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# Analytics

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# Welcome to *Analytics*

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— GARY BENNETT, *Director of Marketing, INFORMS*

# Data-Driven Decision-Making

In the good old days, many "savvy" corporate CEOs and other assorted head honchos in the public and private sector routinely made critical decisions by the seat of their pants. They relied on their experience, their intuition and their "gut" to determine a course of action that could make or break the organization. Sometimes they were right, sometimes they were wrong, and sometimes the organization went down the drain.

Today, more and more of these C-level decision-makers are turning to analytics for help in the decision-making process. The stakes are just too high and the competition is just too fierce to rely on your "gut." Instead of shouting, "show me the money," savvy CEOs are now shouting, "show me the data and the mathematical analysis first . . . and then I'll show our shareholders the money."

The trend toward data-based decision-making is being driven, of course, by astronomical increases in data, mathematical modeling capabilities and computing power. Thomas Davenport and Jeanne Harris crystallized this phenomenon in their recent book, "Competing on Analytics: The New Science of Winning" (2007, Harvard Business School Press). Davenport and Harris define analytics as "the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions." That encompasses the work of hundreds of thousands if not millions of "analysts" of all stripes around the world.

Which brings us to the online publication you now have opened on your computer. *Analytics* is designed to inform, enlighten, inspire and, yes, even entertain analysts everywhere while bringing them together in an electronic sense to share successes, failures and lessons learned. *Analytics* will also strive to promote the analytical profession and the people who preach and practice it.

Most of the articles in this debut issue were drawn from *OR/MS Today* (www.lionhrtpub.com/ORMS.shtml), the magazine of membership of INFORMS, so when you see terms like "operations research"(O.R.), think analytics. Although INFORMS officially promotes the "operations research" and "management science" professions, its members represent a galaxy of job titles, scientific fields, technical methodologies and special interest groups.

We could have easily filled this premier issue with supply chain stories from the manufacturing sector or articles on revenue management and crew scheduling from the aviation industry. Instead, we decided to publish a collection of articles that showcase the power and diversity of analytics, from preventing potential terrorist attacks to improving patient care. The problems you encounter and the methodologies and job titles you use may be different, but you now have one thing in common: *Analytics*. **ANALYTICS**

— PETER HORNER, *Editor*



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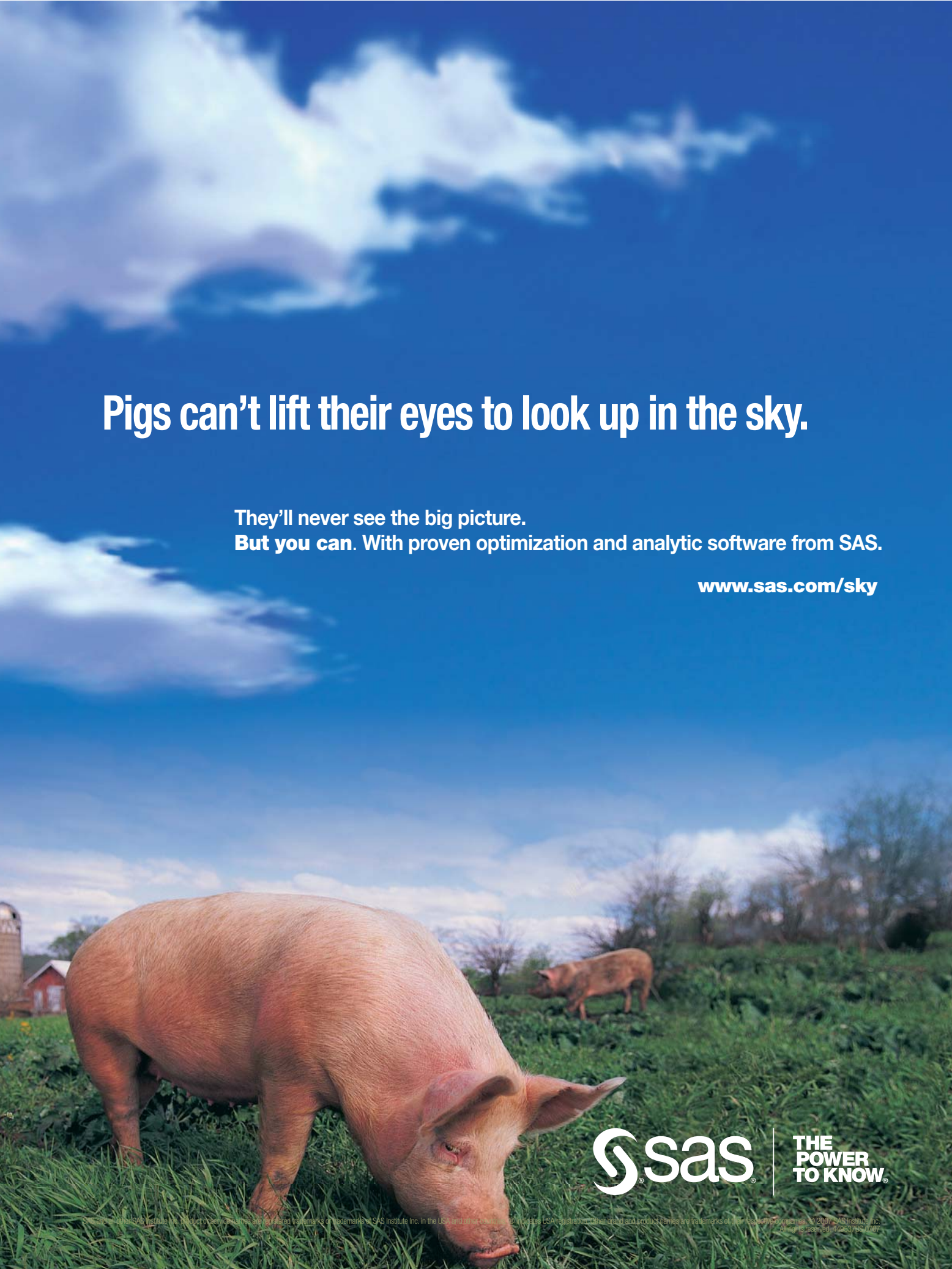

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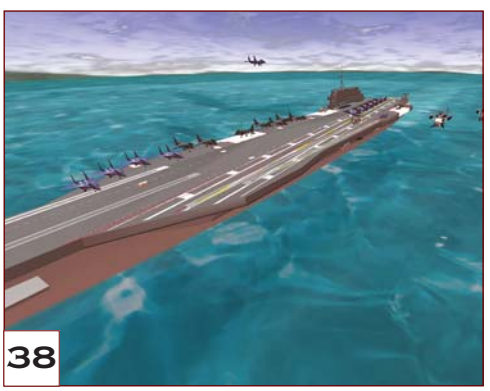


## FEATURES




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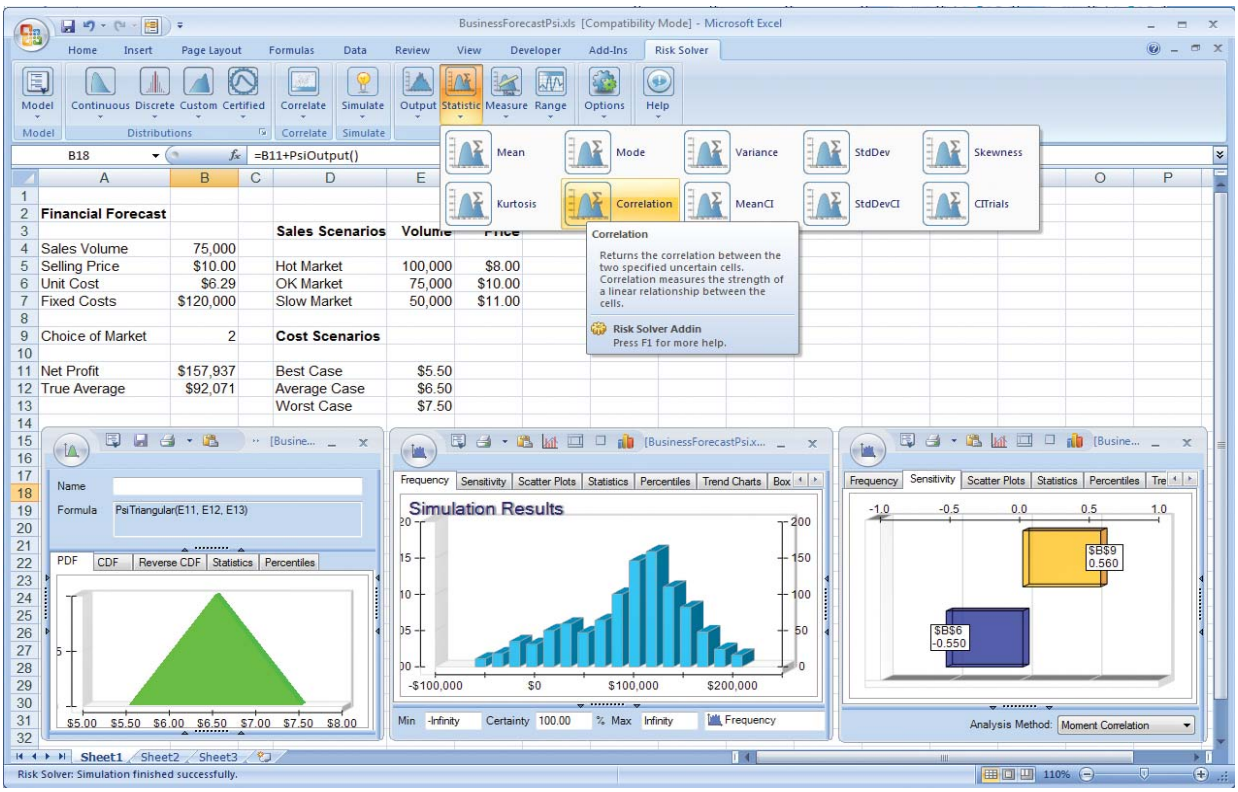


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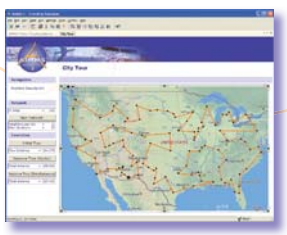

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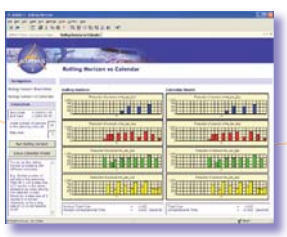

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# Analyzing Decisions to Counter Terrorism

BY RANDOLPH W. HALL

As the defining issue of his presidency, the decision to invade Iraq is without question the most important event of George W. Bush's political career. Had he used decision analysis in making this momentous choice, as proposed in "Should the U.S. Have Attacked Iraq" (*OR/MS Today*, December 2006), perhaps the process would have been more systematic, and perhaps Bush would have found a way to retain public support for his eventual choice. But had he used decision analysis, I hope that Bush would have gone well beyond exploration of the odds that Iraq did or did not possess weapons of mass destruction (WMD), for the success or failure of the mission should certainly not be judged by this question.

WMD is a nebulous term encompassing a range of weapons, some of which are widely available and easy to manufacture, others of which are not particularly destructive compared to conventional weapons. The "weapons" (box cutters and the like) used by the terrorists who perpetrated the 9/11 attacks were so conventional that they could have been purchased at the local grocer, and terrorists in the past have never depended on non-conventional weapons to further their cause. The key question here should not have been whether Iraq possessed WMD, but whether it offered a unique conduit of weapons that would empower terrorists. Were the weapons suspected of being in Iraq unavailable elsewhere? Did Iraq not only possess these weapons, but was it also collaborating with terrorists? Were these weapons so threatening that they substantially added to the danger of catastrophic terrorism?

More important than WMD, the success or failure of the Iraq mission might be judged by a less public argument for the invasion, that of installing a democracy in the center of the richest oil producing region of the world, and a hoped for domino effect influencing the surrounding nations. Here we had a truly visionary goal, but one that was harder to explain to the public than, for instance, the imagery of Secretary Rice's "mushroom cloud" consequence of Iraq's alleged WMD. We also had a considerably more difficult goal to accomplish, one where military action would have been one of many possible tactics and which, in retrospect, was not very effective. In this context, the uncertainty preceding the Iraq invasion was not so much whether WMDs were present, but whether military intervention would bring about long-term stability.

I raise these points to frame the question of how decision analysis might be used to improve our response to terrorism, and to illustrate three challenges: adversarial behavior, interdependencies and politics.

Terrorists are by nature agile and adaptive adversaries; they operate clandestinely and succeed by surprise. They cannot be stopped by protecting individual targets, or by preventing access to any one group of weapons because alternatives will always exist. And history does not provide a very satisfying prediction for the likelihood of future terrorist actions. While it might be noble to envision decision trees that specify the likelihoods of alternative futures, these probabilities are extraordinarily difficult to estimate.

Our strategies for fighting terrorism are highly interdependent because our finite resources are insufficient to protect against all threats. By selecting Iraq for military action, we have made that one part of the war on terrorism our first priority for federal budgeting and allocation of military assets. We have also made it our first priority for the attention of the commander-in-chief, as well as our congressional leaders. Given our limits, the decision to invade Iraq should not be judged just on whether it achieved its mission; it should also be judged on whether Iraq should have been picked over its alternatives, such as addressing the threats posed by Iran or North Korea, or more directly targeting terrorists themselves.

Lastly, the decision to go to war, as with most strategic choices in terrorism, must be placed in its political context. President Bush could not have authorized the invasion without first gaining support from Congress. Reluctantly, he also sought support from the United Nations, and more deliberately he sought active participation from our allies. The steps to convince others to collectively support a choice are in many ways distinct from the steps of making the choice, making it hard to decipher the true goals from past public statements.

All told, it is no easy task to encapsulate the Iraq invasion within a decision tree. Yet decision analysis could have been used to illuminate the question of how best to counter terrorism; to elicit alternative courses of action, anticipate the response of adversaries and specify the goals. Retrospectively, we might look back at the Iraq war and evaluate the decision within the narrow lens of how accurate were our predictions that Iraq possessed WMD. But the decision was considerably more complex, revolving around two complementary goals, one immediate – reducing the threat posed by al-Qaeda – and one long-term – building stability and democracy in the Middle East. And, perhaps most importantly, were we trying to solve the right problem?

As the O.R. community engages in the big challenges of the day, such as how to best counter terrorism, we should not be tempted to squeeze the questions into the framework of our existing models, because the problems may go beyond what we have seen in the past. We should, however, use our skills to stimulate the type of creative thinking envisioned by the 9/11 Commission, in which we reduce the threat of terrorism through better understanding of the motivations and tactics of our adversaries, as well as the available alternatives for reducing the threat. ■ANALYTICS

***Randolph Hall*** *is vice provost for research advancement at the University of Southern California, and was founding principal investigator for CREATE, the Center for Risk and Economic Analysis of Terrorism Events.*

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# The Trouble with ROI

BY VIJAY MEHROTRA

When we left off last time, I had just finished ranting about the first salesperson who came rolling into my presence with a slick return-on-investment model and tried to shove it down our throat in order to somehow close a deal before the close of his fiscal quarter. Sales managers refer to this as "pulling a rabbit out of a hat."

Let's recap a few things about ROI models that this story nicely illustrates.

***It's all about the pronouns.*** This salesman (actually happens to be a male in this example) was basically trying to use his ROI model to justify the purchase of his product to enable him to meet his short-term business goals. Our business, our goals, our priorities, our processes and our risks were all noticeably absent from consideration (note that our costs were specified, though not emphasized).

A couple of things to watch out for here. Many such ROI models purport to be built on your data (for things like labor costs, interest rates and forecasted workload). Dig in further here. How solid is this data? Who within your company has vetted it? How much variability is embedded into it? Moreover, the logic about how this data is used is typically not at all transparent, which leads to our next key point:

***What is the model assuming?*** Most ROI models make extravagant claims about cost savings that are based on very specific logical assumptions. In particular (classic phenomenon), ROI models typically assume that optimization based on forecasted values will be implemented as if this demand is the ordained truth. In contrast, everyone involved with a particular process will be looking closely at their own incentives ("management really looks hard at my labor-to-sales ratio," "I take a huge amount of flack if my on-time percentage is too low," etc.) and will do everything possible to manage their piece of the puzzle, and their localized risk, accordingly. Frankly, given the quality of 99 percent of what people in the business world call "forecasts," you would probably do the same thing if you were in their shoes.

This is a basic, primal phenomenon. Gene Woolsey has talked about this for roughly the last half century (see Woolsey, R. E. D., "Real World Operations Research: The Woolsey Papers," edited by R. L. Hewitt, Lionheart Publishing, 2003). Yet nearly every ROI model I've ever seen ignores it, for the simple reason that it's hard to model well.

***Some key questions.*** Suppose for the moment that with diligent questioning you have managed to understand the crux of the ROI model that has been created. Then you have to ask yourself some fundamental questions:

- How confident are you about the savings and the time needed to achieve them? Because the costs are almost always up-front and definite, and whoever funds this investment will notice that immediately.
- Do you believe the underlying conceptual model? You will have to present it "up" in your organization, both to your management and to finance. They will have a much shorter attention span for the details than you do, so you need to be able to present the core story succinctly. If you don't believe it, you can be sure that they will not either.
- What resources and commitment are needed from which key people or groups to achieve the results that the ROI model claims? Do these people understand what is expected of them? What are their personal motivations to see this project succeed (or fail)? Are any costs associated with these commitments reflected in the ROI model itself?

***Skeptics will abound.*** If you're not skeptical about the ROI model in front of you, either because you believe everything you're told or because you feel that you've dug into it and understand the answers to the above questions, great! But, remember that others who have less invested in the results that the model claims, most notably executives, are likely to be far more suspicious.

There are a number of reasons for this suspicion – overlooked costs, suspicious cause-and-effect relationships, risks associated with execution and all of the things that we've already talked about. Beyond all that, there's also one that we OR types never even think of: Simply saving money, even in the recent economic downturn, is not automatically at the top of the executive agenda. Peter Mayer's recent survey [Meyer, P., 2002, "Is Money the Right Pitch?" *Business and Economic Review,* Vol. 20, No. 3, pgs. 20-22] reinforces well-established ideas (Woolsey again!) that there are in fact different questions that most leaders focus on, such as identifying areas for growth, simplifying business processes and eliminating absurd practices while keeping the machine moving.

To be fair, ROI models have some real virtues, even when presented by salespeople. They are an instrument for structured data collection and business process review, which is often instructive on its own. When your own business processes are far more complex than what the model includes, it may be an opportunity to consider why you do things the way that you do. ROI model results may enable you, through judicious questioning, to learn something about how your competitors are handling similar situations.

But here's the kicker: The people who foist the ROI model upon you are almost never around to deal with the complexities of trying to achieve the results that their model promised would magically appear. The people that you presented the results to almost always are. **ANALYTICS**

***Vijay Mehrotra*** *(drvijay@sfsu.edu) is a faculty member in the Decisions Sciences Group in the College of Business at San Francisco State University and an operations management consultant.*

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# What's an IT Guy Doing at an O.R. Conference?

BY JERRY YANG

The Cisco team learned how to improve efficiency and increase revenues at the 2007 INFORMS Practice Conference.

When I first learned that I was going to the operations research conference held in Vancouver, Canada, last spring, I had been supporting the Cisco Analytical Forecasting Team as an information technology analyst for about eight months. The team's manager had decided to bring along the IT counterparts to the conference since we had been closely collaborating with team members for many months. I did not understand why I was going at first, and it was not until I was at the conference that I realized why I was there. At that time, I had no idea what INFORMS or O.R. was about and was more confused and nervous than curious. I thought, "Are there only going to be business people or statisticians at the conference? Am I going to be the only IT person?" In the end, however, I was very glad that I had gone. Before I jump to why that is, let me start from the beginning and explain how I went from confused to enlightened in a matter of three days.

Before the conference even started, I had a sense that O.R. was more than just analytical forecasting when I looked through the INFORMS Web site and saw the catalog of sessions. "Hmm," I thought, "what are all these companies doing at an operations research conference? Why are there so many delivery companies here? They don't have any inventory, so why would they need to forecast or do any research?" I eventually realized that my mistake was paying too much attention to the words "operations" and "research" individually rather than the combined term, operations research.

On my first day in Vancouver, I attended the morning breakfast before the plenary session. I figured I might as well get acquainted with people from other companies and see what they were doing. I talked to one individual who had been a professor at a prestigious university and who currently works for a big industry. He described what he had been doing and got into some details of how he was using O.R., which was a bit over my head, but I had my first taste of what operations research could be about.

When he asked me what I was doing with O.R., I explained that I was part of the IT support for the analytics team. There was an immediate awkward pause.

The man murmured, "IT?"

I gave him a nervous nod.

"Boy, do I have a few words to say about IT!" the man said angrily.

Thankfully, before he had a chance to start, it was already time for the plenary and I was saved by the bell. I wondered to myself, "Am I in the wrong place right now?" The experience did not deter me from wanting to learn about O.R., however; it ignited more curiosity of what O.R. was really about and made me wonder how IT fit in the whole picture.

The turning point of the conference was when the sessions started. I sat through all the sessions that I thought could pertain to learning what O.R. was all about, as well as sessions that sparked an interest in me. For example, I attended the "Sports and O.R." session, where they used an O.R. tool to optimize the lineup of different sports teams. With O.R., you can not only optimize the lineup, but also find the flaws of a non-O.R. lineup and justify changing it. The presenter used a graphical user interface to do all these calculations, and I thought, "Hey this is probably where I would be useful. They would definitely need IT to set up and support the application!"

These sessions convinced me that O.R. is extremely important, and that IT needs to be involved to help execute and support the applications in those situations.

I also attended the sessions on how O.R. can be used by the military for combat situations, hospitals for ambulance dispatching and UPS for optimizing delivery routes (got my answer on how a service provider company would use O.R.!). These sessions convinced me that O.R. is extremely important, and that IT needs to be involved to help execute and support the applications

in those situations. In addition, I was tremendously glad that my own company is heading toward that direction and agrees that the use of O.R. for analytics is critical to our success.

For me, the most useful and most enlightening part of the O.R. conference was participating in the Birds-of-a-Feather discussion group. The session I attended was "Optimizing the Relationship between IT and ORMS."

Of course, I was very nervous given my experience at breakfast earlier in the day. But in this session, I was able to discuss issues that people are confronting: in particular, issues that O.R. professionals have encountered when they work with IT. I got a sense that O.R. professionals realize the need for IT since many applications need IT support in planning and execution, but many challenges must be addressed. The main challenge that was discussed in this session was the quest for an "end state," or a freeze in the requirements. In practice, IT always needs an "end state" to the requirements of a project in order to start the development and testing process. However, in O.R. there is never a true "end state," since O.R. is constantly changing to find the most optimal model. By nature, this is a cause of conflict and frustration between O.R. and IT.

Another interesting topic was whether it is better to use an "out-of-the-box" application as the solution to an O.R. problem or to use an "in-house" customized tool created by the IT staff. O.R. professionals, in general, are not fond of an out-of-the-box solution because the implementation is slower and because most vendors create a "one application fits all" product that hasn't been optimized for O.R.'s specific needs. So O.R. professionals tend to be bigger fans of a customized solution. From an IT perspective, we like an out-of-the-box solution because we do not want to reinvent the wheel. If it is on the market already, then more than likely the product is a stable and popular tool that has been well tested and has support from the vendor to help its integration with our existing systems. I was able to discuss the IT's point of view. I think a few of the O.R. professionals at the discussion got a good understanding of how IT staff felt about this, and I got a good understanding of the O.R. perspective.

In the end, we decided that there is no one answer to these differences between IT and O.R. We realized that a compromise has to be made to fulfill each other's needs and that collaboration is the key to success. Overall, this discussion was definitely worthwhile, and I hope that some O.R. professionals will more actively involve their IT partners in their projects. I also hope that INFORMS continues to have discussions that involve O.R. and IT in future conferences.

By the end of the conference, I became more knowledgeable in the capabilities of O.R. and its potential impact on society through the way it affects how a company operates and the solutions it creates. I realize that having O.R. can not only have a significant impact on the company, but can also be applied in any every field of work where a decision needs to be made or where an area can benefit by optimization. I would strongly recommend that all companies consider bringing their IT partners to the INFORMS conference to help them learn the importance of O.R. and the significant impact O.R. has on the company. In the end, if IT team members know the importance of what O.R. is doing, they are more likely to work harder to see the success of any O.R. application and projects. That will reduce the headaches and sleepless nights worrying about whether IT will be on the same page with the O.R. team. I would love to go to the INFORMS Practice Conference again next year to see more of the results of some of the groups and many more applications of O.R. and how IT played a role in their success. It would be fascinating to see what kind of results came from the sessions that I attended this year and what progress companies have made using O.R. **ANALYTICS**

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**EDITOR'S NOTE:**

The 2008 INFORMS Practice Conference (www.informs.org/Conf/Practice08), which will focus on the competitive advantage of analytics, will be held April 13-15 in Baltimore. A preview of the conference appears on page 42.

## ANALYTICS... in the News

### P&G'S WEGRYN ADDRESSES ANALYTICS CONFERENCE

**Procter & Gamble's Glenn Wegryn, speaking at the recent CFO Performance Analytics Conference in San Francisco, covered the spectrum of analysis methods in use across the company. Wegryn, the associate director of Product Supply Analytics, provided rationale for the growing need for analytics in business to stay competitive by managing increasing complexity, leveraging the exploding creation and availability of data, better understanding shifting customer markets, and smarter cost and cash management.**

**"One of the most important contributions of analytics is the ability to focus on what needs to be decided, then harnessing the right advanced analysis tools and information to evaluate a wide spectrum of options efficiently, leading to the right course of action to take," Wegryn said.**

**Wegryn went on to describe how analytics is managed within P&G's shared services organization, enabling availability of the service to all business units and flowing the right resources at the right time, enabling faster, more informed decisions by executive clients at the company.**

**"We focus our skilled analytic resources on the highest-value decisions, keeping to the strategic high-ground," Wegryn added. "This enables an extremely high return on investment for the company."**

**Wegryn concluded with insights on how analytics changes the competitive playing field both inside the company and with external partners by improving operations and relationships with P&G's suppliers, service vendors and customers.**


# Making Skies Safer

## Applying analytics to aviation passenger prescreening systems.

By Laura A. McLay, Sheldon H. Jacobson and John E. Kobza

*Images Courtesy of Dreamstime.com*
*Top left: Fred Goldstein; Main image: Elena Ray*

**THE TERRORIST EVENTS ON SEPT. 11, 2001, WILL FOREVER ALTER THE WAY OUR NATION VIEWS AVIATION SECURITY.** The article by Barnett (2001) in *OR/MS Today* highlighted numerous important questions and issues surrounding the events of that day and how air travel has been and will continue to be affected. Since then, aviation security systems have undergone significant changes, though the analysis of such systems continues to lag well behind their actual operation. Operations research provides a unique set of methodologies and tools for designing and analyzing aviation security systems, since the foundation of operations research is based on applying analytical methods to optimally allocate and use scarce assets in making better informed decisions.

The purpose of this article is to provide a brief survey of aviation security system applications that have been used or are well positioned to benefit from operations research modeling and analysis techniques. The research efforts discussed apply operations research methodologies to address problems in the area of passenger prescreening, an important and highly visible aspect of aviation security operations. Three specific issues are highlighted: identifying performance measures, analyzing how passenger prescreening systems can fail or succeed, and designing effective passenger screening systems.

Over the past several years, there have been numerous changes to all aspects of aviation security systems, all designed to prevent a reoccurrence of the events on Sept. 11, 2001. Some of the changes include reinforcing cockpit doors, expanding the federal air marshal program, allowing only ticketed passengers to enter the enplane side of airport terminals, using bomb-sniffing dogs and screening all checked baggage for explosives.

Many of the changes implemented have been politically driven – they have been a direct result of the "kneejerk" emotional response to Sept. 11, rather than from any coordinated, systematic analysis and planning. For example, within two months after the attacks, the United States Congress mandated 100-percent screening of checked baggage by a federally certified screening device or procedure by Dec. 31, 2002, as part of the Aviation and Transportation Security Act. Prior to Sept. 11, only a small fraction of checked baggage was screened in this manner. The rapid deployment of explosive detection devices in order to meet this deadline resulted in several billion dollars being invested before any type of systematic analysis of baggage screening security systems was performed. Operations research provides methodologies that can be used to determine how taxpayer dollars can be optimally spent and how security system assets can be optimally used.

### Passenger Screening and Prescreening

THERE ARE TWO basic approaches to passenger screening: uniform screening and selective screening. From the introduction of passenger screening in the early 1970s until 1998, a *uniform screening* strategy was used, whereby all passengers were screened in the same manner. During this period, passengers were screened by X-ray machines, and their carry-on baggage was screened by metal detectors. The main argument for uniform screening is that all passengers should receive the highest level of screening since anyone could pose a threat. In contrast, a *selective screening* strategy targets additional security resources on a few passengers perceived as being of higher risk. The main argument for selective screening is that directing expensive security assets toward fewer passengers may be more cost-effective since most passengers do not pose a threat to the system.

Passenger screening systems can be designed to detect *items* that are a threat or *passengers* who are a threat. Through the use of X-ray machines and metal detectors, the passenger screening systems currently being used in the United States focused on detecting items that are a threat. Although this does not prevent terrorists from boarding airplanes, detecting threat items removes the tools that can be used to stage an attack. The Transportation Security Administration (TSA) has pursued the notion of detecting passengers who are a threat by coupling selective screening systems with a *passenger prescreening system,* an automated computer system that performs a risk assessment of each passenger prior to their arrival at the airport. If such a system is used, how the passengers are screened at the airport is a function of their assessed risk.

In 1998, a selective screening system was implemented that used a computer-aided passenger prescreening system (CAPPS) that selected passengers for additional screening. CAPPS was designed to eradicate human bias in the risk assessment decision-making process. Those passengers who were cleared of being a security risk were labeled *nonselectees,* while those who could not be cleared of being a security risk were labeled *selectees.* The main screening difference between these two classes of passengers is that checked bags of selectees were screened for explosives. Although the exact information used by CAPPS is classified, reports in the popular press indicate that it used information provided at the point of ticket purchase, including demographic and flight information, frequent flyer status of the passenger, and how the passenger purchased their ticket.

CAPPS has been in use since 1998. After Sept. 11, aviation security moved in the direction of uniform screening with the enactment into law of the 100-percent checked baggage screening mandate, which eliminated the distinction between selectees and nonselectees. The TSA revisited selective screening policies through the development of CAPPS II, a refinement of CAPPS. However, on July 14, 2004, the TSA announced that CAPPS II would not be implemented due to privacy concerns, despite having invested $100 million in its development. Shortly thereafter, the TSA announced plans to replace CAPPS II with *Secure Flight,* a passenger prescreening system akin to CAPPS II, which partitions passengers into three risk classes: selectees, nonselectees and a third class of passengers who are not allowed to fly. This third group is extremely small and is, in part, based on FBI watchlists.

Cost-benefit analyses of different baggage screening strategies provide a method of assessing and comparing the value of such approaches. Virta et al. (2003) perform an economic analysis capturing the tradeoffs of using explosive detection systems (EDSs) to screen only selectee baggage versus screening both selectee and nonselectee baggage (i.e., the 100-percent baggage screening mandate). They conclude that the marginal increase in security per dollar spent is significantly lower for the 100-percent baggage-screening mandate than when only selectee bags are screened. Jacobson et al. (2005) incorporate deterrence into this model (one of the indirect benefits of screening both selectee and nonselectee baggage), based on a remark by the inspector general of the United States Department of Transportation, and conclude that the cost effectiveness of

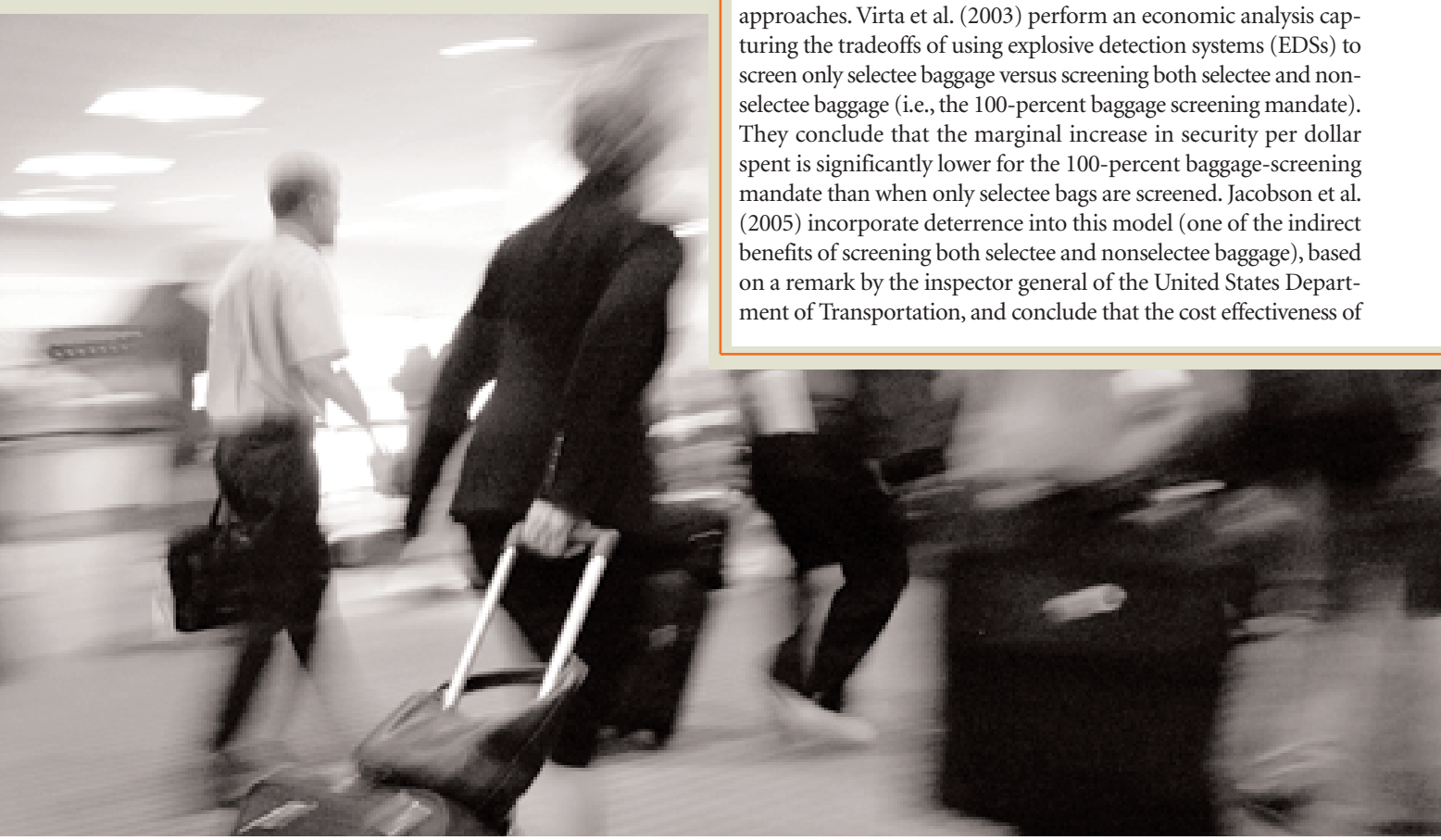

Image provided by Youssouf Cader | Agency: Dreamstime.com

the 100-percent baggage screening mandate depends on the degree to which it can reduce the underlying threat level.

Barnett et al. (2001) perform a large-scale experiment at several commercial airports in the United States to estimate the costs and disruptions associated with a positive passenger baggage matching policy (PPBM). Under PPBM, unaccompanied checked baggage is removed from aircraft on originating flights. PPBM can be applied to all or a portion of checked baggage. The findings of Barnett et al. (2001) counter predictions by the airlines that using PPBM would be expensive and result in widespread delays when used on all checked baggage. They found that on average, one in seven flights experienced a delay, with each such delay averaging approximately seven minutes.

### Identifying Performance Measures

BASED ON THE NUMBER of aviation security changes that have been implemented since Sept. 11, 2001, and the fierce political and public debate surrounding these changes, it has become apparent that it is a challenge to define what good aviation security is. Identifying performance measures of interest is not only important for long-term planning of security systems, but also for efficiently managing day-to-day operations and effectively managing security systems in transition. These performance measures can be incorporated into various types of passenger screening problems, including applications in discrete optimization models, applied probability models, cost benefit analyses and risk assessments.

Since Sept. 11, 2001, much of the interest in passenger screening systems has been limited to reducing the false clear rate – the conditional probability that there is no alarm response for a threat passenger or bag. An alternative is to reduce the false alarm rate – the conditional probability that there is an alarm response for a nonthreat passenger or bag. The false clear and false alarm rates cannot be simultaneously minimized (Kobza and Jacobson 1997). For example, if all passengers were allowed to board their flights with no screening, the false alarm rate would be 0 percent while the false clear rate would be 100 percent.

Since the vast majority of passengers are not threats, most alarms are in fact false alarms. A system with a low false clear rate may have a large false alarm rate, which can be very expensive, since there must be secondary screening procedures in place to resolve such alarms. In rare cases, the bomb squad must inspect a suspect bag or an airport terminal must be shut down for several hours, resulting in millions of dollars in losses to the airlines for a single false alarm incident.

Other performance measures deal with passenger screening systems in transition. When CAPPS was used to determine which checked baggage was screened for explosives between 1998 and 2001, there was an insufficient number of baggage screening devices available in many of the nation's airports to screen all selectee bags for explosives. This partial baggage-screening problem has not been made obsolete by the 100-percent baggage-screening mandate following Sept. 11. It models any such scenario when a new screening technology has been partially deployed and is used under a selective screening system and, because of limited capacity, not all selectees can be screened by the new technology. These performance measures focus on the types of risk that can be reduced by a single screening technology or a series of screening devices working together in a system. There may be other types of risks on a flight that are not considered by these performance measures.

Fully utilizing baggage-screening devices is one possible performance measure for the partial baggage-screening problem. Intuitively, it is equally desirable to screen additional checked bags such that the new screening devices are being used up to their capacity. Jacobson et al. (2003) introduce two alternate performance measures that capture risk across a set of flights and incorporate them into discrete optimization models. The measures are considered for a set of flights carrying both selectee and nonselectee baggage. A flight is said to be *covered* if all the selectee bags on it have been screened and cleared. One measure considers the total number of covered flights. Optimizing over this measure minimizes the number of flights that may be subject to a particular risk. Another measure considers the total number of passengers on covered

**A weakness of any selective screening system is that it may be possible to game it through extensive trial-and-error sampling.**

flights. Optimizing over this measure minimizes the total number of passengers on flights that may be subject to a particular risk. Note that by optimizing over these measures, the utilization of the baggage screening devices is indirectly maximized, though depending on which measure is chosen, the security of the system can be determined to be optimal in two distinct ways, putting either fewer flights at risk or fewer passengers at risk.

### Analyzing Selective Passenger Screening Systems

AVIATION SECURITY professionals have expressed concern over the actual effectiveness of selective screening systems like Secure Flight in preventing attacks, given the variety of ways in which such systems can fail. Three research efforts are highlighted to illustrate how operations research tools such as risk analysis, algorithm design and applied probability can be used to analyze the flaws in selective screening systems.

A weakness of any selective screening system is that it may be possible to game it through extensive trial-and-error sampling. At present, passengers are aware of whether they have been classified as selectees or nonselectees each time they travel (most notably, by an indicator on their boarding pass, as well as by the additional screening attention they receive at the security checkpoint.) Terrorists can exploit this information to determine how they are most likely to be classified as nonselectees by flying on a number of flights and effectively sampling the characteristics that result in a nonselectee classification. Therefore, terrorists do not need to understand how the prescreening system works; they merely need to be able to manipulate the prescreening system to get the desired result (i.e., be classified as nonselectees). Chakrabarti and Strauss (2002) present this strategy as the "Carnival Booth" algorithm, which demonstrates how a system using prescreening may be less secure than systems that employ random searches.

Another weakness of any selective screening system is its dependence on passenger information to accurately assess passenger risk. The specific details underlying the currently used selective screening system are classified. Moreover, it is not clear how such a system will correctly identify terrorists as selectees when compared to random screening. It is also a challenge to accurately assess whether a selective screening system has been effective, since terrorist attacks are rare events, and how terrorists behaved in the past may not be predictive of how terrorists will behave in the future.

Barnett (2004) uses risk analysis, applied probability and data mining to analyze these issues regarding prescreening systems. He concludes that using a prescreening system such as Secure Flight may improve aviation security under a particular set of circumstances, namely, if it does not reduce the screening intensity for nonselectee passengers, if it increases the screening intensity for selectees, and if the fraction of passengers identified as selectees does not decrease. For all these reasons, Barnett (2004) recommends that Secure Flight be transitioned from a security centerpiece to one of many components in future aviation security systems.

The TSA developed the Registered Traveler Program to use in conjunction with Secure Flight. The program is designed to avoid "wasting" security resources on extremely low-risk passengers. To enroll in the Registered Traveler Program, a passenger must pass a voluntary background check and submit biometric information for identity verification when traveling. Once part of the program, these passengers undergo expedited screening in designated security lanes. Barnett (2003) outlines several potential problems with such a program, and suggests that in the worst-case scenario, the Registered Traveler Program improves screening efficiency without improving the ability to positively identify terrorists. The Registered Traveler Program pilot program is currently being tested at airports throughout the United States.

These weaknesses of selective screening systems raise the question of whether to spend security dollars on improving intelligence or on building more effective screening technologies. McLay et al. (2005c) explore this issue by performing a cost-benefit analysis using concepts from applied probability and optimization. In their analysis, more effective (though more expensive) screening technologies are considered for screening selectee baggage, given a range of accuracy levels for a prescreening system in assessing passenger risk. Several selective screening scenarios are identified that are preferable to screening all passenger baggage with explosive detection systems (EDSs), by reducing the number of successful attacks with moderate cost increases. They conclude that the accuracy of the prescreening system is more critical for reducing

**Should security dollars be spent on improving intelligence or on building more effective screening technologies?**


REFERENCES

1. A. Barnett, R. W. Shumsky, M. Hansen, A. Odoni, and G. Gosling, 2001, "Safe at Home? An Experiment in Domestic Airline Security," *Operations Research,* Vol. 49, pgs. 181-195.
2. A. Barnett, 2001, "The Worst Day Ever," *OR/MS Today,* Vol. 28, No. 6, pgs. 28-31.
3. A. Barnett, 2003, "Trust No One at the Airport," *OR/MS Today,* Vol. 30, No. 1, pg. 72.
4. A. Barnett, 2004, "CAPPS II: The Foundation of Aviation Security?" *Risk Analysis,* Vol. 24, pgs. 909-916.
5. V. Butler and R. W. Poole Jr., 2002, "Rethinking Checked-Baggage Screening,'' Reason Public Policy Institute, Policy Study No. 297, Los Angeles, Calif.
6. S. Chakrabarti and A. Strauss, 2002, "Carnival Booth: An Algorithm for Defeating the Computer-Aided Passenger Screening System," *First Monday* 7, www.firstmonday.org.
7. S. H. Jacobson, J. E. Virta, J. M. Bowman, J. E. Kobza, and J. J., Nestor, 2003, "Modeling Aviation Baggage Screening Security Systems: A Case Study," *IIE Transactions,* Vol. 35, pgs. 259-269.
8. S. H. Jacobson, T. Karnani, and J. E. Kobza, 2005, "Assessing the Impact of Deterrence on Aviation Checked Baggage Screening Strategies," *International Journal of Risk Assessment & Management,* Vol. 5, No. 1, pgs. 1-15.
9. J. E. Kobza and S. H. Jacobson, 1997, "Probability Models for Access Security System Architectures," *Journal of the Operational Research Society,* Vol. 48, pgs. 255-263.
10. L. A. McLay, S. H. Jacobson, and J. E. Kobza, 2005(a), "A Multilevel Passenger Prescreening Problem for Aviation Security," Technical Report, University of Illinois, Urbana, Ill.
11. L. A. McLay, S. H. Jacobson, and J. E. Kobza, 2005(b), "Integer Programming Models and Analysis for a Multilevel Passenger Screening Problem," Technical Report, University of Illinois, Urbana, Ill.
12. L. A. McLay, S. H. Jacobson, and J. E. Kobza, 2005(c), "When is Selective Screening Effective for Aviation Security?" Technical Report, University of Illinois, Urbana, Ill.
13. J. E. Virta, S. H. Jacobson, and J. E. Kobza, 2003, "Analyzing the cost of Screening Selectee and Non-selectee Baggage," *Risk Analysis,* Vol. 23, No. 5, pgs. 897-908.

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the number of successful attacks than the effectiveness of the baggage screening devices used to screen selectee baggage when the proportion of the passengers classified as selectees is small.

## Designing Effective Selective Passenger Screening Systems

PROHIBITIVE COSTS, long security lines and questionable effectiveness in preventing attacks have impeded passenger screening initiatives. Significant infrastructure changes have been made at several airports to accommodate new screening devices, and passengers have been subjected to long lines in airport lobbies awaiting screening. Passenger screening system designs must consider the potential impact of cost, space, throughput and effectiveness. Three research efforts are highlighted that use operations research methodologies to design selective screening systems.

One solution to this situation focuses on designing *multilevel* passenger prescreening systems. Multilevel systems are those in which an arbitrary number of classes for screening passengers are considered, rather than the two classes (i.e., selectees and nonselectees) currently being used. A class is a set of procedures using security devices for screening passengers. The nonselectee class, for example, may screen checked baggage with EDSs, passengers with X-ray machines and carry-on baggage with metal detectors.

One way to improve selective screening systems is to use expensive baggage screening technologies with low throughput to screen passengers perceived as higher-risk. This has the potential to be a more cost-effective approach to screen passengers primarily by increasing throughput. Butler and Poole (2002) design a layered approach to screening passengers and baggage instead of the existing TSA policy of 100-percent checked baggage screening using EDSs by considering the economic impact of using different screening technologies. They consider three groups of passengers: lower-risk passengers who have volunteered for extensive background checks, lower-risk passengers about whom little is known and higher-risk passengers. They recommend screening baggage with three layers of baggage screening devices. By weaving passengers through three layers of security devices composed of EDSs, high-throughput backscatter and dual-energy X-ray devices, and hand searches, throughput is increased while the overall false clear rate remains at a level comparable to that of the 100-percent baggage screening mandate. Butler and Poole make similar recommendations for passenger screening. One implication of this screening system is that the resulting improved throughput indirectly decreases space requirements and waiting times in airport lobbies, which is of interest because many airport lobbies were not designed to accommodate extensive screening systems and excessively long waiting lines.

Two multilevel passenger screening problems (that are formulated as discrete optimization models) give insight into how screening devices should be purchased and deployed (McLay et al. 2005a,b). An analysis of a greedy heuristic for the first problem suggests that using only two classes is particularly effective, which supports the two-class paradigm of Secure Flight. For the first problem, each of the classes is defined in terms of its fixed cost (the overhead costs), its marginal cost (the additional cost to screen a passenger) and its false clear rate, with a passenger prescreening system such as Secure Flight used to differentiate passengers. The objective is to minimize the overall false clear rate subject to passenger assignments and budget constraints. The second problem, a complementary problem to the first, considers screening devices that have been purchased and installed. The second problem illustrates how devices shared by multiple classes are used. Each class is defined by the device types it uses, and each device type has an associated capacity (throughput) in a given unit of time. Optimal solutions to examples with more available classes are more sensitive with respect to changes in passenger volume and device capacity. This research suggests that incorporating prescreening systems into discrete optimization models provides insight into efficient selective screening systems.

## Conclusions

OPERATIONS RESEARCH practitioners have the unique opportunity to make a difference in aviation security. New directions in aviation security need not merely be makeshift political solutions for mending complex problems; they can be the result of modeling, analysis and planning. By illustrating several ways in which operations research has made an impact in passenger prescreening systems, it is shown to have a place in the design and analysis of aviation security systems. However, there are some limitations. When doing operations research modeling (or in fact, mathematical modeling of any type), one must often make assumptions that may limit the applicability of the results obtained. Though such assumptions are often based on reasonable and realistic factors, they may pose difficulties in facilitating the transfer of the operations research analysis to decision-makers, since errors can lead to security breakdowns that may place people at an unnecessary risk. Second, operations research models quite often look at an application's average or mean performance. In aviation security systems, average performance does not always capture the most interesting and salient aspects of such operations, which are often concerned with rare events and events "at the extremes."

The issues discussed here represent but the tip of the iceberg. There are numerous problems in aviation security that can benefit from operations research methodologies, including improving perimeter access security with respect to airport employees, designing models for cargo screening, analyzing passenger throughput and space associated with security lines, and modeling secondary screening of passengers and their baggage when screening devices give an alarm response, to name just a few. By using operations research methodologies to gain insight into ways to improve aviation security system operations and performance, our field can make a lasting impression on our nation's security and well-being. **I ANALYTICS**

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**Analytics help French automaker overhaul its supply chain from a built-to-inventory to a built-to-order perspective.**

BY ALAIN NGUYEN

# Renault Speeds Up

In the face of a very competitive Western European market, French automaker Renault decided in 1999 to launch the "New Delivery Project" aimed at offering its customers all the diversity of the product range while shortening delivery times. Lead times between the customer order and the arrival in dealerships were to be reduced from six weeks on average to three weeks in Western Europe. The three weeks include the production and transportation of the customer vehicle.

The assumption was that if a client can get exactly the right model with the right color and all the options he or she wishes in a "reasonably short" delay (i.e. three weeks), Renault will gain benefits simultaneously on three levels:

- Reduction of car inventory level. (Thanks to short delivery times, customers can wait for their cars, so that dealerships can lower their stock levels.)
- Reduction of the price discounts designed to sell cars that do not match exactly clients' desires.
- Since all the options are available to customers with short delivery times, expectation of selling a more profitable product mix.

In other words, Renault decided to switch its supply chain from a built-to-inventory to a built-to-order perspective, while offering a more diverse product range with shorter delivery times!

Such an ambitious strategy required a tremendous speed-up of the entire planning process, ranging from the national sales companies (NSC) to the assembly plants via the headquarters. Let us examine this planning process. At the start of each month, NSCs all over Europe define monthly sales forecasts for every model for years Y and Y+1. Then the headquartered sales department reviews the figures with industrial planners so as to ensure that resulting productions comply with plants' capacities, those of Renault and of its suppliers. The discussion between sales and industrial departments may lead to the upgrading of industrial capabilities or to the lowering of sales targets, due to industrial bottlenecks. This planning process took nearly a month each month! The New Delivery Project required the planning process to be shortened to three weeks.

Alongside the planning process, customer orders taken in dealerships are sent daily to headquarters, which in turn dispatches them to vehicle plants once a week. At the end of the supply chain, assembly plants perform daily the planning and scheduling of their productions. The New Delivery Project required the customer orders to go down a continuous pipeline from dealerships straight to assembly plants, thus bypassing the weekly dispatch by headquarters.

Unfortunately, except for the last step (the planning and scheduling in assembly plants), the whole planning process was supported by legacy information systems (IS) on main-

# Delivery

frame environments. These IS represented a huge bottleneck. They could no longer deliver because of the wider variety of product range (more models, more options, more combinations of options, etc.). All the computations were performed by hours-long night batches. Simulations were naturally impossible, nor any kind of interactivity between end-users and IS.

In addition, severe misunderstandings between salespeople and industrial planners were caused by divergent product description languages and lack of thorough answers to basic questions: What are the objectives of the respective planning processes of sales and industrial departments? What are the decision variables of each other? What kind of common constraints should be taken into account?

### O.R. Rides to the Rescue

SINCE WE WERE SUCCESSFUL in developing the tools for the planning and scheduling in vehicle plants, our O.R. team was charged with handling the overhaul of Renault's supply chain management IS.

Renault's O.R. team staff varies from three (today) to eight members (at peak time in the project). The team works mainly on logistics, which is sourced to numerous optimization issues. Timid contacts were made with sales and marketing departments, but optimization issues are much less visible in these areas. The O.R. team focuses on the development of optimization components, while the logistics information technology department is in charge of the data management and GUI modules.

A thorough analysis led us towards in-house developments versus generic ERP software, because of the great specifics of Renault product range description (which fit poorly into generic tools frameworks) and the experience of the O.R. team, acquired from the developing of planning optimization tools for vehicle plants. However decision-makers, especially from the sales department, were more interested in "attractive" ERP software, the likes of I2, SAP, Manugistics and so on. Compared to the aggressive marketing of software suppliers, the dull image of the IT department did not help the O.R. effort.

Reluctantly, we started developments of the planning tools with a well-known ERP software. The result could not be worse mid-course. We encountered cumulated problems from our supplier: badly managed transition of the ERP software from a client-server to a Web-based architecture, mismatch between the distinctive features of automotive product range and the framework provided by the ERP software, and misunderstandings between the in-house team and supplier's consultants. After a common agreement (the supplier did admit its failures), we reversed to in-house developments, trashing all the work done with the ERP software (a few men-years).

A MILP-based (mixed integer linear programming) optimization tool (3P) was rolled out in all the NSCs to help them fine-tune their sales forecasts so as to comply with industrial capacities and product range constraints. 3P implements MILP-based, multi-objective goal programming techniques. Taking sales forecasts as inputs, 3P minimizes mix changes needed to satisfy product range and capacity constraints. Sales forecasts are defined as goals, and the objective function is to minimize the sum of slack variables (representing mix changes). The trick was to perform goal programming while remaining in a linear framework, thus taking full advantage of powerful linear solvers like CPLEX or XPRESS.

This optimization is multi-objective, since it focuses first on model mix, then on critical options mix (engine, gearbox), then on secondary options mix. There is an optimization computation at each step, which takes as constraints the objective functions values of all the preceding steps. Such lexicographic implementation of multi-objective optimization may seem brute force; however this approach is well understood and comfortable for end-users. Indeed it is much more difficult for them to define compensation levels between objectives, that is to answer questions like "How much can one lower model mix quality in order to improve critical options mix?" and so on.

"Feasible" sales forecasts are then sent to headquarters, where industrial planners handle a MILP-based optimization tool (OPTIM), which also performs multi-objective goal-programming to define the optimal weekly output of car factories so as to satisfy the sales targets. In this step, very detailed industrial constraints are taken into account, as well as smoothing objectives in the dividing of monthly plant productions into weekly figures.

But in order to be used in OPTIM, sales forecasts were first translated into detailed volumes for every vehicle option. Indeed, sales figures were defined by sales managers only in terms of models and a few highly visible options, which is clearly incomplete information for industrial systems. Again an LP-based optimization IS (SAPHIR) is used to generate detailed volumes for every car option as coherent as possible with historical statistical trends, while satisfying sales targets and product range constraints.

Industrial planners also plan the weekly output of power train plants so as to supply engines and gearboxes to vehicle plants. A MILP-based optimization tool (OPM) solves a multi-item, multi-period lot-sizing problem with finite capacities, demand and inventory shortages in order to generate a production plan for power train facilities. Again, the optimization is multi-objective since OPM must: (1) meet the demands of vehicle plants, then (2) maximize the satisfaction of security inventory levels of power train factories, and finally (3) minimize the overall costs (production, inventory and transportation costs).

On the vehicle plant floor, operators handle both the building of a production plan on a day-by-day basis with a MILP-based IS (CARNETS), and the car sequencing of each production day with a simulated annealing algorithm. The car sequence is built so as to smooth the workload on the assembly line and to minimize production costs in the paint shop due to color changeovers in the car sequence, which require the washing of painting tubes.

The O.R. tools described above are all live since the years 2000-2002 at Renault. They were implemented with an in-house MILP-toolkit that is interfaced with well-known linear solvers (CPLEX, XPRESS, LPSOLVE, COIN) and which integrates goal-programming techniques. This toolkit is the result of years of experience in goal programming, solvers tuning, memory and response times optimizations. It now represents a major asset to develop quickly O.R. proof of concept prototypes.

The coherence of all these O.R. tools results from the simple fact that they were hard-coded by the same team. It also demonstrates a complete mastering of Renault's O.R. tools by the in-house O.R. team, whose members are now recognized as O.R. experts within Renault.

With O.R. modeling, we brought a completely new approach to our end-users. Instead of focusing on how they do the planning (all their tricks, heuristics and so on), we define with them what the planning problem is (and not how they solve it): What are the constraints? What are the decision variables? Which objectives are to be optimized? Then we focus on what should be the characteristics of a "good" solution, so as to be sure to take into account all the business rules.

Such questions may seem very basic from an O.R. viewpoint, but they brought a great clarification to business people. An important lesson was that the modeling of the objective function must be validated by business people, even though O.R. technicalities are not easy to grasp for them. But since the solutions quality depends completely on this critical objective function, its modeling is not a mere technical issue.

We also impose the same language for sales and industrial departments, by defining a common body of decision variables, industrial and sales constraints, and objective functions. Each department selects in this body the items relevant to its process. For instance, the sales department focuses on monthly model mix and options mix satisfaction on a country-by-country basis, while industrial planners work on weekly model production volumes on a plant-by-plant basis.

All the O.R. tools were initiated with proof of concept prototypes that enable us to get validations from end-users before going into full-scale software developments. These prototypes were critical in getting user validation, since more often than not the business process is overhauled with the arrival of optimization tools, and it is quite difficult for end-users to validate on paper only the couple new process-new tool.

Thanks to the highly visible level of the New Delivery Project (it was called the CEO's project!), we could make the top management take the major and clarifying strategic decisions, so that O.R. tools can follow crystal clear and undisputed directions in optimization objectives. For instance, it was stated that in factory production planning, the satisfaction of customer delivery deadline outweighs cost optimizations. Period.

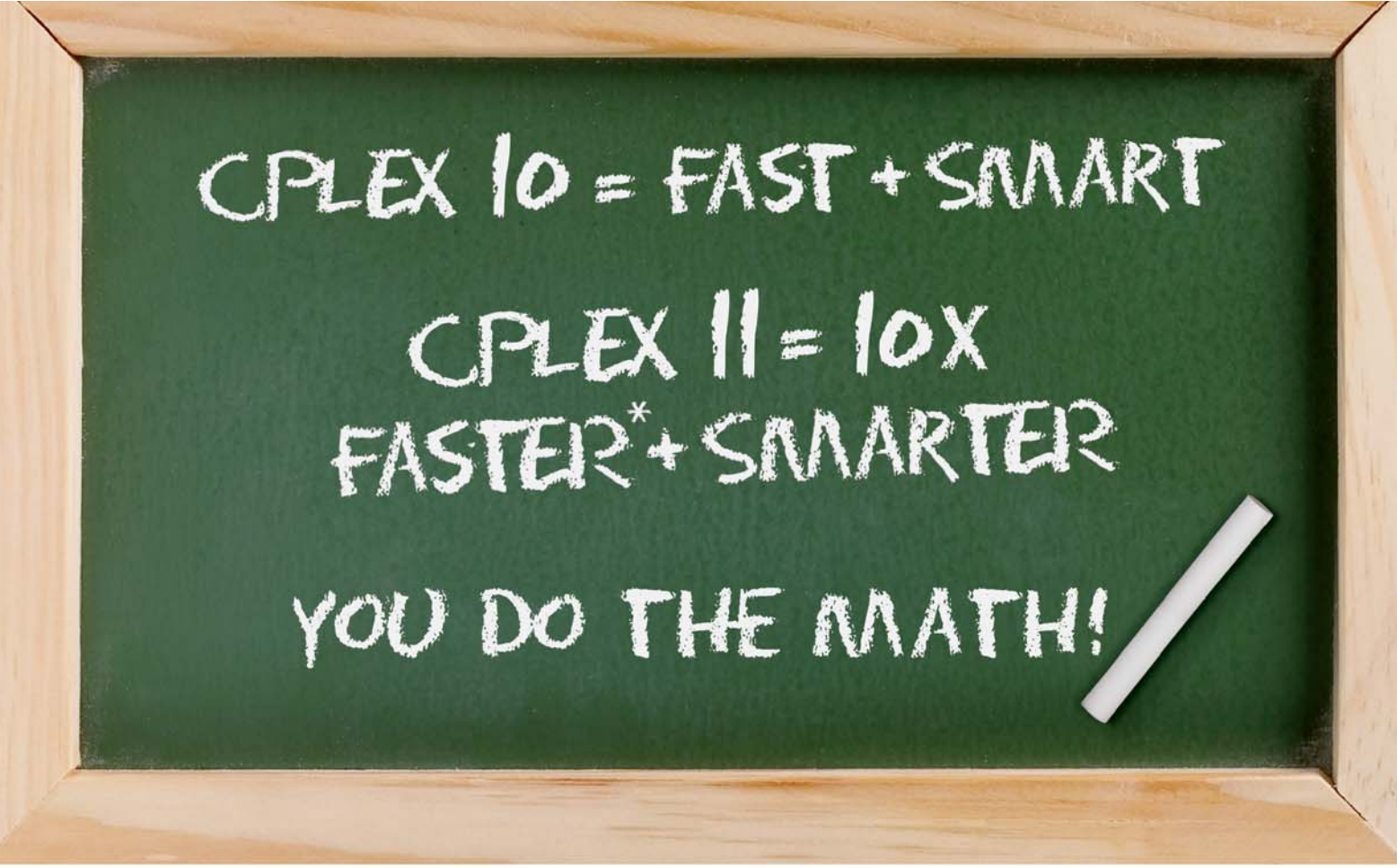
### The ROADEF Challenge

AFTER THE COMPLETE ROLLOUT of the supply chain management O.R. tools in the years 1999-2003, came the stress of the top management on further production costs optimization. We cited above an in-house car-sequencing tool based on a simulated annealing algorithm. It was rolled out in 1993. In 2003, plant operators were complaining about the poor quality of car sequences (too many color changeovers and mitigated satisfaction of assembly line constraints). They asked for an overhaul of this algorithm.

In order to benchmark the best O.R. algorithms, we submitted the Renault's Car Sequencing Problem to a competition among O.R. teams, the ROADEF Challenge, hosted by the French O.R. society (ROADEF). The competition attracted a record 55 research teams from Europe, Canada and Brazil.

The results were so astounding that we acquired the winners' code and put it into production in our plants. Although we did not expect such an outcome, we did specify the real-life problem with real-life data and impose execution time constraints (runs were limited to 10 minutes on a Pentium-IV PC). In return, we were able to plug-in quickly the winner's local search algorithm in our car sequencing tool with very few adaptations. This algorithm is clearly a best in class. One telling statistic: It performs more than 140 million evaluations of the objective function in the 10 minutes runtime! Decision-makers were thrilled by the ROADEF challenge. If only they could benchmark all Renault's IT software among world class competitors, and acquire the best for their business! **ANALYTICS**

***Alain Nguyen*** *(alain.nguyen@renault.com) is the head of the O.R. team at Renault's IT Department and thus the resident O.R. expert within Renault.*

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# To Queue or *Not* to Queue?



## In a U.S. presidential election, that should *NOT* be a question!

**By Alexander S. Belenky and Richard C. Larson**


# Will the 2008 U.S. presidential election be decided by election queues?

**We don't know, but operations research could be used to make every vote count and help secure the integrity of the voting process.**

**Queues in U.S. presidential elections first drew national attention in the 2000 election, when voters queued for more than two hours to cast their votes in some counties in Florida [1], and the election hours were extended due to the queues in some battleground states [2]. In the 2004 election, Ohio voters queued for as many as 10 hours in some precincts in Columbus, Cincinnati and Toledo [3], and long queues were reported in other states as well [4, 5, 6].**

Besides the inconvenience of waiting, why is this important? Think of two words from queueing theory: balking and reneging. Potential voters who see a long queue may balk from entering it. Others may enter the queue but leave it later, renege, due to frustration at the slow pace of the line. Unwillingness to wait may be due to time personal constraints, such as job or family obligations, or maybe just impatience. If those who balk or renege are differentially more from one political party than another, then the party most affected will complain, saying that some of "its voters" did not vote due to long lines.

### Did election queues decide the 2000 and 2004 U.S. presidential elections?

THEY WELL MIGHT HAVE. In each of the two elections, one state decided the fate of the election: Florida in 2000 and Ohio in 2004. In 2000, more than 5,801,000 votes were cast in Florida, and the official vote tally favored the winner by only 537 votes. With widely reported long queues in the precincts, nobody knows how many of those who came to vote balked or reneged. If there were at least 538 such voters, less than 0.01 percent of all the counted votes, one cannot be sure which candidate could have won Florida – in the absence of balking and reneging. In reviewing the 2000 election, one news analyst summed it up this way: "There were a variety of reasons for these votes not being cast or counted." After recounting technological problems, he states, "Finally at some voting stations the lines of voters were simply too long and many voters abandoned their attempt to vote because they were not willing to queue for hours" [7]. Abandonment = reneging.

In the 2004 election, with the Ohio winner's margin less than 119,000 votes, 4-plus hour queue delays [3, 8] could have affected the outcome. Consider the math: 12 of the 88 Ohio counties account for 6,560 of the 11,360 Ohio precincts, and John Kerry won a majority of the votes in these 12 counties [9]. With 72 percent voter turnout of registered voters, 119,000 voters constitute less than 1.5 percent of the registered voters. Anecdotal evidence is compelling: In Columbus, which has 472 precincts, between 5,000 and 15,000 voters were reported to be frustrated and thus balked or reneged [3]. If only 19


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*potential* voters who came to vote in each precinct in these 12 counties balked or reneged, one cannot be sure that the 2004 election outcome in Ohio would have been the same.

Result: the queues might have decided or at least substantially affected the 2000 and 2004 election outcomes.

The political controversy created by misallocation of voting machines is illustrated in this quote by Sen. Barbara Boxer, a Democratic from California: "So, it seems to me that under the Constitution of the United States of America, which guarantees the right to vote, we must ask ourselves several questions today. Why did voters in Ohio wait hours and hours and hours in the rain to vote? Why were voters at one precinct, for example, made to wait in line until nearly 4 a.m., four in the morning, to vote because there were only two machines? At Kenyon College, there were 1,300 voters. They needed 13 machines; they had two. Why did poor and predominantly African-American communities have disproportionately long waits? Why in Franklin County did election officials use only 2,798 machines, when they said they needed 5,000? Why did they hold back 68 machines in warehouses that were perfectly good? Why were 42 of those machines in predominantly African-American districts?" [10].

We take no sides in this debate. But we point out that the substance of the debate is balking, reneging, long waits and the deployment of voting machines – just the types of issues made for O.R. analyses.

### Can election queues decide the 2008 U.S. presidential election?

YES, PERHAPS – if nothing is done about managing the voter queues, and if the 2008 election is as close as were the last two elections.

In the course of the 2000 election, the slogan "Every vote counts, and every vote must be counted" became popular, and soon afterwards, the Carter-Ford Commission on Federal Election Reform was formed to improve the system of electing a U.S. president. However, due to "hanging chads" and related iconic images of the Florida election, most of attention has been paid to the second part of this slogan, i.e., to voting machines and technologies to audit votes already cast. Only after the 2004 election in Ohio were two bills initiated jointly by two groups of congressmen and U.S. senators [11]. These bills for the first time address the problem of establishing certain voting standards, including the maximum time in queue to cast a vote. Though both bills are pending, their chances to reach the floor of the U.S. Congress seem slim, and the attention of the media to the problem of queues in U.S. presidential elections seems to have faded away.

In the absence of queueing standards and related decision-aiding tools, the allocation of voting machines and personnel to precincts will be at the discretion of local election officials. Queues in the 2008 election may then appear either as a result of poor judgment or intentional manipulation of voting resources. And, with the deployment by both political parties of information technologies for developing "digital states" [12], it becomes even easier to design situations in which voters favoring a particular political party are discouraged to vote by long queues caused by insufficient numbers of voting machines.

### Top nine reasons for queueing in U.S. presidential elections.

1. ***Underestimated voter turnout.*** A bigger-than-expected voter turnout may catch off guard election officials who are supposed to respond quickly to such an event if/when it occurs.
2. ***The election budget.*** An insufficient election budget may imply that *rho* >1.0 during all or part of Election Day. Here *rho* = *p* is the queue utilization factor. As we all know, *p* >1 implies queues that grow.
3. ***Types of voting machines.*** Different types of voting machines have different service times and thus affect queueing differently. As far as we know, no research showing how particular types of voting machines may affect queues on Election Day has so far been conducted.
4. ***Activities aimed at mobilizing voters.*** The 2004 election demonstrated that political parties can increase the participation of low-propensity voters [13]. Success at bringing new voters or reluctant voters to the polling precincts can increase the queueing *lambda,* or (λ), the arrival rates to the queues, thereby making the queues longer.
5. ***The demography of the electorate.*** Changes of the number and types of voters in a county affect service times and thus election-day queues, even if the voter turnout is unchanged compared to the previous election year.
6. ***Early voting options.*** Many states now allow voting in federal elections several days before Election Day in order

not to lose voters who are unwilling to stand in queues on Election Day. This decreases Election-Day ($\lambda$).

7. ***Training voters to operate voting machines.*** Some types of voters – for instance, elderly people, undereducated voters, new immigrants and first-time young voters – generally require more assistance in the precincts than, say, educated 35-year-olds. Out-of-queue training of these voters may reduce service times and thus queues on Election Day.
8. ***Weather.*** Voter turnout is dependent on weather. Good weather usually implies higher turnout; bad weather the reverse. This makes even more difficult the prior estimation of queue parameters.
9. ***Unscientific deployments of voting machines and poll workers.*** The deliberate or accidental misallocation of voting machines among the precincts seems to remain the major cause for long queues in national elections.

### A strategy to deal with queues in U.S. presidential elections.

TO START TO USE O.R. in a serious way, we need queue wait standards to be set and agreed upon by stakeholders in the voting process. A standard may be stated in the form, *"No more than 5 percent of the voters should wait more than 30 minutes in the voter queue."* Of course, the 5 percent may be 1 percent or 10 percent or any other percentage, just as the 30 minutes could be 10 or even 60 minutes. Whatever the standard, it must be stated in a way that acknowledges that less than 100 percent of the voters will enjoy the standard – due to unavoidable random fluctuations in the queue arrival and service processes.

Standards *can* be agreed on even in the public sector. The U.S. Postal Service (USPS) has a five-minute standard to serve retail customers. And, to motivate the approach we are proposing, their goal is met in large part by "…using the retail analysis staffing and scheduling model to determine how many employees should be on duty during all periods to maintain service levels within these guidelines" [14]. That's right, the USPS uses queueing models to staff their retail postal lobbies. If it's good enough for the U.S. Postal Service, it should be good enough for ensuring equity of access to America's most precious right: exercising the right to vote.

Suppose the standard is established by the state law and accepted by most if not all stakeholders. Solving the problem of allocating voting machines among county precincts now becomes an O.R. problem in queue design and management. First there is a *feasibility test:* Are there enough voting machines in the county to meet the standard? If not, how many more do we need? The way we do this, once we have a validated queue model, is to find the minimum number of voting machines needed at each precinct to meet the standard, and then sum over all precincts. Comparing this to the total number currently available determines the overage or underage that we face.

The details of a valid and useful queueing model will of course depend on the realities on the ground. Is real-time information available to county managers who can communicate with leadership in each of the precincts? If information is available, can voters who appear at a congested precinct be transported to a nearby uncongested precinct? Or, can voting machines at an uncongested precinct be moved during the voting day to more congested precincts, thereby balancing the load and reducing queue delays at the congested precincts? Would special mobile voting units, which could service voters in their neighborhoods early in the morning and be moved to congested precincts during peak hours, be a comparable or even a better solution? Can voters be informed by radio and television about hours of anticipated congestion and hours of small or zero-length queues, thereby redirecting those who have vote time flexibility to appear during off-hours? In measurement tests of potential voters with long waits, what are the state-dependent probabilities of balking? What are the dynamics of reneging? Does steady-state analysis make sense during the voting day, or must the entire model be transient in nature?

All of these questions and more must be settled by careful research. If we are to bring O.R. to bear on America's voting system, we must do it with the utmost respect and care. Erlang's famous equations of 1915 – created for analysis of centralized telephone switching systems – will not be up to the job. More than likely, new queueing models will have to be created.

Politicians and their constituents are crying out for proven, tested methods for deploying fairly and equitably voting machines and related resources to voting places. This is illustrated by a December 2004 letter from Rep. John Conyers Jr., Rep. Melvin Watt, Rep. Jerrold Nadler and Rep. Tammy Baldwin to the Honorable J. Kenneth Blackwell, Ohio secretary of state:

1. How much funding did Ohio receive from the federal government for voting machines?
2. What criteria were used to distribute those new machines?
3. Were counties given estimates or assurances as to how many new voting machines they would receive? How does this number compare to how many machines were actually received?
4. What procedures were in place to ensure that the voting machines were properly allocated throughout Franklin and other counties? What changes would you recommend be made to insure there is a more equitable allocation of machines in the future? [15].

### On engineering systems for servicing U.S. presidential elections.

U.S. PRESIDENTIAL ELECTIONS have traditionally been considered a subject of politics and political science. While establishing voting standards may involve a political process, scientifically handling the voter queues – once the standard is set – should have nothing to do with politics. Developing decision-making systems for servicing American voters according to their constitutional rights is an important step in insuring the integrity and fairness of the process. Training election officials in the use of these systems and informing the voters about the capabilities of these systems should accompany the implementation of such decision-support systems.

We hope to develop a prototype of the first system of such a kind with support of interested organizations that care about the integrity of the election process.

**Summary**

FROM AN O.R. POINT OF VIEW, a voting precinct is a multi-server queueing system. Problems of allocating available voting machines, and perhaps finding the required number of additional voting machines, can be formulated as mathematical programming problems. All of these problems are non-routine due to complications arising in practice: uncertain voter turnout, the ability of the election authorities to deal with long queues, types of machines available, experience of voters, use of early voting options, etc. Whatever the difficulties, we are unaware of any method superior to O.R. for sorting out all the issues and creating a valid and unbiased way to deploy scarce voting resources on Election Day. May O.R. save the day! **ANALYTICS**

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## REFERENCES

1. "News Hour with Jim Lehrer," transcript, Nov. 10, 2000.
2. C. Orman, "State Sen. Scott Addresses Pachyderm Club," *Sedalia Democrat,* March 11, 2006.
3. M. Powell, P. Slevin, "Several Factors Contributed to 'Lost' Voters in Ohio," *The Washington Post,* Dec. 15, 2004.
4. H. McGee, "My Opponent Looks Like Saddam's Son," *Irish Examiner,* Oct. 27, 2004.
5. P. Donovan, "It was About Poor People's Right to Vote," *The Irish World,* Nov. 12, 2004.
6. J. Jones (reviewed by), "U.S. Election 2004," BBC 1, Nov. 2, 2004.
7. R. Bloor, "Electronic Voting and the U.S. Election," Oct. 27, 2004, www.it-director.com/article.php?articleid=12348.
8. Rev. Jesse Jackson, "Something Fishy in Ohio," *Chicago Sunday Times,* Nov. 30, 2004.
9. "State results. President by county," *USAToday.com*, Nov.4, 2004.
10. "Contesting Ohio Electoral Votes," transcript of press conference: Sen. Barbara Boxer and Rep. Stephanie Tubbs Jones, *Federal News Service,* Jan. 6, 2005.
11. Testimony of Norman J. Ornstein, Commission on Federal Election Reform, June 30, 2005, James Baker III Institute for Public Policy, Rice University, Houston, Texas.
12. T. Edswall, "Democrats' Data Mining Stirs an Intra-party Battle," *The Washington Post,* March 8, 2006.
13. D. King, "Youth Came Through with Big Voter Turnout," *The Boston Globe,* Nov. 4, 2004.
14. Postal Operations Manual, Sec. 125.21: www.lunewsviews.com/pdfs/Service%20Levels%20-%20POM%20125.2.pdf; and http://globalresearch.ca/articles/BOX501A.html.
15. http://globalresearch.ca/articles/HRE412A.html (letter dated Dec. 2, 2004).

## ANALYTICS... in the News

### BLUMSTEIN GIVES NEW INSIGHT INTO CRACK WARS

**"When crack first became popular, there was an increase in murders and other crimes associated with the drug. But the bloodshed was not necessarily the result of something inherent in crack.**

**"Instead, most of that violence was typical for what happens when any illegal drug is introduced and drug dealers with guns compete for new markets, said Dr. Alfred Blumstein, a professor of urban systems and operations research at Carnegie-Mellon University."**

*Source:* **Fox News**

### BEST SOLUTION TO HOLIDAY LINES IS SINGLE QUEUE

**"North Americans spend a lot of time waiting to be served. In malls. In airports. At amusement parks. In his book 'On An Average Day,' writer Tom Heymann claims Americans spend more than 100 million hours a day waiting in line.**

**"We spend more time queued up, paunch to haunch, in December than in any other month. No surprise there. Last year, according to Statistics Canada, Canadians spent an average of $874 each in December compared to about $630 in other months.**

**"With so much money at stake – Canadian stores reaped nearly $30 billion last December alone – you'd figure retailers would have reached a consensus on how best to keep lineups moving briskly. Nope.**

**"There are two basic queue management models. Banks and airports use what's called the single-line, multiple-server model. First come, first served. Most stores, however, use the traditional multiple-line, multiple-server system. This is how supermarkets work. You pick a line and hope it's a fast one.**

**"Mahmut Parlar, a management science professor at McMaster University, favours the one-line system. 'Both math and practical experience tells us that if you have a single queue with multiple servers, you get more efficient service,' he says."**

*Source:* **Ottawa Citizen**

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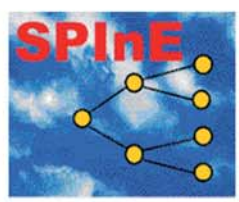


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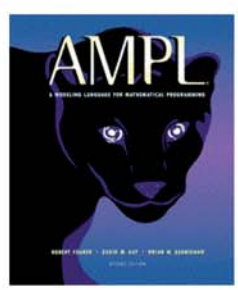


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# PATIENT FLOW

## The new queueing theory for healthcare.

By Randolph W. Hall

**From birth to death,** we are all part of the healthcare system. We rely on both public and private organizations to provide preventive care (such as inoculations) and to treat our illnesses, diseases and injuries. Healthcare is perhaps the strongest determinant of both our quality of life and our longevity.

**Worldwide, and in the United States in particular,** healthcare consumes an increasing percentage of our economic product. This rising cost can be attributed in part to aging populations and the expense of new, advanced treatments. Just as importantly, it can be attributed to inefficiencies in healthcare delivery. Simply put, the science of healthcare has progressed much more rapidly than our ability to manage healthcare as a truly integrated system.


## Patient Flow

PATIENT FLOW represents the ability of the healthcare system to serve patients quickly and efficiently as they move through stages of care. When the system works well, patients flow like a river, meaning that each stage is completed with minimal delay. When the system is broken, patients accumulate like a reservoir, as in the chronic delays experienced in many big city emergency departments. Put another way, good patient flow means that patient queueing is minimized; poor patient flow means that patients suffer considerable queueing delays.

Healthcare systems resemble any complex queueing network in that delays can be reduced through: (1) synchronization of work among service stages (e.g., coordination of tests, treatments, discharge processes), (2) scheduling of resources (e.g., doctors and nurses) to match patterns of arrival, and (3) constant system monitoring (e.g., tracking number of patients waiting by location, diagnostic grouping and acuity) linked to immediate actions. But healthcare has unique features that make queueing problems particularly difficult to solve:

• ***Waiting creates additional work for clinicians.*** Patients must be monitored and served while waiting, and their conditions even deteriorate, necessitating additional work once they are seen. Thus, as queues become large, the workload increases and the capacity to serve patients deteriorates.

• ***It can be difficult to distinguish productive waiting (e.g., recovery) from unproductive waiting (e.g., waiting for tests).*** In a traditional queueing system the most desirable outcome is a zero time in system with instantaneous service; in a hospital, it is undesirable to push length of stay all the way to zero, as patients need to be monitored and cared for during recovery periods. The result can be conflicting objectives in managing hospital beds as a limited resource.

• ***Healthcare organizations operate within a unique regulatory and business environment*** that falls partly in the private sector and partly in the public sector. Hospitals may find it impossible to manage queues through pricing, and reimbursement schemes may be misaligned with costs. For example, under the Emergency Medical Treatment and Active Labor Act (EMTALA), hospitals are mandated to see all patients presenting to emergency rooms independent of their ability to pay. Thus, the economic environment precludes queueing solutions often found in the private sector, such as peak-period pricing. At the same time, physicians frequently act like independent entrepreneurs, making it difficult for healthcare organizations to fully integrate their systems under sound managerial practices.

## Characterizing Patient Flow

MY FIRST EXPOSURE to the field of patient flow came through the Institute for Healthcare Improve-

ment (IHI), an outstanding organization devoted to improving the quality and value of healthcare. IHI's approach centers on the open sharing of best practices within "collaboratives," groupings of hospitals and clinics, clinicians and managers, organized around common objectives, such as reliability, safety or patient flow.

Important to the operations research community, IHI has emphasized evidence-based decision-making, meaning that performance measures and patient outcomes should be tracked and integrated into a system of continual improvement. Though not directly linked to industrial engineering, management science or operations research, IHI has adopted these field's methods, focused on making radical improvements in health, not through creating new technology or treatments, but through using what we have now to maximum benefit.

At the University of Southern California, my colleagues David Belson, Maged Dessouky and I have used this philosophy as the launching point for a comprehensive evaluation of the Los Angeles County/University of Southern California (LAC/USC) General Hospital, one of the largest hospitals in the country. Like many urban public hospitals, healthcare at LAC/USC is dominated by the flow of patients through its emergency department. Patients by and large come to LAC/USC for one of two reasons: They believe that they have no other option due to lack of health insurance or they have suffered trauma or another emergency condition somewhere in the hospital's vicinity and were taken there by ambulance or helicopter.

As at all hospitals, care is provided through many specialized departments, such as radiology, surgery and various types of patient wards, as well as by ancillary departments, such as admissions, medical records, laboratory, pharmacy, housekeeping and transportation. A patient arriving through the emergency department encounters repeated waits as he or she progresses from stage to stage, waiting for rooms, equipment, physicians, nurses, technicians, beds, medications, records, gurneys, orderlies and continuing care facilities once the patient is ready for discharge. As in other hospitals, when the system becomes overloaded, the patient may wait hours or even days from being seen in the emergency department until placement in a ward. A patient may have to wait days or even weeks for a surgery. These conditions are in some respect extreme, but certainly not unusual throughout the United States.

Our work has revealed that healthcare professionals are unusually committed to their jobs, even when working under extremely challenging conditions. They show a passion for their work and a camaraderie that is unlike what we have seen in other economic sectors. Yet clinicians, in particular, are frustrated because they cannot control activities that occur outside their own departments. We have also observed three major causes of queues in hospitals:

- ***Idle capacity*** due to a failure to synchronize complementary resources (e.g., ensuring that needed technicians, nurses, physicians, supplies, patients, etc. are present at the same time to provide a needed service).
- ***Inadequate communication*** to ensure downstream departments are prepared to receive patients from upstream

# REDUCING DELAYS

## Through Improved Surgical Scheduling

By Maged Dessouky, David Belson and Randolph Hall

**Managing length of stay (LOS) is one of the most vexing challenges for any hospital. Though patients do need minimum stays for recovery and monitoring, LOS is sometimes too long because patients are forced to wait for surgeries. As a result, patients suffer and hospitals incur "denied days" – an insurer's rejection of reimbursement because the stay is not medically necessary.**

**A research team at the University of Southern California, consisting of the authors and graduate students Pavankumar Murali and Bo Zhang, is addressing the LOS problem at the Los Angeles County General Hospital by targeting surgical scheduling and operations through process modeling, process improvement, optimization and simulation. We focus here on the last two steps: optimization and simulation.**

**Operating rooms are a scarce resource that must be properly allocated among a set of specialties. Each surgical specialty (cardiac, ortho, neuro, etc.) wants its share of the available time. A common hospital surgery scheduling method is "block scheduling" where operating rooms are assigned weekly among each specialty and then the specialty selects among its patients to fill up its allotted block time. The planned weekly block times are a result of compromises among the competing demands.**

**A reduction of patient waiting times could be accomplished by accurately balancing the room allocation blocks with amount of demand for surgeries from each specialty. In the past, allocation decisions were the result of many factors. For example, since this is a teaching hospital, each specialty requested sufficient time to provide learning experiences for its medical students.**

**Surgery demand could be forecast based on the past frequency of surgeries by specialty. The average length of surgeries follows a consistent distribution. The surgeries within each specialty include inpatients who occupy a hospital bed until served, outpatients who are scheduled in advance and "red blanket" emergency patients who must be served immediately by preempting the existing schedule. All three of these subcategories follow a consistent pattern that we could use for allocating blocks.**

**Based on the demand pattern, we formulated a finite-horizon integer programming (IP) model that determines a weekly operating room allocation template that maximizes patient service. A number of patient type priorities (e.g., emergency over inpatient) and clinical constraints (e.g., minimum number of hours allocated to each specialty) are included in the formulation. The solution from the optimization model is entered into a computer simulation that captures the randomness of the processes (e.g., surgery time, demand, arrival time) and no-show rate of the outpatients) and non-linearties. Our models were created in conjunction with nurses, anesthesiologists and surgeons to assure the relevance of the system to their practice.**

**Results have been significant. The answers from our approach provide daily plans that reduce patient waiting and assure that the correct surgical team and surgery suite is available when needed.**

***Maged Dessouky*** *is a professor and* ***David Belson*** *is a senior research associate and lecturer in the Daniel J. Epstein Department of Industrial and Systems Engineering in the Viterbi School of Engineering at the University of Southern California.* ***Randolph Hall*** *is vice provost for research advancement at USC.*

# OPTIMIZATION

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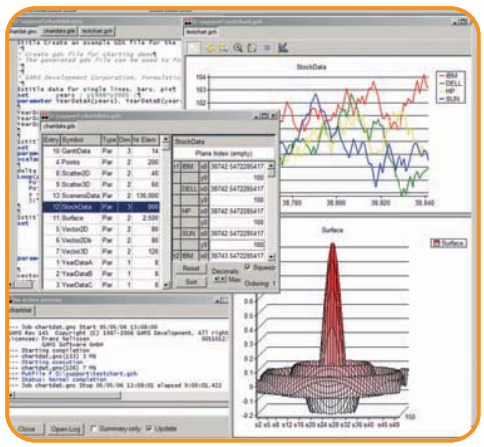

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- Ready to use COIN-OR solvers are part of the regular GAMS distribution (free of charge).
- Close collaboration with the Department of Mathematics at Humboldt-Universität zu Berlin results in the COIN-OR project GAMSlinks (https://projects.coin-or.org/GAMSlinks, project leader Stefan Vigerske), open-sourcing the linking code for all supported solvers.
- Addition of (mixed-integer) non-linear COIN-OR solvers to the GAMS distribution.
- Continuous performance improvement (see performance plot) of COIN-OR solvers.
- GAMSWorld QA tools (e.g. PAVER www.gamsworld.org/performance/paver) are being used to automate test and performance procedures, providing feedback to the COIN-OR community.
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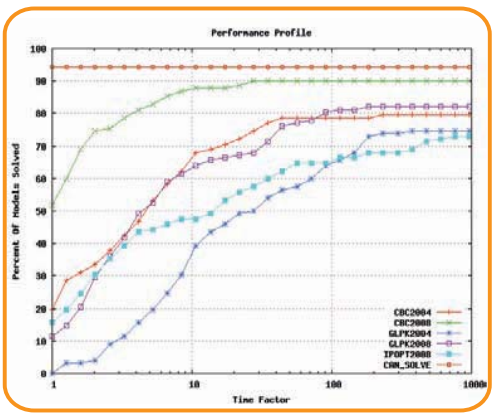


Performance Profile of LP Models from GamsWorld's LINLIB.

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departments and to ensure that all parties are prepared for foreseeable demand.
- ***Inefficient processes*** that require more work than necessary or un-needed repetition of work.

For example, patients may wait for placement in a hospital bed because:
- Other patients are waiting too long to complete the discharge process.
- Beds remain idle too long from when a patient departs until a bed is prepared for the next patient, until "bed control" is notified of its availability, and until the next patient is transported to the bed.
- Communication is poor between the emergency department and the ward as to the exact time patients will arrive and the care needed immediately upon arrival.
- The suitability of individual beds for individual patients cannot be ascertained due to inadequate processes for tracking patients and their medical records and inadequate processes for tracking the state of hospital beds.

Similar observations can be made in surgical and radiological departments. A patient with a serious fracture cannot be operated on until the CAT scan is completed, which is delayed because there is a shortage of technicians, because cycle times are too long (the result of not sufficiently prepping patients before the test), or perhaps even because there is an inadequate number of gurneys to transport patients. Surgical capacity is wasted due to cancellations, because surgical times are mis-estimated or because insufficient hours are scheduled.

## Techniques

HEALTHCARE SYSTEMS can be changed for the better through a strategy that combines participation and creativity. But change cannot be sustained without vigilance and without analysis based on data. Herein lies the opportunity for the O.R. community. For instance, the O.R. community can work with hospital clinicians and administrators in these areas:
- ***Process modeling*** to ascertain how patients are currently served, to determine where inefficiencies exist and to prioritize future changes. Process modeling can reveal unnecessary repetition, miscommunication, and inconsistency in methods.
- ***Simulation modeling*** both to evaluate new processes and to understand and demonstrate the current causes of delay. For instance: simulating delays before and after, implementing a new appointment system, changing the methodology for assigning patients to beds, or implementing an electronic patient record system.
- ***Optimization*** can be used in many aspects of system design, such as scheduling nurses, scheduling operating rooms or facility layout.
- ***Queue analysis*** is invaluable when executed on a real-time basis to highlight the delays currently experienced throughout a hospital, and to make this information available to all key decision-makers, so that they can better understand delays both upstream and downstream, and act on these delays through reallocation of resources and appropriate prioritization of patients.

## Future Challenges

THE RESEARCH CHALLENGE in patient flow goes back to the uniqueness of healthcare queues, namely understanding the human elements of the queueing system.
- In some hospitals, the demand for patient care is perpetually larger than the capacity to serve patients. Unlike what theory may predict, queues do not grow without bound – instead, the system is brought to equilibrium by patients who leave without being seen.
- The capacity and motivation to serve patients are greatly impeded when queues grow long, in the form of crowded waiting rooms, queues of patients waiting for placement to beds, and patients occupying beds while waiting for surgeries or tests. The performance of healthcare systems and its many actors (patients, nurses, doctors, administrators) under these stressed conditions is largely unknown and, for this reason, it can be extremely difficult to predict the effects of change.

Beyond these two examples, it is critical to create an environment whereby change is embraced throughout the organization and, in particular, to change the perspective from "how others are causing problems for my area" to "how I can make the entire system operate better." The collaborative approach advocated by IHI is therefore essential.

The O.R. community can make a difference in the field of patient flow. This is not just a matter of improving efficiency. It is a case where our methods and talents can reduce suffering and save lives. **ANALYTICS**

***Randolph Hall*** *is vice provost for research advancement at the University of Southern California and editor for "Patient Flow, Reducing Delay in Healthcare Delivery" (Springer, 2006).*

## ANALYTICS... in the News

### SCHEDULE YOUR NEXT CHILD WITH DECISION ANALYSIS

"The science of decision-making is available to help women determine when to have a child, two U.S. business scholars suggest.

"Professor Ralph Keeney and doctoral student Dinah Vernik of Duke University's Fuqua School of Business developed a logical decision model to help a woman weigh her options according to her values in a systematic way.

" 'This decision is too complex to logically consider all the relevant aspects intuitively in one's head,' the researchers say in a statement. 'Yet, for many, it too important and consequential to simply go with one's feeling.'

"The model, published in the journal Decision Analysis, doesn't discount emotion or a partner's input but aims to balance the benefits of motherhood against the effects on career ..."

*Source:* EarthTimes.org

FairIsaac | dash optimization

# DECISION MANAGEMENT HAS JUST BEEN OPTIMIZED

**Fair Isaac is pleased to announce we've acquired Dash Optimization, the world's leading developer of optimization software.**

Now Dash's Xpress-MP suite—including Xpress-Optimizer, Xpress-Mosel, and Xpress-IVE—joins Fair Isaac's expertise and leading solutions in predictive analytics and business rules technology. Together, Dash and Fair Isaac can bring a new level of precision, power and agility to your most complex business challenges.

To find out how our unique analytic partnership can help you, visit: *www.fairisaac.com/dash.*

# The top five misconceptions about starting an IEOR consulting career.

By Carrie Beam

# Reality CHECK

**So here you are,** starting your last school year. Perhaps you're finishing a B.S. in operations research, with a double minor in something utterly practical, like computer science and accounting, and an unholy fascination with the left nullspace of a certain type of sparse matrix. Or perhaps you're polishing off a Ph.D. in industrial engineering, while managing to take as many Italian art classes as you can for free while you're still a full-time student. Or perchance you're an undergrad majoring in applied mathematics because your school doesn't offer a full-blown OR/MS major, and while you can program a little and learned to order another cappuccino in Italian while in Rome last summer, you have spent the vast majority of the past few years working your way up to being president of your sorority, a position which now quite frankly consumes more of your time than your senior thesis.

Every time you run into a grownup, he or she asks, "So what's next? What are you going to do after graduation?" You've been thinking of consulting – OR/MS consulting, to be exact. This idea of being paid to tell other people what to do while being your own boss and doing interesting technical work really appeals to you. If you have had this thought, my friend, this column's for you. I'm writing from the perspective of a sole proprietor who has built an OR/MS consulting practice from the ground up, immediately following graduate school, with three major tools: a telephone, a laptop and a Ph.D.

How many of these misconceptions do you entertain, however briefly?

**1. I don't need to know how to dress well, schmooze or make pretty PowerPoint presentations. In school they assigned me hard problems and I solved them. I'll do the same when I go to work.**

If you are going to be working for yourself, this is not only false, but deadly. A small-time practitioner is much better off dressing well, schmoozing exceptionally and using excellent PowerPoint to present mediocre mathematical results. Why?

First, according to veteran O.R. consultant Harlan Crowder, in the real world, "you not only have to determine the 'answer' to the question, you also need to figure out the question. Most executives and managers you work for – as an employee or consultant – will know they have a problem, but will not be able to articulate what has gone wrong in their organization or business." Crowder says some of his greatest successes as an O.R. practitioner have come from the ability to work with clients to help determine exactly what problem needs to be solved. The real skills needed for real-world problem formulation are: 1) interpersonal, 2) communication 3) ingenuity and, above all, 4) patience.

Second, in general, your clients hire you because you are better at math than they are, and hence they can't really judge how optimal a particular solution is. What they can judge are clothing and PowerPoint, and (for better or worse) they will often decide how valid your mathematical results are based upon your shoes and the color scheme on a slide. Third, the sad reality is that much of the business world is run on eighth-grade algebra. The silver lining inside this cloud is that with an OR/MS major under your belt, you should be batting very close to 1.000 on all of these, even the story problems involving trains leaving Chicago and St. Louis at different times.

**2. Delivering great work on time and within budget is enough.**

Possibly false again. If you work for a big company, your career skill ladder will look something like this: do the work (entry-level), manage the work, sell the work, build the brand (partner). At the "do-the-work" level, yes, doing great work on time and within budget will make your manager quite happy, especially if you get along well with the client while you do it.

If you work for yourself, your skill ladder will look something like this: sell the work, do the work, sell more and more work, hire somebody so you can manage the work, sell even more work, build the brand and continue selling more work. The on-time and within-budget bit is nice to have but certainly not a requirement. You'll be better off with excellent sales skills and good project management

skills, so you can gently let a client know you'll be late and running over budget, and spin it so he's delighted to hear that news.

### 3. I'm looking forward to working; $150 an hour amounts to $300,000 a year! I'll have a nice car, a great place to live and an expense account. What a life!

Maybe false again, my friend. If you work for a big company, some of this plus a daily Grande at Starbucks can be yours immediately after signing on the dotted line. According to executive recruiter Ray Fortney, a partner in a Bay-Area based executive search firm, "Salaries for upper-level executives with an O.R. background can easily start at $150,000 and range to $250,000, not counting bonus. And don't forget benefits including a 401k or stock options. Compensation packages like this are particularly true if the individual is an excellent manager, has strong leadership skills and strong customer skills. These skills are generally learned working for top tier companies. Picking the right company early in your career can be key to your long term success." And with that sort of start, you can quickly upgrade your Starbucks habit to the Venti, and even progress to the ones with the whipped cream and the chocolate swizzles and the big plastic bubble thing on the top.

And now for the sad news. If you start your own company, you get paid last: after Kinko's, after your liability insurance, after the hotel stay in Manhattan that the client will take seven months to reimburse you for, after the $2,000 for attending a trade conference at which you got food poisoning and didn't make any contacts after all.

Those professors who make $300+ an hour to consult? They have two things going for them that beginners typically don't. First, they're world experts and have years of experience going for them. Second, they're selling time at the margin; they don't need to fill 40 hours a week, 50 weeks a year at those sorts of rates. The university pays their bread and butter, so the professors have the luxury of waiting for the big, juicy job to come along, all the while sharpening their expertise and broadening their spectrum on the university's nickel.

My first year in business my income was something like minus $4,000. That's right, my bank account was $4,000 *smaller* after that first year. For my first big out-of-town job, rather than spending money on hotels or restaurant meals, I dug up a grad school friend in that city, stored groceries in her kitchen and slept on her floor. And my first three years in consulting, I was driving a 1984 blue Volvo station wagon with the right front headlight alternately hanging off at a wild angle or stuck on with duct tape. I parked around the corner when I went on sales calls, because I was sure that any prospect who saw that car would immediately count me out.

For those of you keeping track of these things, I'm now driving a 1998 Saturn with Cheerios all over the back seat, and every time I drive a client anywhere I have to get worked up into a wild vacuuming frenzy first. The only exception to this rule is if the client also has children and has let me into his or her fully-Cheerio-laden car first.

### 4. It's rude to talk about money.

This is somewhat true. You have to be careful what figure you share with whom. At a big company, you'll be responsible for tallying up your accomplishments each year and negotiating with your boss for a raise. As a sole proprietor, you are the boss and you will be talking about money in every other sentence, and you simply will have to get over the social aversion. You will be asking prospects for the sale. You will be asking about corporate discounts on travel. You will be negotiating with vendors and contractors to get the best rate. You will be dealing with your bankers about lines of credit that they will only grant once you don't really need the money. You will be dealing with your brokers about retirement plans. As I write this, I am finishing up Project B for a client and knee-deep in Project C for them, and they have still not paid for Project A, for which I sent the invoice two months ago.

Money, money, money drives the small-time operator's world. And between the thoughts about dollars and selling, you can think about linear programming, inventory systems or, in a flash of inspiration, see if you can come up with a snazzy rhyme for "stochastic process." (The best I can do is "gymnastic bosses" or "spastic rhinoceros," and I must admit I actually spent a good deal of my first year in the Ph.D. program at Berkeley contemplating this precise issue. It's a wonder I passed my comps.)

### 5. Running a consulting practice is the same as running a consulting business.

False again. A consulting practice is typically one "expert" (this is you) person hiring themselves out, with possibly a small support staff, such as an administrative assistant, an accountant and a travel agent. The expert bills by the hour. As every good process engineer knows, the expert should be the bottleneck, and if the expert is busy, the work has to wait. If the expert retires or quits, the practice is nearly worthless.

A consulting business looks much like any other professional services business (think Accenture, KinderCare or Jiffy Lube). The work is well-understood and repeatable. It can be subcontracted out or done by employees. It can be sold by somebody who can't actually do the work. And it is typically done on a fixed-bid basis, a certain deliverable for a certain amount of money. If the founder retires, the business is worth something – these sorts of things can be sold for the value of the client list plus the employees, methodology and work in progress.

As soon as you move from running a practice to running a business, you no longer desperately need only an administrative assistant. You also desperately need nerdly people whom you can teach to do the work, and even more desperately you need non-nerdly people who can't necessarily do the work but who can manage it, budget it and above all, sell it.

If you are remotely close to the proverbial OR/MS student who is president of your sorority, whose ambition it was to be the weakest student the department ever had who still got the degree, and who has successfully sold anything from Girl Scout Cookies to life insurance, please e-mail me. The only thing harder to find than good nerds are good nerds who can sell. **ANALYTICS**

***Carrie Beam*** *(carrie@carriebeamconsulting.com) received her Ph.D. in industrial engineering and operations research from U.C. Berkeley in 1999 and has been self-employed as an IE/OR consultant for nearly a decade. Her projects have run the gamut from benchmarking the DMV to segmenting a database of rum drinkers, and her clients have ranged from other sole proprietors to Fortune 100 companies. She lives in the San Francisco Bay Area with her family.*

By James J. Swain

# New Frontiers in Simulation

## Biennial survey of discrete-event simulation software tools

**We use simulation to realize our imagination** in a specific and detailed way – rendering what we imagination in a way that we can grasp. For instance, one may use laser devices to simulate the effect of actual arms during a military exercise, while preserving the dust, heat and fatigue that soldiers experience during actual operations; or simulate the equations of motion to provide the sensation of flying an airliner under adverse conditions to prepare a pilot to deal with an emergency; or model the interactions among producers and suppliers to predict the performance of an international supply chain. However we use it, simulation tools are there to aid our imagination to probe the frontiers of knowledge, to teach or simply to entertain.

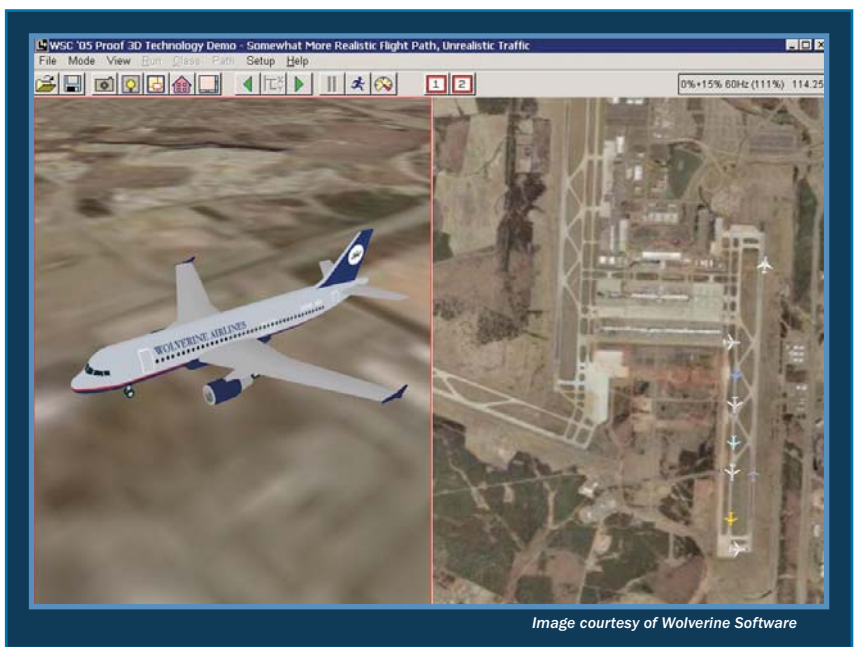


Image courtesy of Wolverine Software

Simulation has grown ubiquitous: the widespread availability of personal computers (and gaming computers) means that everyone has access to this technology. In the last decade simulation has moved out of the classroom and lab and into the public domain, becoming widely familiar and accepted though games and movies. This emergence into the public consciousness has already opened new business opportunities and will no doubt open new frontiers for the application of simulation.

The migration of simulation into the public arena over the last decade may prove to be the most significant recent change in the field. For most of the history of simulation, specialized technical applications have driven the development of simulation, which tended to limit the field's growth. By contrast, commercial simulation products in entertainment open lucrative new markets that may very well spur an increasingly rapid pace of innovations. Academic programs are now being offered to train the next generation of games developers. Simulation has not had a large impact on the classroom as yet, but advances in gaming will contribute to development of simulation-based teaching tools.

The widespread availability of simulation technology also means novel fields of application. For instance, psychologists are using existing military games as the basis for a treatment of Post Traumatic Stress Disorder (PTSD). One treatment approach is exposure therapy, in which stressful situations are relived in such a way that they can be faced. One advantage of simulation is that the exposure can be graduated, allowing the patient to approach the stressful memory slowly, through different levels of detail and intensity. One tool in development for Iraq War veterans includes virtual reality immersion complete with sounds, a shaker platform that provides vibration to simulate the passage of a helicopter flying overhead or nearby explosions, and even scents that can be used to complete the sensations associated with the memory. The treatment is made possible by the existing simulation games and virtual reality components that drastically reduce the cost of development.

Simulation-based training is already in use for commercial applications, such as specialized maintenance activities for aircraft equipment. Simulation-based instruction is not yet widespread in the college classroom. Yet, games such as America's Army illustrate that

simulations can be used to immerse the players within a realistic simulated environment that can be used for role-playing. Many of these games are also structured to provide interaction between multiple players. Immersive activities might be developed that provide a context for problem-solving in a course such as design of experiments or quality control in statistics, model formulation and application in operations research or engineering design. Such an immersive approach would provide both more realism and also match the interactive activities that the current generation is used to.

Image courtesy of AnalyCorp. Inc.

## Survey

THE ACCOMPANYING ONLINE SURVEY (www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html) is the eighth biennial survey of simulation software for discrete-event systems simulation and related products (Swain, 2005). All product information has been provided by the vendors. Products that run on personal computers to perform discrete-event simulation have been emphasized, since these are the most suitable for usage in management science and operations research. Simulation products whose primary capability is continuous simulation (systems of differential equations observed in physical systems) or training (e.g., aircraft and simulators) are omitted here.

Forty-eight products are listed in the survey, taken from 65 products submitted, making it one of the larger surveys. The range and variety of these products continues to grow, reflecting the robustness of the products and the increasing sophistication of the users. The information elicited in the survey is intended to provide a general gauge of the product's capability, special features and usage. This survey includes information about experimental run control (e.g., batch run or experimental design capabilities) and special viewing features, including the ability to produce animations or demonstration that can run independent of the simulation software itself. A separate listing gives contact information for all of the vendors whose products are in the survey. An expanded version of the survey is available on the Lionheart Publishing Web site (www.lionhrtpub.com) and will include vendors who missed the publishing deadline. Of course, most of the vendors provide their own Web sites with further details about their products. Many of the vendors also have active users groups that share experience in the specialized use of the software and are provided with special access to training and program updates.

A number of technical and professional organizations and conferences are devoted to the application and methodology of simulation. The INFORMS publications *Management Science, Operations Research* and *Interfaces* publish articles on simulation. The INFORMS Simulation Society sponsors simulation sessions at the national INFORMS meeting and makes awards for both the best simulation publication and recognition of service in the area, including the Lifetime Achievement Award for service to the area of simulation. Further information about the Simulation Society can be obtained from the Web site www.informs-cs.org. This site now provides the complete contents of the Proceedings of the Winter Simulation Conference from 1997 to 2006, and also contains links to many vendors of simulation products and sources of information about simulation, simulation education and references about simulation. The Society for Modeling and Simulation International (www.scs.org) is also devoted to all aspects of simulation. Their conferences include the Huntsville Simulation Conference that takes place annually in Huntsville, Ala.

The Simulation Society and the Society for Modeling and Simulation are sponsors of the annual Winter Simulation Conference (WSC). The 2008 WSC will be held Dec. 7-10 at the InterContinental Hotel in Miami. The program includes tutorial, methodology and applications tracks, including specialized areas such as computer modeling, financial models, transportation and logistics and other operations. Further information and registration information is available from the site www.wintersim.org. The sponsors of the conference are also ready sources of information about simulation.

## Legacy of Simulation: Ancient Roots, Modern Application

THE USE OF SIMULATION is so central to the modern Department of Defense (DoD) that there is probably no aspect of procurement, operations or doctrine that is not currently studied by simulation. Simulation is also used extensively in training. The DoD has extensively invested in all aspects of distributed simulations, where models of individual fighting units of all types are joined to models that determine what sensors (such as radar) can "see," how communications will perform under field conditions, and how command and control will function. The DoD has evolved standards for validation and model certification, and is actively exploring the means for the effective reuse of code developed in one model for use in other, newer models. Visualization has also been brought to a high level of development to make training as realistic as possible.

The reliance on simulation is anything but new – the military has used gaming for several centuries to train its officers, to plan future operations and to perform staff studies to update doctrine. Military war gaming using sand tables and maps using various counters to represent bodies of troops predate computer models. A major limitation was the manual evaluation of casualties units using dice and special tables. Our own military academies included war gaming into their curriculum from their inception.

The rapid changes in technology during the last century necessitated ongoing studies to determine how the new weapons could be utilized and to provide an appreciation of their effectiveness. For instance, during the interwar period many nations formed experi-

mental armored units to study the size, composition and operations of the new units. Many of these units evolved from exclusively armored formations to the combined arms units that predominated during WWII. Likewise, the U.S. Navy conducted a series of fleet exercises in the Pacific in the 1930s to study the effectiveness and the proper role of aircraft carriers. Over time, these studies led to an appreciation of their offensive capability and a transformation in naval doctrine. For instance, Fleet Exercise XIX in March of 1938 presaged the attack on Pearl Harbor, when planes from the Saratoga simulated a pre-dawn attack on aircraft at Hickam and Wheeler air fields in Hawaii. These exercises had a definite impact on naval thinking that prepared officers and planners for the conduct of operations in the Pacific during WWII.

The phenomenal growth of simulation throughout industry and particularly within the DoD has led to a growing demand for simulation professionals to develop models and modeling tools, and to manage large and complex simulation based projects. Academic programs in modeling and simulation have appeared at the University of Arizona, University of Central Florida, Old Dominion University, Georgia Tech and the University of Alabama in Huntsville, among others. Organizations such as the Alabama Modeling and Simulation Council (www.amsc.to) have been formed to represent all aspects of simulation, including the commercial, technical standards and training, academics and applications.

### Frontiers

MILITARY AND INDUSTRIAL operations rarely operate from a single symphonic "score," but more nearly resemble improvisations among interacting players. A limitation of the traditional simulation has been the limits on autonomy provided in the modeling constructs. Even entities that represent workers typically operate by rules that are not dissimilar to those of the machines. For instance, in a typical manufacturing simulation, products may be pushed through the system using a schedule of orders to be processed. Workers tend to individual or groups of machines according to well-defined rules, priorities and characteristics of the work. Few models provide any meaningful autonomy to make decisions, to learn from their environment or to cooperate with each other when problems arise.

Newer simulation products are beginning to provide autonomous agents that can act on their own and interact among themselves. These agent-based simulations (Samuelson and Macal, 2006) have evolved from earlier studies of complex systems whose behavior has defied easy explanation. Models of biological systems involving interacting members have been built to understand how these complex behaviors have led to social behaviors in foraging. Generalizing what has been learned from these studies has led to simulation agents with the ability to sense their surroundings, interact with other agents, reason and choose a course of action. Software has been developed that make it possible to program agents to sense their surroundings, learn, remember or to make decisions. One example is available in this survey, as the AnyLogic (XJ Technologies) software supports simulation agents.

Modeling using simulation agents is being applied in transportation and other areas where interaction and local decision-making might play an essential role. Agents have been used in traffic simulations, where driving behaviors are affected by local conditions, variations among drivers, and may include the decision to change routes based on traffic density and the awareness of alternative routings. Large simulations of air traffic include the provision for centralized traffic control and the autonomous control of their pilots. Other applications include crowd simulations, tactical warfare and pedestrian traffic. **ANALYTICS**

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**Editor's note:** *We received more than 65 packages for this survey. Due to space constraints, we could only list 48 in the printed version of* OR/MS Today. *Among the submissions left out were multiple versions of simulation packages from certain vendors, packages that didn't fit the parameters of the survey [such as Expert Fit (www.averill-law.com) and Stat::Fit (www.geerms.com), which are not actually simulation programs, though they support simulation] and packages that arrived after the deadline. A more complete list of packages, including those not seen here and those that arrived after the deadline, can be found online at: http://lionhrtpub.com/orms/surveys/Simulation/Simulation.html.*


REFERENCES

1. J. J. Swain, 2005, "Gaming Reality: Biennial survey of discrete-event simulation software tools," *OR/MS Today,* Vol. 32, No. 6, pp. 44-55.

2. D. A. Samuelson and C. M. Macal, 2006, "Agent-Based Simulation Comes of Age," *OR/MS Today,* Vol. 33, No. 4, pp. 34-38.


## ANALYTICAL SOFTWARE SURVEYS

*OR/MS Today* (www.lionhrtpub.com/ORMS.shtml), the membership magazine of the Institute for Operations Research and the Management Sciences (INFORMS), regularly conducts surveys of software of interest to a broad spectrum of analysts. Most of the surveys are updated on a biennial basis.

Each survey includes a directory of vendors and side-by-side comparisons of software packages, including such metrics as system requirements, performance capabilities, key features, technical support and vendor comments.

Several software surveys are available online, including:

**Vehicle Routing (February 2008)**
www.lionhrtpub.com/orms/surveys/Vehicle_Routing/vrss.html

**Simulation (October 2007)**
www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html

**Linear Programming (June 2007)**
http://www.lionhrtpub.com/orms/surveys/LP/LP-survey.html

**Statistical Analysis (February 2007)**
www.lionhrtpub.com/orms/surveys/sa/sa-survey.html

**Decision Analysis (December 2006)**
www.lionhrtpub.com/orms/surveys/das/das.html

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ORMS TODAY

The famous Inner Harbor will provide the backdrop for INFORMS Practice Conference in Baltimore.

# Analytics: The New Competitive Advantage

**HOW DO YOU DEPLOY THE POWER OF ANALYTICS FOR COMPETITIVE ADVANTAGE?** That question is expected to draw more than 500 analytic professionals – both practitioners and academics – to the 2008 INFORMS spring conference on "Applying Science to the Art of Business." Attendees will come to learn from the best practices of executives and analysts from organizations such as P&G, Schneider National, JCPenney, Intel, Pepsi, U.S. Army, The World Bank, UPS, Pitney Bowes, FAA, Mayo Clinic, HP and over 60 more. Well-known academic speakers from schools such as Stanford, Northwestern, Penn State, UNC and others will provide training on strategy and O.R. methodologies.

The 2008 INFORMS Practice Conference will be held April 13-15 at the Baltimore Marriott Waterfront, set on the edge of the city's famous Inner Harbor, just steps from restaurants, shops and museums. It's a perfect location for this high-intensity meeting that has become known for high-quality presentations, structured networking opportunities, innovative programs for young researchers and graduate students, and in-depth methodology and software training.

### Workshops on Technology and "Soft Skills"

NEW THIS YEAR is a Soft Skills Workshop, being held as a pre-conference program on Sunday, April 13. Attendees can choose a half-day or full-day course on the interpersonal and group facilitation skills needed to work effectively with business decision-makers and those who implement analytics solutions. Other pre-conference workshops on Sunday will be offered by leading software companies and feature introductory and advanced training in technology solutions.

# Conference Tracks

### Supply Chain Management with "OR Inside"

- Procter & Gamble – William Tarlton, Supply Chain R&D Manager, Personal Beauty Care, on implementing inventory optimization in consumer packaged goods.
- Pepsi Bottling Group – Arzum Akkas, Senior Project Manager, Supply Chain Technology, on retail out-of-stock reduction in a direct store delivery environment.
- Penn State University – Terry Harrison, Professor of Business, Supply Chain & Information Systems, and Thomas Robbins, Instructor, S. C. & Info. Systems, on the emerging science of service management.
- Xilinx – Alex Brown, Principal Engineer & Supply Chain Architect, on using demand information to improve forecasting and supply chain performance.
- IBM – Markus Ettl, Manager of Supply Chain Analytics & Architecture, IBM Research, and Blair Binney, Manager of Demand/Supply Planning Process Transformation, IBM Integrated Supply Chain, on improving distributor and IBM performance in the supply chain.
- University of North Carolina – Brian Tomlin, Assistant Professor of Operations, Technology and Innovation Management, on supply chain risk management.

### Theories of Practice: Deploying Analytics

- UPS, HP, P&G, AT&T – High-level panel on how internal analytics is funded within enterprises. Glenn Wegryn, Associate Director of Global Analytics, P&G; Jack Levis, Director of Package Process Management, UPS; Sam Parker, Executive Director of Research, Quantitative Analysis & Systems, AT&T; Shailendra Jain, HP Solutions & Service. Moderator: Zahir Balaporia, Director of Decision Engineering, Schneider National.
- Pitney Bowes – Rungson Samroengraja, Vice President, New Product Development, on building better business models.
- ILOG – Jean Pommier, Vice President, Methodology, on ILOG's methodology for implementation of decision-support systems.
- INFORMS Prize Winner – The company that receives the 2008 INFORMS Prize will describe their work in effectively integrating analytics into organizational decision making.

### OR Applications in Health Care

- Univ. of Texas MD Anderson Cancer Center – Scott B. Cantor, Associate Professor, Dept. of Biostatistics, on decision analysis in medicine.
- Mayo Clinic – Mark J. Hayward, Vice Chair, Facilities & Systems Support, and Associate Administrator, Outpatient Operations, on applications of OR approaches at the Mayo Clinic.
- CHS Medical – Mel Hall, Chairman and CEO, on workforce health management and health risk analysis.
- RTI International - Stephanie R. Earnshaw, Global Head of Health Economics US, and Stephen M. Beard, Global Head, Health Economics and European Operations, on supporting reimbursement of pharmaceuticals.
- George Mason University– Ariela Sofer, Professor and Chair, Systems Engineering & OR, on OR in cancer treatment.

### Analytics for Government, Military and Public Policy

- The World Bank – Shanta Devarajan, Chief Economist, South Asia, on the role of general equilibrium models in national and international policy making.
- US Army and AT&T – Col. Kent Miller, Chief, Army Manpower Strength Analysis & Forecasting, US Army HQDA, DCS-G1, and Judith Kerbel, AT&T, on producing the active Army military manpower program.
- US Dept. of Agriculture, Economic Research Services – Neil Conklin, Director, on models for policy design and analysis in agriculture.
- International Resources Group – Gary Goldstein, Senior Manager, energy and strategic planning in a carbon-constrained world.
- Texas A&M – Bruce A. McCarl, Regents Professor of Agricultural Economics, on modeling for government policy analysis.
- US Army, Center for Army Analysis – LTC Robert D. Bradford, OR Analyst, on the Army Reserve stationing study.

### Managing Uncertainty

- Intel – Jay W. Hopman, Researcher/Strategic Analyst, on managing demand risk using forecasting markets.
- InfoLogix – Douglas A. Samuelson, President, and Principal Decision Scientist, Serco, on managing competing risks.
- Land O'Lakes – Jim Williams, Manager, Operations Research, on continuous improvement for demand planning.
- Applied Quantitative Sciences – Michael A. Kubica, President, on applying simulation to align supply chains with consumer demand for novel products.
- George Mason University – Robin Hanson, Associate Professor of Economics and Research Associate, Future of Humanity Institute at Oxford University, on prediction markets and OR.

### Applying Decision Analysis Tools

- Innovative Decisions Inc.– Kenneth P. Kuskey, Senior Principal, on a framework and scalable process of deliberative decision analysis.
- CH2M Hill – Daniel R. Pitzler, Consulting Economist, Decision Analysis, on decision analysis applications in local government.
- Strata Decision Technology – Don N. Kleinmuntz, Executive VP & CFO, and Professor, USC, on resource allocation models for terrorism risk management.
- Decision Strategies Inc. – Patrick Leach, Engagement Leader, and author of Why Can't You Just Give Me the Number?, on the battle against Bayesian amnesia.
- Kromite – Homie Razavi, Senior Partner, on pharmaceutical industry DA from a consultant's viewpoint.
- Innovative Decisions Inc.– Dennis M. Buede, Executive Vice President, on making product development (system design) decisions with DA.

### Methodology Tutorials

- Probability Management - Sam Savage, Consulting Professor, Management Science & Engineering, Stanford University.
- Open Source Solvers and OR - Brady Hunsaker, Software Engineer, Google.
- Nonlinear Complementarity and Extensions - Michael C. Ferris, Professor of Computer Sciences and Industrial & Systems Engineering, University of Wisconsin.
- Urban Network Design – Hani S. Mahmassani, Patterson Distinguished Chair of Transportation, Northwestern University.
- Reverse Supply Chains: Maximize Value Recovery for Product Returns - Daniel Guide, Associate Professor, Operations & Supply Chain Management, Pennsylvania State University.
- System Dynamics - Jim Hines, Senior Consultant, Ventana Systems; President, System Dynamics Society.
- Achieving Optimal Solution Performance - Bjarni Kristjansson, President, Maximal Software.
- The Art of Modeling - Jeffrey D. Camm, Professor and Department Head, Quantitative Analysis and Operations Management, University of Cincinnati.
- Designing Distribution Networks Using Simulation and Optimization - Thomas Cartwright, Sr. Manager, Logistics Planning Strategy & Analytics, JCPenney.

The Franz Edelman Competition is a highlight of the meeting. Six finalists will demonstrate their applications of high-impact analytics during the day on Monday (see accompanying story), with the 2008 winner announced at a gala awards ceremony and banquet that evening. Admission to the banquet is included in the conference registration fee. This year for the first time, the winner of the INFORMS Prize will also be announced. The INFORMS Prize is awarded annually to the company that effectively integrates analytics into organizational decision-making and has repeatedly applied O.R. principles in novel and lasting ways.

### From Analyst to CEO

CHRISTOPHER LOFGREN, CEO of Schneider National, will open the conference on Monday morning with a plenary talk on "Making the Transition from Analyst to CEO." Holder of a Ph.D. from Georgia Tech, Lofgren began his career as a supply chain analyst and later took the steps into management as VP, CIO and COO at Schneider, the largest truckload carrier in North America. Lofgren will reveal how his perspective on the value of analytics has changed as he made that transition.

On Tuesday, the morning plenary will reprise the 2008 winning Edelman presentation. In the afternoon, Edward Kaplan, Professor of Management Sciences, Public Health and Engineering at Yale University, will describe some "Adventures in Modeling." An elected member of both the National Academy of Engineering and the Institute of Medicine of the U.S. National Academies, Kaplan's research has been reported in the *New York Times, Wall Street Journal* and *Newsweek,* as well as in numerous professional journals.

### Real-World Applications

THE CONFERENCE PROGRAM incorporates more than 80 sessions in eight tracks each day, including these focus areas: supply chain management, deploying analytics, health care applications, managing uncertainty, public policy and military, and decision analysis (see accompanying story). A 21-member council of practitioners and academics, chaired by Karl Kempf, Director of Decision Technologies at Intel, identified topics and invited speakers to address those topics.

Additional select presentations were chosen through a rigorous submission and review process. "We hope the program overall provides attendees with a cross-industry view of high-impact analytics applications in the real world, along with some skill-building tutorials and software training," Kempf says.

Two special programs are designed for young researchers and graduate students nominated by department chairs or senior managers. The Young Researcher Connection provides junior faculty and young industry professionals with new perspectives into critical problems facing industry. The INFORMS Professional Colloquium offers career guidance to master's and Ph.D. students who are interested in practice careers.

*Analytics* readers can register for a conference at a discounted rate of $820. **Click here** and use password: Analytics12. For continuing updates on the meeting, go to: http://meetings.informs.org/Practice08; 800-343-0062 or 401-722-2595; meetings@informs.org. Early hotel reservations are advised since rooms in the INFORMS block at the Marriott Waterfront may sell out before the cut-off date of March 14. **ANALYTICS**

## Edelman Competition and Awards Gala

Six finalists will compete for the top prize in the 2008 Edelman Competition, the "super bowl" of O.R. practice, showcasing analytics projects that had major impacts on their client organizations. The competition takes place April 14 at the INFORMS Practice Conference and is open to all conference registrants. That evening, the six finalists will be honored and the 2008 winner announced at a gala awards ceremony and banquet. In addition, the winner of the 2008 INFORMS Prize, a company that effectively integrates analytics into organizational decision-making, will also be announced.

### 2008 Edelman Finalists:

- City of Stockholm, Sweden – "O.R. Improves Quality and Efficiency in Home Health Care"
- StatoilHydro and Gassco – "Optimizing the Offshore Pipeline System for Natural Gas in the North Sea"
- Federal Aviation Agency with Metron Aviation and The Volpe Center, U.S. Department of Transportation – "Airspace Flow Programs"
- Netherland Railways – "The New Dutch Timetable: The O.R. Revolution"
- U.S. Environmental Protection Agency – "Reducing Security Risks in American Drinking Water Systems"
- Xerox – "LDP Lean Document Production®: Dramatic Productivity Improvements for the Printing Industry"


## Get an inside look at how successful organizations are using data, models and prediction to make better decisions.

SCHNEIDER NATIONAL Christopher Lofgren, President & CEO

JC PENNEY Thomas Cartwright, Sr. Manager, Logistics Planning Strategy & Analytics

P&G Glenn Wegryn, Associate Director of Global Analytics

THE WORLD BANK Shanta Devarajan, Chief Economist, South Asia

YALE Edward Kaplan, Beach Professor of Management Sciences, Public Health & Engineering

PITNEY BOWES Rungson Samroengraja, VP, New Product Development

ILOG Jean Pommier, VP, Methodology

STANFORD Sam Savage, Consulting Professor, Management Science

US ARMY Col. Kent Miller, Chief, Army Manpower Strength Analysis & Forecasting

MAYO CLINIC Mark Hayward, Vice Chair, Facilities & Support Services

XILINX Alex Brown, Principal Engineer & Supply Chain Architect

UPS Jack Levis, Director of Package Process Management

NORTHROP GRUMMAN John Tingle, Senior Decision Analyst

NORTHWESTERN Hani Mahmassani, Patterson Distinguished Chair of Transportation

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BY TED GIFFORD

***Editor's note:*** This is another in a series of articles profiling members of the INFORMS Roundtable.

# The Schneider Enterprise

**FROM ITS BEGINNING IN 1935 WHEN AL SCHNEIDER SOLD THE FAMILY CAR TO BUY HIS FIRST TRUCK,** Schneider National, Inc. has grown to become a premier provider of transportation, logistics and intermodal services. With combined revenues of $3.7 billion, the Schneider enterprise portfolio of integrated services includes truckload, intermodal, transportation management, dedicated, bulk, supply chain management, warehousing and international logistics services. Schneider operates more than 14,000 tractors and 48,000 trailers with over 15,000 drivers. Last year, Schneider trucks moved two million loads and drove 2.5 billion miles. Schneider Logistics, a part of the Schneider National enterprise, is an international logistics provider to two-thirds of the FORTUNE 500 companies.

Schneider Logistics helps customers capture strategic business value from their supply chains in the form of lower distribution costs, reduced inventory, improved customer service and increased availability to working capital. Schneider Logistics operates two units in China: Schneider Enterprise Consultancy (Shanghai) Co. Ltd. and Schneider Logistics (Tianjin) Co. Ltd. Services include supply chain consulting, as well as transportation and logistics services for the domestic market. Schneider National conducts business in more than 28 countries in North America, Europe and Asia, and continues to grow its international service offerings.

## Operations Research at Schneider

OPERATIONS RESEARCH-INSPIRED work at Schneider has developed along two somewhat distinct threads, both driven by business opportunities and the need to leverage sophisticated mathematics-based approaches to realize these opportunities. Work around the first thread began in 1976, when the Schneider truckload freight network had grown to the point where complex planning models could be easily justified. Initial development began on two applications. The first was a precursor to later revenue management models and was formulated to determine the "optimal" freight mix given a selection of load opportunities and fixed set of assets. The second was a linear programming formulation with a sophisticated pre-processing engine to solve the classic driver-to-load matching problem. To our knowledge, Schneider was the first truckload company to address these problems with modeling and optimization.

With the deregulation of the trucking industry in the early 1980s, Schneider grew from its upper Midwestern base to encompass a national transportation network. To support this growth, engineers at Schneider helped develop plans for a broad network of operating centers using set-covering models in combination with available information on national freight flows. In the late 1980s, O.R. projects included the development of techniques to design dedicated network tours routing of inter-plant movements. This period also fostered the implementation of statistical tools to address a variety of customer-specific analyses.

The second thread of activity began in the early 1990s when Schneider realized the opportunity to expand from an asset-focused transportation provider to a broader offering of freight management and logistics services that were asset-light. In 1993, a separate entity, Schneider Logistics, was incorporated to meet this need; it now provides a broad range of domestic and international logistics services ranging from transportation management to supply chain management and warehousing.

These new service and product offerings generated additional opportunities and demands for O.R.-based projects. For the expanding third-party logistics (3PL) business, shipment planning and carrier selection tools were developed. A sophisticated shipment planning system included components for mode selection, consolidation and multi-stop routing. The carrier selection module utilized integer programming to model complex carrier commitment constraints. For the truckload business, numerous regression models were devel-

oped to better understand the profitability impact of freight flows and characteristics. In support of the information technology infrastructure, fast approximation algorithms and highly efficient data structures were developed for distance and rating engines. The rating engine technology was subsequently patented.

During this period, a supply chain engineering group was commissioned within Schneider Logistics. This group, which developed many of its own tools for facility location and network modeling, was engaged primarily in business development and in fee-based consulting for logistics and 3PL customers. Through the late 1990s and early 2000s, these two spheres of O.R. activity continued to flourish in two separate groups. Enterprise software-based, decision-support systems continued to be developed and enhanced by the Decision Analytics group which was housed within the Application Development arm of the IT organization, while the Supply Chain Engineering group, responsible for both internal and external O.R. consulting, supply chain modeling and business development support, reported directly into the Schneider Logistics business unit.

In 2003, as collaboration and resource-sharing had steadily increased, Schneider decided to merge the two teams into a single Engineering and Research Department headed by a vice president reporting to the CIO, while maintaining close ties to the Logistics business unit. This integration proved to be a precursor to much closer alignment and product integration that soon followed across the company's customer-facing business units.

Today, the Engineering and Research Department is comprised of 44 professionals with varied academic backgrounds and industry experience. The group's academic backgrounds range across not only operations research, but also industrial engineering, mathematics, computer science, finance and business administration, with a combination of bachelor's master's and Ph.D. degrees. A number of team members bring significant prior transportation operations experience, which helps ensure that the department pursues solutions that are relevant, practical and credible. The group is organized into four activity-specific teams, each lead by a director with accountability to deliver business value to a corresponding constituency. With overlapping skill sets, cross-training and resource sharing, these groups are able to both maintain specific focus as outlined below, as well as to flex in size to support changing business needs.

***Business Development:*** Design and operational planning for dedicated fleet networks, modeling to support feasibility studies, analysis for new business proposals, international logistic support. Primarily supporting internal business units and key sole-source customer accounts.

***Supply Chain Engineering:*** Development of solutions for route design, scheduling and facility location problems. Primarily serving after-market parts distribution systems for heavy equipment, automotive manufacturers and tier one suppliers.

***Research:*** Development of algorithms and optimization models that form the basis for decision support engines embedded in corporate-wide operational planning and execution systems. Development and execution of off-line simulation and optimization models to support strategic and tactical planning and policy development.

***Consulting:*** Statistics and data mining, industrial engineering analysis, business process simulations, general consulting and problem analysis using a wide-range of O.R. techniques. Development of productivity tools to support the work of the E&R group.

## All About the Roundtable

INFORMS has two types of members: individual and institutional. The latter (usually a company) joins by joining the INFORMS Roundtable and appointing as its representative the person in overall charge of O.R.

The Roundtable has been very active since its founding in 1982, with three meetings each year and much communication in between. It, its member institutions and its member representatives take a strong interest in how INFORMS serves the needs of practitioners, and have undertaken many initiatives and provided many services toward this end. These involve, for example, public awareness of O.R., both of the annual INFORMS conferences, continuing professional education, one of the prizes and various committees.

In addition, the Roundtable has an advisory responsibility to INFORMS. One bylaw states that it "... shall regularly share with INFORMS leadership its views, its suggested initiatives and its implementation plans on the important problems and opportunities facing operations research and the management sciences as a profession and on the ways in which INFORMS can deal proactively with those problems and opportunities ..." By tradition, it meets with the newly elected INFORMS president-elect each spring to discuss practice-related topics of interest to him or her, and with the entire INFORMS Board each fall to discuss topics of mutual concern.

The Roundtable membership comprises about 50 organizations. Further information is available at http://roundtable.informs.org.

This series of articles aims to share with the INFORMS membership at large some information and insights into how O.R. is carried on in practice today.

### A Diverse Spectrum of Opportunities

SCHNEIDER APPLIES O.R. in a comprehensive array of decision-making contexts. The following examples will serve to illustrate the breadth of application areas and the variety of skills and methodologies represented by the organization.

***Network Value Engine:*** Schneider has created a number of proprietary applications to institute revenue management principles in its truckload and intermodal lines of business. Chief among these applications is Network Value Engine (NVE), which estimates the profitability of individual loads. NVE estimates these network-related profit impacts of loads using marginal values produced by solving a large, complex math programming model. While NVE was originally developed to support load acceptance decisions, network value has become central to the mindset of decision-makers in other contexts including load solicitation, asset repositioning, and spot pricing.

***Tactical Planning Simulator:*** TPS is a large-scale modeling environment that is particularly effective for analyzing problems and policies which are sensitive to micro-level details and, therefore, not addressable via more traditional aggregated-flow, min-cost type models. Developed jointly with CASTLE Laboratory at Princeton University, TPS uses approximate dynamic programming in conjunction with mathematical optimization at sub-problem nodes and sophisticated pattern-matching techniques to enforce operational policy adherence. The system has been used to improve business decisions related to the geography of driver hiring, driver work-rule impacts, driver time-at-home policies, new business profitability analysis and other areas.

***Driver recruiting:*** Recruiting and training drivers represent significant costs for the trucking industry. Schneider has developed several data-mining approaches (regression trees, cluster analysis, etc.)

to improve its understanding of relationships between applicant characteristics and measures of driver effectiveness, including time-to-hire, productivity, retention and safety.

***Forecasting:*** Utilizing the tool set of a third-party forecasting package, the group has refined and extended statistical techniques to generate impressive improvements in forecast accuracy for monthly load volume (1.7 percent error enterprise-wide over the second half of 2005). The group is now working on new operational (0-7 day) forecasting models to better predict network flow imbalances so such situations can be addressed proactively rather than reactively.

***Dedicated fleet analysis:*** Dedicated networks operate semi-autonomously within the Schneider One-way truckload network. Using both third-party and internally developed optimization software, Engineering and Research sizes and designs these sub-networks to minimize operating costs, maximize synergy with the broader network, and reduce the impact of freight surges and flow imbalance. In 2005, incremental revenue for Schneider from designed networks accounted for more than 6 percent of total dedicated revenue.

***Customer service:*** Over the past five years, Schneider has embarked on a pervasive process redesign journey. Industrial engineers within the Analytics group have played a key role in this work. Using statistical process control methodologies adapted from manufacturing (e.g., Six Sigma and control charting), the group has been instrumental in facilitating, understanding and improving work flow, customer service representative productivity, on-time performance and other areas. The group has developed simulation models to evaluate alternative workflows for newly structured call center operations.

***Shipment consolidation:*** Schneider's internally developed optimization engine for shipment planning, consolidation and routing has been continually upgraded over the last 10 years as software and hardware capabilities have advanced. As originally conceived, the system relied primarily on simulated annealing and a palette of local search heuristics. The current version uses a novel combination of constraint programming and integer programming to provide optimal solutions for most problems and near-optimal solutions for the remaining, largest problems.

## Partnerships

A KEY COMPONENT in the success of O.R. at Schneider has been an organizational willingness to invest in applied research, as well as projects specifically focused on delivering near-term business benefits. In addition to internally staffed activities, the group is actively engaged in joint projects with several leading universities and with domain-specific external consultants. Among current academic relationships are projects to improve inter-modal scheduling and dray optimization (University of Wisconsin-Madison), to explore the use of control-theory techniques to better understand and address network stability and flow balance (Michigan Technological Institute), and the development of a large-scale transportation network simulator, based on approximate dynamic programming, to evaluate the effect of operating policies, resource allocation models and revenue management strategies (Princeton University).

Recently completed projects include development of a short-haul schedule and route optimizer utilizing column-generation schemes (Georgia Institute of Technology) and studies of driver behavior and preferences (University of Minnesota-Morris).

## Perspectives on Success

SCHNEIDER'S USE OF O.R. began more than 25 years ago. Over the subsequent decades, Schneider's O.R. applications have grown more sophisticated and diverse, taking advantage of technological advances and responding to growth and expansion of Schneider's business portfolio. In addition to providing the organization and its customers with a competitive edge through well-informed decision-making, the use of O.R. has made positive contributions to Schneider's bottom line: Annual earnings have increased by more than $10 million.

Success through O.R. does not come overnight, nor does it occur in a vacuum. Keys to the long-running success of the O.R. effort at Schneider are:

- Commitment of time, resources and leadership to mentoring and training, both technical and soft skills.
- Commitment of dedicated resources to the development and maintenance of productivity tools.
- Adopting a philosophy of high bandwidth interaction with customers. This takes two forms: enabling non-engineering business associates to take on lower-level engineering tasks and moving engineers into business leadership roles.
- The vigilant search for new opportunities and application areas for O.R. This helps keep the staff fresh and motivated and helps condition the business to realize the broad range of areas where O.R. can deliver value. The complexities of moving and managing freight throughout an international supply chain continue to surface in today's global economy. For global supply chain service providers like Schneider National, O.R. will continue to play a significant and lasting role in managing those complexities, mitigating risks and ultimately delivering the type of service, visibility and reliability customers require. **ANALYTICS**

***Ted Gifford*** *(giffordt@schneider.com) is the vice president of Engineering and Research at Schneider National. Schneider won the 2006 INFORMS Prize for its "effective integration of operations research into organizational decision-making."*

# Napoleon's Parable

BY DOUG SAMUELSON

The junior O.R. analyst was troubled and frustrated. "I just don't see why this model isn't tracking right," he sputtered. "I've been over the code carefully, half a dozen times. I ran some test cases that came out right. But some of the data points we're trying to forecast in the holdout sample are just way off. There don't appear to be coding errors in the data, either – I've gone back and checked the bad points against source documents. Help, Carl! What more can I do?"

"Well, let's see, Bob," the older analyst said soothingly. "You're trying to model loan behavior, right? And your 'bad' data points are loans that did much better or worse than expected?"

Bob nodded.

"Then it's probably not a mathematical error," Carl told him. "More likely there's some simplifying assumption, one you didn't even realize you'd made, that is violated in these few cases. And are the bad points related in time, somehow?"

"I'm not sure," Bob admitted. "We group them by cohorts, sets of loans that were made at the same time. The problems occur at different times since origination."

"Aha," Carl responded, "but that means they could be at the same time, couldn't they?" Bob looked confused.

"I saw this in a military manpower model I worked on several years ago," Carl explained. "We'd see these sets of similar misfits in different cohorts. But after a while we figured out that an error in month 24 since they joined for a group of people who joined in, say, May 1996, and an error in month 23 for a group that joined in June 1996, and so on, were really simultaneous. We'd go back and ask the sergeant major what had happened in that month, and it always turned out he'd say, 'Oh! That's the month we announced such-and-such a change in the bonus program.' What we'd seen as a complicated modeling issue really was an event we didn't know about, affecting whole sets of people at the same time in the same way. I'll bet your problems in your loan analyzer are also coming from events you didn't know about, like changes in the loan programs that were offered."

"I'll check," Bob affirmed, but he still looked dubious.

"This sort of thing is more common than you realize," Carl added. "A few years ago, I got to hear a seminar by Dennis Cook, who's famous for one of the best books on applied regression analysis. He said he'd discovered, after years of work, that what looked like a complicated model often turned out to be a mixture of subpopulations, each with a simple model. The real, underlying trouble was that some analyst had decided to consider the whole population as more or less alike, and didn't realize there was this mixing going on."

Now Bob was getting excited. "How come, with all the stuff that's been written out there about statistical analysis, this sort of thing isn't mentioned more often?" he asked.

"Oh, it is out there in the literature," Carl said, "although admittedly not as often as the newest and fanciest new technical add-ons to help build those more complicated models. But people often don't see that they've overlooked something simple – and it's hard to admit to a client when you find out that's what you've done! And then, of course, there's the additional problem of analysis plans."

Bob looked puzzled again. "What do analysis plans have to do with it?" he inquired.

"That's where the hidden assumptions get set in concrete," Carl replied. "Most clients and bosses want a plan of analysis first, before you've had any chance to see what the data really look like. So it's easy to fall into the trap of planning, let's say, linear regressions, and then find out the data violate some of the assumptions of the technique you intended to use. They're not linear, or they have relationships you didn't expect among variables that are supposed to be independent, or they're discrete when you need them to be continuous. And try explaining that sort of thing to a client!

**Analysis plans: the place where hidden assumptions get set in concrete.**

"Napoleon wrote, 'No plan of battle ever survives the first contact with the enemy,'" Carl concluded. "From my experience I'd add: No plan of analysis ever survives the first contact with the data."

"I won't argue," Bob agreed, "from my own experience. But what can you do?"

Carl suggested, "Write your plan to start with an exploratory stage, where you've proposed some techniques depending on what the data will support, and your first step is to determine whether the data are what you expected and whether they fit the assumptions of the technique you wanted to use. Your next step, as you can probably guess, usually is to come up with different ways to analyze, depending on what nasty surprises you got. Build in some steps of going back and verifying whether important events have been left out and need to be included – like the changes in bonus programs in the manpower model. And, of course, don't forget the most important – and least often stated – assumption in any analytical modeling method."

"What's that?" Bob asked.

Carl smiled and said, "The assumption that the future will be like the past. If what happens next isn't, in the ways that count, pretty much like what you saw before and analyzed, you have no chance of getting it right, no matter what analytical method you use." ANALYTICS

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# Should Analytics or Rules Drive e-Sales?

BY ANDREW BOYD

Businesses devote tremendous effort to managing rules. Whether the rules dictate payment terms under a contract or compliance with government regulations, rules are an important part of running a business.

Software for managing rules has re-emerged in the market of late following a "near death experience" [1]. Originally known as expert systems and later knowledge-based systems, the term "business rules engines" has gained favor in recent years as vendors seek to capitalize on market opportunities.

Business rules engines are certainly a good approach to automating rules of compliance such as billing procedures, but are they an appropriate framework for decision-making? Consider a company selling travel packages over the Web. A visitor to the company's Web site might click on "warm weather deals" and be taken to a page that lists Caribbean destinations. Rules of this nature go beyond compliance to the very foundation of the sales process. Should Caribbean or desert destinations be displayed? Both? What options? By analyzing the continuous flow of information on how customers purchase, a company can adjust its actions to better achieve sales goals. In a nutshell, this is the e-sales promise of analytics/operations research.

Analytics and rules offer very different conceptual approaches to e-sales. While they are not altogether contradictory perspectives, the practical reality is that they evolved from different roots on different paths. As operations researchers, we appreciate the power of analytics as embodied in models, algorithms and data analysis. But rules constitute a view of the world many key decision-makers are more comfortable with; a world in which decisions are made and then executed. Attractive as business rules may appear, many hidden problems are often overlooked when adopting a business rules framework. Among the problems:

- ***Adopting a business rules framework postpones the difficult task of making decisions.*** Business rules engines provide a means by which to implement rules. It is easy to be enticed by a business rules engine's ability to implement rules only to find that when it is deployed the question of what rules to implement still remains. Without supporting analytics, a business rules engine represents a means by which to make poor decisions far more quickly and efficiently. Off-line analytics can be performed to help write the rules, but this circumvents the real-time potential of the e-commerce model.

- ***Performance measurement is difficult in a business rules framework.*** Businesses are adamant about justifying projects based on their return-on-investment. Since the value proposition of business rules engines is implementing rules, their return-on-investment is implicit – streamlining processes or providing a mechanism to apply rules more efficiently (again, sidestepping the value of the rules themselves). Systems based on analytics are designed from the outset to monitor revenue improvement against baseline metrics.

- ***Business rules proliferate.*** With a powerful tool in hand, it is easy for business users to create new rules, causing the list of rules to grow ever larger and more complex. Eventually it becomes difficult to determine if the rules are doing what they are intended to do. When instances are discovered where rules are not leading to expected results, the response is typically to add more rules.

- ***Business rules can impede analytical inquiry.*** Analytical approaches to e-sales derive their value from inferring future customer behavior. These inferences are more dependable when offers are made in a way that lends itself to analysis, specifically, limiting the type of offers in order to develop statistically significant conclusions. Business rules engines generate a web of offers that often make it difficult to infer what caused a customer to behave in a particular way: if A then B unless C except when D, in which case perform F until G or H.

- ***Suboptimal legacy practices are easily institutionalized.*** An early selling point of expert systems was the ability to automate the decision processes of human experts. If these processes can be improved upon by analytics, then business rules engines only serve to institutionalize suboptimal legacy practices.

The growth of the Internet is providing a rare opportunity to fundamentally rethink how we sell. By understanding what customers want and responding accordingly, higher sales and customer satisfaction can be achieved. While analytics and rules both have their place, decision processes with demonstrable value require an analytical foundation. Realizing the full potential of the Internet as a sales channel requires the dynamic application of analytical tools.

As systems for driving e-sales evolve, it is important that we remain sensitive to decision-makers' comfort with rules. But it is also important that we provide the intellectual leadership necessary for analytics to flourish at this critical period in the evolution of commerce. **ANALYTICS**

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## REFERENCES

1. Frye, C., "Business Rules are Back," *Application Development Trends*, July 2002. See also http://www.adtmag.com/article.asp?id=6492.

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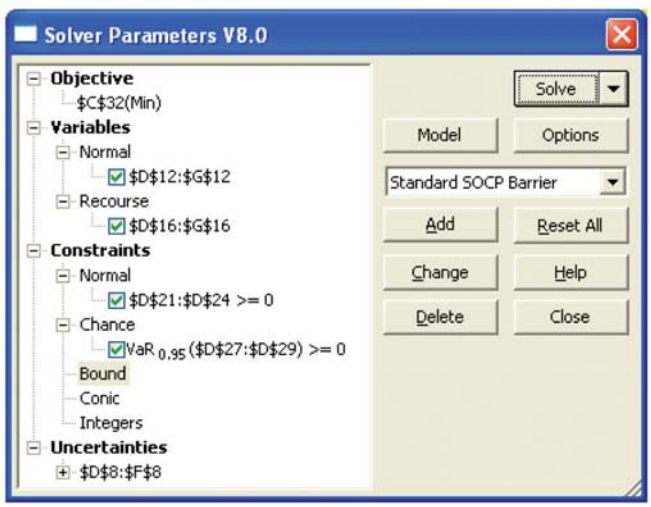


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