Systems Thinking for Sustainable Development and Enterprise

University of Michigan Ross Business School and
School of Natural Resources and Environment

Winter 2008
Strategy 566, Section 001 & 451
NRE 550, Section 001
Wednesdays 7:00 – 10:00 p.m.
Classroom: E1405, Tozzi Center B-School
January 9 – April 16
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Course Objectives:

1. To develop critical skills of **Global Systems Thinking** (note that the phrase "global" has two meanings in this course: a] of, relating to, or involving the entire world, and b] of, relating to, or embracing all considerations in a complex system). Will also develop a set of communicating, visioning and conversational skills associated with systemic leadership for a sustainable future.

2. To acquire the skills of **Systems Dynamics Modeling** using state-of-the-art Stella and iThink simulation software for enhancing mental models and understanding of complex systems – via active and participative learning by doing (i.e., building and simulating models of dynamic systems and processes regarding issues of global change).

3. To foster awareness, sensitivity and literacy regarding **Global Environmental and Social Change**, including challenges such as population growth, persistent poverty, social disintegration, biodiversity loss, climate change, freshwater scarcity, gender bias, megacities, food insecurity, political instability, terrorism, etc., focusing especially on the roles of industry in relation to these challenges.

4. To understand **Sustainable Human Development and Enterprise** as an ongoing, adaptive learning process, examining "what if" possibilities regarding future development pathways and exploring the most promising opportunities for business in helping to ensure that human needs are met while the planet's life-supporting environment is nurtured and restored.

Course Materials:

1. (JM) John Morecroft, **Strategic Modelling and Business Dynamics: A Feedback Systems Approach** (John Wiley, 2007) (purchase at local textbook stores). Note: Comes with a compact disk with chapter models, learning materials and iThink save-disabled modeling

software. [NOTE***Apparently out-of-print until late January…we'll scan copies of early chapters!!!!!!!].

2. **STELLA Version 9.0/Student** (Windows or Mac) systems dynamics software (order from iseesystems at www.iseesystems.com , info@iseesystems.com , Phone: 603-448-4990, Toll-free:800-987-6758, Fax: 603-448-4992. I'll be providing iseesystems with the class roster for confirmations right after the first class. Perpetual License is $129; 6 Month License is $59. [NOTE: may want to share this software; will first use in class on Jan. 30).

3. Other assorted readings, cases, handouts, psychographs, etc. to be posted on course tools site, distributed in class or downloaded from the web.

Student Performance Evaluation:

1. (20%) **Class Participation Throughout** (including topic teammate evaluations for team reports below).

2. (20%) **Global Change Topic Team Expert Report** (due Feb. 6) (a detailed report on your selected global change topic including definitions, indicators, data sources, trends, geographical patterns, primary determinants, primary consequences, role of industry, implications for sustainability, prior modeling efforts, simple causal looping, etc. – guidelines for report to be provided).

3. (20%) **Topic Team Model Building Report** (due March 5) (an individual topic team Stella model building effort converting causal looping from the prior Expert Report into a relatively simple Stella dynamic model to acquire the basics of Stella modeling—guidelines for report to be provided).

4. (20%) **Dyad Team Model Building Report One** (due March 26) ("random" uniting of two global change topic teams [e.g., poverty and population] to build and simulate a dynamic Stella model connecting the two topics--united teams will follow four stages of model construction: conceptualization, formulation, testing and implementation-- results to be presented in class emphasizing implications for industry and sustainable development—guidelines for report to be provided.)

5. (20%) **Dyad Team Model Building Report Two** (due April 16) (a second "random" uniting of two global change topic teams [e.g., climate stability and biodiversity] building and simulating a dynamic model connecting the two topics – same process as above).

Systems Dynamics, Thinking and Sustainability Websites:

1. Sastry and Sterman, "Desert Island Dynamics: An Annotated Survey of the Essential Systems Dynamics Literature," (1992) (at www.web.mit.edu/jsterman/www/DID.html)
2. The Sustainability Institute (at www.sustainer.org).
3. Forum on Science and Technology for Sustainability (at www.sustsci.harvard.edu).
4. World Business Council on Sustainable Development (at www.wbscd.org)

5. International Council for Science (at www.icgu.org).
6. United Nations Population Fund (at www.unfpa.org).
7. Rocky Mountain Institute (at www.rmi.org).
8. SustainAbility Ltd (at www.sustainability.com).
9. Stockholm Environmental Institute (at www.tellus.org).
10. International Forum on Globalization (at www.ifg.org).
11. Natural Capitalism (at www.natcap.org).
12. Turning Point Project (at www.turnpoint.org).
13. The World Bank (at www.worldbank.org).
14. Worldwatch Institute (at www.worldwatch.org).
15. United Nations Development Programme (at www.undp.org).
16. Friends of the Earth (at www.foe.org).
17. Greenpeace (at www.greenpeace.org).
18. Third World Network (at www.twnside.org.sg).
19. United Nations Development Fund for Women (at www.undp.org/unifem).
20. Foreign Affairs (at www.foreignaffairs.org).
21. Foreign Policy (at www.foreignpolicy.com).
22. Tomorrow Magazine (at www.tomorrow-web.com).
23. Tom Fiddaman's System Dynamics Bookmarks (at www.home.earth.net/~tomfid/sdbookmarks.html).
24. Systems Dynamics Society (at www.albany.edu/cpr/sds/).
25. Complexity, Complex Systems & Chaos Theory Website (at www.brint.com/systems.htm).
26. Pegasus Publishers (at www.pegasuscom.com).
27. Island Press (at www.islandpress.org).
28. Systems Dynamics Group at MIT (at www.sysdyn.mit.edu).
29. World Game Institute (at www.worldgame.org).
30. Beijer International Institute of Ecological Economics (at www.beijer.kva.se).
31. Atkisson Inc. Sustainability Consulting (at www.atkisson.com).
32. Conservation Ecology (at www.consecol.org).
33. Santa Fe Institute (at www.santafe.org).
34. World Resources Institute (at www.wri.org).
35. The Systems Thinker (at www.thesystemsthinker.com).
36. Center for Health and the Global Environment, Harvard Medical School (at www.med.harvard.edu/chge/).
37. Environmental Sustainability Information (www.environmentalsustainability.info/)
38. Woodrow Wilson International Center for Scholars—Global Environmental Change and Security Program (at www.wwics.si.edu).
39. The National Endowment for Democracy (at www.ned.org).
40. Freedom House (at www.freedomhouse.org).
41. Systems Links by Bill Brawn (at www.hlthsys.com/pub/systems.htm).
42. Systems Dynamics/Systems Thinking Mega-Link-List (at www.uni-klu.act.at/~gossimit/linklist.php).
43. Resource Links on Self-Organization, Complexity and Artificial Life (at www.calresco.org/links).
44. The Resilience Alliance (at www.resalliance.org).

45. The International Dimensions Programme on Global Environmental Change (at www.ihdp.org).
46. Theories for Sustainable Futures (at www.sustainablefutures.net).
47. Center for International Earth Science Information Network (at www.ciesin.columbia.edu).
48. Center for Sustainability and the Global Environment (at www.sage.aos.wisc.edu).
49. United Nations Commission on Sustainable Development (at www.un.org/esa/sustdev/).
50. Population Action (at www.populationaction.org)
51. Ecotrust (at www.conservationeconomy.net).
52. WorldChanging (at www.worldchanging.com).
53. Ecological Footprint (at www.ecofoot.net).
54. True Cost Economics (at www.truecosteconomics.org).
55. Bellinger Simulation and Modeling (at www.outsights.com/systems/welcome.htm).

Class Meetings and Assignments:

Class #1: Jan. 9 – Course Overview and Sustainable Development

Topics: Course Details; Trend Exercise; Learning Processes; Life Orientation Test; Course Topic Selection; Global System Pressures; Meanings of Sustainable Development; Systemic and Sustainable Thinking, Business Case for Sustainability (Modeling: Sustainable Development and Enterprise).

Read: [NOTE: can read after the first class]

1. [Key] Robert W. Kates, et.al., "What is Sustainable Development? Goals, Indicators, Values, and Practice," (2005) Environment: Science and Policy for Sustainable Development 47(3): 8-21 (download at http://sustainabilityscience.org/ists/docs/whatisSD_env_kates_0504.pdf).
2. [Key] Thomas N. Gladwin, et.al., "Shifting Paradigms for Sustainable Development: Implications for Management Theory and Research," Academy of Management Review (October 1995) CTools Site.
3. [Key] David Bent and Stephanie Draper, "Lucrative Business Strategies for a Sustainable Future," Forum for the Future (2007) CTools site.
4. [Key] UNEP, Global Environment Outlook/GEO4/Summary for Decision Makers (Oct.2007) CTools Site.
5. [Resource] Ecotrust, "What does a Sustainable Society Look Like?" (view the pattern map animation and explore the pattern index at www.conservationeconomy.net).
6. [Resource] Anthony A. Leiserowitz, et.al., "Sustainability Values, Attitudes, and Behaviors: A Review of Multinational and Global Trends," Annual Review of Environmental Resources (2006) CTools Site.
7. [Resource] WRI/UNEP/WBCSD, Tomorrow's Markets: Global Trends and Their Implications for Business (2002) (download at www.wbcsd.org).
8. [Resource] Robert W. Kates, et.al., "Sustainability Science," (2001) (download at http://sustainabilityscience.org/keydocs/fulltext/2000-33.pdf).

Class #2: Jan. 16 – Dynamic Complexity and Systems Thinking

Topics: Growing Dynamic, Social and Generative Complexity; Complex Adaptive Systems; Systems Thinking; System Dynamics Approach and History; Cognitive Barriers; Mental Models; Policy Resistance; Complexity Games; (Modeling: Systemic Thinking)

Read:

1. [Key] [JM] Chapter 1: "The Appeal and Power of Strategic Modelling" (note: skim for now as we will come back to this chapter in a few weeks).
2. [Key] Jianguo Liu, et.al., "Complexity of Coupled Human and Natural Systems," Science (Sept. 14, 2007) CTools Site.
3. [Key] Dana Meadows, "Dancing With Systems," Whole Earth (Winter 2001) (download at http://www.sustainer.org/tools_resources/papers.html).
4. [Key] John D. Sterman, "All Models are Wrong: Reflections on Becoming a Systems Scientist," System Dynamics Review, (Winter 2002) CTools Site.
5. [Key] David Snowden and Mary Boone, "A Leader's Framework for Decision Making," Harvard Business Review, (Nov. 2007) CTools site.
6. [Key] Barry Richmond, "Systems Thinking and the iThink Software," CTools Site
7. [Key] Thomas N. Gladwin, et.al., "Why is the Northern Elite Mind Biased Against Community, the Environment and a Sustainable Future?" (1997) CTools Site.
8. [Background Resource] Jay Forrester, "The Beginning of Systems Dynamics," in Chapter 1 of Morecroft Textbook CD.
9. [Resource] Henry Birdseye Weil, "Application of System Dynamics to Corporate Strategy: Evolution of Issues and Frameworks," System Dynamics Review (Summer/Fall 2007) CTools Site.
10. [Resource] Bela Banathy, "A Taste of Systemics: Why a Systems View?" (download at www.isss.org/taste.html).
11. [Resource] "Complexity Theory: Actions for a Better World," (download at www.calresco.org/action.htm

Class #3: Jan. 23– Causal Loop Mapping and Systemic Archetypes

Topics: Reinforcing vs. Counteracting Loops; Multiple Loops; Notation; Loop Polarity; Pinpointing Delays; Loop Dominance; Limitations of Causal Mapping; Generic Archetypes; Short Story Theories; Fixes That Fail; Limits to Success; Success to the Successful; Tragedy of the Commons; Escalation (Modeling: "The Commandments of Capitalism").

Read:

1. [Key] [JM] Chapter 2: "Introduction to Feedback Systems Thinking"
2. [Key] George Richardson, "Problems with Causal Loop Diagrams," (download at http://sysdyn.clexchange.org/road-maps/rm-toc.html
3. [Key] Alex de Sherbin, et.al., "Population and Environment," Annual Review of Environmental Resources (2007) CTools Site (basis of in-class exercise).

4. [Key] "System Archetypes" CTools Site.
5. [Resource] (Skim as an example of comprehensive looping) Robert E. Powell, "The Tangle of Growth: A Dynamic Analysis," (download summary at http://www.exponentialimprovement.com/cms/TangleofGrowth.shtml).

Class #4: Jan. 30 – Structure and Behavior of Dynamic Systems (and STELLA Tutorial 1)

Topics: Fundamentals of Dynamic Behavior; Stocks, Flows and Accumulations; Identifying and Mapping Stocks and Flows; Relationships Between Stocks and Flows; Graphical Integration and Differentiation; Behavior from Systemic Structure; Generic Activity Templates; Language of Systems Thinking; Operational Thinking with STELLA; (Modeling: Bath Tub Dynamics and Climate Change).

Read:
1. [Key] [JM] Chapter 3: "Modelling Dynamic Systems"
2. [Key] STELLA Software Tutorial (instructions to be provided)
3. [Resource] Linda Booth Sweeny and John Sterman, "Bathtub Dynamics: Initial Results of a Systems Thinking Inventory," System Dynamics Review (Winter 2000) CTools Site.
4. [Resource] John Sterman and Linda Booth Sweeney, "Cloudy Skies: Assessing Public Understanding of Global Warming," System Dynamics Review (Summer 2002) CTools Site.
5. [Resource] John Sterman and Linda Booth Sweeney, "Understanding Public Complacency About Climate Change: Adult's Mental Models of Climate Violate Conservation of Matter," Climatic Change (2007) CTools Site.

Class #5: Feb. 6– Cyclical Dynamics and Model Building (and STELLA Tutorial 2)

Topics: Topic Report Integration Exercise; Team Model Building Process; The STELLA "Writing Process;" Problem Articulation; Dynamic Hypotheses; Model Construction Process; Validation and Model Testing; Modeling for Learning; Information Smoothing; Stella Tutorial # 2 (Modeling: World of Showers and Commons Tragedies).

Read:
1. [Key] [JM] Chapter 5: "Cyclical Dynamics and the Process of Model Building"
2. [Key] [JM] Chapter 4: "World of Showers" (skim in preparation for classroom exercises).
3. [Key] Jorgen Randers. "Guidelines for Model Conceptualization" (1980) CTools Site.

Due: **"Global Change Topic Team Expert Report"** (results to be integrated in class)

Class #6: Feb. 13 – Simulation Experiments: Global Fisheries

Topics: Practicing with System Dynamics and Flight Simulators; Dana Meadows video on "Sustainable Systems;" Experimenting with Global Fisheries Model.

Read:

1. [Key] [JM] Chapter 9: "Public Sector Applications of Strategic Modelling" (note: pay special attention to the Fishery Dynamics section starting p.335…experimenting will be done in class.
2. [Key] [JM] Chapter 1: "The Appeal and Power of Strategic Modelling" (note: pay special attention to the "Puzzling Dynamics" section starting on p.7…experimenting will be done in class.
3. [Key] Play the "Fishing Game" for at least an hour to see if you can be a successful fisherperson while preserving the common fishing grounds for everyone. Simulation game at http://www.seed.slb.com/en/scictr/watch/climate_change/anim/toc/index.htm Carefully read instructions before starting the game.
4. [Resource] Sustainability Institute, "Commodity System Challenges: Moving Sustainability into Mainstream Natural Resource Economics," April 2003 (download at www.sustainer.org/resources).
5. [Resource] Arun Agrawal, "Sustainable Governance of Common-Pool Resources: Context, Methods and Politics," Annual Review of Anthropology (2003) CTools Site.
6. [Resource] Special Issue on "Tragedy of the Commons? Science Magazine, December 12, 2003 at www.sciencemag.org including: Donald Kennedy, "Sustainability and the Commons;" Andrew Sugden, et al. "Where Do We Go From Here;" Thomas Dietz, et al, "The Struggle to Govern the Commons;" Jules Pretty, "Social Capital and the Collective Management of Resources;" W. M. Adams, et al, "Managing Tragedies: Understanding Conflict over Common Pool Resources;" Mark W. Rosegrant, "Global Food Security: Challenges and Policies;" A. J. McMichael, et al, "New Visions for Addressing Sustainability;" C. G. Nicholas Mascie-Taylor and Enamul Karim, "The Burden of Chronic Disease;" K. Hasselmann et al, The Challenge of Long-Term Climate Change;" Robert T. Watson, "Climate Change: The Political Situation;" and Oliver Houck, "Tales from a Troubled Marriage: Science and Law in Environmental Policy.

NOTE: NO CLASS FEB 20: B-SCHOOL WINTER A EXAMS

NOTE: NO CLASS FEB 27: UNIVERSITY WINTER BREAK

Class #7: Mar 5—Topic Team Systems Modeling Reports

Topics: Business and Sustainability implications of Global Change Topic Team Modeling efforts; Class consultation on modeling challenges and techniques.

Due: **"Topic Team Modeling Report"** (instructions previously provided and results to be presented in class) [NOTE: Teams will be selected at random for classroom presentations]

Class #8: Mar. 12 – Dynamics of Growth, Overshoot and Collapse

Topics: Positive Feedback and Exponential Growth; Overshoot and Collapse; Nonlinear First-Order Systems; Modeling Multiple Loops, Video: Dennis Meadows, "Growth on a Finite Planet" (Modeling: Mayan Collapse and The Limits to Growth).

Read:

1. [Key] [JM] Chapter 6: "The Dynamics of Growth from Diffusion"
2. [Key] Donella Meadows, et.al., "A Synopsis of The Limits to Growth: The 30-Year Update," download at www.sustainer.org/pubs/limitstogrowth.pdf
3. [Key] Jorgen Randers, "From Limits to Growth to Sustainable Development," System Dynamics Review (Fall 2000) CTools Site.
4. [Key] Jared Diamond, "The Last Americans: Environmental Collapse and the End of Civilization," Harpers (June 2003) CTools Site.
5. [Key] Vernon L. Scarborough, "The Rise and Fall of the Ancient Maya: A Case Study in Political Ecology," (2007) CTools Site.
6. [Resource] Mathis Wackernagel, et al, "Tracking the Ecological Overshoot of the Human Economy," Proceedings of the National Academy of Sciences, July 9, 2002, (download at www.pnas.org/doi/10.1073/pnas.142033699)
7. [Resource] [JM] Chapter 7: "Managing Business Growth" [SKIM]

Class #9: Mar. 19 – Model Validation and Abrupt Nonlinear Change

Topics: Path Dependence and Positive Feedback; Tipping Points; Nonlinear Dynamics; Thresholds; Forced Vs. Coupled Dynamics; Surprise; Abrupt Change (Modeling: Climate Change Feedback Acceleration).

Read:

1. [Key] [JM] Chapter 10: "Model Validity, Mental Models and Learning."

2. [Key] Will Steffen, et.al., "Abrupt Changes: The Achilles' Heels of the Earth System," Environment (April 2004) CTools Site.
3. [Key] W. Steffen, et. al., "Executive Summary: Global Change and the Earth System-A Planet Under Pressure," (2004) CTools Site
4. [Key] Tim Lenton, "Tipping Points in the Earth System," download at http://researchpages.net/ESMG/people/tim-lenton/tipping-points/
5. [Key] Ervin Laszlo, "Paths to Planetary Civilization," (April 2006) Ctools Site.
6. [Resource] Peter Schwartz and Doug Randall, "An Abrupt Climate Change Scenario and its Implications for United States National Security," (Oct. 2003) download at www.gbn.com
7. [Resource] Jonathan Overpeck and Julia Cole, "Abrupt Changes in Earth's Climate System," Annual Review of Environmental Resources (2006) CTools Site.
8. [Resource] David Wasdell, et.al., "Planet Earth We Have a Problem: Feedback Dynamics & the Acceleration of Climate Change," download at www.apollo-gaia.org
9. [Resource] [JM] Chapter 8: "Industry Dynamics" [SKIM]

Class #10: Mar. 26 – Dyad Group Systems Modeling Report #1

Topics: Business and Sustainability Implications of Dyadic Integration of Global Challenges

Due: "**Dyadic Team Model Building Report #1"** (instructions previously provided; results to be presented in class)

Class #11: April 2– Designing Biomimetic and Resilient Systems

Topics: Biomimicry; Resilience; Robustness; Living Systems; Adaptive Capacity; Vulnerability; Nature Play (Modeling: Resilient Systems).

Read:

1. [Key] Joseph Fiskel, "Sustainability and Resilience" CTools Site.
2. [Key] Joseph Fiskel, "Designing Resilient, Sustainable Systems," (2003) CTools Site.
3. [Key] Janine Benyus: The Thought Leader" Strategy & Business (Autumn 2006) download at www.strategy-business.com/press/article/06310
4. [Key] Gilberto C. Gallopin, "Linkages Between Vulnerability, Resilience, and Adaptive Capacity," Global Environmental Change" (2006) CTools Site.
5. [Resource] Oran. R. Young, et.al., "The Globalization of Socio-Ecological Systems," Global Environmental Change (2006) CTools Site.
6. [Resource] Hartmut Bossell, Indicators for Sustainable Development: Theory, Method, Applications (1999) [a great set of principles regarding sustainable systems] (download at www.iisd.org/pdf/balatonreport.pdf).

7. [Resource] Donald R. Nelson, et. al., "Adaptation to Environmental Change: Contributions of a Resilience Framework," Annual Review of Environmental Resources (2007) CTools Site.
8. [Resource] Peter Senge, "Creating Desired Futures in a Global Society," Reflections (Fall 2003) CTools Site.
9. [Resource] Peter Senge, et. al., "Systems Thinking Primer for Natural Capitalism: The Four Basic Shifts download at www.sustainer.org/tools_resources/papers .

Class #12: April 9- Transforming Whole Systems for Sustainability

Topics: Whole System Transformation; Discovering Leverage Points; Multiple Scenario Analysis; Force Field Appraisal of Barriers and Accelerators of the Transition to Sustainability; Video: Dana Meadows: Envisioning a Sustainable Future (Modeling: Global System Intervention and the Future of China).

Read:

1. [Key] Dana Meadows, "Leverage Points: Places to Intervene in a System," (1999) download at http://www.sustainer.org/tools_resources/papers .
2. [Key] Dana Meadows, "Envisioning a Sustainable World," download at www.sustainer.org/tools_resources/papers .
3. [Key] Thomas M. Parris and Robert W. Kates, "Characterizing a Sustainability Transition: Goals, Targets, Trends and Driving Forces," (July 2003) download at www.pnas.org/cqi/doi/10.1073/pnas.1231336100 .
4. [Key] Peter Senge, et.al., "Awakening Faith in an Alternative Future," Reflections (Vol. 5/No.7) CTools Site.
5. [Key] Gladwin, "China Facts and Trends," read in preparation for classroom simulation, CTools Site.
6. [Key] "Future of China Resource Pack," CTools Site.
7. [Resource] Adam Kahane and Zaid Hassan, "The U-Process: A Social Technology for Addressing Highly Complex Challenges," download at www.generonconsulting.com/publications/papers/pdfs/U-Process_Social_Technology.pdf .
8. [Resource] Paul Raskin, et.al., Great Transitions: The Promise and Lure of the Times Ahead, download at www.gtinitiative.org/documents/Great_Transitions.pdf .

Class #13: April 16- Dyad Group Systems Modeling Reports (during Final Exams)

Topics: Business and Sustainability Implications of Dyadic Integration of Global Challenges

Due: "**Dyad Team Model Building Report #2**" (results to be presented in class).