

Course B2: Model-based analysis and policy design (GEO-SD 303) (10 ECTS) Prof. Erling Moxnes

1. Course Description

Introduction to System Dynamics analysis of non-linear, dynamic systems with emphasis on the relationship between system structure and behaviour, and on policy design and implementation. Level: graduate; 10 ECTS points. The course is conducted entirely in English.

2. Learning Outcomes

Knowledge and understanding

Students gain extended knowledge about the System Dynamics method with particular emphasis on model based problem identification and analysis as well as hypothesis formulation and analysis in policy design. They also get to know about the intimate relationship that exists between structure and behaviour (dynamics) in non-linear systems and the shifts in causal loop governance that may take place in such systems. They obtain knowledge about the significance of a robust strategy development, the associated policy design and the resulting decision making (i.e management). The students will know of the basic concepts of systems dynamics theory, methods, techniques and tools.

Applying knowledge and understanding

Students will apply their knowledge in a series of comprehensive case studies that will be presented in class. Students are challenged to investigate the turbulent dynamics arising from an underlying, non-linear structure by way of computer based modelling and simulation. Particular emphasis will be placed on their recognition of dynamic patterns of problem behaviour and the corresponding underlying structures, as well as their ability to propose and evaluate policies to address such problems. Students are trained to distil the essence of their insights and present it in the form of compact causal loop diagrams.

Making judgements

Students learn to make judgements about both how well a model structure contributes to the explanation of an observed or hypothesised dynamic behaviour.

Communication

Students are encouraged to and do participate actively in class. The students will be trained both in writing and in oral presentations to explain the relationship between structure and dynamic behaviour in non-linear systems.

Learning skills

The course is putting the student on the track of becoming a skilled modeller, a problem identifier and a policy designer. It equips the student with the basic skills and tools to progress in the investigation of systems in ever more complex domains and familiarise the student with relevant scientific literature in the field.

3. Course Content

- Introduction to complex, dynamic structures and their associated dynamic behaviour.
- Principles of simulation (of discrete and continuous systems)
- Modelling non-linearity, accumulation and delays
- Modelling the formation of expectations
- Knowledge distillation and presentation
- System dynamics analysis, policy design and the concept of robustness
- Link and loop gains and endogenous shifts in structural governance
- Model analogies and transparency
- Case 1: Mr. Wang repair shop (capacity constraints as origin of oscillations)
- Case 2: The Beer Game (misperceptions along a supply chain as origin of oscillations)
- Case 3: The Tragedy of the Commons (population) Model
- Case 4: The Urban Dynamics Model
- Case 5: The Market Growth Model
- Case 6: The Commodity Market model
- Case 7: The Petroleum Life Cycle Model
- Case 8: The World Dynamics Model
- Case 9: The Romeo and Juliet Model
- Case 10: The Disease Diffusion Model
- Case 11: The Predator Prey (Lotka – Volterra) Model
- Case 12: The Human Resource Model
- Case 13: The Workers Burnout Model
- Case 14: The Technology model

4. Course Design

The course is comprised of lectures on introductory material and case studies, and of classroom modelling and simulation activities both by lecturer and teaching assistant and is completed by a four hour written exam.

5. Students' evaluation

Assessment is carried out by means of evaluation of individual assignment/s and an exam. To sit for the exam, the student must have pass marks on all the assignments. An ECTS grade is provided to the student at the end of the course according to the A–F scale. Students not successfully fulfilling all the course requirements within the regular time frame have the option of a re-sit once the following semester.

6. Course Admission Requirements

The course requires a Bachelor's degree in any subject. The course is open to students enrolled in the Erasmus Mundus master program and to graduate and undergraduate students at the University of Bergen.

7. Literature

Basic reading list (more specific references will be provided in the introductory session):

- Andersen, D.F. (1980). How Differences In Analytic Paradigms Can Lead To Differences In Policy Conclusions. In J. Randers (ed.), *Elements of the System Dynamics Method*. (pp 23-57). Cambridge MA: MIT Press.
- Goodman, Michael R. (1989). *Study Notes in System Dynamics*. Pegasus Communications (original version published by MIT Press, 1989). Chapter 1 – 4, Exercise 4 – 12.
- Davidsen, P.I. (1992). The Structure-Behavior Graph. Understanding the relationship between structure and behavior in complex, dynamic systems. in *Proceedings of the 10th System Dynamics Conference*, Utrecht, 1992, System Dynamics Society, Albany, N.Y..
- Davidsen, P.I., Sterman, J. D., Richardson, G.P. (1990). A Petroleum Life Cycle Model for the United States with Endogenous Technology, Exploration, Recovery, and Demand, *System Dynamics Review*, 6,1 (Winter 1990), pp. 66 – 93, J. Wiley & Sons.
- Forrester, J.W. (1956). *Dynamic Models of Economic Systems and Industrial Organizations*. Note to the Faculty Research Seminar, D-0000, Sloan School of Management, MIT.
- Forrester, J.W. (1980). System Dynamics – Future Opportunities. In Legasto, A., J.W. Forrester and J. Lyneis (eds.) *System Dynamics TIMS Studies in Management Sciences 14*. New York: North Holland.
- Forrester, J.W. (1968). Market growth as influenced by capital investment, *Industrial Management Review* 9(2), 83 - 105.
- Forrester, J.W. (1971). Counterintuitive behavior of social systems, *Technology review* 73(3), 52 - 68.
- Forrester, J.W (1992). Policies, decisions and information sources for modeling. *European Journal of Operational Research* 59(1), 42 - 63.
- Hamilton, M.S. (1980). Estimating Length an Orders of Delays In System Dynamics Models. In J. Randers (ed.), *Elements of the System Dynamics Method*. (pp 23-57). Cambridge MA: MIT Press
- Lane, David C. (2008). The Power of the Bond Between Cause and Effect: Jay Wright Forrester and the Field of System, *System Dynamics Review* 23 (2-3).
- Low, G.W. (1980): The Multiplier Accelerator Model of Business Cycles Interpreted from a System Dynamics Perspective. In J. Randers (ed.), *Elements of the System Dynamics Method*. (pp 23-57). Cambridge MA: MIT Press
- Meadows, D.H. (1980). The Unavoidable A Priori. In J. Randers (ed.), *Elements of the System Dynamics Method*. (pp 23-57). Cambridge MA: MIT Press.
- Richardson, G.P. (1986). Loop Polarity, Loop dominance and the concept of dominant polarity, *System Dynamics Review* 11(1), 67 - 88.
- Richardson, G.P. (1986). Problems with causal loop diagrams, *System Dynamics Review* 2(2), 158 - 170.
- Richardson, G.P. (1986). Problems with causal loop diagrams revisited, *System Dynamics Review* 13(3), 247 - 252.
- Sterman, J.D. (1987). Expectation Formation in Behavioral Simulation Models, *Behavioral Science* 32, 190 - 211.
- Sterman, J.D. (1988). Modeling the Formation of Expectations: The history of Energy Demand Forecasts, *International Journal of Forecasting* 4, 243 - 259.
- Sterman, J.D. (1988). “A Skeptic’s Guide to Computer Models.”, In Grant, L., *Foresight and National Decisions*. Lanham, MD: University Press of America, 133-169.
- Sterman, J.D., Richardson, G.P. and Dauidsen, P.I (1988).: Modeling the estimation of petroleum resources in the United State, *Technological Forecasting and Social Change* 33(3), 219-249.
- Sterman, J.D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill, Chapters 9, 11 to 20.

Suggested readings:

Warren, Kim: Strategic Management Dynamics, 2008, John Wiley & Sons, Ltd. (private sector applications)

Ford, Andrew: Modeling the environment, 2009 (second edition), Island Press. (public sector applications)

Lecture notes by Pål I. Davidsen:

The Structure Behavior Graph "

Counterintuitive Behavior and Policy Design.

Case studies and Lecture Notes in System Dynamics

8. Further Information

Course Schedule

Course meetings include 36 lecture hours and 18 hours of lab assistance over a 6-7 week period (two lectures and one lab per week) from mid-August until the mid-October. The exam is in the middle of December.