

Judges' Commentary: The Outstanding Kidney Exchange Papers

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Introduction

Eight judges prepared for this year's ICM judging by studying the Kidney Exchange Problem and calibrating their criteria. When prepared for their task, they had the opportunity to read and compare an excellent set of creative and interesting papers. It is likely that many students and some advisors would find it surprising that the judges face challenges as complex as those tackled by the ICM contestants: The judges must determine how best to evaluate, grade, and score a myriad of papers as fairly and accurately as possible over a very short period of time. Their goal is to insure that awards are given to the best teams and that the papers published in *The UMAP Journal* represent the finest student work produced in the contest.

The papers were assessed in three key areas:

- effective use of current data and policies relevant to the U.S. organ transplant network to reveal supply and distribution bottlenecks and to identify means for producing improvements in the efficiency and fairness of the organ-donation network;
- application of an appropriate modeling process and appropriate use of the model to perform insightful and critical analysis; and

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- integration of mathematics, science, ethical principles, and common sense to render appropriate recommendations to the decision-makers.

Overall, the judges were impressed by the considerable efforts expended by the contestants and by the prodigious and sophisticated work produced by many of the teams. This year's problem was particularly challenging because it involved multiple tasks and the teams having to take on several diverse perspectives, ranging from mathematics and sciences to ethics and social policy.

The Problem

The issues raised in the Kidney Exchange Problem are real, and the problem is timely. Organ transplant problems and opportunities are often discussed in the news, and there is an ongoing stream of new proposals seeking to improve organ transplant management. Many of these proposals are being debated by both the U.S. Congress and members of the executive branch of the government. A wide array of professional researchers, staffers, and analysts are engaged in work on many of the same questions, challenges, and procedures that the teams had to address over the contest weekend. Some of these professional working groups are also engaged in advocacy—writing letters to members of Congress or to executives in the Department of Health and Human Services, processes mirrored by two of the required tasks faced by the contestants.

The data needed for the problem were readily available on the Internet. And while there are a number of articles and even fully developed models in the literature, the problem required more than mere research: Real, robust, creative modeling and critical interdisciplinary thinking were needed to complete successfully the required analyses. Several disciplines in addition to mathematical modeling had to be included for full consideration of this problem; ethical, medical, sociological, political, cultural, and psychological perspectives were all essential components to the development of complete and creative solutions. The dilemmas surrounding the issues of organ donation are undeniably and genuinely interdisciplinary in nature, and they have global relevance. Useful solutions to these challenges clearly require robust modeling if the current inefficiencies of present-day organ-donation systems are to be reduced or eliminated.

Judging Criteria

In the end, the judges selected two papers to be designated as Outstanding. Both of these efforts, and another special paper, will be considered later in this article. The judges organized the evaluative rubric into five categories (listed below), and we use this framework to summarize the judges' perspectives and determinations.

- **Quality of the Executive Summary:** Most teams demonstrated that they knew that it was important to provide a good executive summary. Moderately successful efforts only summarized the requirements and stated their recommendations. The more successful efforts also provided a logical link between the research issues, the models, and the recommendations.
- **Scientific Knowledge and Application:** Many papers demonstrated their significant knowledge of organ transplant science by providing well-written reports of the technical and social issues inherent to the transplant process and the organ distribution network. Many also provided excellent summaries of the widely differing issues regarding the role of government, public health policy, ethics, psychology, international culture, and social issues involved in the procurement and distribution of organs. It was clear that this problem was both very complex and demanding. Although most papers addressed the basic issues of the transplant systems, some papers addressed the complexities of this capacious issue better than others, through use of creative models and insightful analyses. The least successful papers were those that did not go beyond reporting information from the Internet or journal articles. Papers in this category sometimes included unnecessary or irrelevant scientific information, and they sometimes failed to fully integrate and/or document the information they presented. These kinds of papers did not fall into the highest-level categories. Some of the moderately successful papers were rather disjointed and apparently had the science section written by one part of the team and the modeling and analysis sections written by another. Although these sections may have been quite good when considered in isolation, they typically were not well-integrated and therefore did not present a strong synthesis of key elements. The most successful papers used the scientific knowledge as a basis for their models and their subsequent analysis as the basis for their policy recommendations. Almost every team was able to cite an enormous amount of information from the open literature and clearly had used Internet sources fully and effectively. But the stronger teams not only gathered an abundance of information, they examined international procedures and ideas to suggest potential improvements to the U.S. organ donation network that sometimes stumbles along under current public policies and social constraints. In other words, these papers demonstrated that the authors had an understanding that network functionality was critically important in the design of an outstanding solution to this problem.
- **Modeling:** The most effective papers made their assumptions explicitly from the scientific foundation that they developed to build their models. As one judge noted, some of the models appeared to be hammers looking for nails—making some models so complex that the entire report was devoted to developing the model without devoting time to any thoughtful analysis or meaningful recommendations. Some teams demonstrated their abilities to make appropriate model refinements in the follow-on tasks that addressed

the more interdisciplinary issues of ethics and politics. It was important that the modeling process was well formulated and robust; but unfortunately, some papers had wonderful models that offered little explanation of how the model functioned or provided little use of the results in the analysis.

- **Analysis/Reflection:** Successful papers discussed the ways in which their models were able to address the issues and tasks involved in improving the current organ donation system. The most effective modelers verified the sensitivity and robustness of their models. This problem asked many questions, and even a long weekend does not provide much time to perform all the tasks for this very complex and interdisciplinary model. The most effective papers, however, found the time to recommend new policies based on their analyses, and the policies that they recommended were fully justified by the model analysis they had performed. The weaker papers did not address the questions with effective mathematical modeling or simulation, but relied instead solely on Internet research. The papers that addressed the policy issues well seemed to show that the U.S. was not doing enough to increase the population of donors and provided plausible solutions that were verified or used by their models. The problem tasks led many teams to talk about ethical concerns; but to the dismay of the judges, many other teams did not include consideration of ethical concerns in either their models or in their analyses of the issues.
- **Communication:** The quality of writing in the reports this year seemed to have slipped a bit compared to papers in previous competitions. This decline in quality may have been a consequence of the unusually high number of tasks and requirements for this year's problem compared to those in previous years. Nevertheless, this year's most effective papers demonstrated clear organization throughout the modeling process by establishing logical connections between sections of the report. Good communicators also understood that well-selected graphics were a highly effective means for making their points. As to the length of the papers, succinct with adequate explanation was preferred. Long, rambling papers were judged to be less effective because they created the frustration of requiring the judges to read unnecessary details and irrelevancies. Some papers hinted of good analysis but lacked sufficient clarity in their presentation. These teams apparently reasoned better than they communicated and consequently their important ideas and good arguments were not made readily apparent to the readers. The strongest papers presented the problem, discussed the data, explained their analyses, and fully developed their mathematical models. The biggest difference between the stronger and weaker papers was whether or not they were able to inform the reader about what they did, and more importantly, how they did it. Clear presentations allowed the judge to comprehend the logic and reasoning of the successful modelers. The top papers artfully blended the scientific literature with humanistic concerns, strong argument, and elegant mathematics.

Analysis of the Outstanding Papers

The papers judged to be Outstanding shared several common elements: robust modeling, insightful analysis, effective communication, and a touch of creativity. What truly distinguished these papers from the less successful, however, was their passion for the problem. They demonstrated a desire not only to solve the tasks at hand, but also to improve the overall health and well-being of real-world patients who suffer from organ disease. It is not surprising that given the complexity of the problem, both of the Outstanding papers still contained some weaknesses.

"Optimizing the Effectiveness of Organ Allocation" from Duke University "quantitatively analyzes kidney allocation, possible improvements to live donation, and many other strategies to improve the current process" (Executive Summary). Their model showed how list-based pairing could dramatically increase live donations, and they creatively addressed both ethical and political considerations. This team's letters to Congress and Director of the Health Services were crisp and clear with solid, well-supported, recommendations.

The Princeton paper entitled "Complete Analysis of Kidney Transplant System using Markov Process and Computations Models" made excellent use of the team's model to investigate the effects of policy changes. The authors recommended presumed consent and paired-kidney exchange. They also modeled the psychology of donating through the use of a "consumer decision theory model to explain the decisions that potential donors face when deciding whether or not to donate a kidney" (Executive Summary). Their analysis of the marketing of kidneys led them to reject the idea of making organs available on the free market because of their astute analysis of the serious ethical concerns such a system raises, even though it could potentially supply many kidneys to the organ donation network.

One other paper, while not designated Outstanding, also deserves mention because of the high quality of its creativity and presentation style. "The Giving Tree" submitted by a team from Berkshire Community College, provided a model that was "delicately designed so that the best ethical practices compliment the most efficient strategy, all while remaining economically feasible" (Executive Summary). The team proposed the very creative concept of "mandate choice," in which potential donors are required to declare their donation preferences when they seek driver's licenses. This team also included incentive strategies to educate citizens to the benefits of organ donation. All and all, this was a highly notable paper and one of the first that we have so favorably received from a small two-year institution.

Plagiarism

Unfortunately, this year's contest was marred by the disqualification of strong papers because of improper referencing, over-reliance on the published

work of others, and a failure to appropriately and fully acknowledge the use of sources. The contest rules state that failure to credit a source will result in disqualification from the competition, and we were disappointed that this had to be done at the conclusion of this year's competition.

The Joy of Interdisciplinary Modeling

Talk of modeling, science, mathematics, psychology, communication, summaries, transplants, HLA, PRA, TTCC, OPN, references, algorithms, and computer programs echoed in the air; and then intense discussion of scores, rubrics, and criteria ensued as the final decisions were made. All this happened as the eight final judges came together to evaluate the finalist papers. As judges and interdisciplinary problem-solvers, we were most happy when we found papers full of excellent modeling, detailed mathematics, scientific facts, deep analysis, informative graphics, interesting solutions, successful collaboration, and especially strong evidence of student passion. This approach made mathematics all it should be: exciting, relevant, and potentially transformative.

Conclusion

The judges congratulate all the members of the successful teams. We saw evidence that all teams recognized and struggled with the challenges of a real, large-scale, interdisciplinary problem and hope that all of the ICM participants learned from their experiences as a part of this process. We believe that participation in the ICM contributes to the development of contestants in their quest to become sophisticated and effective interdisciplinary modelers. The effort and creativity demonstrated by almost every team was inspiring, and many papers served to reveal clearly the power of interdisciplinary problem-solving. We look forward to both continued improvement in the quality of the contest reports and increasing interest and participation in the annual ICM.

Recommendations for Future Teams (with help from the triage and final judges)

- Spend as much time as you can on analysis of the model, not just its development. Do not just report the model output and data. If possible, summarize your analyses clearly in tabular or graphical form.
- Clear communication makes it easier to identify outstanding work. Check your equations to avoid typographical errors resulting in a relationship that is inconsistent with the written description. State your assumptions, limitations, and strengths, and be sure to integrate fully and appropriately your

research sources with your model. Do not allow the background research to stand alone, unrelated to the model that you propose. The science that you report should be relevant to the model, and the model should reflect the science.

- Evaluate your results and discuss their implications. Explain how your results compare to similar work in the literature.
- Keep in mind that simple explanations suffice. If you are doing something super-elegant or ultra-complex, do not lose the reader in super-ultra-elegant complexity. Overly complicated models are not good ones. A significant part of the art of modeling is choosing the most important factors and using appropriate science and mathematics to simplify the problem.
- Long papers are not necessarily good papers. If you cannot describe your models clearly and succinctly, then they probably are not good models.
- The final important reminder is that any material that comes from other sources, even if paraphrased, must be carefully and completely documented; it must be placed in quotation marks if taken verbatim from another source.

About the Authors

Chris Arney graduated from West Point and became an intelligence officer. His studies resumed at Rensselaer Polytechnic Institute with an M.S. (computer science) and a Ph.D. (mathematics). He spent most of his military career as a mathematics professor at West Point, before becoming Dean of the School of Mathematics and Sciences and Interim Vice President for Academic Affairs at the College of Saint Rose in Albany, NY. Chris has authored 20 books, written more than 100 technical articles, and given more than 200 presentations and 30 faculty development workshops. His technical in-

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Kathleen Crowley is a Professor of Psychology at the College of Saint Rose. Her Ph.D. in educational psychology was earned at the State University of New York at Albany. Her teaching interests include parenting, child development, gender development, and the history of psychology; and she has taught a variety of courses at both Saint Rose and the University of Hartford in these subjects. Kathleen's research interests involve gender development, the psychology of women, and teaching of psychology. Recently, she has written on psychology as it relates to the post-modern philosophy. Always interested in using the latest technologies, Dr. Crowley has taught courses online and often uses service learning to enhance her courses. In addition to teaching, she has served as acting dean of the School of Mathematics and Sciences at Saint Rose for several years and as chair and member of many faculty committees. Enjoying travel, theatre, and film, she is the mother of two boys and active in her campus community. Recently, she took trips to London and California and was on an American Psychological Association delegation to Vietnam, Cambodia, and Hong Kong. Her latest hobbies include reading, singing, dancing, and soaking in her hot tub.

