Principles of Modeling: Real World - Model World

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Welcome

Welcome to Principles of Modeling

We all build models on a daily basis. Sometimes we build them deliberately, but often we are unaware, and build models subconsciously.

This presentation introduces you to the **Real World** and the **Model World** where you will discover how models play an important role in planning and natural resource management decision-making.

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Basic Elements Of Model Construction

You will be introduced to the four basic elements of model construction:

(1) the real world, which we attempt to model
(2) the model world, which is a simplified version of the real world
(3) the model, containing the working parts to run the model
(4) the data, which is required to run the model

You will discover the differences between the real world and the model world. It is important to a have a firm understanding of these differences to begin the model building process.

You will explore conditions and time constraints required to build a purposeful model.

And finally, you will investigate problems that commonly arise when attempting to build a model.

What Is A Model?

A model is a simplification of the real world
It's also a tool for problem solving

Why Model?

Models help us communicate
Models allow us to clarify and test understanding
Models create credibility and accountability
Models help you organize your thoughts
Models simplify and solve problems
Models help you understand your data

Meet the Presenter

Welcome to the Principles of Modeling class. My name is **Tony Starfield**, and if you're wondering where the accent comes from, it's Minnesota, Minnesota overlaid on South African. I grew up in South Africa. I studied as an applied mathematician and then ended up doing a Ph.D. in mining engineering.

Solve a Problem

You don't learn about modeling by listening to me talk about modeling. So I'm going to give you a problem to solve. And I'm going to ask you to solve it in exactly one minute.

What I want you to do is imagine a ping-pong ball, and then I want you to look around the room that you're in and tell me how many ping-pong balls you can fit into the room without squashing any of them.

You've got one minute to go.

Think!

Remember, you only have one minute. What factors will you consider? Will you guess? Will you build a model? Can you explain that model?

PAUSE the slide and take a moment to jot down some ideas.

What Is Your Answer?

Well, what was your answer? Of course, you're all sitting in different rooms. I have no idea of whether you're anywhere near right or wrong. But luckily, I don't care about your answer. What I really care about is how you got there, because in order to come up with an answer, in order to solve a problem, you had to build a model. So what was your model of the room?

How Did You Solve the Problem?

The room I'm in looks like a big box. That probably fits most rooms. So maybe you thought of the room as a box.

What about the ping-pong ball? Was your ping-pong ball a sphere? Or maybe it wasn't a sphere. Maybe you found it easier just to think of it as a little cube. So maybe when you were trying to estimate how many ping-pong balls you could fit into this room you were really looking at how many little cubes you could fit into a big box.

What about the details in the room? This is a studio. There are chairs. There are computer screens. There are lights. There are all sorts of things in it. I don't know what's in your room, but there are probably desks and chairs and stuff like that, maybe computers. Did you include them in your calculation or did you conveniently forget about them?

Building the Model

Well, it turns out this example really works very well as a theme that we can carry through to explain to you what one does when one builds a model.

I'm going to kick off by drawing a diagram, and I'm going to start off by putting in a squiggly little box like that, and I'm going to call that the real world. I'm just going to label it "real." I've drawn it in a very squiggly sort of way because the real world's messy. It's complicated.

Now, from the real world, if I go back to the diagram, I create something neat and simple. I'm going to put it in as a box like that. And I'm going to call that the "model world."

The Model World Is Different

And the model world is different from the real world in the sense that it leaves things out.

For example, my model world doesn't contain anything like the computers and the screens and the lights in this room. And it can even distort things. Ping-pong balls can change from spheres into cubes.

We'll come back to how you design the model world in a moment, but let's just get the big picture first.

Describe the Model

If we go back to the diagram, once you've designed a model world, you forget about the real world altogether and you build a model. And this is where mathematics comes into play. Because if nothing else, mathematics is the language that one uses for describing the model to somebody else. You might not need calculus. You might not need anything complicated. But you do need some kind of language to describe your model.

Model Formula

I'm going to show you my very simple model for the ping-pong ball problem. If you look at this formula, it says the number of ping-pong balls is the length of the room times the width or breadth of the room times its height. And I shouldn't even be talking about the room, I should be talking about the box that represents the room.

And if I treat a ping-pong ball as a cube then the volume of a ping-pong ball is the size of the ping-pong ball cubed. So this formula really says that the number of ping-pong balls is the volume of the box divided by the volume of the ball.

Now, if you treated a ball as a sphere, you would either have to remember here what the formula is for the volume of a sphere or else you're going to say, "What the heck, let's pretend it's a cube."

Now, I want you to notice in this formula that there are four pieces of information we need. We need to have a number for L, W, H and S. L, W, H and S are called the parameters of the model. That's where we've got to go and collect data. We need data for our parameters.

Develop Model Parameters

So if we go back to our original diagram, having used mathematics to develop the model, we now need to get some data. And data comes from the real world side of the diagram.

We take data, we feed it into our model, and we do some calculations. Those calculations could be mental arithmetic, or they could be on a computer, or they could be on a supercomputer. And then having done those calculations, we get an answer.

Interpret the Model

Again, if we go back to the diagram, a very important point is that the answer one gets from a model doesn't tell you directly what's happening in the real world; it tells you what is happening in the model world.

We haven't calculated how many ping-pong balls can fit into the room. We've calculated how many little cubes we can fit into a big box. And then having gotten an answer in the model world, we have to interpret it back to the real world.

Example A

Now, what do I mean by interpretation? At that point we have to say, what is the difference between what we have in the real world and the model world?

So, for example, I might argue, gee, I left out in my model world all the details, all the things that clutter the room. I left out myself. You probably left out the desks, the chairs, the tables, the clock on the wall.   Because, I left those out, my answer is going to be too big.   I'm going to overestimate the number of ping-pong balls that fit into the room.

Overestimate / Underestimate

On the other hand, if I treated the ping-pong ball as a cube, cubes can't fit into each other, they can just stack on each other, whereas spheres can fit into each other. So by making the ping-pong ball a cube, I have underestimated the number of ping-pong balls I can fit into the room.

So one of my assumption means I overestimate. Another one has caused me to underestimate. I would begin by saying, gee, I think those are awash, and maybe I'm not happy with the answer that I get from this model. If, on the other hand, all my approximations, all my assumptions led in one direction only, then I'd be worried that the answer was too big or too small.

Note: If ALL our major assumptions lead to an underestimate of the answer, or if they ALL lead to an overestimate, then one needs to be concerned about the accuracy of the answer.

Evaluate: Good Model - Bad Model?

Okay. So we've built a model. But the next question we have to ask is: Is it a good model or is it a bad model? What do you think? Good? Bad? Indifferent? Well, if you've come up with the answer "I don't know," or "It depends," that's a good answer. If you said that your model is good or bad, you've stuck your neck out, and the reason you stuck your neck out is because there's no way I can evaluate a model without knowing why I wanted to build it.

Let me illustrate that. . . .

Example B

Suppose, you are not in a room that belongs to you but somebody else's room, and suppose it's your boss' birthday tomorrow, and suppose everybody has decided it will be a really neat idea to fill the room with ping-pong balls and make sure that he or she walks into the room first thing tomorrow and gets a big surprise. And the question is, can you afford to do that? And are there that many ping-pong balls available? Well, I reckon if that's the purpose of the model, the box and square model, or the box and cube model, is a pretty good model. You don't care whether you're going to have to spend five or six bucks apiece. But you do care whether it's going to be five bucks or 50 bucks.

Example C

On the other hand, suppose that, gee - well, suppose there are budget problems in the federal government. There are always budget problems in the federal government. And suppose you work for one particular agency and - in resource management - and suppose somebody in the White House, for example, has suggested that instead of cutting everybody's budget, what you should do is take the total research budget for resource management and give it to one agency only, and all the other agencies get nothing for the next biennial.

Then the question is, of course, which agency is going to get the money? So what we decide to do is to pick the particular room you're in, and each agency is going to come up with a team, and the team that comes up with the best prediction of how many ping-pong balls can fit into that room is going to be the agency that gets the money.

Purpose and Resources

Well, for a start, if that was the stake, you wouldn't want to - have to solve that problem in one minute. So a possible answer to my question was, was this a good model or a bad model might have been, it was the best model I could build in a minute. And so there are two things that come into play in deciding whether a model is good or bad.

The one is the **purpose** of the model and the other are the **resources** at your disposal. I reckon the purpose is the main point, and then you've got to make sure that your resources match your purpose.

So if you were trying to decide whether you would get your research budget, you would say, give me a week, and then every single detail would be important. You'd have people rushing around the room measuring every chair, measuring every table. If you're going to be in the room, they're going to create a three dimensional image of you and see how many ping-pong balls you displace.

What Drives the Model?

So what drives a model is the **purpose**. One cannot design the model world or talk about whether a model is a good model or a bad model without first establishing the purpose.

What Goes Wrong?

Okay. Having made that point, I'd like to go back to the diagram and talk about what goes wrong in this process of modeling.

If we look at the diagram again, you see that the way I've spelled it out, it looks kind of neat. You go from the real world, you design your model world, you build a model, you get your data, you do a calculation, you go back to the model world, and interpret the answer back to the real world.

In practice, of course, it never works like that. You go forward and back and forward and back, but eventually you get back to the real world with some kind of answer. But every single arrow in this diagram is potentially a problem. And I'm going to talk a bit about what can go wrong with modeling before I talk about how to make modeling go right.

Vague Purpose

The first difficulty starts right in the real world, and that is that I have just said that a model is driven by a purpose, and very often people in the real world haven't worked out for themselves what the purpose of the model is.

I quite often get pulled in as a consultant. Somebody gives me a call and says, "We've been working on a model and we're having trouble. Can you come around and help us?" And I end up going there, and the first thing I say to the team of people working on the model is, "What's your objective? What's the purpose of this model?"

And I usually get answers like, "Purpose? Gee, we had a purpose. Can anybody remember what the purpose was?" Or else one person says the purpose is this and somebody else says the purpose is that. And I've discovered that nine times out of ten, if I can get people to figure out what the purpose of their model is, they don't need me as a consultant. They know what to do.

Too Much Detail

So, first problem going back to the diagram is the purpose isn't spelled out. Second problem is the design of the model world, and I'm using the word "design" deliberately.

The question is, how much detail do you want to put into the model world? And inevitably what happens is people try to play it safe, and by playing it safe, they try to put in more detail rather than less.

So typically, I don't know - what's the most insignificant thing in your room? Is it maybe the clock on the wall?

Inevitably, if there's something insignificant, there's going to be an expert on it. And so let's imagine you have a clock expert and the clock expert says, "Your model world doesn't contain my clock. Where's my clock?" And you say, "Well, we didn't think we needed to put the clock in." And the clock expert says, "I've spent my life studying clocks. Clocks are important." So what do you do? You put the clock into the model just to keep that person happy, and very quickly your model becomes cluttered.

Now, is this a problem or isn't it? There are people who would argue that computers are very powerful and so if the model is too complicated, so what? The computer can handle it. My problem is not with the computer. My problem is with my brain. Because brains haven't improved in the last couple of hundred years. And to me, a model is a combination of computer and person. I've got to interpret it. I've got to understand it. I've got to collect the data that goes into it. And every unnecessary detail I add distracts me in my ability to understand what I'm doing.

Is the Model too Complex?

Remember the formula we had for our very simple model. It had only four parameters. What happens if we put the clock in? We're going to need at least two parameters to describe the clock. So suddenly we've increased the number of parameters that we have to deal with and the amount of information we need by 50%, just to put that one little clock in.

Throw in the chairs, throw in the tables, throw in the people, throw in little quirks in the shape of the room, and very, very quickly you end up with a huge complicated model and you have no idea of which parameters you need to calculate - you need to estimate or measure carefully.

So, the problem with a **model world** is that it gets too complicated.

Don't Let Math Drive the Model

Now let's go from the model world to the model itself. This is where mathematicians come in.

So you're going to have somebody come along and say, "Gee, I'm an expert in partial differential equations? Why don't you have a partial differential equation model here?" Or "Why don't you use this type of model?" "Or why don't you use that type of model?“

The danger there is that the mathematics might drive the model instead of the purpose driving the model. Mathematics is fantastic when it fits and helps you. It's dangerous when it forces you to think in a way that's different than what you need.

What Data Do You Need?

Okay. Back to the diagram. Next question is the data. Now, there are people who are going to say, even before you get to this point, "We don't have the right data, so how can you possibly build a model?" Or "What data are you going to need?"

In other words, people start in the Real World and want to go straight from the Real World to the Data.

You don't know what data you need until you've designed your Model World and thought about your Model. And even if you don't have the data, you can guess at it, and as I'll show you, you can guess at it and you can come back from that guess with a better idea of how to collect the data and how accurately you need it.

Don’t Let Experts Drive The Model

Okay. Back to the diagram. We have seen data can be a problem. Calculating your answer can also be a problem. This is where the computer scientist comes into play.

The computer scientist says, "gee, you're going to build a model for this room, why don't you have a three dimensional geographic information system?" Or "Why don't you use this computer code rather than that computer code?" Or "Object-oriented programming is what you need." And again, there's a danger that the expertise of the computer person will drive what you do rather than the needs of the problem.

The Worst Problem

Back to the diagram. Final and worst problem is that instead of going from the model answer back to the model world, you **go straight from the Model back to the Real World**. By this time you have been dealing with the model for so long that you have forgotten that it's just a model. And so you think the answer that comes out of the computer is the answer that you need in the real world.

Modeling Spectacles

What I like to do when I'm thinking about modeling and I'm thinking about this model world/real world diagram is I like to try and think of myself as designing a pair of modeling spectacles. For the purposes of the problem, I come up with a prescription, and when I put on my glasses, for example, in the ping-pong ball problem, suddenly everything disappears from the room, the shape of the room looks like a big box, and if you show me a ping-pong ball I see a cube.

And so every modeling exercise requires the design of a pair of modeling spectacles through which you look at the real world. By the time you've been through the whole modeling exercise, you've kind of forgotten you're wearing those spectacles and so the danger is that when you go back to the real world you are still wearing those spectacles and you don't know that you're wearing them, and the result of that is gross miscommunication between you, the modeler, and whoever you built the model for, the manager or the decision-maker or the public.

What I would do as a modeler before I present any results to anybody in the real world is tell them why I designed my modeling spectacles in the way I did. I want to get them comfortable with looking at the world through these glasses before I actually talk to them about answers.

What happens if I don't do that? I go back and I say, "Gee, we need 63,201 ping-pong balls." And the first thing the person I'm talking to says is, "Gee, that's a lot of ping-pong balls, what happens if we put a few more chairs into the room? How many ping-pong balls will we save?" And I'm going to say, "Chairs? My model doesn't contain any chairs. I can't answer that." Immediately I've lost the confidence of the person that I'm talking to. I needed to tell that person beforehand why I wasn't looking at chairs. They needed to understand my model and the assumptions.

Review

- The most important task in modeling is to clearly identify the purpose of the model
- A model is a tool to help you think through a problem
- Model objectives and resources available to build the model need to meet each other

Skill Check

Now let's exercise your mental modeling skills.

A project team was tasked to develop a model to determine how many ping-pong balls it takes to fill a room.

Due to the time constraints, the modeler assumed the room was an empty box and the ping-pong ball was a cube.

However, after studying the results of the model, the reviewer thinks the model is too simple.

Think. . . . How would you respond to the reviewers concerns?

I'm the reviewer
I'm the modeler

Reviewer: Everyone knows a ping-pong ball is a sphere, not a cube. This model is not realistic.

Modeler: A model is not about realism. It is an efficient tool to reach an objective.

Reviewer: Nobody works in an empty room. Where are all the other objects in the room?

Modeler: Depends on your objective and how accurate the answer needs to be.

Reviewer: I would like to use this model to calculate how many ping-pong balls are needed if we take people out of the room. Your model won't let me do this.

Modeler: That was not the original purpose of this model. If the model needs are different, then the objective was not well defined.

Reviewer: You don't have real data and are guessing at the diameter of a ping-pong ball. How can you build a model before you collect the data?

Modeler: How accurate do you need the answer to be? We might not have accurate data, but we have solid estimates of a lower and upper bound. Let's use our model to see what difference those estimates make in our answer.

Reviewer: You haven't defined what you are going to use this model for.

Modeler: Good point. You are right. Back to the drawing board. I can't build a model if I don't know the purpose. We need to communicate better.

Reviewer: How can you be so certain of the model results? There has been no discussion about the limitations of this model.

Modeler: Oops! I must have been wearing my modeling spectacles when I wrote the report. I committed a critical modeling error by interpreting the model back to the real world rather than to the model world.

Reviewer: I get the impression that this model was built very quickly. Surely more time should have been spent in developing it.

Modeler: The time I allotted to work on the model met the objective. Model objectives should always take time constraints into consideration.

Reviewer: What mathematics are you using in this model? Did you use calculus?

Modeler: Calculus is not required to build this model. You don't need to complicate the model. But you do need some kind of language to describe your model.

Summary

You haven't done any real modeling yet. But consider what you have learned about modeling already! You even know what kinds of questions to ask when somebody asks you to review their model.

Modeling Diagram: Real World - Model World

This diagram is really important. It captures the essence of modeling. In fact, it is a model. It is a model of the modeling process. It is a conceptual model.

In other words, it is a model that doesn't actually run on a computer or produce results, but it too is useful. Its purpose is to explain modeling, and to help you think about what you are doing when you develop a model.