Systems Thinking for Sustainable Development and Enterprise

Syllabus

Course Number: NRE550; Strategy 566
Term: Winter 2016
Course Time: Thursdays, 6:00-9:00 pm
Location: 1024 Dana

Instructor: Prof. Jeremiah Johnson
Asst. Professor, School of Natural Resources & Environment
jxjohns@umich.edu

Instructor Office Hours: Wednesdays 2:00-3:00pm and Fridays 11:00am-12:00pm, Dana 3508

Graduate Student Instructor: John Serron
jserron@umich.edu

GSI Office Hours: Wednesdays 5:00-7:00pm, location to be determined

Course Objectives:
(1) Students will develop critical skills in global systems thinking, with global defined as relating to the entire world, as well as embracing all considerations of complex systems.

(2) Students will develop skills in system dynamics modeling using STELLA software.

(3) Students will develop awareness in issues related to global environmental and social change.

(4) Students will build an understanding of sustainable human development and enterprise.

Enrollment Qualifications
Graduate students are eligible for this course, with enrollment preference given to SNRE and Ross students. There are no pre-requisites for this course.

Course Materials
1. John Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World (Irwin Mcgraw-Hill, 2000). Note: This text is very expensive if you buy it new. Shapiro Library has reserved five hard copies of this text. You will not need the associated CD that comes with the text, so if you wish to own the text, I recommend buying it used if possible.


3. STELLA Version 10.1.1/Student, $59 for six month license; $129 for perpetual license (details on purchasing process to be discussed in class)
Grading

- Class Participation 5%
- Individual Causal Loop Mapping Assignment 10%
- Individual Systemic Archetype Assignment 10%
- Individual STELLA Assignment 10%
- Global Change Team Expert Report 20%
- Global Change Team Modeling Report 25%
- Final Exam (take home, open book) 20%

Class Policies

- Course materials will be made available on Canvas.
- For assignments, you may discuss problems and solution approaches with your peers, but work should be individual. If you choose to discuss assignments with your peers, list their names on the submission.
- Assignments and reports are due at the beginning of class (6:10 pm). Late assignments will be accepted up to 48 hours past this deadline at a penalty of 20%. Assignments will not be accepted more than 48 hours after they are due.
- All references must be appropriately cited.
- Challenges to grades must occur within one week of the return of the assignment. Challenges must be in writing and will result in a complete regrading of the assignment (i.e., scores may increase or decrease).
- Attendance is expected. If you have the need to miss a class, contact me and the GSI prior to the class.
- If you need accommodation for any disability that affects your performance in this class, please contact me as soon as possible.
- Electronic devices should not be used in class with the exception of laptops for note taking and modeling.
- Email policy: Questions about assignments should be directed to John Serron at jserron@umich.edu with [NRE 550/STRAT566] in the subject line. Questions and associated answers may be shared with the entire class.

Communities Values Statement

Personal integrity and professionalism are fundamental values of our University community. The Ross Academic Honor Code (www.bus.umich.edu/Academics/Resources/communityvalues.htm) provides comprehensive information on how to avoid academic misconduct and how be sure that you have not plagiarized the work of others. This course will be conducted in strict conformity with this Academic Honor Code. Claimed ignorance of the Code and related information appearing on the site will be viewed as irrelevant should a violation take place.

Version: January 10, 2016
## Course Outline

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Readings</th>
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| [1] 1/14 | Introduction to Systems Thinking | *Course details*  
*Global system pressures*  
*Meanings of sustainable development*  
*Systems thinking*  
*Business case for sustainability*  
*In-class: Beer production-distribution game* |  
*Nidulomlu et al “Why sustainability is now the key driver of innovation” 2009.*  
*Lubin and Esty “The Sustainability Imperative” 2010.* |

**Learning objectives:** Introduction to systems thinking and sustainable development; “structure produces behavior”

| 2/21 | Learning in and about Complex Systems |  
*Dynamic complexity*  
*Feedback*  
*Cognitive barriers*  
*Mental models*  
*Policy resistance*  
*Leadership and complexity*  
*Project matching* |  
*Sterman, Ch 1*  
*Meadows, Introduction*  
*Meadows, Ch 1*  
*Sargut, McGrath “Learning to live with complexity” 2011* |

**Learning objectives:** Understand the need for systems thinking, the role of feedback, and requirements for successful learning in complex systems

| 3/28 | Causal Loop Mapping |  
*Reinforcing and balancing loops*  
*Notation and polarity*  
*Delays*  
*Loop dominance*  
*In-class: Garbage in NYC; Borneo* |  
*Sterman, Ch 5* |

**Learning objective:** Develop diagramming skills to capture the structure of systems

**Due 1/28: Individual Causal Loop Mapping Assignment (Fukushima)**

| 4/2/4 | Structure and Behavior of Dynamic Systems |  
*Exponential growth*  
*Goal seeking*  
*Oscillation*  
*S-shaped growth*  
*Overshoot and collapse*  
*“Systems zoo”*  
*In-class: Tragedy of the Commons* |  
*Sterman, Ch 2*  
*Sterman, Ch 4*  
*Meadows, Ch 2* |

**Learning objectives:** Build an understanding of the relationship between system structure and behavior; identify modes of behavior in dynamic systems; review representative system types
<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Readings</th>
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<tbody>
<tr>
<td>5/21</td>
<td>Stocks and Flows; Systemic Archetypes</td>
<td>• Sterman, Ch 6</td>
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<td></td>
<td>• Stocks, flows, and accumulation</td>
<td>• Sterman, Ch 7</td>
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<td>• Mapping stocks and flows</td>
<td>• Meadows, Ch 5</td>
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<td>• Dynamics of stocks and flows</td>
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<td>• System traps</td>
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<td><em>In-class: Success to the Successful; the Flu</em></td>
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**Learning objectives:** Introducing concept of stocks and flows in systems; modeling behavior and relationship between stocks and flows; understand system structures that produce problematic behavior (archetypes)

Due 2/11: Archetype Assignment

<table>
<thead>
<tr>
<th>Session</th>
<th>Modeling and Simulation Process</th>
<th>Readings</th>
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<tbody>
<tr>
<td>6/2/18</td>
<td>• Problem articulation</td>
<td>• Sterman, Ch 3</td>
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<td>• Dynamic hypothesis</td>
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<td>• Simulation model</td>
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<td>• Testing</td>
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<td>• Policy design and evaluation</td>
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<td><em>In-class: Fishery dynamics; Flight simulators</em></td>
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**Learning objectives:** Recognize the purpose of modeling, the process of system dynamics modeling, the role of the client, and the modeler’s responsibilities

<table>
<thead>
<tr>
<th>Session</th>
<th>Dynamics of Growth, Overshoot, and Collapse</th>
<th>Readings</th>
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<tbody>
<tr>
<td>7/2/25</td>
<td>• Linking feedback to stocks and flows</td>
<td>• Sterman, Ch 8</td>
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<td>• Non-linear first order systems</td>
<td>• Sterman, Ch 9</td>
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<td>• Phase plots</td>
<td>• Meadows, “A Synopsis of the Limits to Growth: The 30-Year Update”</td>
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<td>• S-shaped growth</td>
<td>• Randers, “From Limits to Growth to Sustainable Development” 2000.</td>
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<td>• Tipping point</td>
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<td><em>In-class: Mayan collapse; Global economy</em></td>
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**Learning objectives:** Impacts of nonlinearities; understanding how S-shaped growth models apply to models for innovation, infectious disease, and markets for new products.

Due 2/25: Individual STELLA Assignment

<table>
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<tr>
<th>Session</th>
<th>Dynamics in Complex Systems: Path Dependence and Delays</th>
<th>Readings</th>
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<tr>
<td>8/3/10</td>
<td>• Path dependence and positive feedback</td>
<td>• Sterman, Ch 10</td>
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<td>• Lock-in and standards formation</td>
<td>• Sterman, Ch 11</td>
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<td>• Material delays</td>
<td>• Meadows, Ch 4</td>
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<td>• Information delays</td>
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**Learning objectives:** Identify system characteristics that lead to path dependence and lock-in; understand the structure and behavior of delays.
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<th>Readings</th>
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| [9] 3/17 | Coflows, Aging Chains, and Decision Making | • Structure and impact of aging chains  
• Modeling attributes of a stock  
• Principles for modeling decision making  
*In-class: Urban dynamics* | • Sterman, Ch 12  
• Sterman, Ch 13 |

**Learning objectives:** Understanding the role of stock and flow attributes (such as age of items) on system behavior

**Due 3/17:** Global Change Team Expert Report

| [10] 3/24 | Modeling Nonlinearity and Instability | • Formulation of nonlinear relationships  
• Shapes and values for nonlinear functions  
• Instability in supply chains  
• Planetary boundaries  
*In-class: Climate change feedback acceleration* | • Sterman, Ch 14  
• Sterman, Ch 17  

**Learning objectives:** Methods to estimate nonlinear functions; understanding stock management in supply chains and the origin of oscillations; risks of exceeding planetary boundaries

| [12] 4/7 | Designing and Managing Resilient Systems | • Resilience  
• Self-organization  
• Hierarchy  
• Robustness  
• Adaptive capacity | • Meadows, Ch 3  
• Sterman, Ch 21  

**Learning objectives:** Identify characteristics of highly functional systems; learn principles of model validation and testing

| [13] 4/14 | Transforming Whole Systems for Sustainability | • Leverage points in a system  
“Systems wisdoms”  
*In-class: The Future of China* | • Meadows, Ch 6  
• Meadows, Ch 7  
• Harich “Change Resistance as the Crux of the Environmental Sustainability Problem” 2010. |

**Learning objectives:** Identify places to intervene in a system and recognize counterintuitive leverage points; reflect on systems wisdoms

**Due 4/14:** Global Change Team Modeling Report

| 4/21 | Final Exam (take home, open book; details to follow) |  |