

## **State and Transition Conceptual Modeling**

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Okay. So this is really neat. It's a simple model which produces exactly the kind of output we want to produce and which one can easily put onto a spreadsheet. Those are its pluses. But what are its minuses? They're quite serious. First of all, where did the numbers in the matrix come from? They come from data. Now, why would I want to build this model in the first place? Well, let me give you some background as to why I chose this particular type of situation in northern Minnesota.

There's been a controversy in Minnesota for some years in which the local DNR has been saying there used to be a lot more of white pine and red pine on the landscape. And what can we do to try and restore it? And there tend to be two alternative viewpoints. The one says, fire management is what is keeping out white and red pine from the system. The other says it's those deer. We've let the deer population grow too high, and if we could reduce the deer population, we would see more white pine and red pine on the landscape.

So the purpose of building a model like this would be to look at the interaction between fire and deer on that time line, to try and maximize the amount of time you are in white pine and red pine. In other words, you would want to look at different management strategies to see how they affect the likely outcome of the model.

Well, we've been talking about fire and deer, but fire and deer are not in this model. All we have are a set of data that were presumably obtained from current circumstances, with controlled fire and uncontrolled, or relatively uncontrolled, deer. So if one were to try and get the data for a Markov model in which you, for example, remove half the deer. You would actually have to remove half the deer and collect the data, by which time you wouldn't need the model. Or alternatively you would have to guess. Unfortunately, Markov models are fairly sensitive to those probabilities. So small changes in guesses can lead to large changes in outcomes.

So in summary, the beauty of the Markov model is that it's something you can put onto computer and produce results from. But its weak point, its soft underbelly, is that it doesn't

describe mechanisms. It's data driven. So in the sense of looking for an alternative to the bottom-up approach, Markov modeling isn't that promising.

So one goes back to the drawing boards, and when one goes back to the drawing boards, one finds an alternative out there which is called **State and Transition Conceptual Modeling**. And, I'll explain why the word "conceptual" is in there, in a moment. Well, what would a state and transition model for jack pine, white pine and spruce look like? It would look something like this. The idea here is that each circle represents one of the states. So those are the states, jack pine, white pine, spruce. Each arrow represents a transition. So that arrow represents a switch from jack pine to white pine and I've numbered it as arrow number 1. That arrow represents the switch from spruce to jack pine, and I happen to have called it number 4. Occasionally one puts in arrows that start on a state and end on the state if you want to emphasize the conditions under which you remain in that state, and in this particular case I've called that arrow number 3.

Well, having drawn this diagram, and notice by the way there's no arrow from spruce back to white pine, which corresponds to that zero in the matrix model. Having drawn this diagram, what you do is tell a little story. You write a paragraph relating to each of the arrows. So, for example, if I look at arrow number 4 here, and I speak to people and speak to experts about the conditions under which you switch from spruce to jack pine, I get told, "This switch occurs whenever there is a fire. When you have a fire in a spruce patch, it is going to be a crown fire and it is going to be a stand-replacing fire. If fires are not controlled, the fire interval is likely to be about 20 years." So that tells you something about the conditions under which that arrow occur.

Notice, by the way, how it ties in with the matrix model. Because remember, the matrix model had a .5 probability of staying in spruce. .5 probability of staying in spruce with a 10-year time step, means you switch once in 20 years, on average. In other words, those data came from the uncontrolled fire situation.

If I look at one of the other frames, for example, the switch from state jack pine to state spruce, number 2 reads like this, "This switch occurs after about 80 to 100 years if fires are strictly controlled and the density of deer is high." And behind that explanation is that if fires are controlled, you are going to remain in jack pine. If the deer density is high, you are going to debilitate the growth of white pine in the landscape or handicap it as compared with the growth of spruce in the under story. And so when the jack pine die a natural death after 80 to 100

years, you will have a spruce-dominated patch. So that is the kind of thinking behind the state and transition model.

Well, let's talk about what's right about this and what's wrong about it. It certainly solves the problem of mechanisms, because the description of each transition spells out the mechanisms. On the other hand, it is conceptual, because that's as far as the model goes. It doesn't produce anything that runs on the computer. It just tells a story. And the idea is that an intelligent person reading that story who has certain objectives for that patch should be able to figure out what to do and what not to do.

So if we go back to the diagram, for example, and we have the stated objective that we want to increase the amount of white pine on the landscape. Then what we are trying to do in a single patch is to get into white pine as often as possible and get out of white pine as little as possible. So one would read the description for arrow number 1, and a prudent manager would try to do everything possible to make arrow number 1 happen. And then one would read the descriptions for the arrows going out of white pine, and a prudent manager would try to do everything possible to stop those from happening.

So the state and transition model can, in fact, provide guidelines and ways of thinking that managers could find very useful. But I'm not entirely satisfied with that. I'd like to go one step further, and that one step further would be to take this idea and actually produce a running model. I want to have a running model where I can fine tune my strategies and look at multiple outcomes. Because if we think for example, of decision analysis, while the DNR might want to see a lot more white pine on the landscape, it's possible that forest companies might want to harvest it as well. So you might be looking for strategies where you have your cake and eat it, produce a lot of white pine, but at the same time harvest it. And hunters might want more deer out there. And fire managers might be concerned about large fires, so they might want to control fires. So there are trade-offs. One wants to be able to investigate those trade-offs in a simple model.

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