MITRE'S CENTER FOR DATA-DRIVEN POLICY

THE SCIENCE AND ART OF MODELS – PRACTICAL INFORMATION FOR DATA-DRIVEN DECISIONS

By Charles Worrell, Jim Cook, and Justin Lyon

The COVID-19 pandemic is one of the most complex global crises in generations. The impact on public health and the economy is still unfolding around the world—and probably will be for years to come.

From viruses to natural disasters, mass migration, war, and terrorism, leaders across government and industry must frequently make decisions based on incomplete or conflicting data, and on models with varying maturity, precision, or unclear underlying assumptions.

But instead of dismissing the value of models because some are imperfect, or ignoring the data because of the inherent variability, leaders from government, industry, academia, think tanks, nonprofits, and research organizations can do more to collaborate and integrate "ensembles" of models to help inform decision-making—at a time when there are no easy answers. While the benefits of such a coalition will go beyond the pandemic, the need is particularly clear now.

Data-Driven Decisions

Efforts to make evidence-based decisions depend on access to reliable data, trusted forecasts, and credible analysis in line with the objectives of the Information Quality Act, Office of Management and Budget Memorandum to agencies M-19-15 (April 24, 2019).

Modeling Across Multiple Domains

Models are abstract representations of a problem domain that can be used to facilitate analysis and decision-making. Some models are instrumented with simulation tools that can generate detailed data that approximate aspects of the situation under study and possible future states.

Some problems require analysis across multiple domains and are best understood by examining models from multiple disciplines. For example, to understand the impacts of an epidemic on a country, leaders need a consolidated view of factors, such as:

- The spread of an infectious disease, from virologists
- The effectiveness of containment strategies, from epidemiologists
- The financial impacts of containment measures, from economists
- Trends in public sentiment, from sociologists

Good decisions need to be informed by all these considerations, as well as the cause-and-effect relationships and interdependencies that exist between them. Consolidated views of detailed data from models of all these domains can help leaders to perform a composite analysis that optimizes outcomes. But detailed consolidated views are hard to come by.

Decision-makers and analysts both will understandably tend to favor techniques based on their academic or professional backgrounds, which will often introduce biases into analysis. These factors combine to increase the challenge of making sound decisions and building consensus in difficult times.

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Accounting for Disagreements

COVID-19 has sickened millions of people, shut down cities, closed borders, and prompted an unprecedented global response with severe economic and health consequences. Public- and private-sector leaders have turned to a variety of experts in an effort to anticipate what will happen next and whether their planned responses will produce good outcomes.

Models and simulations are important tools in that effort, but they are sometimes difficult to interpret. Not all experts agree with each other. Not all models reflect the same aspects of the problem. And of course, some of the forecasts are updated to reflect changing conditions on the ground and issue different estimates at different points in the crisis.

Although not always obvious, these sources of disagreement can be managed. The confusion that arises from the absence of that management often results in proclamations that the models were "wrong." We heard similar declarations during the 2008 financial crisis, and for similar reasons. These sources of disagreement originate from the analytic methods we use, and they can be managed with analytic methods available to us.

Decisions made during the current crisis will determine our future for decades. Many experts are understandably focused on a single discipline, supported by models that do not fully account for the cross-domain effects of policy responses. For example, an infectious disease model developed by epidemiologists to inform decisions about containment strategies may not best represent the resulting effects on the economy or on public sentiment. The intricate decisions that leaders face require consolidated views of data from many disparate sources.

> While the costs of trial and error in the real world are high, integrated "ensemble" models and simulations can save lives by estimating the impact of alternate courses of action in a safe, virtual environment.

The Value of Composite Models

The magnitude of our losses from the pandemic can be minimized, but good solutions to this problem involve a complex interplay between:

- Public health
- Government policy
- Fiscal constraints
- Material resources
- Commercial activity
- Financial markets
- Public confidence

As leaders consider potential courses of action, they are forced to weigh the associated tradeoffs and risks. The determination of likely outcomes is too interwoven to calculate easily, and the costs of trial and error in the real world are too high. However, experimentation through trial and error can be achieved through simulation. And composite models can facilitate successful outcomes.

Now more than ever, decision-makers need support from tools like:

- Modeling and simulation
- Data management
- Data visualization

Although they usually occur on a different scale, the same challenges—and opportunities—exist in industry. Running well-managed simulations of models that represent the forecasts of multiple experts can provide leaders a deeper understanding of the implications of any given course of action, or of taking no action at all. With simulations, it becomes possible to examine the impact of every available course of action and generate insights into their possible resulting future states.

Lessons Learned Through Experience

Leaders with experience using simulations in the decision process are selective about how they apply different models. Some models are used to produce estimates of future conditions, or forecasts, while some are just used to confirm a decision-maker's intuition. Models can be used to identify the extreme boundaries (worst/best case) of an event's possible outcomes. Some can help develop intuition about situations not previously encountered, while some can be used to compare the expected outcomes from alternate courses of action.

Experience in facilitating complex decisions using models makes a few things clear:

- Bringing multiple voices with a diversity of opinions to the table yields tremendous benefits. It can avoid unintended consequences and result in more resilient solutions.
- Gaining visibility into the assumptions behind a conclusion leads to deeper understanding. It can avoid miscommunication and help build consensus among stakeholders.
- Deliberate consideration of the full range of potential actions and outcomes leads to better decisions. When all alternatives have been examined, it is often easier to recognize the strongest options, even if imperfect.
- Building fact-based consensus across stakeholders results in greater resilience and better execution. Results tend to stick better when everyone works together.
- Ready access to reliable data and trusted forecasts is vital to navigating dynamic problem sets. Missing or distorted information leads to poor decisions and poor outcomes.

Current Risks

Our traditional way of working, with distributed centers of excellence that develop analytic approaches independently and then compete for attention, brings some unintended consequences. Current practices result in key data and forecasts being dispersed among disparate (sometimes competing) institutions that may not be familiar to each other and may not all be accessible to decision-makers.

A proliferation of standards and protocols often makes it difficult to quickly combine needed inputs from separate teams of analysts, leading to delays, unexpected costs, and confusion when those experts are called upon to come together. Additionally, credibility and trust between institutions is sometimes lacking, which can prevent effective communication and collaboration.

Leverage the Power of Partnerships – National M&S Consortium

Government and industry leaders regularly make complex, multi-faceted decisions with major consequences. To meet their challenges, they must equip themselves with tools equal to the task and work in new partnerships to not just measure but predict the impact of interdependent actions. This new model for partnership would involve:

- Government-sponsored creation of an open and accessible modeling and analysis "consortium" that operates in the public interest to bring together different models and data, convening disparate parties to provide objective assessments with an unbiased comparison of conflicting forecasts. The Information Sharing and Analysis Center (ISAC) model is a particularly relevant construct to meet this need. Sponsorship of this new ISAC, the "M&S ISAC," could be a combined effort for the Office of Science and Technology Policy (OSTP) and the National Science Foundation (NSF).
- Proactive development, integration, maturation, and evaluation of new models and data for current and emerging challenges. Essentially, the M&S ISAC serves as a "data SWAT team," pivoting to new problems as the need arises and developing new ways of measuring and predicting events and simulating different scenarios to proactively inform leaders and responders.
- Inputs and data from relevant experts in government, industry, and academia, as required for the task at hand. Incentives for participants would include access to new sources of data, and the opportunity to see their anonymized models baselined against those from their peers.

- Agile creation of visualizations of many trusted forecasts with traceability provided to the underlying data and assumptions, allowing for a fuller understanding of what the community of experts has to say.
- A data-driven consensus view of the tradeoffs involved with each of the available courses of action.
- An unbiased, trusted third party to coordinate or operate the consortium or ISAC free from conflicts of interest, with the ability to protect any intellectual property and proprietary or sensitive data that might be required for the analysis.

Benefits to be Realized

Many benefits exist to maintaining this sort of capability:

- Reliable data, trusted forecasts, and credible analysis will be available to support complex decisions, both in the regular course of business and at times of crisis.
- Advanced tools for decision support will become more accessible to leaders. Better access to expertise will be achieved using an extended community of collaborators, and better access to insights will be achieved through the expert use of curated visualizations.
- Effective use of models and scenario-based simulations will reduce the unknowns and enable data-driven decisions. The ability to accurately forecast during disruptions will increase stability and reduce economic risk.
- Stakeholder biases will be managed by providing transparency into data and methods, allowing leaders from all backgrounds to better understand the insights provided through unfamiliar methods.
- Conflicting and ambiguous analyses will be managed by providing visibility into underlying assumptions and developing composite views of likely outcomes that reveal the true drivers of the resulting conflicts.
- Shared access to reliable data and analysis will lead to easier consensus and increased resilience, both among leaders and affected communities. Improved transparency and reproducibility of analyses will lead to increased public trust in the decision-makers.
- Tradeoffs between problem domains will be made more explicit, allowing experts from different fields (e.g., medical, economic, and legal) to address problems with more similar language and metrics.

Responding to Real-World Problems

Creation of a modeling and analysis consortium will help prepare leaders and policymakers for the next crisis. Decision-makers will benefit from access to repeatable methods and from confidence that they can support their decisions with quantitative data. The consortium will bring the world's best experts and best information to bear on society's biggest problems, and stakeholder communities will be better served with increased transparency and fairness.

Perhaps most importantly, many unintended consequences will be avoided through the foresight that comes with the capacity to "look ahead" with rigorous simulations and sound expert analysis.

Justin Lyon is a leading expert in agent-based simulation and artificial intelligence. He has worked with business, government and civic organizations around the world. He is currently CEO of Simudyne, a London-based simulation technology company.

For more information about this paper or the Center for Data-Driven Policy, contact us at policy@mitre.org

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