Practitioner's Commentary: The Outstanding Lawful Capacity Papers: The Answer Is Not the Solution

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Introduction

I would first like to thank *The UMAP Journal* for inviting me to write the practitioners article for this years Mathematical Contest in Modeling. The topic is of interest to me in that I have some direct experience solving problems and implementing solutions in the public safety arena. My hands-on training in this area includes spending time in burning buildings, cutting people out of wrecked cars, and, unfortunately, putting a few people in body bags.

As a result of these experiences, I developed sufficient knowledge and credibility to develop a method that the Denver Fire Department uses for selecting sites for new fire stations. The station-siting problem that I addressed is similar to your contest problem in that my mathematical training enabled me to find the correct answer, but focusing exclusively on a mathematical solution moved me further away from a solution which could be implemented. As the practitioner commentator for this years Contest in Modeling, let me suggest that in pursuing a mathematical solution to the maximum occupancy problem you may have moved away from a solution which could be implemented.

Let me outline what I plan to discuss:

- I want to congratulate not only the five winning teams whose papers are published in this issue but also the 202 other teams whose papers were not selected for publication.

The UMAP Journal 20 (3) (1999) 335–341.

- I would like to discuss some of the common assumptions made in solving the maximum occupancy problem.
- I would like to challenge the contest participants and readers to elevate their problem-solving skills by focusing on what's required to get a solution implemented. Hence my title, "The Answer Is Not the Solution."
- Finally, I would like to offer some suggestions regarding how to effectively communicate technical information to the public.

Background (Mine)

To accomplish these objectives, let me provide a bit of personal background which should help the reader interpret my comments. I hold three graduate degrees in quantitative/analytical fields: a Ph.D. in operations research, a master's degree in mathematics, and a master's degree in economics. I mention these academic credentials not to impress you but to impress upon you that my academic training only helped me begin to solve "real-world problems"—and in the initial stages of my career, it actually got in the way.

I might have successfully convinced you that the training required to complete three graduate degrees would enable me to solve virtually any quantitative or analytic problem. I used to believe that myself, until I left the safety of academia. What I quickly found out is that in the real world, all bets are off. There are no pure analytic problems. There are no standalone quantitative problems. There are quantitative problems embedded in political problems. There are analytic problems embedded in economic problems. There are technical problems encrusted in hidden agendas with stakeholders whom you don't even know exist, much less their agendas, interrelationships, or side agreements. I'm not saying these things to discourage you, but rather to let you know up front that they do exist—and to let you know that these problems are much more fun to solve than the textbook problems that you encounter in school. I also want to let you know that if you can solve these types of problems (and based on what I've seen, you can), you can solve just about any problem.

Congratulations

I want to congratulate all those who participated in this year's contest. To dedicate an entire weekend focused on a single problem, particularly one foreign to your prior problem solving experience, is commendable. Further, to outline and detail the quality of solutions evidenced by the published articles is extraordinary. You truly exhibit the problem-solving skills needed in the world today.

I was particularly impressed by your abilities to outline a solution approach (including your assumptions) and decision criteria. The communication of

these components will be critical to your future success. Frequently when one presents a solution to senior management, the assumptions and methodology are more important than the answer. That may sound strange at this point in your academic training; but trust me, after you graduate and present a few solutions, you will understand what I'm saying. It is your assumptions and modeling approach that determine, to a great degree, the answer that you get. It is in developing the approach and building the model that you gain a rich understanding of the problem. Your ability to truly understand a problem not only enables you to solve the problem, but more important, empowers you to implement the solution—and implementation is where you provide value to an employer and prove value to yourself.

I was impressed as I read the five solution approaches published in this journal. The level of understanding and variety of mathematical tools employed to solve the problem were far beyond anything I encountered at the undergraduate level. Of course, back then we scratched our solutions on cave walls and held up torches so that our professors could read them. Well, I'm exaggerating a bit; but your understanding and sophistication are well beyond anything I possessed or encountered at the undergraduate level. I was also impressed with your written communication skills, your ability to put thoughts on paper and communicate them clearly and succinctly. Frequently, the people who master problem-solving are among the weakest at communicating the results. I encourage you to continue to refine your communication skills. They will serve you well and are perhaps even more important than your quantitative problem solving skills.

Assumptions

Enough congratulations, I was truly impressed. Let's discuss some assumptions. The common assumption that I saw in the models was the one I will paraphrase as, "when exiting a room or building, during an emergency, people will exit via the nearest exit." Unfortunately, this not the case. According to Denver Fire Chief Richard Gonzales, "studies have shown that in the case of fire, people exit via the door they entered, regardless of the nearest exit. During a fire people do not always act rationally. They generally remember the way they came in and retrace that path even if another exit is much closer." This finding, based on actual experience, further complicates the maximum occupancy problem and creates a need to understand how people enter a room or building to determine how they will exit. This adds a level of complexity to determining how quickly people will exit and therefore the maximum number to let in.

Let's examine another common assumption. I will paraphrase this one as, "the average person can exit at a rate of x feet per second." Having entered and exited burning buildings on more than a few occasions, I can challenge this assumption based on first-hand experience. I have been in several burning

buildings where the smoke was so thick that I couldn't see my hand in front of my face. It's also not unusual for the power to go out because of the fire or water used to fight it. Unless the room has emergency lighting (or it's daytime and the room has exterior windows), you're moving around in darkness. In smaller fires, or in the early stages of a fire, it can be difficult to see across a well-lit room; and many public places, such as restaurants, bars, dance halls, and theaters, are not well lit. The point is that visibility is a critical variable that impacts the speed at which people can exit or even find the exit they remember entering.

In addition, most people have never exited a room or building during a fire, and this lack of experience impacts they way they react. Our common evacuation experiences occur during fire drills, and fire drills do not accurately represent emergency conditions. (As an aside, when was the last time you participated in a fire drill at a restaurant, bar, dance hall, or theatre?) The reason why people practice fire drills is so that they know where the exits are and which one to use in the event of a fire. But knowing what to do and doing it are two different things. If they were the same, we would ace every exam, never get in a car wreck, and always say the right thing.

The next assumption that I would like to address was actually implied in each of the published articles. I will paraphrase the assumption as "people behave rationally in an emergency." In a private conversation, Chief Gonzales cited several examples of just how irrationally some people behave. The Chief's examples are best summarized by the comments of a restaurant patron who refused to leave a burning building, even as the room was filling with smoke. The man argued with fire department personnel, "I paid for this steak and I'm going to eat it." This may be an extreme example; but extreme or not, it highlights a point: You have to account for human behavior, whether it's logical or not, because that behavior represents reality. Failure to do so leaves your model, and therefore your solution, open to attack.

The message that I hope you're hearing is this: Your model or solution approach must account for critical real-world conditions. Failure to do so will impact your credibility and therefore acceptance of your solution.

Will They Use Your Solution?

Let's move on to implementation requirements. To maximize the probability of a successful implementation, your solution, model, or method must address the issues of each stakeholder. This implies that you must first figure out who the stakeholders are. In the case of the maximum occupancy problem, Chubb and Williamson [1998] provide a fairly complete list of construction project stakeholders, each of which has a stake in the maximum occupancy decision:

> Construction projects require an owner or developer who defines a specific need. The owner must usually obtain or arrange for the acquisition

> or transfer and expenditure of capital to finance the project. This capital will be used to procure skilled designers, builders, and the materials they need to execute the project. To protect this investment, insurers will be retained to underwrite the performance of the contracted designers and builders, and insurers will ultimately assume a portion of the risk exposure once the project is completed. Regulators will insist on reviewing the project throughout design and construction as well as throughout the period of occupancy to ensure compliance with regulatory mandates. Besides preserving public confidence in building safety and safeguarding the public from involuntary exposure to fire risk, their activities also help ensure a secure tax base. Finally, the occupants or tenants themselves will often participate to see that their individual needs are met. … The complexity of fire safety decisions is amplified by the individual agendas these actors bring with them.

After the relevant stakeholders have been identified, you have to identify the needs and concerns of each stakeholder group. This is best done by talking to them, in person, on their turf and in their terms. During the discussion, ask lots of "why" questions ("Why is that important?" and "Why do you feel that way?"). The answers to these questions enable you to understand what each stakeholder values. You can then define a solution space that incorporates what the stakeholders told you was important. You then begin to weigh priorities and make tradeoffs based on politics, economic impact, risk, importance to the decision makers, and/or the ability of a stakeholder group to block the implementation of your solution. And yes, you can now incorporate your mathematical findings.

For what it's worth, I have never (outside of academia) seen a mathematical solution dominate the other decision criteria. In really good solutions, the mathematical findings complement the solution, but they never dictate it. Regarding the use of mathematical models to solve real-world problems, my point is best captured in the words of Chief Gonzales, "These models work in an ideal world, but that world doesn't exist."

Telling the Story

Let me address the newspaper articles written for local newspapers, defending your analysis. It has been my experience that when communicating to the general public, one's message is best received when it is presented in simple, clear, and succinct terms that address the audience's hopes, fears, and dreams as they pertain to the topic at hand. To that end, let me suggest that an article defending your method should focus on its ease of use, grounding in common sense, and the amount by which the results you generate exceed what they already have. A quote from a highly visible and respected official never hurts either.

As an example of what not to do, I submit the following.

Dear Mr. And Mrs. Public,

Concerning our award-winning method to determine the maximum occupancy level of your child's elementary school classroom, we used a polyhedral approach to approximate a statistically unbiased estimator that incorporated Euler's formula to model crowd movement based in small rooms. This model incorporated Chebyshev's inequality as it applies to elementary-school traffic patterns.

We then fed our results into a simulation model utilizing software that we built ourselves based on tools that we downloaded from the Internet.

While this method is probably way over your head, we have full confidence in its ability to forecast the probability of an emergency during school hours.

This information enables us to set the maximum occupancy of your child's classroom at 183 plus or minus 7%.

Yours truly,
Contest Winners

The correct approach would be to convince the public that your method yields a solution that increases their safety and improves the likelihood of the survival of their loved ones. As an old farmer once told me, "No one wants to know how we make sausage, they just want to know how good it tastes."

Summary

Let me close by summarizing my key points:

- I commend you on your ability to frame the problem and communicate your assumptions and solution approach.
- Always test your assumptions to make sure they are grounded in reality.
- Identify the relevant stakeholders, elicit their concerns, and address those. You don't have to give everyone what they want, but you do have to demonstrate that you listened and considered each request.
- When communicating to the public (written or oral), use simple, clear, and succinct language that address the audience's hopes, fears, and dreams as they pertain to the topic at hand. Focus on the benefits that they will receive and how your solution represents an improvement over what they now have.

If you do these four things, your successes will outnumber your failures and people will respect your work.

Good luck and keep up the good work.

Reference

Chubb, M.D., and R.B. Williamson. 1998. Value-based fire safety: A new regulatory model for mitigating human error. In *Human Behaviour In Fire—Proceeding of the First International Symposium*, August 30—September 2, 1998, edited by T.J. Shields, 105–114. Belfast, Northern Ireland: University of Ulster.

About the Author

Richard Hewitt has solved problems and implemented solutions in a variety of industries, including oil and gas exploration, public safety, and telecommunications. His work includes two trips to Antarctica on behalf of the National Science Foundation to realign support operations for the NSF Antarctic Research Program. Dr. Hewitt's work has directly resulted in the generation of over $500 million in new revenue and annual cost savings in excess of $65 million. Dr. Hewitt is currently developing a performance feedback system for U S WEST, a Fortune 100 corporation in the telecommunications industry.