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# MODEL BUILDING AND SIMULATION using StochSD

**− Material for a course or for self-studies**

**− License**

# Background (LG)

When I first met modelling and simulation in the early 1970s, I became fascinated by the possibility to use mathematics, statistics and logics in an integrated way. In the end of this decade, when I had studied different types of simulation, I started to give courses in model building and simulation. For macro modelling, the System Dynamics approach of describing differential equations as stocks and flows opened the way to also teach simulation to less mathematically educated students from various fields.

Now when I am retired after more than 40 years of research, project works and teaching, I want to share my knowledge and experience from university courses on all levels by uploading my lectures and laboratory exercises on the net.

Together with my sons Erik and Magnus, we started in 2017 the development of the open-source simulation language, StochSD, based on the System Dynamics approach.

This material for a course in model building and simulation or for self-studies is available and free for all to use or teach. You may also modify it to fit your own requirements without a permission.

# Content

# (All course material is free and available at the StochSD home page.)

* **Lectures L1 - L9:** About 270 Powerpoint® slides contain the theoretical parts of macro modelling and simulation. But remember that just showing slides will put the auditory to sleep. Tell the story, use the black or white board, demonstrate by building models, discuss the results from simulations, etc. Powerpoints can work well for repetition and can be used as documentation of the course for the students. The slides also use Powerpoint’s Animation feature.
* **Five laboratory exercises:** By building their own models and making experiments the students will understand what modelling and simulation is about.
* **StochSD:** A macro simulation language based on the System Dynamics approach.
* **StochSD User’s Manual and Tutorial.**
* **Model examples:** Some models for demonstration.

**Suggested use of this course material**

We provide course material. You decide what, when and how to modify and use it.

Below is a suggested order for sections you want to include. (‘**L**’ stands for Lecture and ‘**Lab**’ for Laboratory exercise.) Note that the lectures L1 to L9 varies largely in size. (They are ***not*** fitted to one lesson each! Each laboratory exercise takes about one day’s work.)

**Suggested schedule** (Each **Lx** contains material for several hours, **Lab x** about one day)

|  |  |  |
| --- | --- | --- |
|  | **Section** | **Comments** |
| **L1** | Basic concepts | System, systemus, model, purpose, etc. |
| **L2** | Modelling in StochSD | Model building and preparations for Lab1 |
| **Lab 1** | **Structure and Behaviour** | You model the structure and the simulation shows the behaviour. |
| **L3** | Important techniques | Sensitivity analysis, Optimization, Model fitting. The tools Sensi & Optim do this. |
| **Lab 2** | **Model fitting, Optimization and Sensitivity analysis** | Practicing L3. |
| **L4** | Randomness, Statistical distributions and Random numbers | Basic statistics and Random numbers. |
| **L5** | Stochastic modelling | Including different kinds of uncertainties into the model. |
| **Lab3** | **Deterministic vs. Stochastic Model Building and Simulation** | Practicing L4 and L5. Showing that deterministic modelling can be misleading and insufficient. |
| **L6** | Statistical output analysis  (and the tool StatRes) | The outcomes from a stochastic model varies, why many runs and statistical analysis are required. StatRes does this. |
| **Lab 4** | **Stochastic Modelling of Uncertainties** | Modelling different types of uncertainties. Using the StatRes tool. |
| **L7** | Experimental Design and Variance Reduction | Some more advanced knowledge. |
| **Lab 5** | **Time handling and its problems** | Brings insight to how the model is updated timestep by timestep, and some problems with this approach. |
| **L8** | The Modelling project | Describes the strict requirements for a modelling and simulation project. |
| **L9** | Simulation vs. Speculation | Discusses the use and limitations of modelling and simulation. The use of simulation as a crystal ball to predict the future must be condemned, not to cause false, dangerous and costly conclusions. |
| **Exam.** | **Examination** (if required). The main examination is completed laboratory exercises. | The examination should focus on basic concepts, understanding, how to perform a modelling project, the use and limitations of simulation. Further, the strict distinction between systemus and model, and the understanding where information comes from is crucial. |

• **Suggested book**: “Thinking in Systems: A Primer” by Donella Meadows is an excellent introduction to System Dynamics and macro modelling.

• In a postgraduate course, a Modelling Project can be included.

## **Some experiences and conclusions**

* Each student should have his/her own StochSD and building his/her own models – although free to discuss with co-students.
* In a shorter course you may exclude stochastic modelling (L4-L7 and Lab 3 – Lab 5).
* Modelling and simulation is a two-step obligation: 1) The model must reflect the system under study, and 2) the model must be created so that it displays the model’s behaviour. Unfortunately, many courses in simulation focus only at the technical skill to produce a model that behaves (which every executable model does), and forgets to teach how to fit, validate and evaluate that the model reflects the studied system. Therefore, lectures **L8** and **L9** are necessary to separate good modelling from nonsense.

# Legal aspects

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