Lectio Praecursoria

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Doctor Custos, Doctor Opponent, ladies and gentlemen.

For the past five years, me and my colleagues have been trying to bring the theory and the practice of model based problem solving closer to each other. We've had two principal methods for advancing this objective. Firstly, we have tried to advance the theory of practice of modelling – so that modelers, and especially modelers of the future, would be better equipped to understand and manage phenomena that they may face in practice. Second, we have tried to disseminate ideas that can be useful for the practitioners. Our publications can be of interest to people working in fields, such as, operations research, management science, systems analysis, environmental management, policy analysis, and to people working in planning. The reason for broad relevance is the fact that we work with an element that is common to all of these areas, *that is people, and groups of people*, working with mathematical models in order to solve problems and to find opportunities for improvement.

In our field, there is a famous saying *all models are wrong but some are useful.* All models are wrong because they are simplified, often abstract, representations of the real world. There are surprisingly simple everyday examples. These include miniature models, maps, as well as words and sentences. Maps, for example, are "wrong" in the sense that they are never 100 per cent exact copies of the areas they are representing. They only show those aspects of the area that are interesting for the user of the map. Words and sentences can also be seen as models. After all, they are approximate ways to describe some aspects of the world.

So, what are the ways in which models can be useful? First of all, the process of *creating a model* can help us, or even force us, to *think carefully*. When we create a model, we take ideas from our head and give them a concrete form that we can examine and improve. An architect, for instance, can use a miniature model to check how different shapes and features fit together. People who do serious writing often notice that writing helps them to think more clearly. Second, once we have a complete model, we can *use* it for several purposes. Words help us communicate, and maps can help us identify opportunities. We can use a map, for example, to find a route or to identify a suitable place to build a camp. In general, models can support our creativity and give us insight in many different ways.

In a mathematical model, we use numbers and equations. We use them to describe things, and to describe relationships and interactions between things. An environmental model, for example, could state that increasing emissions by 100 units makes a certain disease two times more likely. There are special advantages in using numbers and equations. First of all, numbers help to understand and compare magnitudes, and using equations helps to think precisely how things interact. If we increase the value of a parameter by 10 percent, the overall impact is very different if this parameter has a multiplicative instead of an additive effect. Secondly, mathematical models enable us to do the various calculations and computational analyses. The goal of such calculations can be, for example, the numerical comparisons of alternatives, or a numerical prediction of the effects of a new policy or a solution. Computational analyses are especially important in situations where trial-and-error is very expensive, time demanding, or dangerous.

Route planning applications like Reittiopas, and election machines are two everyday examples of applications of mathematical models. Reittiopas calculates the fastest way to get to your destination. Election machine calculates how well your answers to a set of questions match with the answers given by politicians. And these are just two simple examples. Models are used everywhere in the world in problems ranging from simple data analysis to complex problems related to climate policy.

Without question, today, with modern information technology and the ease of collecting data, the possibilities offered by mathematical models are greater than ever. At the same time, this means that we have to pay very careful attention to how the models are used, and to discuss their limitations. It is easy to get excited about mathematical models when we only talk about their potential benefits. Still, we need to remember that models are like tools. In the right hands, they can be extremely useful and good, and in the wrong hands they can be disastrous.

Numbers and equations can help our thinking but they can also hide bad thinking and they can lead us astray. For example, building a mathematical model can easily lead us to narrow our focus to those things that are easily quantifiable. What we gain in the exactness and the precision of the model, we may lose in its comprehensiveness. Models can also become ways to escape responsibility. People sometimes do things just because the model says so. This is a great danger especially with large and complicated models that easily lose their transparency. How can we trust that the assumptions and the thinking behind these models makes sense? Another issue is the quality, and the comprehensiveness of data. Today, there is more data than ever, but we still have the problem of choosing the relevant pieces of data for each problem we analyze. Garbage in results in garbage out. Furthermore, even today there is not data about everything.

For example, the election machine only collects information regarding opinions, but does not really help to evaluate the effectiveness of politicians. For a technologically and a mathematically oriented person, it easy to create models that look fancy and produce beautiful results, but clearly this is not enough. *Even if models and algorithms might soon drive a car, at least in places with sunny weather, for the foreseeable future models cannot and should not drive our problem solving processes especially when we are dealing with complex high stakes decisions like climate policy.* The model should only be a tool to help its user.

In their book, “Introduction to Operations Research”, published in *nineteen fifty seven* the pioneers of our field C. West Churchman and Russell Ackoff emphasized the role of the users and the developers of models. Still, for many decades this perspective received only minor attention in the scientific journals, apart from few anecdotal experiences of successful modelers. Fortunately, the focus on human behavior has again gathered substantial momentum since *two thousand thirteen* when Hämäläinen, Saarinen and Luoma coined the term Behavioral Operational Research. This is the scientific area, to which my dissertation aims to contribute.

The main premise of my dissertation is that using mathematical models to support real world problem solving is a social process driven by the choices made by humans and that relies heavily on human judgment over-all.

The title of my dissertation includes the word “systemic”. This is a scientific term that emphasizes over-all perspective and interactions among things. In our publications, we show that it can be useful to view the modeling process as a sequence of steps, or as a dynamic process evolving over time. Examples of steps could be: Somebody identifies a problem, the problem is studied, a modeling team is built, the modelers choose a set of frameworks to start with, they develop models, they use the models together with the problem owners, the results are communicated to other stakeholders, and so forth. In practice, there are almost always many plausible and justifiable ways to carry out each stage in the modeling process. Therefore, it is not surprising that in several cases it has been observed that different problem solving teams have obtained different results when the same problem has been given to them. In the language of my dissertation, *there is path dependence in the practice of model based problem solving.* In modeling projects there is almost always alternative paths available, and these paths can lead to different results.

So, if different modelling teams can end up in different results, how can we trust our mathematical models? My first answer is that having multiple different results is not necessarily a problem at all. Sometimes we simply have multiple satisfactory solutions to our problems, and we have no way of knowing which solution is the “best” one. My second answer is to compare modeling to thinking. How can we trust our own thinking, or someone else’s thinking? Familiar practices that we all sometimes use include sleeping over problems, seeing if we can reach the same result from different starting points, asking outsiders to evaluate our ideas, and generally subjecting our thinking to criticism. The same recipes can also work in modeling, when we want to build confidence in the results that we have obtained.

So, optimistically, one might think that mistakes made in modeling projects are usually easy to notice and correct. Well, this is not necessarily the case.

A modeling process can get stuck on a poor path, for example, due to budget and time constraints, hidden motives, cognitive biases such as confirmation bias, and also due to a social environment where people hold back critical opinions.

The ways in which people interact with each other can generate trust and openness, but also an environment of fear in which people are not positively engaged. Tight groups or communities of practice can easily convince each other of the correctness of their model without critical thinking or consideration of alternative viewpoints.

The behavioral issues listed in the first two papers of my Dissertation can give useful clues for starting to figure out what might go wrong in modelling, and for detecting inefficient practices prevailing in an organization that relies on models. Detecting mistakes sounds negative, but finding gaps is also a positive thing. It means that there is a possibility to improve. Another important thing to notice, is that people usually prefer constructive feedback while they are building something, rather than receiving criticism afterwards. Therefore, in our modeling projects we should build in proactive practices, that force us to critically evaluate our approaches already before problems emerge. One example is assigning the role of a Devil's advocate to one member of the modeling team, another is the use of checkpoints.

The papers 3, 4 and 5 in my Dissertation relate to Decision Analysis, which is a branch of model based problem solving. The process of building and using decision analysis models is an especially subjective one, as the goal is to help people make subjective decisions. This makes it very important to pay attention to the behavioral factors, such as cognitive biases, involved. Together, the third and the fourth paper describe how the idea of path dependence opens up a new perspective on analyzing biases in decision analysis processes. To some extent, the earlier research has been lacking a big picture view on mitigating cognitive biases.

In the fifth paper, our goal is to help environmental managers to use state-of-the-art portfolio modeling and software in practice. In this paper, our main contribution is bringing knowledge from one field to another one. In general, this type of a contribution can be very valuable in today's academic world as disciplinary silos are often very strong. It is often the case that researchers in different communities do not follow what is happening outside of their own specialty.

Now, I would like to conclude with the following thoughts.

First, our field has evolved over time and we are now in a mature stage with a very fine body of mathematics based methods. For example, the decision theories introduced by Keeney and Raiffa in nineteen seventy six are still widely regarded as the soundest ones for practical use. Now, if we keep on building more and more complicated theories, and keep on concentrating on more and more specialized topics, we risk drifting too far from the real world, and too far from each other.

At this point in the path of our field, *we need more bridge builders*. *We need to strengthen the bridges both, between the theory and the practice, and to strengthen the bridges between disciplinary silos.*

Second, with modern computers and software technology, modeling has become technically easier than ever. Today, almost anyone can create graphs and calculations that look convincing. To counterbalance this phenomenon, it is more important than ever to embrace the professional ethics of modelers, and to educate modelers with a behavioral perspective and the ability to critically reflect on their practices. The ability to reflect, after all, is essential to continuous self-improvement and to learning. These are key elements for becoming wise and successful in modelling.

This concludes my lectio praecursoria.

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I ask you Professor Ralph Keeney as the opponent appointed by the Aalto University School of Science to make any observations on the thesis which you consider appropriate.