How math helps stop oil spills and plane crashes

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Jason Merrick, Ph.D., says that his daughters tell people that their father stops oil spills, plane crashes and terrorist attacks with math. That's one way to describe Merrick's research, which at its core involves developing complex mathematical models to help people make difficult decisions about risk – those involving significant uncertainty and trade-offs.

Merrick, who is a professor of decision and risk analysis, and simulation in the Department of Statistical Sciences & Operations Research in the VCU School of Humanities and Sciences, is involved with both theoretical and applied research.The mathematical models he develops can be used to simulate what would happen in a real-world situation on a computer – which is a relatively safe and fast way to perform experiments.

Merrick's work has helped government agencies, environmentalists, industry and the Coast Guard come to agreement on effective ways to reduce the risks of oil spills and accidents. He's led studies in the state of Washington and on San Francisco Bay in California and Prince William Sound in Alaska.

In one report published in 2002 in the journal Interfaces, Merrick, together with engineering colleagues from George Washington University and Rensselaer Polytechnic Institute, provided a risk assessment of Prince William Sound, Alaska, where the grounding of the Exxon Valdez occurred in 1989.

The team developed a detailed risk model to reduce the risk of oil spill. Their goal was to reduce the accident frequency in the area and improve safety management systems. It involved working closely with a number of key groups including company stakeholders, the International Maritime Organization, the ship escort/response vessel system (SERVS) and others.

The final report – which included technical documentation of the methodology used in the study, results of the modeling and recommendations – was presented to the steering committee and reviewed by the National Research Council. The committee acted on the findings and implemented a variety of recommendations as suggested by Merrick and colleagues.

In other work, Merrick and colleagues have worked with the United States Coast Guard to develop the ports and waterways safety assessment model, PAWSA, to help make decisions about safety in U.S. ports and waterways. In 1999, PAWSA was adopted by the U.S. Coast Guard as a permanent part of its safety management tool kit. As a result of the PAWSA model, the Coast Guard received funding for four new vessel traffic service centers and determined new technology needed for commercial vessels in U.S. waters.

His work has been supported through the National Science Foundation, the Federal Aviation Administration, the Coast Guard, the American Bureau of Shipping, British Petroleum and Booz Allen Hamilton.

Merrick recently received a 2013 Distinguished Scholar Award from the VCU College of Humanities and Sciences. His role at VCU includes mentoring student researchers from the undergraduate level through post-doctoral.

Below he discusses his passion for his work, how he got started in the field and his advice to up and comers.

What drew you to research and why study this specific field?

Merrick: I did my undergraduate degree at Oxford University in mathematics and computation, or computer science. It was very high brow and theoretical. It was only when I came to the U.S. to do my Ph.D. that I found out that you could actually use this stuff to help people. I got involved in the Prince William Sound study and I had oil company presidents and Coast Guard admirals listening to what I had to say. I was hooked!

The interesting part to me is that people don't just hear what my model recommends and just do it. The helpful part comes when I build the model with them and it helps them understand the problems they are facing. The process really changes their mental models and provides those light-bulb moments. We also deal with groups of stakeholders such as oil companies and environmentalists who start the study with significant disagreements. The modeling process and the improved understanding often give them common ground and allow a better dialogue. It doesn't always work, but it is very satisfying when it does.

You primarily employ a technique known as Bayesian statistics for formulation of the statistical models you develop. What is it and what does it offer that other techniques in your field do not?

Merrick: When making decisions, you need a best guess (an estimate) of how good or bad a given choice might be, but you also need to know the confidence in that guess (the remaining uncertainty). Classical statistics takes in data and gives you an estimate. Bayesian statistics gives you an estimate too, but it also tells you the level of remaining uncertainty. When dealing with oil spills and terrorist attacks, you need to know how confident you should be in a model's recommendations. Is there sufficient evidence for action? Or should you gather more data and refine the model before you act?

What do you hope to learn through your research?

Merrick: I am currently working on a study in Washington state for the Makah tribal council and the Puget Sound Partnership. A report from this study was read by officials in the White House and ultimately helped the Makah obtain some federal funding to increase their ability to respond to oil spills. This also helps their economy and provides jobs.

After our work in Prince William Sound, Alaska, they used our study to justify buying new escort tugs ($30 million), they redesigned their tug response system that saves disabled vessels and they went to the International Maritime Organization and got the traffic lanes changed to reduce the chance of vessels running aground. I find it very satisfying when the work I am involved in is actually useful.

Moving forward, where do you see your research field headed?

Merrick: My latest grant supports research for improving methods for making counter-terrorism decisions. The goal is to help the U.S. government make better decisions, and we optimize their choices using computational techniques. We determine how they should make their decisions. However, you also have to model the terrorists' decisions—how they adapt as we defend against them. Existing approaches assume that the terrorists are also optimizing their choices perfectly, but psychologists have shown people don't make such perfect decisions. They have developed methods to find the decisions that people do make, instead of the decisions they should make. So I am working with my Ph.D. students to develop methods to determine the decisions the US government should make by taking into account the decisions that the terrorists do make. It's a lot harder than it sounds!

What is it you want your students to walk away with?

Merrick: I try to teach my Ph.D. students the usual things: how to do research, how to get published, etc. I also try to teach them how to make it useful. It could be that the research is useful to other researchers in our field. It could be that the research is useful to people in other research fields. I think it is most enjoyable when it is useful to people in the real world. But in the end, I hope my students walk away with a job and a career that they enjoy.

What advice do you have for students looking to enter the research field?

Merrick: First, find a topic that you enjoy, but make sure it is useful to other people. Second, choose your adviser carefully. You want an adviser that is very research active, but some people are productive when they are left alone to do their thing. You want an adviser who really enjoys the interaction with students on research. You want an adviser that really cares about your outcome, not just how you can help their research.

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