**Why Model?**

Everyone models, every day. A model is no more (and no less) than a representation of something that exists ‘out there’ in the world. Every observation we make of the world is filtered by the mental models we hold. Every decision we make is based upon a model of how the world will respond to our behavior. We model because otherwise we could not function in the world.

But, some models are more explicit – or more ‘formal’ – than others. We use modeling conventions such as maps (1 inch = 1 mile) or mathematics (Force = Mass \* Acceleration) because these models help us to better communicate our understanding of the world, or to better predict or control elements of that world. Formal simulation models are an aid to thinking and communicating about complex, dynamical situations where intuition fails.

In the context of this workshop, we are generally referring to formal models. Even amongst formal models, different purposes will suggest different methodologies, data requirements, and analysis techniques. Here I give a rough outline of various purposes for modeling, organized into three groups. First are three different ways researchers use models to understand and describe a system: *theory building*, *theory testing*, and *problem-space mapping*. Next, I give three ways that policy makers use models to influence the behavior of a system: *policy development*, *system design*, and *forecasting*. Last are three different ways that models can empower groups and individuals living within a system such as a workplace or community: *teaching systems thinking*, *training system operators*, and *facilitation*.

**The first three purposes of modeling have to do with using models to explore and understand a system.**

1. *Theory Building*

One of the primary benefits of a formal model is that it provides a rigorous link between a theory of system structure and statements of system behavior. This is helpful for social scientists interested in describing the way individual actions aggregate to form patterns at the scale of societies; or the way that various parts of an organization work together to fulfill that organization’s mission. Modelers may choose to omit system structure that is not necessary to the focal behavior mode, in order to demonstrate the sufficiency of the mechanisms under examination. The resulting models can provide a parsimonious theory of the system’s behavior.

1. *Theory Testing*

Simulation models can help with both the design and implementation of empirical tests of social theory. When theories about social phenomenon can be formalized, the experimenter can identify regions in the parameter space where the theories in question diverge, and find ways to conduct a critical experiment in this space. Experimenters can prototype an experimental design and analysis, substituting a model for the empirical setting in order to test the experiment’s determinacy. Simulation models can also provide a ‘virtual world’ for experimental subjects to interact with, in order to assess the way individuals make decisions in complex systems. To have confidence in their use of simulation, the model must plausibly replicate the behavior of the world as is expected by the theory, experimental method, or test subject.

1. *Problem-Space Mapping*

Models can also be useful for identifying an appropriate boundary for study, and any gaps in knowledge. The process of formalizing knowledge in a model is an opportunity to identify self-deception and incomplete thinking about a system. Each step in the modeling process – identifying behavior modes, qualitative modeling, developing equations and assigning units to variables, simulation, and testing – is an additional opportunity for the modeler to discipline their thinking. The modeler should follow the process, adding detail, as long as it continues to reveal important gaps in their knowledge.

**The second three purposes of modeling have to do with using models to explicitly guide decision making in a system.**

1. *Policy Development*

An operational policy guides the behavior of a system without changing the underlying *structure* of the system. A model may be used to encode various decision parameters such as varying production starts in order to respond to fluctuations in product demand, or treatment resource allocations for managing disease within a population. In supply-line problems, or other situations in which the ‘physics’ of a system are well understood, these models can be quite well parameterized. Optimization and sensitivity analyses may suggest specific values for policies.

1. *System Design*

In some situations, the system is susceptible to structural change – either in the creation of a new organization, or through the introduction of new flows of information into an existing system. A design for a new organization is a theory of how a hypothesized social structure can give rise to a desired behavior. In contrast to *theory building* models, the desire is not merely to show that a particular mechanism is sufficient to generate the desired behavior. Instead, the modeler hopes to design a system that will reliably produce that behavior when all confounding interactions are taken into account. System design models have strong requirements for parameterization and analysis, both before and after the structural change. System designers are generally interested in both the mean or expected performance, and the robustness of the system to extreme conditions and other uncertainties.

1. *Forecasting*

Forecasting refers to using a model to numerically predict the future behavior of a system. In complex systems, this is difficult to do for any long timescale, as small errors may compound rapidly. It is also of relatively limited utility, as in most situations the modeler wishes to change the behavior of the system, not merely to predict it. Prediction has value in situation such as modest investment in commodity markets, where one investment decision will have only small impact on the market’s trajectory. In these situations, attention to parameter values and proper sensitivity tests are essential.

**The last three purposes have to do with using models and modeling to help individuals think about and react to changes in a system, and to interact with one another.**

1. *Teaching Systems Thinking*

Systems thinking is the ability to understand in general terms the connection between a system’s structure and its behavior. The process of modeling can help individuals to make analogies between two structurally similar systems and to use knowledge from one context to help in understanding another. An example is in using knowledge about disease epidemics to build insight for the diffusion of attitudes and behaviors. Modeling experience can help individuals identify situations in which mental models may be sufficient to guide decision-making, and understand conditions when more formal analysis is required.

1. *Training System Operators*

Before commercial pilots sit in the cockpit of an actual 737, they spend many hours in a simulator, training to react appropriately and automatically to unexpected disturbances. The same principle can be applied to the management of any complex, dynamic system in which the timescales of stimulus and reaction encourage the decision maker to rely upon intuition rather than deliberation.

Models for this purpose are used in the background, and a model’s audience need not be familiar with its structure. The model must be well parameterized to the system that it attempts to represent, or at least must robustly respond to the inputs of the operator in such a way as to train their behavior to produce the correct response when they apply the skills developed in simulation to the real world.

1. *Facilitation*

The process of modeling helps individuals make their thoughts clear to themselves and to others, and so can be used to facilitate discussions between stakeholders with different understandings of a system or problem of interest. A group model-building process can be useful for surfacing and integrating a variety of perspectives. The resulting model can form a common language for stakeholders to work together to solve a problem.

Modeling scope and analysis are useful so far as they continue to facilitate communication. For certain applications, this means that analysis may be limited by the capacity of stakeholders to meaningfully participate in the discussion. In other applications, the model may succeed in building enough trust between stakeholders that the team may choose to develop a more robust *policy development* model.

The purpose of a model will have dramatic consequences for the style of modeling, the model’s level of detail, data requirements, the extent and type of analysis, and the way the model is used. The most common failure mode for modeling projects is to pay insufficient attention to the purpose for which the model is constructed, and subsequently to allow deep exploration, proper parameterization, or thorough sensitivity testing to fall by the wayside.

Modeling is enjoyable, and modeling a new system or class of problems may satisfy an intellectual or aesthetic curiosity. However, when the purpose of the model is not made precisely clear, it is easy to fall into the trap of modeling a system ‘just to have a model of it’, or ‘because we can’. To avoid this trap, it is helpful to begin a modeling project by stating the goals for the model, and to revisit or revise those goals whenever the modeling process stalls, disagreement arises, or a new phase in the project is begun. While this list is far from exhaustive, I hope that it will provide a useful starting place for clarifying the purpose of a modeling effort.

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