
Herndon VA 20170 USA
imrum@powersim.com

The economists call it game theory and the psychologists call it theory of social situations, but whichever way one chooses to call it, the theory simply focuses on how people interact under competitive circumstances. In order to achieve their personal or even group goals, agents could either choose to co-operate or not to co-operate when interacting with each other. Most applications of game theory relate to situations where agents act to achieve personal economic benefits over their rivals. Other situations where the theory is as well very relevant are where agents have a larger common goal and yet act competitively in their strategies, thus becoming some kind of 'accidental adversaries.'

This paper examines a two-agent system dynamics model for the resolution of conflicts in private or public sector work environment. The two agents are identified in this study as union and management. Conflicts may arise for one of two reasons- management initiated changes in terms and conditions of employment or union initiated changes in working conditions. Conflicts may be nipped in the bud if the two agents try to negotiate (cooperate) proposed new changes in the onset or escalate if each agent tries to outwit the other to its own advantage by taking unilateral actions. The aim is to analyze joint (cooperative) versus separate (non-cooperative) strategies of labor-management relations with a view to identifying potential loss due to non-cooperative strategies.

The model builds on a scenario of collective and midterm bargaining agreements in federal establishments in the US, where management has a general obligation to bargain over terms and conditions of employment. The model examines a couple of scenarios and the strategies adapted to deal with the potential conflicts that may result from them.

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Competition, Symbiosis and Predator-Prey Interaction Among Technologies: Understanding Dynamics of Technological Change with a System Dynamics Approach

Nazareno Ventola
EniTecnologie S.p.A.,Via Maritano 26, 20097 S. Donato Mil. (MI), Italy

Edoardo Mollona
London Business School, Sussex Place, Regents Park, London NW1 4SA, UK
Università "Luigi Bocconi", Milano, Italy

Technological change occurs everyday, and its consequences may represent either a threat or an opportunity for anyone involved in the business environment. From a managerial point of view, to understand how technology and business dynamics influence each other is becoming nothing more than a base request.

Although this problem has been extensively approached in the field of technology forecasting and technology management, questions still remain open : the one addressed in this paper points out to the inner nature of technological "competition". Pistorius and Utterback (1995) recently proposed a conceptual multi-mode framework, in order to overcome an oversimplified single-mode approach based on "competition" and to account for other modes of interaction, i.e. "symbiosis" and "predator-prey". Such framework has been further developed by the same authors (1996) into a mathematical model, by means of modified Lotka-Volterra equations. This framework seems to be promising in order to address technology strategy issues. In this paper System Dynamics is proposed as an approach in order to make such framework transferable at an operational level: this is particularly relevant when one considers the evolutionary nature of technological change.

After a brief description of the traditional approaches, the multi-mode framework is analyzed in further detail, showing how System Dynamics adds value to it, giving insights and providing a powerful simulation environment for further theoretical as well as "business case" applications and developments.

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A Framework to Facilitate Conflict Resolution in Protected Areas Based on Group Model Building Interventions

Nuno Videira, Paula Antunes, Rui Santos
Department of Environmental Sciences and Engineering
College of Sciences and Technology - New University of Lisbon
2825 Monte da Caparica - Portugal
videira@virtual.dcea.fct.unl.pt, mpa@mail.fct.unl.pt; rfs@mail.fct.unl.pt

In a world where environmental, social and economic systems change rapidly and overlap each other's goals, conflicts are inevitable and have often undermined biodiversity conservation objectives in protected areas. Managers of these areas have multiplied conflict solving efforts and specific tailored responses, as discussed by Lewis (1996), but many fail to acknowledge the complex dynamics of the conflict and therefore produce ineffective results.

This paper presents a new framework aimed at tackling protected areas management conflicts, based on a group model building process which has a set of well identified components, independently of the cultural, political and social context of the conflict. The framework facilitates stakeholder participation and attempts to build consensus and increase team learning by eliciting and creating a higher level of knowledge among participants.

The presented work is expected to contribute to practitioners in different domains. It was not designed to stand solely as one facilitated group model-building effort applied to environmental science. System dynamicists are presented with explicit and clearly specified outcomes that build on past results in the field, following the guidelines suggested by Morecroft and Sterman (1994) Richardson and Andersen (1995), Andersen *et al* (1997) and Vennix (1996).

On the other hand, protected areas managers are introduced to a new tool, suited to foster consensus between stakeholders, to improve performance at the strategic decision-making level of their organizations and to reinforce their commitment to a strategic decision.

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Judging the SymBowl System Dynamics Modeling Fair

Wayne Wakeland

Content:

1) The criteria used to judge Symbowl,
2) The document provided guidelines for the teachers and students,
3) The background and qualifications for the judges, including the need for diversity on the panel, and
4) The various stages of the actual judging process, including worksheets used to streamline the process.

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A Dual-Industry System Dynamics Model for Studying New and Developing Industry and Traditional Industry

Qifan Wang and Jianguo Jia
School of Management
Fudan University
Shanghai, China, 200433
qfwang@fudan.sh.cn

It`s well known that we are now stepping into an age of information economy. As a new and developing industry, the information industry is expanding rapidly in recent decades, and is becoming the leading industry in the economy of many countries. From the qualitative view, we can see that the image of the mutual action of the information industry and the other industry is as the following. Firstly, with the information industry mushrooming, the information technology is pervading into the other industries, and its great re-engineering action brings the new developing vigor to the traditional industry; it now is leading the whole economy into a new age. Secondly, growing from the traditional industry, the information industry always struggles for labors, capital and other resources with the traditional industry in its long run growth, and it leads to the resources flowing between them.

In this paper, by simplifying the whole industry into two industries---the new and developing industry and the traditional industry (or the whole developed industry), we put forward a dual-industry SD model. With this model, we tried to theoretically explore the dynamic relationships of the two industries in economic growth in long term, their interactions, the labor and capital's distribution and flowing between them, the new technology's spreading, the industry-developing life cycle, and etc. Though, our present model is theoretical and preliminary.

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The Study on Objective Model of Organizational and Managerial Reformation: Facing IT

Qifan Wang, Yang Di, Zhaotian Zhou
School of Management
Fudan University
Shanghai, China, 200433
qfwang@fudan.sh.cn

The enterprises world-wide, especially in Mainland China, are now facing a historical reform in economic development. The progress of Information Technology (IT) has been one of the fundamental and most important factors to stimulate the enterprises reshuffle since 1970s. It has expedited the process of forming an integrated market and economy and led to the tendency of Business Processes Reengineering (BPR) in the world. Due to IT's impacts on highly assembling and sharing information, BPR shouldn't be only an approach for readjusting the product-processing, but also challenges the organizational and managerial model of enterprise under the traditional surroundings.

In fact, once the new information technology is adopted in an organization, relative modification or reformation in organizational structure and managerial style should be made in order to obtain the maximum efficiency, otherwise it will cost the organization a lot or bring the additional burden. Therefore, we supposed that the concept of BPR needs to be expanded to include organizational structure and managerial processes.

Hundreds of large modern enterprises have already come out in Mainland China in the past decades, but they are also facing a new reshuffle now. We analyzed the new features and conditions of the enterprises using new IT, and according to the modern management ideas and principles, we designed a new organizational and managerial structure with network shape, which has at least four advantages compared with the traditional one:

1. less administrative layers and broader span of control;
2. fewer managers and shorter decision cycle because of the use of computer network;
3. higher organizational efficiency and lower management cost;
4. more flexible feature in management and production.

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Linking System Dynamics to Enterprise Data Modeling

Wei-young Wang and Yi-Ming Tu
Department of MIS
National Sun Yet-sen University
wyoung@mis.nsysu.edu.tw

All decision behaviors can be divided into two parts. One is the process of data collection and processing, and the other part is mental simulation and prediction. The two processes iteratively proceed to accomplish decisions. Organizations, the two parts of the process are done separately. Data collection and processing task are often done by the management information systems and mental simulation and prediction task is done by other supporting frameworks and tools. There are seldom interactions between them during the design phase. First, the policy designed from mental modeling tools may not be available in daily management decisions. Second, the information systems can not effectively aid actual decision makings. The paper intends to abstract the activities in one organization with system dynamics and to transfer the abstract model into data model to support the development of databases and information systems. We hope to establish an integrated and simple information system architecture for the both objectives of policy design and data process. By doing so, more well understanding and agreement of organizations may be achieved.

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From Business Strategy to Corporate Strategy dynamics - wielding System Dynamics to attack strategy for the multi-business firm.

Kim Warren
London Business School
Sussex Place
LONDON NW1 4SA - U.K.
kwarren@lbs.lon.ac.uk

A paper to the 1997 International System Dynamics conference (Warren, K.D., 1997, 'System Dynamics and Strategic Management - a Call to Arms', proceedings the 1997 International System Dynamics Conference, Istanbul) outlined the resource-based view of Competitive Strategy and showed how the problems of strategy dynamics could be attacked with System Dynamics. This paper will outline how the dynamic resource-system (DRS) perspective of the firm can be extended to tackle the problem of building strategy across a multi-business firm. Although it is widely believed that firm diversification may be more successful if 'related' to prior activities, the dynamics of how related

diversification unfolds is poorly understood. The paper builds on established Strategic Management definitions of resources and competences, and provides a standard method for formulating these issues in diagnosing and designing business strategy. It extends the framework to a formal method for representing inter-business resource- and competence-based synergy. Competitive advantage can be built in several markets simultaneously, and new businesses established quickly, by transfer or sharing previously accumulated strategic resources. Where resource-transfer is not feasible, competitive advantage can still be built by leveraging competences that have arisen from learning about resource-building elsewhere. The framework's application is illustrated by modelling the history of the retail consumer services activities of Whitbread PLC, formerly a major brewing firm. Following robust growth of one restaurant chain to 1985, resources were shared and transferred into several related businesses. Where resource-transfer was not feasible, competences were leveraged through sharing of support functions. The model will illustrate not only the leverage of this transfer and sharing, but also its limits.

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The System Dynamics of Failure for Core Competence-Based Strategy.

Kim Warren
London Business School
Sussex Place
LONDON NW1 4SA - U.K.
kwarren@lbs.lon.ac.uk

A paper to the 1997 International System Dynamics conference (Warren, 1997) outlined the resource-based view of Competitive Strategy and showed how the problems of strategy dynamics could be attacked with System Dynamics. This paper provides a formal view of firm strategy as dependent upon the performance of the firm's 'dynamic resource-system' (DRS). It then shows how the established Strategic Management concept of 'core competences' can be added to this DRS. Strategic competences determine the firm's ability to accumulate strategic resources, whether tangible (staff, products, customers) or intangible (quality, unit-cost, morale, reputation). Competence-building arises from firm experience at accumulating and maintaining these strategic resources, though it depends on the effectiveness of organisational processes for capturing learning. Although 'core competence' analysis is being widely used by firms and strategy consultants to develop firm strategies, several of the well-known businesses possessing such allegedly unassailable advantages have been surpassed by apparently weaker rivals. The paper will therefore show, by operationalising and simulating the DRS, that a core competence can be readily overwhelmed by a rival possessing a modest advantage in system-wide competences. The framework is applied to a consumer goods firm, and shows that the firm's relative competitive performance does not reflect its widely acknowledged lead in a core competence. This performance shortfall is contrasted with the stronger progress of a rival, known to be weaker on the core competence, but more skilled at other resource-building activities that would not classically be recognised as core competences.

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Using System Dynamics to Model Policy Change in an Academic Library

Jon Warwick
School of Computing, Information Systems and Mathematics
South Bank University
Borough Road
London SE1 OAA, UKUnited Kingdom
warwick@sbu.ac.uk

The analytical modelling of systems that involve significant human interaction is particularly difficult when the nature of the interaction is dependant on expected system response. Traditional models can capture the steady state behaviour of such systems, but frequently fail to capture or predict explicit changes in behaviour brought about by policy changes within the system.

An example of such a system is an academic library. The effective usage of a stock of books depends on demand, and can be controlled by policy decisions such as loan periods or levels of duplication but changes in demand for books occur both in the medium term (as teaching programmes change, class sizes change etc.) and in the short term (as assignments are set, exams need to be revised for and so on). Student experiences with the library system will govern their usage of the system and these interaction must be modelled.

A model of such a system is developed using System Dynamics which captures the feedback mechanisms involved between system and user, and allows system performance to be predicted over differing sets of operational policies. The advantages of this approach over analytical models are drawn out and examples of model usage demonstrated.

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The Skills Paradox in Times of Change

Graham W. Winch
University of Plymouth Business School
Drake Circus, Plymouth PL4 8AA, England
graham.winch@pbs.plym.ac.uk

The skill base of an enterprise rises and falls as a result of staff turnover, training and other development processes, and with the change in the relevance of the skills to its current circumstances. A simple *Skills Inventory Model* (SkIM) is proposed using the familiar stock-flow structure. The SkIM model helps articulate the dynamics of this key variable, and may suggest why some firms find major change in insuperable barrier. It reflects how in stable times, the received wisdom of retaining staff applies, as skills lost when staff leave must be recovered through those of their replacements or through training and other staff development. In times of relatively slow change, staff retention may be even more important, as change leads to faster skills obsolescence, which would otherwise put a double burden on skill replenishment.

In times of major change, however, the picture may be quite different. In these circumstances the rate of skills obsolescence becomes rapid, and normal staff development processes may simply prove inadequate in building up the necessary new skill base. In which case, the ability to enhance the skills inventory through staff recruitment may be necessary. This poses a particular challenge to firms whose natural staff attrition is low and growth is not leading naturally to the creation of new posts.

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Balanced Strategies for Balanced Scorecards: The Evolving Role of System Dynamics in supporting Balanced Score Cards

Eric Wolstenholme
Professor of Business Learning, Leeds Business School
Director, COGNITUS

This paper will describe the enormous potential of system dynamics models to support balanced score card initiatives in business.

Balanced scorecards are being used by an increasingly large range of companies to develop performance measurement thinking outside the pure finance area. They have created an awareness of the need for companies to balance measures of financial performance with measures of internal processes, customers and human resources, in particular to recognise the intangible assets of a company such as intellectual capital and competency.

These methods represent a first step in holistic thinking by recognising the existence and importance of the full breath of operational aspects of business and the way in which these support the financial. Additionally, users of the approach are increasingly recognising another other systems concept - that such performance measures are interdependent.

In systems terms, performance measurement is an important, but limited application of systems thinking representing only one aspect of the feedback cycle System dynamics has an important role to play in extending this trend in performance measurements to a full systems approach.

This paper will describe the way in which system dynamics is being used by the author to support the design, testing and use of balanced score cards, involving the use of models to relate today¹s investment and strategy decisions to tomorrow's scorecards.

The paper will also comment on this work as an excellent example of the way in which the use of system dynamics in business can be rapidly accelerated by integrating it into current semi-systemic management initiatives.

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An Easy and Formal Method for Generating Structural High Leverage Policy in System Dynamics Models

Showing H. Young and Chia Ping Chen
Department of Business Management
National Sun Yat-Sen University, Kaohsiung, Taiwan
syoung@mail.nsysu.edu.tw

Designing high leverage policy is a very crucial and challenging step in system dynamics approach. However, very limited formal methods were developed in this area. Literature showed three kinds of these methods: the algorithm method, the mathematical method, and the guideline method. The algorithm method is easy to use and suitable for nonlinear models, but can only obtain "parameter policy", not "structural policy". The mathematical method can obtain "structural policy", but is not easy to use and not suitable for nonlinear models. The guideline method uses guidelines induced from some special cases to design policy; it is easy to use, but its generality is very weak.

The objective of this research is to develop an easy and formal method for generating structural high leverage policy in system dynamics models. The idea of the method came from our experimental studies of microworlds. We observed that if the subjects repeatedly play a microworld by trial and error, they can often unconsciously learn how to control the microworld even when they did not know the underlying structure. This kind of cognitive behavior is useful for controlling system dynamics models. So we imitate it to develop a conceptual framework for generating structural high leverage policy. Then we follow the conceptual framework to direct the development of our method. In short, this kind of cognitive behavior has two major activities: selecting information and organizing information.

We adopt the genetic algorithm as the mechanism for selecting information. This algorithm is suitable for searching huge solution domain; probabilisticly searching with natural selection, but without blind search; being able to obtain global satisfactory, not local optimal solution.

We adopt the back-propagation algorithm as the mechanism for organizing information. This algorithm is a kind of artificial neural network with learning capability, and has showed its effectiveness in system control. The actual operation of this method is as follows. First, we use the conventional optimization algorithm to obtain the optimal trajectory of decision output, the so called open-loop solution. Then we use a hybrid software of genetic algorithm and back-propagation algorithm developed in this research to find a decision function which produces approximation to the optimal trajectory, what is called closed-loop solution. In the hybrid software, genetic algorithm is used to find the independent variables of the decision function from the observable level variables in the system dynamics model; back-propagation algorithm is used to generate the functional relationship among the independent variables. We have applied the method to the model developed by Forrester in his paper "Market Growth as Influenced by Capital Investment". The result showed that the performance of the policy obtained by our method is better than that of Forrester's policy.

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A New Mathematical Method for Improving the Behavior of The Market Growth Model

Showing H. Young and Chia Ping Chen
Department of Business Management
National Sun Yat-Sen University, Kaohsiung, Taiwan
syoung@mail.nsysu.edu.tw

It is difficult for system dynamics models with high order and nonlinear property to straightforwardly obtain high leverage policies by mathematical method. In current literature, almost all of these mathematical methods were originated from the linear system mathematical skill of control engineering. They must simplify and linearize the system dynamics model first, and then use sophisticated mathematical skill to obtain a "guiding equation" for the simplified and linearized model; the equation then directs the design of high leverage policy for the original system dynamics model. However, the new mathematical method developed by this study neither needs to simplify and linearize the system dynamics model, nor uses sophisticated mathematical skill, but utilizes the insight from system archetypes and fundamental calculus to obtain a high leverage policy. The new method has been successfully applied to Forrester's "market growth model". The underlying idea is as follows. In the condition of the demand growth due to the dominance of the positive feedback loop, we fix "the adequacy of capacity to satisfy demand" to calculate how much capacity is able to prevent it from decreasing. If "the adequacy of capacity to satisfy demand" does not decrease, the negative feedback loop which inhibits the growth of the positive feedback loop will not be activated, and the growth can thus sustain. From the calculated capacity function, we can then derive high leverage investment policy. According to the new method, this study further developed a quantitative planning framework for dynamic growth. The framework can clearly calculate how to allocate critical resources to sustain corporation's growth.

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Using A System Dynamics Model To Assess The Implications Of Welfare Reform: Policy Analysis And Sensitivity Tests

Aldo A. Zagonel-Santos
Nelson A. Rockefeller College of Public Affairs and Policy
University at Albany, State University of New York
300 Milne Hall, Albany, NY 12222 - USA
zagonel@aol.com

Researchers at the University at Albany, working in conjunction with the New York State Department of Family Assistance, Office of Temporary and Disability Assistance, built a fairly large system dynamics model to help New York State, and its counties, think through the implementation of Welfare Reform. This modeling effort was based upon a series of group modeling conferences, occurring between February and December of 1997. Public welfare practitioners and experts --drawn from state and local public agencies, such as Social Services, Education, Health and Labor, as well as from not-for-profit providers, among others-- embedded a wealth of knowledge in this model, in the

form of hundreds of equations describing the structure, the flow of clients, and the interrelationships between the several sectors of their welfare services systems. Last year in Istanbul, we began to report on this effort.

In this paper, we will discuss the results of the analysis of the implications of the 1996 welfare reform act, in light of the insights derived from this model. In order to assure that those insights are robust, we will also report the sensitivity tests used to determine the confidence intervals that contain the behaviors observed in the simulation of the model. This prototype has been used already by two counties in New York State for the purpose of strategic planning, leading to resource reallocations both within and across public and private providers. As an exercise in optimization, we will also propose alternative investment strategies that maximize benefits and minimize costs, given different objective functions, i.e., goals.

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British Petroleum Is Not Jackson Middle School:
Different Best Modeling Practices For Different Environments

Ron Zaraza and Tim Joy
CC-SUSTAIN Project
1151 SW Vermont
Portland OR, 97219 USA
rzaraza@pps.k12.or.us, tjoy@pps.k12.or.us

Recent discussions on the MIT K-12 System Dynamics listserve focused on modeling a system versus modeling a problem. George Richardson, referring to Jorgan Randers' thesis on model conceptualization and his own work on conceptualization in "Introduction to System Dynamics Modeling with DYNAMO", presented the view that best, or perhaps common practice, in modeling focuses on identifying problems within a system, then modeling that problem in the context of the system.

This approach certainly translates well to much of what has traditionally been done in educational uses of system dynamics. The Mahenjo Daro model and the Sahel model, available from the Creative Learning Exchange, provide excellent examples of models in which a clearly defined problem, resource depletion, is explored in two specific contexts. Similarly, virtually all models developed for physics and mathematics follow a similar, problem-centered pattern. The models focus student attention on understanding and solving a specific problem. As such, system dynamics serves in an ancillary role as a support for traditional curricular topics.

An emerging use for system dynamics in education moves away from using a system to solve or exhaustively explore a problem. Instead, crude models of systems are used not to address problems, but to motivate questions. These questions may then lead to formal models of parts of the systems, or explorations of the system in search of other problems.

Examples of such a process have been observed repeatedly in classrooms using very basic models. A teacher presents a population model when discussing problems facing a third world country. Students, when confronted with dramatic exponential growth, immediately begin to question and criticize the results of the model. Their questions are woven into a series of individualized assignment by the teacher, individual explorations of aspects of the larger system. These explorations allow a flexibility in thinking that traditional educational approaches do not. This occurs because the broad model of the system led to thinking about parts of the system. The focus is not on solving a problem, but on motivating exploration of many related problems, the real purpose of learning. The model of the system provides a jumping off point, rather than a solution or an exploration of possible solutions. The focus is on SYSTEMS rather than a system.

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Modeling in the Educational Environment - Moving from Simplicity to Complexity

Ron Zaraza and Scott Guthrie
CC-SUSTAIN Project
1151 SW Vermont
Portland, OR 97219 USA
rzaraza@pps.k12.or.us

Educators often become interested in system dynamics because they are introduced to models that illustrate a problem in their content area. The opportunity to explore the problem by running a model, changing values of some parts, then re-running the model and seeing very different results, is a very powerful example of how students can learn using system dynamics. Characteristically, these models are fairly complex and detailed models developed by experienced models for a specific purpose or problem.

Unfortunately, these models have potentially negative impact on teachers as they begin to develop their own models. Perhaps the greatest potential for damage lies in setting expectations too high. Teachers feel that they must build models of equivalent elegance and complexity to have good, useful models. This perception may well have

been a major factor in slowing the growth of modeling in some of the school systems that were among the pioneers in system work.

A second potential problem arises if teachers are not discouraged. The complex models may remain the "ideal", ignoring the simpler models that are easier to build and more accessible (easier to understand and use) to students. Work in schools that both teach students to model and use models in a broad range of classes indicates that beginning with simple models, then modifying and enlarging them to deal with student questions as they arise, is a more generally effective approach to modeling. It not only uses the model as a tool to teach content, but is also develops a greater understanding of system concepts in students.

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Causality and Conjugate Variables in System Dynamics Modeling: Enhancements or Impediments

Maciej Zgorzelski and Timothy M. Cameron
Department of Mechanical Engineering
Kettering University (formerly General Motors Institute)
Flint, MI, 48504

Causality has been condemned by system thinkers from Bertalanffy to Senge. It is generally perceived as a synonym of reductionism, thinking about the world in terms of simple cause-effect chains. System dynamics teaches that everything operates in the form of interacting feedback loops, and in these it is inherently impossible to distinguish between cause and effect. The balancing behavior of negative feedback, or the instability of positive feedback, is a structural property of a system, irrespective of which variable is considered the input to start the (computational) analysis.

Nevertheless, classical system dynamics modeling, from Forrester and the early Dynamo, imposes causality. One may argue that causality is incorporated because of computational requirements, nevertheless changing the input variable(s) requires creating a new model. Consequently, we can only determine reactions of a system to specific inputs (causal). We are unable to draw behavioral conclusions about a system based on its structure only.

In the study of engineering systems these issues have been approached before. It is widely known that an electrical circuit diagram (without current direction arrows!) is an acausal model, which will exhibit oscillatory behavior if it contains L and C elements, regardless of input choice. The less known technique of bond graphs (Paynter, Karnopp, Rosenberg) is also inherently acausal, and is especially powerful for modeling multi-disciplinary engineering systems. Its extensions to social and economic systems (Brewer) have never been fully explored. The present authors present the bond graph technique for modeling the dynamics of a variety of social systems, focusing on the controversial causality issue. This may lead to potential extensions of the current system dynamics modeling techniques.

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Poster Session Papers

Production Policies in a Norwegian Utility Company: Multiple Stakeholders and Trade-offs Between Technical and Economic Optimisation

Ann van Ackere, Ph. D., Cand. Polit. Morten Ruud, and Mag. Art. Pål I. Davidsen.

XXX is a utility company producing hydro-electric power. It is jointly owned by the companies YYY, ZZZ and VVV. The owners use their share of the power produced, or sell it on the open market. They have a variety of other sources from which they can acquire electricity. A government agency has the right to utilise a fraction of the capacity of one of XXX's power stations whenever called for. This paper addresses the issue of planning electricity production so as to optimise the use of water. There are two aspects to this issue: (i) managing the water inventory most effectively and (ii) timing production to take advantage of large price fluctuations and the requirements of the owners. To illustrate the complexity involved: The owners have rights to a certain volume of water, not to a share of the electricity produced. The value of a m^3 of water depends, however, on the current amount of water in all the reservoir, as well as the current speed of the turbines, since these factors affect the quantity of electricity produced from one m^3.

This paper outlines a system dynamics model designed to address issues like:
- The trade-off between a technically and an economically optimal operation of the utility company.
- Negotiations between multiple shareholders with diverse objectives.
- Positive and negative externalities, , as well as a free rider issue.
- Investments and maintenance in the face of continued private ownership vs. ownership reverted to the government in the year 2006.

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Insights about Stability from a Simple Model of the Russian Economy

Bent-Erik.Bakken

Bent-Erik.Bakken@ffi.no

Economies in transition appear more subject to instability than more well established economies. A simple model of the russian economy has been designed to investigate causes of and consequences from instablity. The model endogenously shows the russian GDP decline 1990-1997 and also growth in the future. It is indicated that threats to stability may arise from issues such as poor institutinional transparency, high ownership concentration and lack of equitable and enforceable tax schemes. The policy implications for russian and world economic policies are discussed.

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System Dynamics as a Complete Method of Systems Inquiry

John Barton

Department of Management

Monash University, Australia

John.Barton@BusEco.monash.edu.au

Over the past few years the System Dynamics Review has featured a range of articles emphasising the importance of model validation, group learning and evaluation of systems thinking interventions.

This paper proposes a framework for integrating these various aspects into a complete method of systems inquiry.

This framework identifies three characteristics of systems inquiry- the definition of the system of interest through the articulation of the systems principle, the particular logic of systems applied, and the design of the systems intervention. This framework is used to interpret system dynamics as a complete method of systems inquiry.

This interpretation has importance in reinforcing the degree of rigour required in using system dynamics and, following Peirce and Popper, the interpretation of the complete system dynamics method as an example of the application of an evolutionary epistemology.

Further benefits are that this framework provides a succinct approach to communicating the essence of system dynamics to new audiences, a way of interpreting the historical development of the field, and a basis for comparing system dynamics to other approaches to systems inquiry.

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Recruitment of Treatment Foster Parents

Conrad Braun
cbraun@v-wave.com

To date I have been working on a model for gaining insight into the recruitment of Treatment Foster Parents for high needs children who have been abused, molested, neglected and/or have disabilities of varying kinds. To care for these children takes commitment and training, but the best solution for their eventual success in life is to be placed in a family setting. Currently, the chronic problem exists that there are increasing numbers of children needing care and decreasing numbers of families available. Through a series of sessions, data relative to the problems associated with ensuring a reasonable availability of homes has been collected, and a model depicting variables involved has been started. The hope is that some insight might be gained regarding strategies to use for recruiting. This likely will result in policy challenges to the Alberta Government Social Services Department and/or the agencies involved. The children who are not matched generally stay in group homes or hotel rooms. Not only is this very expensive, but it accelerates dysfunctional behaviors and sets in motion cycles of increasing need for resources as behaviors become more pronounced. This particular project is not my main research, but a volunteer effort to assist the people in this field, as my wife and I are also foster parents.

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Automotive Scenario: Fuel and Lube Demand Trends for the Italian Sector

Massimo Chindemi, Raffaella Turatto, Nazareno Ventola
EniTecnologie SpA
Via Maritano, 26 - 20097 S. Donato Milanese (Milan) - ITALY

Analyses, from a dynamic point of view, of such an heterogeneous environment like the one related to the trends in car population, emissions, fuel and lubricant specifications are becoming increasingly puzzling.

On the other side, it is extremely useful to build general frameworks in order to support strategic evaluations and decisions.

System Dynamics scenario modelling enables to describe and capture main trends and basic relationships among engine and lube technology, fuel and lube economy, automobile emissions (with particular concern to the present and future EU regulations), fuel switching (from gasoline to diesel), incentives policy and market growth hypotheses.

A model is presented with the aim of answering some aspects of the fundamental question: "How much fuel and lube demand will change, following the EU regulations, engine technology improvement and lube evolution, facing a dieselisation of passenger cars?".

The model, considering a medium/long term time span and average behaviours typical of the Italian market, explores interactions among the above mentioned variables and offers scenario simulations according to different starting options.

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Using System Dynamics Modelling to Support Oil Field Value Management

David Corben and Richard Stevenson
Cognitus
david@cognitus.co.uk

Computer modelling has long been an accepted and valued tool in the oil and gas industry. At the oil field level, for example, the field management team will typically have access to a number of models, each of which provides detailed information about specific aspects of the business. Such tools include detailed reservoir simulators, production and processing facility models, financial spreadsheets and tax planning models.

Precisely because these models are detailed and specific however, none of them can provide the management team with the Œbig picture¹ of the field as a whole. The independent nature of such models also makes it difficult and time consuming to explore a wide range of assumptions and strategies.

Recently, a number of oil fields have adopted a new approach - holistic modelling using system dynamics. Holistic models do not replace, but integrate outputs from the detailed analysis tools. Because the models can incorporate detail relationships where necessary, but use simplified ³rule of thumb² operational assumptions wherever possible, the computational overhead of more detailed tools is avoided. Models run on desktop computers and many different scenarios can be tested in a short time. The strength of the holistic approach is to enable operational, financial and commercial issues to be modelled in the same environment, with interdependencies explicitly represented.

The authors have pioneered the development of this holistic modelling approach using system dynamics as the vehicle to capture knowledge and to accelerate learning about alternative futures, across the field management teams.

The approach has been successfully applied to three north sea fields in different stages of their life cycles. Firstly to support the development of a Œlate life¹ strategy for a large complex field, secondly to understand the

complexities of produced water management for a mature field and, most recently, to aid the concept development stage of a new field.

The paper will describe recent consultancy experiences in applying high level modelling in the oil industry and comment on the content and process of the activity, with particular emphasis on management interaction.

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Improving Manufacturing Performance Applying Qualitative Analysis Through System Dynamics

Adolfo Crespo-Márquez, Rafael Ruiz-Usano,José Manuel Framiñán Torres
Escuela Superior de Ingenieros
Avda. Reina Mercedes s/n, 41012 Seville, Spain

Modern manufacturing methods offer a wide range of opportunities to production managers. However, selecting the most suitable production technique is becoming a difficult task. The reasons for this can be found in the permanent technological evolution of the manufacturing environments and the increase of the complexity in the scenarios is increasing.

System Dynamics can be used to accomplish qualitative analysis of the production system, and by means of this is able to provide the managers with new insights of their environment, helping them to optimize the performance of the system according with their selected measures.

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Experiments with a Non-linear Model of Health-related Actions

Cor van Dijkum, Etzel van Kuijk, Janneke Mens-Verhulst
Department of Methodology and Statistics,
Faculty of Social Sciences,
Utrecht University
Heidelberglaan 2
3584 CS Utrecht.
The Netherlands.
c.vandijkum@fsw.ruu.nl

In 1987-1988 a nation-wide survey was conducted by the Netherlands Institute for Primary Care (NIVEL). The participants kept a health-diary for 21 days. For this period the participants reported what complaints they had and what health-related actions they undertook to handle these complaints.

For these data a system dynamic model is constructed. A guide-line for the development of the model was a theory about health-behavior (Leventhal & Schaeffer, 1990). In this (learning) theory a feedback cycle is postulated between: (1) complaints; (2) health-related actions; (3) and the knowledge which reflects the relation between these two variables .

Mathematical analysis of the equations of the model showed that the model is non-linear. As a consequence the model produces patterns of bifurcation in the development of health-related knowledge and actions. The model turns out to be sensitive to one of the key variables in the learning model, 'the speed of learning'. Changing the value of that variable gives rise to a whole sequence of transitions to different bifurcation patterns.

The pattern the model produces are reflected in the data, although this is limited because of the restrictions in the data of the diaries. As a consequence the validation of the model is still a problem, also because the methodology of validation of non-linear models needs further development.

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Partial Differential Dynamics

Douglas Franco

System Dynamics improves modeling and simulation of systems of several variables. Because it integrates slices of reality rather than slices of equations, as in traditional finite element methods; so, flow conservation is preserved.

Distributed policy design shows edges of dynamic behavior, enhancing understanding of system performance.

System Dynamics variables are usually multidimensional. But, ordinary differential equations dominates modeling. A common method to deal with functions of several variables is to write them out of products of single variable factors. The variables are separated; thus, Partial Differential Dynamics breaks into combinations of ordinary differential equations. Jay Forrester uses this old trick in World Dynamics(1971), writing multidimensional functions as products of single variable functions of pollution, crowding, food and material standard of living. Products of

multipliers are popular among SD practitioners to deal with partial differential dynamics. Unfortunately, this method is not universal. Sometimes, the variables are not independent; or continuous structures set limiting behavior.

System Dynamics has a lot to offer to model and simulate distributed problems.

Traditional finite element methods solve partial differential equations by four steps: (1) Real system is broken into discrete elements, (2) Dynamic Laws are applied to each element, (3) Partial Differential Equations emerge as finite elements go to zero, (4) Partial Differential Equations break into new finite elements, often different from the original ones, that are integrated into numerical solutions. System Dynamics goes directly from 1 to 4, jumping steps 2 and 3, because they are either unnecessary or misleading.

Inconsistencies between physical and mathematical pieces are avoided by applying physical and social laws directly to finite real elements; so, Dynamo, Vensim, Powersim or Ithink plot time related results. Auxiliary equations consider boundary conditions.

Partial Dynamics as a tool for process intervention is applied to increase quality and productivity in a steel plant. Process intervention illustrates distributed policy design. Heat radiation of a steel coil simulates temperature profiles to alter mechanical properties in the final product. Models for process improvement are supplied.

System Dynamics meets Distributed Dynamics, and provides better methods to deal with mutidimensionality. Specific methods to handle PDD in Vensim, Ithink and Powersim are presented.

PDD opens new ways to enhance company performance by System understanding.

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Evaluation of Traffic Information System in terms of User Equilibrium

Atsushi Fukuda, Shigeru Koyama, Satoru Kobayakawa
Transportation Engineering
College of Science and Technology
Nihon University, Japan
kobaya@trpt.cst.nihon-u.ac.jp

This study aims at evaluating by a simulation model what kind of method for providing traffic congestion information can attain the proper use of roads, namely the condition of user equilibrium.

In this study, first, the Block density model is prepared based on the SD theory in order to simulate traffic flows on a network consisting of two alternative routes. The route choice by each driver is estimated from information on the traffic condition in front that is:

1) visually obtained by the driver (i.e. the information on the condition one Block ahead),
2) shown by the information board, or
3) given by the navigation system.

In the case (3), however, only drivers of cars provided with navigation system are counted in, and other drivers are supposed to utilize the information (1).

The simulation is evaluated by a gap in average travel time between the two routes. If the gap is smaller, it can be evaluated that the information system more properly provides drivers with information, consequently leading to user equilibrium.

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System Dynamics Analysis of Network Externality in Complex Market Structures

Yoshitoku Fukunaga#, Yutaka Takahashi#, Nobuhide Tanaka#, and Akira Uchino*
1-5-1 Mejiro Toshima-Ku Tokyo 171, Gakushuin University
* Senshu University
nobuhide.tanaka@gakushuin.ac.jp

In the information technology industry, number of standards are proposed concurrently, but standardization is achieved in relative short time compared to other industries. This is presumed to be due to an existence of network externalities. This study will propose an archetype indicating the adoption process of a standard (product) in the information technology industry with such a characteristic, and an analysis example. In the information technology industry, the even out of multiple standards does not exist. As in the expression " Winner takes all" there is only one dominant and surviving standard. The instigator of that standard only could secure profit. For instance, in the initial stage of the personal computer OS, number of OS existed, but now Microsoft Windows dominate the market. In the standard of home video tape, initially Beta and VHS existed, but now there is only VHS.

The study looks at the case study of the adoption process of two major home video game players, SONY PlayStation and NINTENDO 64, which share the market in Japan. In the Japanese market, currently PlayStation shipment is 9 times that of NINTENDO 64, implying a dominant position in the market. Sony hypothesized the critical importance of utilizing effectively the network externality of software. Consequently Sony formulated a situation in which consumers would select their product by substantial software titles. This resulted in PlayStation capturing major market share in Japan rapidly. The feedback loops between stock-flow systems included in the acquired archetype all

were positive loops. However, the behaviour of the model did not show characteristics for those typical to positive loops.

Appearance of discrepancy between such qualitative analysis and quantitative analysis in a model describing today's growth area demonstrates a need to reconsider SD analytical method.

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The Dynamics of Distance Education Diffusion

Paulo M.Gonçalves
palomar@MIT.EDU

Although the applications of ever evolving technologies have largely changed the characteristics of modern society, to date education technology has had a marginal impact on education. In general, technology has been used as an accessory to the actual forms and methods of education. Distance education is the one exception to this rule, but distance education itself has been a marginal activity in traditional post-secondary education. Based on the fact that new interactive technologies have been central to teaching for distance education, many educators claim that distance education has the potential to revolutionize the education system.

This paper investigates the evolution pattern of distant students enrollment and the diffusion of distance education institutions, and explores the leverage points that allow the diffusion process to accelerate. The results show that the number of distant students grow exponentially, but enrollment is highly dependent on the experience of institutions and teachers, and also on the quality of courses offered. Word-of-mouth, conditioned by distance education quality, is the main driver of institutions' diffusion. Policies dealing with teacher certification and course accreditation are tested and their impact on the diffusion of distance education commented. The model shows a change in institutions' characteristics: institutions become more focused in expertise areas, as the number of courses per institution decrease; and institutions grow in size, as the number of teachers per institution and number of students per course increase.

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Dynamic Analysis of Internet Growth

Won-Gyu Ha*, Doa Hoon Kim**, Jaeho Juhn*
*Electronics & Telecommunications Research Institute, Korea
** Sook-Myung Woman's University, Korea
jhjuhn@etri.re.kr

The realm of cyberspace has been growing and replacing some roles of physical space. Especially, Internet has been playing as a main actor in the cyberspace including EC(electronic commerce), EDI(electronic data interchange), Internet Phone, Internet Broadcasting, EL(electronic library), etc. As a result of the rapid growth of cyberspace including Internet, we have many problems to overcome. But, unfortunately nobody knows the future shape of cyberspace.

In this paper, we made a system dynamics model of Internet growth to get a clue for dynamics of cyberspace. To do that, we started with comparing cyberspace with urban space. Namely, we used urban dynamics model as a basic framework for our Internet model. The population sector in urban space can be matched to users of Internet. Each of the labor sector and the housing sector also corresponds to information production sector and server (transmission capacity) sector in Internet. They can be classified as information consumption, production, and transmission sectors. There were two sub-modes that are composed of one model for single Internet site and another model for two competitive Internet sites.

By simulating these models, we got a few valuable implications. First of all, the information production sector leads the development of whole Internet space. That is, expansion of information production arises for the first time and then growth of the number of users follows it and finally server capacity increases. Therefore, the most important factor for Internet space development is activating information production (information business) sector. Secondly, from the competitive model, there is not path-dependent evolution but a little endowment effect. We also can find out that stagnancy occurs at the same time, even though initial conditions of two competitive sites are different.

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Conflict Analysis of Public Policy Stakeholders Combining Judgment Analysis and System Dynamics Modeling

Naiyi Hsiao
Nelson A. Rockefeller College of Public Affairs and Policy
University at Albany, State University of New York
135 Western Avenue
Albany, New York 12222
nh7365@csc.albany.edu
http://ALPHA1.albany.edu/~nh7365/

Public policy making has been characterized, by both research and practice communities, as struggling with various mutually conflicting interests. Active parties, namely policy stakeholders, take part in policy agenda setting, express their standpoints, and intend to shape policy alternatives which they expect will lead to policy outcomes most in favor of their interests. As an alternate to resolving disputes legally (typically legislative voting and jurisdiction), understanding and further resolving the contradictory interests by third party mediation has been emphasized in many situations and policy issues. Essentially, the key to mediating disputes lies in explicating sources of conflict by eliciting policy stakeholders' subjective values on policy issues.

The current study proposes a conflict analysis procedure. Using the JOBS (Job Opportunities and Basic Skills Training) welfare reform program as a case study and three hypothetical policy stakeholders, the procedure has demonstrated its capability to 1) elicit subjective values of the public policy stakeholders on policy alternatives and outcomes, and 2) deal with complexity of the disputed policy issue. Specifically, judgment analysis experiments elicit policy stakeholders' subjective values and explicate their cognitive conflict. System dynamics modeling contributes to building up important structures of the disputed policy, simulating various policy alternatives (means), and producing policy outcomes (ends). Eventually the means-end conflict would be vividly identified. Combining judgment analysis and system dynamics modeling, this conflict analysis procedure serves as a powerful tool for mediating policy disputes and further as a basis for conflict resolution.

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Airline Safety Dynamics

Ruey-Lin Hsiao
Warwick Business School
University of Warwick
Coventry CV4 7AL
R.L.Hsiao@warwick.ac.uk

Hero Ho
Chief Consultant
Airline Safety Committee
(Taiwan)

System dynamics method is one of the most effective ways to analyse complex strategic issues, capturing the subjective views of stakeholders and identify leverage points for policy formulation. However, its applicability has not been widely tested in other management disciplines such as the strategic change field. This research represents an effort to explore strategic change in relation to airline safety policy issues. The complex nature of airline safety issues offers a good subject for demonstrating the analytical power of system dynamics. This project explores the particular case of the Nagoya disaster in Japan, and traces the major safety issues back to the framework provided by China Airlines and the Taiwanese airline industry and also the governmental context. The aim is to provide new insights into the dominant policy operating in airline companies and government agencies, which emphasises a symptomatic solution in terms of human error (the pilots) and technological design (the aircraft manufacturer). In its practical aspect, the project seeks to obtain a better understanding of the dynamic nature of airline safety issues as well as policy analysis. Furthermore, in the theoretical aspect, the research attempts to show the applicability of system dynamics in the analysis of strategic change, and reviews relevant systems thinking methods in order to distinguish the position of system dynamics. The paper concludes with a review to link the application of soft system dynamics to its sociological roots.

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Improving Processes and Management trough Systems Dynamics Models

Antonio Barron Iñigo
Spain. Telecommunication Engineer. Telefónica de España S.A.
antonio.barron@telefonica.es

The purpose of this paper is to review different areas of a Company, where we can improve their management with the Systems Dynamics models construction, built a few of them, with simple elaboration and easy understanding. So, we will analyze business processes reengineering, as in the action of service orders, and in the

attention to the client, going trough the inventory control, the demand forecast for previous and new business, the analysis of the profitability of services, in monopoly and/or in competition market, calculation and valuation of financial statement, depreciation, cash flow and ratios, investments comparison, human resources management and planning, developing projects and tasks, reviewing policy optimization of the enterprise strategy.

The exposition of the present document will be used as reference to new users of the systems dynamics that ask about the field where to apply these techniques and tools, in the real world of the operative and strategic planning of a Company. Moreover, these models will allow other managers to share the knowledge and behaviour of the different processes, contributing in this manner to the Learning of the complex systems of the Enterprise, developed in huge models.

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Exploring the interactive games capabilities of standard Sotware SD tools, building competition markets models.

Antonio Barron Iñigo
Spain. Telecommunication Engineer. Telefónica de España S.A.
antonio.barron@telefonica.es

In this paper, I will expose the experience in Telefonica de España to build models to explain the transition of monopoly to open markets, in telecommunication business and services.

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HYPERTENSION : A System Dynamics Description and Multimedia Presentation on CD-Rom

Michel Karsky	***Roger and Josyane Lacroix***	***Jean-Christophe Dore***	***Gregory Aich***
Industrial KBS, Paris, France	Faculté de Pharmacie, Tours, France	CNRS, Paris, France	KBS, Paris, France

The authors have developed a System Dynamics model of human Hypertension, which is intended to be used by doctors, medical students and even laymen for self-teaching or as a reminder of the basic theories and medication possibilities of this frequent ailment.

The CD-Rom which we propose to show, and the corresponding model, contain :

- a description of Hypertension biochemical factors and their multiple effects on various parts and organs of the body.
- the description of the effects of all presently known medications (generic drugs), including recently discovered new drugs.

Dosage, frequency of in-take and length of prescription are parameters which can be used during any simulation to judge the effect and efficiency of the chosen generic drug or mixture of drugs, depending on the hypertension of the patient and the stress generated by his environment.

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Conceptual Models for Policy Makers

Sharon Lansing	***Roderick H. MacDonald***
Policy Analyst New York State Division of Criminal Justice Services 4 Tower Place Albany, New York 12203	Rockefeller College of Public Affairs and Policy University at Albany, SUNY Milne Hall, 135 Western Ave. Albany, New York 12222

System dynamics is a powerful tool for bringing structure to and developing insight into complex problems. Unfortunately, its conceptual and visual complexity are among the factors that have frustrated efforts to disseminate its acceptance and use more widely. This paper presents a small concept model for introducing system dynamics to policy makers that builds on recent research concerned with integrating traditional research techniques and systems thinking into public policy evaluation. It is an approach that introduces the power of system dynamics modeling to policy makers by first demonstrating its utility in theory development and research design. The rationale behind this approach is quite simple. Before any tool can be valued, its value must first be understood. Thus, the purpose of this approach is to first illustrate the greater clarity and insights system dynamics modeling can bring to a complex problem though its ability to convert real-life problems into a simulation model that can replicate the complexity, nonlinearity and feedback loop structures found in all social systems. To illustrate this approach, this paper will address the problem of recidivism among juvenile delinquents and the effective targeting of scarce treatment intervention resources intended to reduce the likelihood of a delinquent's continuing involvement in criminal activity.

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Data Capture Methodology for Modelling and Simulating a Product Introduction Process

Rachel Mason-Jones*, Dr Alison Boardman#, Ben Clegg#, Dr Mohamed Naim* and Professor John Boardman#
* Logistics Systems Dynamics Group, Cardiff University, PO Box 907, Cardiff CF1 3YP UK
# Systems Engineering Group, De Montfort University
mason-jones@cardiff.ac.uk

There is considerable pressure in the aerospace industry to focus efforts on Product Cycle-Time Reduction (PCTR) and in particular to eliminate waste time in the Product Introduction Process (PIP). The paper describes a data capture methodology developed in pursuance of a PIP Extended Enterprise Simulation. The methodology consists of a framework that details the stages required from a real world PIP boundary, problems and performance measures definitions through to the development of the PIP simulation model and scenario testing. Various hard/soft system data capture tools and techniques are utilised such as input-output analysis, Ishikawa analysis, process flow mapping and Systemigram models.

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System Dynamics Modeling - A New Way to Analyze Production Networks -

Udo Mildenberger
Lehrstuhl für Allgemeine Betriebswirtschaftslehre und Produktionswirtschaft; D-55099 Mainz, Germany
umild@prod-org.bwl.uni-mainz.de

Production Networks are a specific form of Interorganizational Networks. They are characterized trough tree constitution elements: The cooperation is focus to the production of goods (industrial goods, consumer goods, service etc.), has an more heterachic than hierarchic organization structure and follows more long-term than short term goals. In the paper presented, the evolution of such Interorganizational Networks is explained on the base of the system-based-approach and the resource-based-approach (see the paper of U. Mildenberger; SD-Conference 1997).

The traditional way to analyze Production Networks is the Social Network Analyze. This methodology, developed in the field of Psychology and Sociology, base on the thesis, that individual behavior in a network is totally determined trough the interaction relationships between the partners. Therefore the Social Network Analyze describes Networks, the evolution of networks and the economic potentials of networks only with static criteria, like structure of the relationships, network position of each partner or network-density. A lot of aspects like continuous change of relationships (dynamics of network-relationships), systemic interdependencies of network-relationships, the context and history of each partner in the network as well as the context and the history of the whole network etc. are strongly ignored. Summarized, the methodology characteristics of the Social Network Analyze agree little with the problem characteristics of Production networks. Instead of this, in the presented work a System Dynamics Model is used as a tool to analyze Production Networks.

The prototyped simulation model allows to analyze the consequences of the constitution and the realization of Production Networks for each network partner, shows the evolution process from the perspective of the whole network and describes the effects and the repercussions from the network to the structure of the market (innovation time, customer behavior etc.). Based on the goal of the simulation, the model must be able to reflect the effects of an Production Network in different market situations with different competitive strategies followed by the competitors and different customer behavior.

The paper will present this model from a theoretical view (basic assumptions of system- and resource-based-approach and its translation in SD-terminology) as well as from a practical view (structure of the model, simulation results, etc.)

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Modelling Environmental Carrying Capacity and Developing Sustainability Indicators

Taehoon Moon
Dept. of Regional Development, Chung Ang University
San 40-1 Naeri Daeduck Myun, Ahnsung Kun, Kyung-Ki Do
Republic of Korea, 456-756
thmoon@naeri.cc2.cau.ac.kr

The purpose of this paper is building an environmental carrying capacity model and developing sustainability indicators using the environmental carrying capacity model.

For this purpose, the paper consists of 3 parts. First, the paper examined the evolving definition of the sustainable development and environmental carrying capacity. Second, having examined the concepts, this paper developed a small generic model of environmental carrying capacity focusing on a carbon dioxide emission in a

region. Third, using the environmental carrying capacity model, this study developed an environmental indicators that can be used to monitor the sustainable development of a region.

There are two versions of sustainable development, a weak version and a strong one. The weak version just requires that environmental considerations are given greater weight in public decision making. The strong version, however, requires society to define sustainability constraints or environmental limits, environmental carrying capacity. One of the key issues in the approach to defining a strong sustainable development is how to operationalize the carrying capacity and how to measure change and progress. This may be tackled through system dynamics modelling on carrying capacity and building sustainability indicators based on the model.

In this study, an environmental carrying capacity model was developed based on the simple urban dynamics model (Alfeld et.al., 1976). The model consists of 5 sectors; population, housing, industry, land, and environmental sectors. In environmental sector, key variables are amount of co2 emission from the industry sector, green space, and air pollution index. Green space in this model functions as a source of fresh air supplier and as a co2 sink source. Air pollution index was defined as a ratio of 'co2 emission per unit land' to 'desired co2 emission per unit land'. In the model, the environmental carrying capacity was defined as a number of industry structure, population, and housing that can sustain certain level of air quality which is represented by the air pollution index.

Based on this small carrying capacity model, the sustainability indicators were developed using appropriate variables in the model. Those sustainability indicators are land fraction occupied, number of population and labor force, number of industry, number of housing, amount of co2 emission from industry, area of green space, and pollution index. Values of these variables at the equilibrium point can be used as a maximum human activity that can sustain a certain level of air quality in the region. Monitoring local condition in view of these maximum values can provide an important information whether the region is converging or diverging from the sustainable condition.

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Strategic Management as Decisions of Two Stages on a Set of Competitive Measures

Michiya Morita and Nobuhide Tanaka
1-5-1 Mejiro Toshima-Ku Tokyo 171, Gakushuin University
michiya.morita@gakushuin.ac.jp, nobuhide.tanaka@gakushuin.ac.jp

Our experimental analysis of world class manufacturing firms suggests that Porter's generic competitive strategies are options available to certain firms which meet the condition that all of representative competitive measures like cost and quality are above than competitive average respectively. Then the first stage means the firm should maintain its all of the competitive measures at the competitive level. The first decision consists of the resourceallocation decision which meets the condition.. The next stage is to decide on a particular set of the competitive measures with a specific set of weights, which characterizes the firm's unique strategic position. Only the second decision neglecting the first decision leads to competitive failure.

One of the most important criteria to judge the firm excellent is the firm should maintain its satisfactory performances over time. Many firms sometimes fail to manage to keep the criterion. One reason is they do not take the strategic decision as the two-stage process. They sometimes fail to recognize they are lagging behind the first condition. If too late, they have to move to another position attacked by new competitors. It can be considered as escaping into a market niche which may be shrinking or will be attacked later if it's promising, as pointed by Stalk(1988).

Our paper will present the dynamics of strategic management in the context of the two-stage framework. In the paper we will show the dynamics of strategic management as maintaining certain management capacity and causing synergistic relationships between the competitive measures which can be realized by strengthening the management capacity.

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A System Dynamics Analysis of Gold Production in Kyrgyzstan.

A.O. Moscardini, K.A. Lawler, G.J. Tentieva.
University of Sunderland UK.

Kyrgyzstan is a small republic in Central asia which has just established independence form the former Soviet Union. In the transition from a centrally planned economy to a free market economy, Kyrgyzstan faces many problems. Decisions that are made now will have consequences far into the future. Conventional approaches for understanding and predicting the behaviour of such economies are based on standard macroeconomics and mathematical techniques. These methodologies are often inadequate. The purpose of this paper is to demonstrate how the use of System Dynamics can help to understand macroeconomic models. (all models are implemented in POWERSIM.)

Exploring economic chaos opens a new way to understand behaviour of economic processes and their development In the first part of the paper, the structure of the “Beer Game” devised by Sterman is analysed. The structure is then adapted to model the Gold Production Sector in Kyrgyzstan. As Kygyzstan is such a small country, reliable data can be obtained and this has revealed many probl;ems especially in the infrastructure of the country. Because of this, chaotic “cobweb-type” behaviour was anticipated and the model show that this is indeed the case. The follow -up to this work will be to identify the key parameters which govern such behaviour and to formulate some policies that would avoid unstable.

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Create a Websim in Five Minutes

Magne Myrtveit, Atle Geitung, Morten Fjeldstad, Jon Brunvoll, Bjorn Arild W. Baugsto, David Bridgeland
Powersim AS
N-5120 Manger
Norway
magmy@powersim.no

Look(tm) makes it fast and easy even for non-programmers to create a user interface on a simulation model created in Constructor(tm). The resulting simulator is run as a client server application over the Web. End users just need a Java enabled Web browser to run Look applications. Look is template based. Each template defines a generic simulator front end that you associate with a simulation model and customize to your needs. Using the Quick Plate template you can create a user interface in less than five minutes, while the Base Plate allows you to create a broader variety of websims.

Visit www.powersim.com or www.powersim.no for samples.

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Using Organizational Learning and Decision Aid techniques to construct a Flexible Management System

Javier Pereira and Martin Schaffernicht
Departamento de Informática de Gestión, Universidad de Talca, Avenida Lircay s/n, Chile
jpereira@pehuenche.utalca.cl, martin@pehuenche.utalca.cl
http://www.utalca.cl/~martin/martins.html

We propose a method of intervention towards constructing flexible (autonomous and viable) management systems, that emerge from strategies we explain as rules and meta-rules in a participative process incorporating the different points of view of the actors in the relevant domain.

Parting from constructivist principles (action triggers learning; valid learning needs action; knowledge is uncomplete; failure enables learning), we use techniques from organizational learning and decision aid in a cycle of Observe-Model-Construct-Act. It is a parallel search process for strategies enacted by the implied actors, and couples action and rules in a permanent redefinition by an empirically oriented scientific process.

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Use Of System Dynamics as Corporate Synergistic Communication -
From Learning Environment to Knowledge Accumulation

Nataliya Rozora, M.Sc.
Complex Adaptive Systems Laboratory,
Central European University
H-1245, Budapest V, Hungary,
natroz@hotmail.com

Use of system dynamics for creation of learning environments in corporate management has with no doubt great implementation in the future, however yet another powerful feature of dynamic simulation of corporate activities, namely way of accumulation of knowledge and communication, is not fully explored.

In the paper presented there is investigation of multi-level approach to corporate use of dynamic simulation. The initial level is just a learning environment introduction in order to make managerial staff familiar with systems thinking and to show consequences of decision making in a long term with no risk for the real activities.

However the important point here is that collective use of any simulation package like iTHINK with discussion of systems' elements relationships in dynamics could serve as a means for team building. That means use of a graphical modelling language ideology as a universal and understandable by everybody in team way of expressing knowledge and hence way of communication.

When the simplest way is team playing with management flight simulators, the most sophisticated one concerns experts' involvement for expert blocks creation of complex simulation models.

Both support knowledge accumulation in institutional memory, and both use interrelations making synergistic effects with communication. These ways are suitable for project managers to get better project estimations, for financial plan makers, and even for communication outside. The last means that better results of business negotiations can be achieved with pre-discussions using dynamical simulation as communication tool for better ideas explanation, testing, and support.

A range of models will be presented to illustrate this paper.

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The Dynamics of Electricity Production in a Norwegian Utility Company
Cand. Polit. Morten Ruud, Ann van Ackere, Ph. D., and Mag. Art. Pål I. Davidsen.

XXX is a utility company producing hydro-electric power. It is jointly owned by the companies YYY, ZZZ and VVV. The owners use their share of the power produced, or sell it on the open market. A number of issues re. the trade-off between a technically and an economically optimal utilisation of the water resource has been brought to our attention. There are two aspects to this issue: (i) managing the water inventory most effectively and (ii) timing production to take advantage of large price fluctuations and the requirements of the owners. These issues are investigated using a system dynamics model that consist of a technical component and an economic component.

This paper presents a system dynamics model constituting the technical component of the XXX company. It includes the tightly interconnected water reservoirs, the associated pipelines, a pumping station, the power stations, and the control systems. There is a high degree of complexity involved in the operation of the company including issues such as water supply estimation, reservoir depletion rate optimisation, effective water pressure maximisation (depending on the water supply to the turbines), and turbine effect maximisation, -- all under the constraints imposed by the owners and the electricity market.

The model has been validated using a large amount of data sampled regularly over the last few years. It can be generalised and applied to other hydro-electric power plants and can serve as a component in an interactive learning environment for the training of utility managers and stake holders.

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Strategic Planning with Limited Information Resource
Francesco Sacco
Business Policy Department
Bocconi University School of Management
Via Bocconi 8
20136 Milan, Italy
francesco.sacco@uni-bocconi.it

A survey in the Italian machine tools industry has been carried out interviewing CEO and managers of 36 company in this field to study:

a. characteristics of information held by the firms to define their business strategies;
b. consequences of conditions of limited information;
c. possible remedies for such conditions.

The characteristics of information have been studied on the base of their degree of importance, confidence and accuracy respect to declared business strategies. Results show a general insufficient quality of information that can seriously bias the decision making process and influence its conclusions. Furthermore, declared strategies are not coherent with the available information resulting in a strategic rationality that is not based on data but on a vague idea about the state of the industry and the strategic intents of competitors.

This situation creates the context so that the decision-maker could be seriously prone to cognitive bias (hindsight bias, availability bias, framing effect, illusion of control, availability bias, reasoning by analogy, etc.).

The suggested remedies in literature to improve this kind of decision making process, different from the mere "integration of information", are illustrated and discussed. Finally, the use of causal loop diagram is proposed as a "de-biasing" tool and a methodology is presented.

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System Dynamics Practice: in the Middle of Two Thinkings
Ricardo Sotaquirá Gutiérrez and Jose Daniel Cabrera Cruz UNAB, Colombia
rsotaqui@bumanga.unab.edu.co
Lilia Nayibe Gélvez Pinto Universidad del Valle, Colombia

Our condition of <u>community</u> of System Dynamics (SD) practitioners is threatened. This threat stems from our own practice.

One of the sources of this threat is a deep contradiction in the foundations of our discipline. However, the threat arises not so much from the existence of the contradictions as such as from their hidden status. The latter is weakening what we think is the original “call” that moves the community of SD, namely: to work toward a systemic approach which overcomes the fragmentation of our world and our life. This “call” means that SD is <u>founded</u> on two

thinkings: the systemic one and the anti-systemic (fragmenting) one. Anti-systemic thinking is not an exogenous "enemy" but a constitutive part of SD practice. Its victorious and hidden presence inside SD is the source of deep contradictions.

In order to acknowledge this threat, and maybe transcend it, we need to place SD practice on a historical context. This can help us to thoroughly understand the "call" of SD and, consequently, the two thinkings which actually constitute it.

Full paper: http://www.geocities.com/Athens/Aegean/8396/sd98.html

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Simulation of Policy Alternatives to Prevent Deforestation and Soil Erosion in Turkey

Yeşim Tozan
Research Assistant
Boğaziçi University
Institute of Environmental Sciences
80815, Bebek-Istanbul, Turkey
tozanyes@boun.edu.tr

Increasing human pressure menaces the balance of many systems such as economic, social, and ecological. Nowadays, forests worldwide are threatened by uncontrolled degradation and conversion to other uses because of increasing human pressure.Agricultural expansion, overgrazing, unsustainable logging, and inadequate fire control techniques are the main causes of **deforestation**.

Together with deforestation, another significant problem, **soil erosion** comes to scene on the deforested area due to the lack of necessary vegetation, which prevents the erosion and transportation of the soil via wind and water effects. Geologic nature and slope of the terrain and climatic conditions are the primary factors of "natural erosion" which can be ignored. These factors gain importance and lead to "accelerated erosion" with inadequate management and use of land of which deforestation is also a result.

In Turkey, there is 20.2 million hectares forest area. Unfortunately, 56 percent of our forests are disturbed and nearly lost their typical characteristics. 11.3 million hectares of forest area waits to be reforested in our country. Another frightening situation arises from the fact that 79.43 percent of soil of our country is exposed to erosion of different degrees which corresponds to an area of 61.9 million hectares. These values reveal the significance of these two problems, deforestation and erosion, and show that we should encourage the **sustainable** use of forests and land and develop new policies to control and supress the soil erosion and deforestation.

The aim of this study is to analyze the primary mechanisms that accelerate deforestation and soil erosion and to create a dynamic model of the inter-connected problems, erosion and deforestation, in order to develop and test new policy alternatives that control and dampen the deforested area and eroded soil and reveal the consequences in the future by simulation results. The tool used to costruct the model and analyze the system is **System Dynamics Methodology**, which focuses the use of computer models to simulate the dynamic changes in a system over time.

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Some Challenges to the Taken For Granted Assumptions in System Dynamics

Yi-ming Tu, Chia Ping Chen, Ya-tasi Tseng
National Sun Yat-sen University, Taiwan

Several assumptions are taken for granted in system dynamics field. For example, positive loops generate exponential growth or decay behaviors, and negative loops generate goal seeking behaviors. The study tries to clarify four basic assumptions in system dynamics. First, the representation of net rate in the flow diagram may hide some dominant loops. Some anomalous behaviors may result from dominant power shifting among the hidden loops. Second, depending on the configuration of variables in system dynamics model to infer the behavior of loops is not reliable. For example, what we judge as a positive feedback loop from the configuration of variables may generate goal seeking behavior. Third, if we use the level-net rate diagram to judge which type of loop dominates and whether the dominant loops shift, we should be careful. One curve with positive/negative slope in the level-net rate diagram does not necessarily mean that one positive/negative feedback loop exists. It may be no loops exist at all. So if the slope of a curve changes sign, we may not conclude the dominant loops shifting. Finally, the study tries to clarify the concept of dominant loop. Instead of the statement that "the loop dominates the structure," we shall say that "the loop dominates some variables". The reason lies in that every variable has its own dominant loop(s) during each specific period. We will describe our reasons in more detail in the full paper.

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A Teleological Perspective of the Dynamics of Economic Development:
Soft variables and Development Theory

Imrana Ahmed Umar
Research Fellow, Department of Information Science
University of Bergen, N-5020 Bergen, Norway
imrana@ifi.uib.no

This paper examines how system dynamics could contribute to the theory of development, by adapting a teleological perspective to development studies. It emphasizes the important role of soft variables as the true non-economic causes of development and SD's capability for interdisciplinary studies.

The paper focuses on the different roles of *material resources* and *human or social consciousness* in the process of development. The paper builds its argument from two vantage points— the classical epistemology of causality and change (theory of forms) and the evolutionary theory of economic development. It concludes by examining how these two theories fit perfectly the ontology of SD.

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A System Dynamics Approach to Innovation and Economic Growth

Jaime Rojo de la Viesca
Institute for Prospective Technological Studies
Joint Research Centre - European Commission
World Trade Center. Isla de la Cartuja s/n. E-41092 Sevilla.
jaime.rojo@jrc.es

This paper replicates through a system dynamics framework, several of the main ideas developed in the theoretical models of economic growth. First the results of the neoclassical model of growth (Solow, 1956) are replicated. In the long run, in the neoclassical model the growth rate is driven by technological progress, otherwise a steady-state situation is reached. On the contrary the endogenous growth models endogenize the growth process as a consequence of the externalities generated by the innovation process. Processes of human capital accumulation , learning-by doing and spillovers can generate processes of endogenous growth. A theoretical model (Lucas, 1988) that reproduces an endogenous growth process is simulated using system dynamics. In this model the role of human capital accumulation in the growth process is examined.

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How Internet Access Pricing Strategies affect The Local Telephone Network:
A System Dynamics Approach

Fabrizio Virdone
Consultant Engineer
Via Laurana 93, 90143 - Palermo
EFFEVI@MCLINK.IT

Francesco Di Marco
Telecommunication Engineer
Via U. Saba int B2, 00144 - Rome
ME2006@MCLINK.IT

In the last decade, public telephone networks have been featured by deep changes leading to a growing relative weight of data communications using the telephone network (including access to the Internet), compared to voice, as a consequence of new services offered to customers.

Such a phenomenon has increased the overall system's complexity. In fact, some bottlenecks have been arising, as the Internet call traffic greatly differs (in terms of duration, hourly distribution, flow pattern, etc.) from the voice traffic, which was the main application on whose characteristics traditional public telephone network was originally designed and developed.

In order to face such bottlenecks, public telephone companies have been forced to invest financial resources to re-design and develop their network. It has been difficult, however, for them to justify a return on such investments as traditional telecommunication pricing structures are not suitable for access to and use of multimedia application and moreover tend to encourage inefficient use of local network.

The aim of this work is to analyse dynamics produced by such a "structure" and, more particularly, to describe feedback loops, delays and non-linearities related to inter-relationships between the internet access pricing strategies and the local telephone network.

Such an approach is justified by the need to better understand main outcomes that could be produced by different strategies.

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Problems with KPMG's "Strategic-Systems Auditing" Framework

John Voyer
Associate Professor of Business Administration
and Co-Director, MBA Program
School of Business
University of Southern Maine
voyer@usm.maine.edu

Steven Jackson
Assistant Professor of Accounting
School of Business
University of Southern Maine
sjackson@usm.maine.edu

With *Auditing Organizations Through a Strategic-Systems Lens* (Bell, et al., 1997) the accounting firm KPMG has vaulted to the forefront in the practice and theory of assurance services provided by auditors. Though their effort, a method called the "KPMG Business Measurement Process," is laudable, it is also flawed.

The approach delineated in the monograph purports to advise auditors on how to understand a client's business from a systemic standpoint. However, the framework expounded on at length in the book is based on the systems thinking of Stafford Beer (1981) and as such is heavily skewed toward a cybernetic, as opposed to servo-mechanistic, view of systems (Richardson, 1991). The result is a framework that ignores endogenous reasons for problems confronting the firm and is overly focused on the homeostatic view so favored by the cybernetic school.

The present paper will elaborate on the mental models that flow from this approach and make suggestions as to how elements of the servo-mechanistic school might profitably be integrated into the KPMG Business Measurement Process.

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Joined Feedback Loops and Systems Archetypes

Qifan Wang and Zhaotian Zhou
School of Management, Fudan University, 200433, Shanghai, CHINA
qfwang@fudan.sh.cn

'Feedback loop' is a fundamental concept of SD, and people are familiar with the typical behaviors of balancing and reinforcing loops, which are basic components of systems archetypes. From the viewpoint of SD, systems archetypes are some joined reinforcing and balancing loops (maybe with some delays). What we considered in this paper is, if two (or more) loops being coupled, how the performances of the separate loops influence the coupled loop? If two reinforcing (balancing) loops joined together, should it still a reinforcing (balancing) one? We came to the following conclusions through studying this issue:

1. Provided two feedback loops (reinforcing or balancing) joined together. The first common variable of two loops is important to the behavior of joined feedback loop. This variable is a function of two variables, which belong to two loops separately. If there is a linear relationship between two parts which contain two loops* variables separately in the function expression of the first common variable (that is, supposed the first common variable of two loops is A, the other variables B, C belong to two loops separately, and the function of A is, say, A=f(B)+g(C)), then among these two loops there may be a dominant one, the joined loop's behavior is the same as that of the dominant one. Of course, dominant loop may change.
2. If it is not the situation of case 1, then there may be no dominant loop. We discussed some common functions of variable A, and studied the behaviors of joined loops in those situations.

Additionally, we applied these conclusions to some systems archetypes, and considered their probable performance.

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Using Case Method to Teach Systems Thinking

Sy-Feng Wang
Assistant Processor, Department of Business Management,
Downtown Campus, Soochow University
56, Kuei-Yang St., Sec 1, Taipei, Taiwan
sfwang@mbc1.scu.edu.tw

Systems thinking is a highly aggregated thinking procedure to see the world. In the cognitive point of view, learning systems thinking by doing is more effective than learning by teaching. This paper proposes a tested procedure to using case method to enhance the learning of systems thinking. The 120 subjects were all managers or consultants came from four lectures. The proposed procedure is that,

1. Read the case.
2. Ask subjects to right down "what are the problems" (mapping the linear and reactive mental model) and "what are your solutions" (for challenging mental model in step 10 and step 11).
3. Discuss and identify the problems using systems thinking view.
4. Ask subjects to draw causal feedback diagrams. (run 1)

5. Present the diagrams. Instructor give the cognitive feedback focused on the level of variables, causal links and the sign of loops.
6. Ask subjects to redraw and use the causal feedback diagrams to explain the problems' patterns. (run 2)
7. Present the diagrams. Instructor give the cognitive feedback focused on the level of loops' structures and behaviors' patterns.
8. Ask subjects to abstract the structure by archetypes and dominated loops. (run 3)
9. Present the diagrams. Instructor give the cognitive feedback focused on the level of the transferable abstracted structures.
10. Ask subjects to use the structures to predict the fixes' effects that proposed in step 2.
11. Present the work. Discuss the general counter-intuition system behaviors and the rule to intervene systems.
12. Ask subjects to find the high leverage and to predict the effect by the structures. Present and discuss the work.
13. Test the policies by the computer simulation. Discuss the simulation results.

The proposed procedure should used depend on subjects' degree and case materials. One case is used to demonstrate the procedure and its time interval. Finally, this paper also proposed one framework to classify cases needed to learn systems thinking.

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A Model-based Tool for Predicting Information Systems Requirements Engineering Process Performance

Ddembe Williams
Information Management and Modelling Group,
School of Computing, Information Systems and Mathematics
South Bank University
Borough Road, LONDON SE1 OAA, UK
williadw@sbu.ac.uk

This paper proposes a framework for developing a system dynamics model-based tool for evaluating and predicting the effect of requirements changes on the information systems (IS) requirements engineering (RE) process. The model describes a generic RE process and has potential to provide a requirements project manager with a tool to support policy decisions concerning RE process performance. The strength of the proposed model and its advantages over the existing models is its capability to analyse both hard and soft factors, and the understanding gained from explanatory insights from the feedback structures.

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Stock-Flow Fundamentals, DT and Differential Equations

Kaoru Yamaguchi
Dept. of Management Sciences
Osaka Sangyo University
Osaka 574, Japan
mailto:kaoru@dis.osaka-sandai.ac.jp
www.bekkoame.or.jp/~k_yama/

System dynamics is literally a dynamics of systems and, in this sense, the analysis of dynamics is more fundamental than that of systems. I'm a new comer to system dynamics research, and had an impression that this field of research seems to emphasize an analysis of systems in terms of feedback mechanisms and interdependent relations. In particular this is true when graphics-oriented tools of system dynamics become available in PCs and Macs such as Stella, Vensim and PowerSim, and any beginner can easily build a complicated dynamic model without knowing the mechanism of dynamics and differential equations. This gives an impression that system dynamics and systems of differential equations are two different fields, though they are the two sides of the same coin.

In this paper I emphasize that an analysis of dynamics is more essential to system dynamics than systems thinking itself and show that it automatically leads to systems thinking. I believe this is a most fruitful way to learn the logic of system dynamics in a unified fashion with differential equations so that system dynamics could be a foundation of scientific analysis in many research fields.

These ideas are organized as follows.

1) Stock-Flow are fundamental to dynamic analysis
   The nature of continuous dynamics can be operatively understood in terms of stock and flow relation in system dynamics.
2) Types of Stocks
   Types of stocks needs to be grouped.
3) Analysis of Flows
   Time-dependent flows are most basic flows and their comprehensive analysis is crucial to system dynamics

4) DT and Differential Equations
   DT (Delta Time or the interval of time) is one of the most confusing concepts in system dynamics, but an important bridge to differential equations. It is thoroughly understood by using the above time-dependent flows. Runge-Kutta methods are introduced at this stage.
5) SD as a system of differential equations
   When flows become dependent on other stocks, a self-dynamics evolves into system dynamics.
6) SD beyond a system of differential equations

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The Dynamics of Dominant Design Shifts and Market Growth in Information Industry

Showing H. Young and Shih Hui Lo
Department of Business Management
National Sun Yat-Sen University, Kaohsiung, Taiwan.
syoung@mail.nsysu.edu.tw

Since early 1970s, microprocessor had been the core component of the computer. Dominant designs of the computer had experienced some major shifts in the evolving information industry during the past decades. Integrated proprietary architecture had been replaced by specialization proprietary architecture in computer design through technology innovations.

In the 1980s, IBM compatible PCs had been the dominant design product; however, on the other hand, early Apple computer's product escaped from the dominant design market. In these years, dominant products went through fast changes from generation to generation (286, 386, …Pentium), which resulted in gradually shortening of the product life cycles, sharp changes in prices, and increasing market growth. This research attempts to build a system dynamics model to study the dynamics underlying the shifts of dominant design architecture and the evolution of dominant design products.

The model consists of the life cycle of the diffusion process of adopters, production strategy of manufacturers (e.g., the control of quality, cost and delivery time), the influence of complementary products, and the innovative strategy of suppliers; the behavior patterns of market growth are thus generated. Moreover, the interaction between the innovative strategy of the innovator and the competitive strategy of the follower will also be discussed in this paper.