DEPARTMENT OF CITY AND REGIONAL PLANNING

University of North Carolina at Chapel Hill

PLAN 722: Systems Thinking and Modeling for Planners

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11:15 – 12:30 MW (New East 102)
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Course description and approach

Why do so many planning and policy interventions fail? Why do many others fail to produce lasting results or even backfire and make problems worse? Why do some cities flourish while others stagnate and suffer from periodic crises? Tomorrow's cities and regions will require us to manage complexity on a scale never before encountered. Modern urban landscapes are filled with systems where many interacting parts, multiple feedback effects, long time delays, and nonlinear responses to our decisions create unanticipated and non-intuitive behavior. Learning how to act, plan, or govern in these environments is difficult precisely because we rarely see the full consequences of our most important decisions. In order to improve our communities, we need tools for seeing through the complexity; we need systems thinking, one of the most sought after skills in the management, policy, and planning professions today.

In this course, you will learn how to frame problems and understand systems in terms of interconnected networks of cause and effect. Together, we will explore why policy and planning interventions work, fail, or completely backfire. We will examine why there is no such thing as a side-effect, and why systems often behave in unexpected and non-intuitive ways. You will learn how to forecast these behaviors and analyze their implications for important planning problems, such as energy and natural resource use, community equity, traffic congestion, and economic growth and competitiveness. You will come away from this course with the conceptual and analytical tools to represent complex problems in simple, yet holistic ways, while seeing the big picture in everything you do.

This course will introduce systems thinking and system dynamics computer simulation modeling:

> System dynamics is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems — any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality. The span of applications has grown from corporate and industrial problems to include the management of research and development, urban stagnation and decay, commodity cycles, and the dynamics of growth in a finite world. System dynamics is now applied in economics, public policy, environmental studies, defense, theory-building in social science, and other areas, as well as its home field of management. [Adapted from the *System Dynamics Society*]

The broader goal of this course is to enhance your knowledge and skills in understanding and analyzing the complex feedback dynamics found in nearly all social, economic, and environmental problems. We will also spend substantial time studying how policy interventions affect the behavior and structure of systems. These topics will serve as important background for students' future courses in planning.

Course objectives and prerequisites

The systems thinking and modeling methods taught in the class will provide one of the key lenses with which you can view and analyze planning problems and evaluate solutions. You will learn about techniques that can help you make decisions in complex planning situations, where you can use powerful methods to develop insights, understand key relationships and predict outcomes. We will emphasize the application and interpretation of modeling concepts and output rather than mathematical theory.

In this course, you will develop knowledge and skills to visualize and analyze the complex feedbacks and structures that create dynamics and regulate performance in social, economic, and environmental systems. In doing so, you will learn how to 1) apply systems thinking to structure planning issues in rigorous feedback and causal terms, 2) create models capable of reproducing the dynamic problem of concern, 3) frame concepts in a system of interest as interconnected loops of information feedback and circular causality, and 4) suggest policy recommendations based on model-based understandings and insights.

You will also learn how to quantify causal relationships in dynamic systems. Through the homework, you will learn to identify independent stocks or accumulations (levels) in systems and their inflows and outflows (rates). You will then use simulation models to explore systems as analogies, learn system dynamics software for computer simulation and gaming (i.e., VENSIM), and you will gain expertise in developing and testing computer simulation models in diverse settings.

There are no pre-requisites for this course other than college-level algebra and computer literacy.

What is this syllabus?

This document is many things: 1) it is a planning document, so you can plan your time commitment for reading and assignments; 2) it is a roadmap through the class that aims to give you bearings for each class; 3) it is also a contract of sorts, telling you the level of effort that I intend to put into course as a teacher semester, as well as the level of effort that I expect from you as a student.

How can you do well in this class?

To do well in this course, I expect you to spend significant time and effort: 1) on the semester-long planning project, and 2) working through the reading material in advance of class. I also expect you to 3) attend class and participate (as defined below).

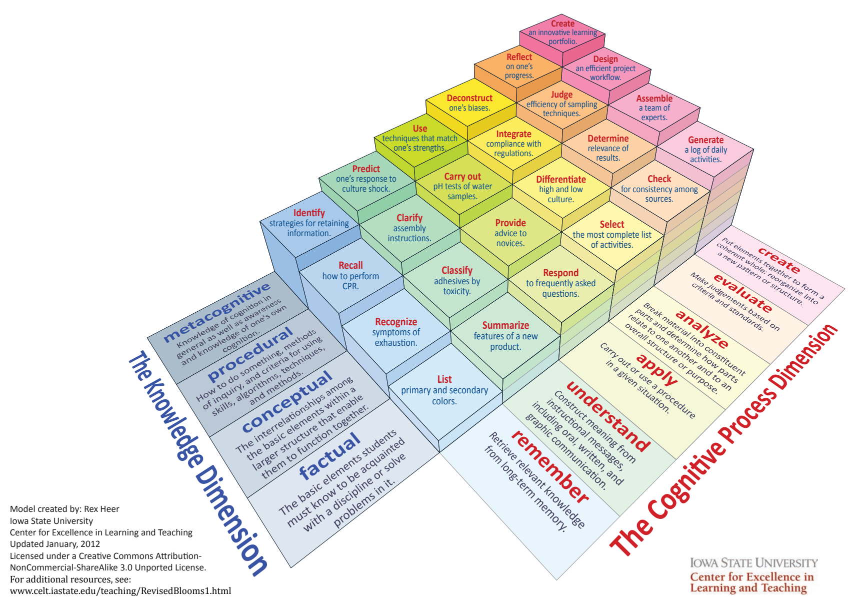
Time Commitment: In this course, you should expect to spend at least 3 hours outside of class for each hour you spend in class. <u>This amounts to at least 7-8 hours per week outside of class.</u>

What is participation? Participation means that you are actively listening and engaging in classroom discussions, as well as engaging the class with your own questions, whether you bring them in class or through the question website that I have created for PLAN 722: http://plan722.web.unc.edu/. <u>Please</u> contact the instructor or TA if you have any questions, problems with the readings or the course, or any other issues that you wish to discuss. Students in this class are encouraged to speak up and participate during class meetings. Because the class will represent a diversity of individual beliefs, backgrounds, and experiences, every member of this class needs to show respect for every other member.

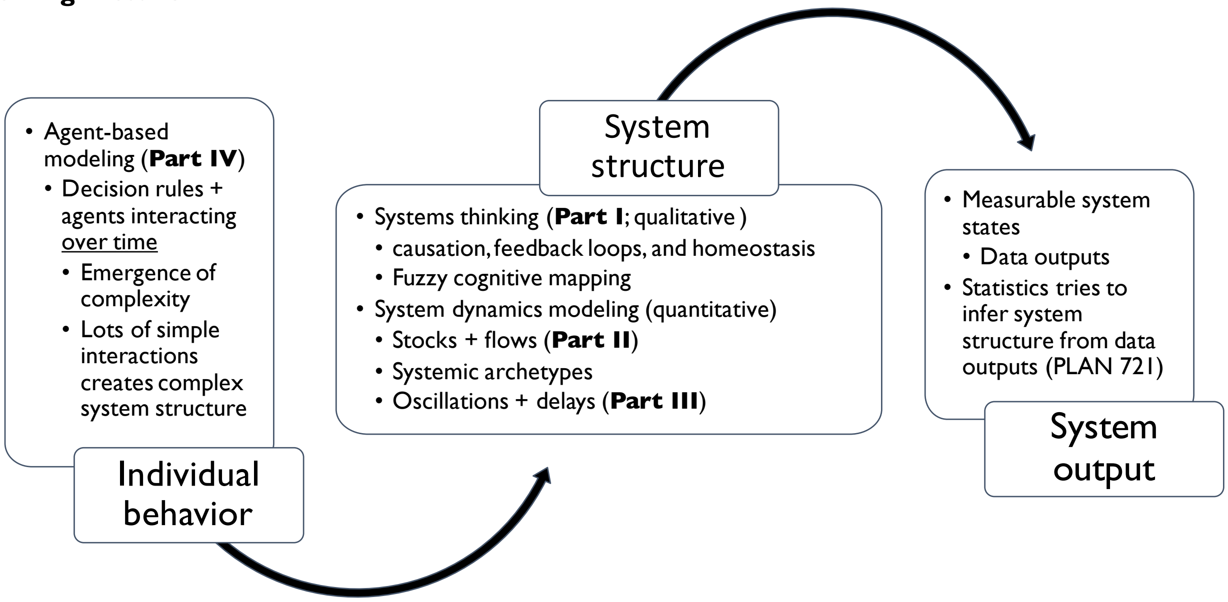
There is a lot of reading. How do I get through it all? The most important thing to do is planning your time. Some tips:

- If you don't have one, <u>get a calendar</u>! Put all due dates and special class activities on your calendar. Probably the easiest and most flexible is Google Calendar, but you may prefer others. You can embed other calendars into your own, such as the UNC City and Regional Planning's, which lists all department events and important academic dates: *https://calendar.google.com/calendar/ical/dcrp%40unc.edu/public/basic.ics.*
- There are lots of resources for time management available, here are a couple:
  http://www.time-management-guide.com
  https://students.dartmouth.edu/academic-skills/learning-resources/time-management
- Everyone reads articles differently, <u>you need to figure out how you can effectively read a large volume of material and come away with the main ideas and key points</u>. *"Some books should be tasted, some devoured, but only a few should be chewed and digested thoroughly." – Sir Francis Bacon*. Skimming is your friend and an important strategy to keep up with the readings, but when you see important points, slow down and digest thoroughly.
- Write down questions as you read! If you are having trouble understanding something from the readings or from class, you can submit your questions: http://plan722.web.unc.edu/. <u>Asking questions is an important part of participating</u> in your own learning process.

Lots of classes discuss modeling, but don't make us actually build models. Why are we learning to build models? Bloom's Taxonomy considers educational learning based on different levels of complexity and specificity. Our goal is to climb this "mountain," where the peak means creating new knowledge and synthesizing the plethora of ideas that you have learned in this course. <u>Creation of new knowledge is the goal.</u>



Semester Big Picture



We will maintain a course website that will contain course information, course readings, handouts, data and links to relevant websites. This website can be found at: http://sakai.unc.edu/.

Course Requirements and Grading

The requirements for this course include:

Active class participation and attendance	20 %
Pre-Class Quizzes (4)	20 %
Assignments (4)	60 %
Total	100%

Assignments (due at beginning of class on the due date) will include exercises that familiarize you with the systems thinking and modeling concepts that we discuss in class. You are expected to complete all assignments individually. Discussions with classmates about assignments are encouraged, *but all final work must be entirely your own.* You are expected to show all work on your assignments. Please submit both electronic (via Sakai's Assignments feature) and hard copies of assignments as grading will be done on paper copies.

Quizzes (15 minutes) must be completed individually and submitted prior to the beginning of class via Sakai's Assignments feature. They will consist of several short answer and multiple choice questions on your knowledge of both the readings and the previous lectures. *Quizzes will become available on Sakai the day before they are due and the Dropbox (where you will turn them in) will close at the beginning of class when they are due.* Two computer lab sessions will be offered during the semester to help familiarize students with the software packages that will be used in the class.

Grading Notes: Generally, an **H** grade is given for exceptional work that demonstrates a real mastery of course material. **L** or **F** work substantially fails to meet minimum requirements either due to incomplete coverage of required information, incorrect results, or sloppy, unprofessional reporting of results.

Summary of due dates and labs

Assignments			**Labs**			**Quizzes**		
HW	Due Date	Topic	Lab	Date	Topic	Quiz	Date	Topic
1	Sept 17	Feedback in modeling	1	Sept 17	Dynamic Modeling I. *Reading: Ford Textbook, Ch. 2*	1	Sept 12	Feedback
2	Sept 26	Building blocks: stocks, flows, and archetypes	2	Sept 26	Dynamic Modeling II. *Reading: Ford Textbook, Ch. 14*	2	Sept 19	Stocks and flows
3	Oct 10	Cyclical behavior				3	Oct 1	Equilibrium and Dynamic archetypes
4	Oct 22	Advanced modeling				4	Oct 8	Oscillations

Other Academic Business

Policy on Late or Incomplete Work: As a matter of departmental policy, and in order to be fair to your fellow students (particularly in light of the extensive time requirements of this course), **late assignments will not ordinarily be accepted**.

- **No extensions will be given.**
- **Zero points will be assigned to work not turned in on time.**

IF YOU HAVE A MEDICAL EMERGENCY, PLEASE INFORM THE INSTRUCTOR AS SOON AS POSSIBLE. Grades of incomplete may be given in the event of a medical or another emergency. In these cases, a written application for an incomplete on any assignment must state the reasons for the request and propose a new deadline.

Resources: Our purpose as professors is to help you to excel in this learning environment. Should you need further assistance beyond the help of the professor, please consult the following on-campus resources:

- The Writing Center: http://writingcenter.unc.edu
- The Learning Center: http://learningcenter.unc.edu
- The Learning Center resources for students with learning disabilities (LD) and/or attention-deficit/hyperactivity disorder (ADHD): http://learningcenter.unc.edu/ldadhd-services
- The Center for Student Success and Academic Counseling: http://cssac.unc.edu
- Counseling and Wellness Services: http://campushealth.unc.edu

The University's Honor Code is in effect. The University of North Carolina at Chapel Hill has had a student-administered honor systems and judicial system for over 100 years. The Honor Code represents UNC-Chapel Hill students' commitment to maintain an environment in which all students respect one another and are able to attain their educational goals. As a student at Carolina, you are entering a community in which integrity matters – integrity in the work you submit, and integrity in the manner in which you treat your fellow Carolina community members. Because academic honesty and trustworthiness are important to professional planning, this is a significant University and Departmental tradition. Your attention is called to the Instrument of Student Judicial Governance for policies and procedures pertaining to the honor system. We are committed to treating Honor Code violations seriously and urge all students to become familiar with its terms set out at https://studentconduct.unc.edu/. If you have questions it is your responsibility to ask the professor about the Code's application. Please consult with the instructor if you are uncertain about your responsibilities under that code with respect to this course.

The University of North Carolina – Chapel Hill facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, chronic medical conditions, a temporary disability or pregnancy complications resulting in difficulties with accessing learning opportunities. All accommodations are coordinated through the Accessibility Resources and Service Office. Any student who feels s/he may need an accommodation based on the impact of a disability should contact me privately early in the semester to discuss your specific needs. Students with documented disabilities should contact the Department of Disability Services at 919-962-8300 (SASB North, Suite 2126; https://accessibility.unc.edu) to coordinate reasonable accommodations.

Required course materials

1. Andrew Ford. 2009. *Modeling the Environment: An Introduction to System Dynamics Modeling of Environmental Systems (2nd Edition)*. Washington, D.C.: Island Press.
2. **On Sakai:** Donella H. Meadows. 2008. *Thinking in Systems: A Primer*. Chelsea Green: White River Junction, Vermont.
3. Scientific/graphing calculator capable of logarithmic calculations (e.g. built-in calculator in Android and iOS smartphones).

Software and Data

STELLA – system dynamics modeling software used to graphically represent complex feedback systems. The STELLA software is available on the UNC Virtual Computing Lab ('VCL'). We will be posting information on Sakai about accessing the VCL during the first week of class.

Vensim PLE (Personal Learning Edition; http://www.vensim.com/) is another sophisticated dynamic modeling package that is freely available online. It is not compatible with STELLA and has a sharper learning curve, but it can perform all of the same (and many additional) functions.

Course Outline

PLEASE READ THE ASSIGNED MATERIAL BEFORE EACH CLASS
PLEASE BRING CALCULATORS, ARRIVE ON TIME, AND TURN OFF CELL PHONES IN CLASS

The professor reserves to right to make changes to the syllabus, including project due dates, when unforeseen circumstances occur. These changes will be announced as early as possible so that students can adjust their schedules.

A special effort has been made to select relevant, timely and well-written readings. The source and style of each reading varies considerably. All course readings and assignment details are on Sakai and should be completed before the class for which they are listed.

Part I: Introduction to feedback

Aug. 22. Introduction to systems thinking and modeling

Textbook: Meadows, Introduction (The Systems Lens)
Kauffman, Draper. 1980. *Systems One: An Introduction to Systems Thinking*. Chapter 1 (What is a System?)

Additional Reading:

Sterman, J. D. (1991). A Skeptic's Guide to Computer Models. In Barney, G. O. et al. (eds.), Managing a Nation: The Microcomputer Software Catalog. Boulder, CO: Westview Press, 209 - 229.

Aug. 27-Sept 3. No class

Batty, Michael. 2001. Models in planning: Technological imperatives and changing roles. *International Journal of Applied Earth Observation and Geoinformation*, 3(3): 252-266.
Dörner, Dietrich. *The Logic of Failure: Why Things Go Wrong and What We Can Do to Make Them Right*. New York, NY: Metropolitan Books, Introduction and Chapter 1 (Some Examples), Pgs. 1-35.

Additional Reading:

Dörner, Dietrich. *The Logic of Failure: Why Things Go Wrong and What We Can Do to Make Them Right*. New York, NY: Metropolitan Books, Chapter 6 (Plannning), Pgs. 153-184.

Sept. 5. Introduction to feedback

Kauffman, Draper. 1980. *Systems One: An Introduction to Systems Thinking*. (Chapter 3: Things in Common)
Textbook: *Ford*, Chapter 9 (Information Feedback and Causal Loop Diagrams).
Textbook: Meadows, Chapter 3 (Why Systems Work So Well) and Chapter 4 (Why Systems Surprise Us)

Additional Reading:

Sterman, J. D. Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, MA: Irwin McGraw-Hill. Chapter 5 (Causal Loop Diagrams. Pgs. 137-190).
Textbook: *Ford*, Chapter 5 (Case #1. Water Flows in the Mono Basin).

Sept. 10. Feedback loops and homeostasis

Kauffman, Draper. 1980. *Systems One: An Introduction to Systems Thinking*. (Chapter 4: Change and Growth and Chapter 5: Putting the Pieces Together)
Textbook: Meadows, Chapter 6 (Leverage Points—Places to Intervene in a System)
Textbook: Ford, Chapter 10 (Homeostasis).

Part II: Building blocks of systems: stocks and flows

Sept. 12: Introduction to stocks and flows

Textbook: Meadows, Chapter 1 (The Basics)
Textbook: Ford, Chapter 3 and 4 (Stocks and Flows: The Building Blocks of System Dynamics Models; Accumulating the Flows).

Sept. 17: Lab 1 – Introduction to Vensim

Sept. 19. Dynamic equilibrium and system archetypes

Kauffman, Draper. 1980. *Systems One: An Introduction to Systems Thinking*. Chapter 2: Stability

Textbook: Ford, Chapter 6 and 7 (Equilibrium Diagrams and S-Shaped Growth).

Textbook: Meadows, Chapter 2 (A Brief Visit to the Systems Zoo)

Part III: Advanced structures and policy applications to urban dynamics

Sept. 24. Minimum structures and policy applications

Textbook: Meadows, Chapter 5 (System Traps…and Opportunities)

Navid Ghaffarzadegan, John Lyneis, and George P. Richardson. 2011. How small system dynamics models can help the public policy process. *System Dynamics Review* 27(1): 22–44

Textbook: Ford, Chapter 13: The Modeling Process and Chapter 16: Managing a Feebate Program for Cleaner Vehicles

Sept. 26. Lab 2 – Exploring policy models in Vensim

Oct. 1. Introduction to cyclical behavior

Textbook: Ford, Chapter 18: Introduction to Cyclical Behavior and Chapter 19: Cycles in Real-Estate Construction

Oct. 3. *Triangle Light Rail SD Model*

J. Kolling, L. Cox, N. Flanders, A. Procter, N. Tanners, A. Bassi, R. Araujo. 2015. Executive Summary: A System Dynamics Model for Integrated Decision Making: The Durham-Orange Light Rail Project. Environmental Protection Agency: Durham, NC.

Additional Reading:

Harich, Jack. 2010. Change Resistance as the Crux of the Environmental Sustainability Problem. *System Dynamics Review* 26 (1): 35–72.

Elsawah, Sondoss, Suzanne A. Pierce, Serena H. Hamilton, Hedwig van Delden, Dagmar Haase, Amgad Elmahdi, and Anthony J. Jakeman. 2017. An Overview of the System Dynamics Process for Integrated Modelling of Socio-Ecological Systems: Lessons on Good Modelling Practice from Five Case Studies. *Environmental Modelling & Software* 93: 127–45.

Collins, John F. 1974. Chapter 1: Managing Our Cities – Can We Do Better? In: *Readings in Urban Dynamics: Volume 1*. Edited by Nathaniel Mass. Cambridge, MA: MIT Press. Pgs 3-11.

Schroeder III, Walter W. Chapter 3: Urban Management Actions. In: *Readings in Urban Dynamics: Volume 2*. Edited by Walter W. Schroeder III, Robert E. Sweeney, and Louis Edward Alfeld. Cambridge, MA: MIT Press. Pgs. 31-48

Textbook: Ford, Chapter 23: CO_2 in the Atmosphere

Part IV: Agent-based (individual level) modeling

Oct. 8, 10: Agent-based modeling

Textbook: Meadows, Chapter 7 (Living in a World of Systems)

Kauffman, Draper. 1980. *Systems One: An Introduction to Systems Thinking*. Chapter 6: Complex Systems

Zellner, Moira. L. 2008. Embracing Complexity and Uncertainty: The Potential of Agent-Based Modeling for Environmental Planning and Policy. *Planning Theory & Practice*, 9(4): 437–457.

BenDor, Todd. Chapter 6: Agent Based Modeling (Chapter 6). *Agent-Based Modeling of Environmental Conflict and Cooperation*. Book Manuscript.

Oct. 22: ***Final assignment due at 5 pm via Sakai Assignments.***