MATHEMATICAL MODELLING AND SIMULATION

(40340 Simulations and Agent-Based Modelling)

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A.y. 2019/2020

Learning Objectives and Course Content:

Mathematical modelling has now become a quantitative systematic approach to deal with decision-making processes under conditions of uncertainty. These techniques are used in all areas of social and political sciences and in policy decision making as they allow to explore the mechanisms underlying certain processes and to make projections on future scenarios under various alternative assumptions.

The course is designed to introduce the concepts and methods of decision analysis and modelling, and discuss their growing range of applications to policy decision-making processes in different research field, particularly but not exclusively health. The objectives of the course are to go through and familiarise with the following topics:

1. present various modelling approaches used for policy decision making (decision trees, Markov models, population dynamic model and agent-based models)
2. understand their theoretical foundation and how they can be developed and implemented
3. get familiar with applications of the modelling framework in the different disciplines of research (from demography, to biology, to epidemiology and economics)
4. explore possible complications that consider realistic scenarios, heterogeneities of agents and realistic network structures
5. stages of the model building process (formulation and assumptions, implementation and parameterization, simulation and prediction)
6. uncertainties and robustness of model result;
7. uses and limitations of these methods in decision making in government, within health care organizations, in private industry, and even at the level of individual patient care.

The course will combine class-work with hands-on modelling. No programming or statistical experience is required although class members will be facilitated if they have some background in quantitative social science (including basic statistical analysis) and they enjoy the computing experience. No previous experience with modelling is assumed.

At the end of the course, each student should be able to: discuss key issues in applying mathematical models, understand the process used to construct the types of models seen in class, be able to implement and run a simple model and to produce model outputs, and critically evaluate published decision analysis modelling studies.

In particular the following topics will be covered:

- Simulation and Social science - history, taxonomy, motives, simulation from the social science point of view
- Simulation as a Method — logic of simulation, stages of simulation-based research

- Theoretical (mathematical and statistical) Framework for simulation based research – equations that describe the processes, derivation of important quantitative parameters and inference on unobserved variables
- System dynamic models – applications in demography, biology, epidemiology and economics. Diffusion processes and agents interactions.
- Simulation modelling in heterogeneous population – homogeneous/ heterogeneous (WAIFW) mixing patterns, social contact data, high-low risk groups.
- Agent-based modelling – description of the characteristics of individual agents, characterisation and inclusion of networks
- Use of simulation models – parameterisation, validation and calibration, prediction.
- Practical classes – use of the softwares R/Python/Excel/Netlogo/Gleamviz

Lecture	Date – Room	Topics	Course materials
1&2	Tue, 07-apr (14.30-17.45) – 1e4sr01	• Intro to Simulation & Modeling (SM); Overview of modeling methods: discrete events, system dynamics, agent-based and decision analytic models • From models to equations: historical perspective. Lotka Volterra stable population and predator-prey system; Mckendrick and Kermack.(paper discussion)	• Pidd Michael. 2004 Computer simulation in management science. Wiley & Sons Ltd, 5th Edition. Chapters 1, 2 and 3 Sterman John D. 2000. Business Dynamics, McGraw-Hill Ed. Chapter 1 • Bacaer Nicolas. 2011. A short history of mathematical population dynamics. Springer Ed. Chapters 10, 13, 16 • Keeling and Rohani. 2008. Modelling infectious diseases in human and animals, Princeton ed. Chapter 2
3&4	Thur, 09-apr (8.45-12) – 3d3sr01	• Compartmental models in epidemiology and extensions to other contagion processes • Paper discussion	• Keeling and Rohani. 2008. Modelling infectious diseases in human and animals, Princeton ed. Chapter 1-2
5&6	Wed, 15-apr (14.30-17.45) – 3d3sr01	• Host heterogeneities, different risk groups, age-stratifications, spatial spread. How to make models more realistic. • Paper discussion	• Keeling and Rohani. 2008. Modelling infectious diseases in human and animals, Princeton ed. Chapter 3
7&8	Fri, 17-apr (14.30-17.45) – 3d3sr01	• Agent-Based modelling, network analysis, shelling model with different network structures	• Eric Bonabeau. Agent-based modeling: Methods and techniques for simulating human systems, PNAS 2002 • Billari F., Simao J. Aggregate age at marriage patterns from individual mate searching heuristics. Demography 2005
9&10	Mon, 20-apr (8.45-12) – 1e4sr01	• Decision Analytic Modelling: Introduction on CE analysis, CE threshold, CE plane, ICER. Comparison among alternative strategies. • Decision Trees Modelling: how to set them up. Sensitivity and specificity, positive and negative predictive values. How to derive ICER	• Hunink M, Glasziou P, Decision Making in Health and Medicine. Chapter 3 and 5 • Barton P, Bryan S, Robinson S. Modelling in the economic evaluation of health care: selecting the appropriate approach. J Health Serv Res Policy. 2004 Apr;9(2):110–8.
11&12	Fri, 24-apr (8.45-12) – 3d3sr01	• Markov models: Markov chain and property. How to set them up. State transition matrix. States. Markov cycle. Simulation and interpretation of results	• Hunink M, Glasziou P, Decision Making in Health and Medicine. Chapter 10 • Sonnenberg FA, Beck JR. Markov models in medical decision making: a practical guide. Med Decis Making. 1993 Dec;13(4):322–38.