Judges' Commentary: The Sandcastle Problem

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Introduction and Overview

This year's Problem B focused on identifying 3-D geometrical foundations for a sandcastle that would enable the sandcastle to last longer. Further, the teams were to measure the effects of rainfall and wave erosion on the duration of the sandcastle. The scenario setting could have been a beach anywhere in the world.

The problem required teams to develop a modeling approach to address multiple required questions, including the traditionally-required memorandum (in this case, couched as a magazine article).

We start this commentary with a short review of the mechanics of this year's judging process and follow that with a discussion and observations from the judging on various elements of the problem. We then discuss the importance of sensitivity analysis, assumptions, and identifying the strengths and weaknesses of a developed model; and we finish by addressing some points concerning communication.

The Process

We believe that it is beneficial for teams to understand the judging process; so, similar to previous commentaries, we once again review the basic judging process for this year's Problem B.

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Triage

Every paper is read by at least two judges during the triage round to determine if the paper contains all of the required and necessary elements that make it a candidate for recognition. If a paper addresses all of the question components/issues and appears to have a reasonable model, then judges are likely to identify it as a paper that deserves more attention.

A paper must be clear and concise, and its summary is critical at this point in the judging. A good summary provides a brief overview of the problem, of the paper's structure, and of specific results, stated in a clear and concise manner. Many papers struggle in the triage because they fail to address fully the question, so the judge decides that a team's efforts will not compare well with the better papers. For example, one critical element overlooked by many teams was to show the duration (time) for the three-dimensional foundation selected.

Fully developing all of the required modeling elements is critical and is often overlooked in papers. For example, sensitivity analysis remains one of the weakest elements and is often entirely missing in papers; such papers do not do well during the triage.

In addition, it is vital that the team express their general approach and results as clearly and concisely as possible in the memorandum (nontechnical position paper). This means providing a broad overview of the problem, of the approach, and of specific results in clear, concise, nontechnical terms. Ask yourself if someone without an education in mathematics can read and understand the paper.

Finally, we expected an informative, one- to two-page article describing your model and its results for publication in the vacation magazine *Fun in the Sun*, whose readers are mainly non-technical. Many memos did not present any results in either the summary or the article.

Clear and concise writing makes it much easier for a judge to identify the team's effort and for the paper to do well in the triage round. However, the best models and the best effort are not effective if the results are not adequately communicated. It is important to remember that this is a modeling competition and that effective communication is a critical part of the modeling process.

Final Judging

The final judging consists of multiple rounds of judging over several days. As the rounds progress, the judging criteria shift from identifying papers that warrant further consideration to a process to identify the very best papers.

The first round of the final judging begins with each judge reading a set of papers. Then all judges meet to discuss the key aspects of the question and what should be included in a "good-to-better" paper. This year, these aspects included, in addition to all of the required elements, a clear discussion of the modeling process for three-dimension foundation shapes and results indicating that the foundation selected lasted longer than other attempted foundations. Sensitivity analysis was key; sensitivity analysis should vary parameters of interest until results change (if that happens).

As the final judging progresses, each paper is read multiple times, with the final set of papers being read by all judges. In these last rounds, the modeling process and the mathematical integrity of a paper begin to identify the Outstanding papers in the competition.

Critical Elements of the Modeling Process

The MCM is designed to be interesting yet challenging, but achievable in the available time. Successful papers require paying attention to all elements of the modeling process. Many teams focus a great deal of their time on developing a fantastic model but find they run short of time and short-change many critical elements. Typically, these include adequately addressing all components of the problem, developing a clear and concise summary and memo, and testing the model. We address a couple of these areas.

Components and Discussion of This Year's Problem

The final judges collectively believed that this year's problem was fairly difficult and not a typical B problem (a B problem usually fosters modeling that involves continuous mathematics). Judges saw a lot of fluid mechanics, physics, and other continuous mathematical equations thrown at the problem.

Teams were expected to select a 3-D foundation that enables longevity of the sandcastle. Judges expected to see a few 3-D foundation shapes and then modeling to determine which of these shapes lasted longest. Thus, time was a variable that was expected to be an ingredient in the model.

Teams spent a lot of time modeling flow of waves. Teams did not have to do this with tidal flow charts or other information; using average wave height and average force were sufficient.

At some point an optimization scheme might have been used.

Models and their elements for the 3-D geometry, effect of waves, and effect of rainfall need to be addressed. The latter two need to reflect back on their effect of the foundation found in the best 3-D geometry.

Executive Summary

The executive summary is a critical element of any document. The executive summary is always read first and sets the tone for the rest of the paper. The executive summary must include methods and results in a brief, concise manner. It appeared in too many instances that the executive summary was written before a team completed their modeling effort! Many executive summaries addressed only how a team planned to model and solve the problem but failed to include any results. The judges considered a clear, concise and fully-developed executive summary as a critical criterion for "good" papers.

Figures, Graphs, and Symbol Table

Too many figures are lifted from other sources and pasted into contest entries without attribution to the sources. Not having a figure is better than using one "borrowed" without attribution. Many teams were close to being disqualified for this infraction; this year, we decided to call it "poor referencing"—but we may cease such lenient treatment. The judges recognize that it is a time-constrained contest, and creating original figures might not be practical; but make sure always to cite the source for a figure.

If graphs are provided, then they need to be well-labeled in a large-enough font, with a clear explanation in the text of what the graph tells the modeler/reader.

Variables and parameters for all models should be listed in a table, with their meanings and units provided.

Assumptions, Sensitivity, and Strength and Weaknesses

In modeling, assumptions drive the model-building and/or use of the model. The better papers tended to provide a concise list of relevant assumptions together with corresponding justifications. For any model, there is always a set of assumptions about when and how to use it, and these should be included in the paper. Many papers essentially repeated the assumptions from the information given in the problem statement with perhaps a few additional assumptions. A common trait was a list of assumptions that were not actually addressed or used in the model.

Sensitivity was once again a big discriminator of papers. No paper was moved forward to the final rounds that did not have good sensitivity analysis (error analysis or model testing is included here). In sensitivity analysis, we are very interested if the results change based on changes in the input values. Since teams commonly used constant coefficients, changing them would be good sensitivity analysis. Often, it appeared that the sensitivity analysis was a token analysis, done only to meet the spirit of the requirement and not a good analysis effort.

Most teams did an adequate job identifying the strengths and weaknesses of their respective models. It was also surprising that teams did not Google existing literature on sand-to-water ratio, where they would have found an acceptable range of values usually between 8% and 15%.

Memo

The 1-to-2-page memo took the form in this year's Problem B of a magazine article. A non-technical summary document is a key outcome of the modeling process, especially for a decision maker. Such a memo is an act of communication designed to translate the technical aspects of the modeling process into clear, concise, and non-technical terms for the reader. The memo is essentially an executive summary for management, who would read it before any of the rest of the paper; and it sets the tone for the remainder of the paper. The memo must include the solution methods and brief results for all questions. The judges considered a clear, concise, and fully-developed memo as a critical criterion for "good" papers. Unfortunately, this year many teams did not provide a satisfactory article; and even most of those who did would have benefited from focusing a little more on it.

Communication

Papers were judged on the quality of the writing, with special attention to the summary and to the non-technical article. The quality of writing, in general, is continuing to improve; but many papers were not well-written. Basic spelling and grammar errors in a paper are a distraction to the reader. We suggest setting aside some time at the end of your modeling process to ensure that you have time to read through your own paper before submission.

Final Thoughts

"Winning" is participating in the contest. Learning to work as a team to accomplish your team's goals and objectives is success. As a reminder, the COMAP classification of papers (Successful Participant, Honorable Mention, Meritorious, Finalist, and Outstanding) is based on a comparison to other papers and the expectations of the judges. The Outstanding teams modeled and presented all the aspects of the problem described in the problem statement, including fully developing the standard elements.

Teams should review their assumptions, sensitivity analysis, strengths and weaknesses, etc., prior to submission. Additionally, teams should develop an effective model, explain the modeling choices made, and write clearly and concisely.

Every year, we continue to be impressed with the quality of the submissions, especially considering the time constraints. We congratulate all participants this year as it was a very difficult year especially due to the coronavirus restrictions around the world.

About the Author

Dr. William P. Fox is currently a visiting professor of Computational Operations Research at the College of William and Mary. He is an emeritus professor in the Dept. of Defense Analysis at the Naval Postgraduate School and teaches a three-course sequence in mathematical modeling for decision making. He received his B.S. degree from the US Military Academy at West Point, New York, his M.S. in operations research from the Naval Postgraduate School, and his Ph.D. in Industrial Engineering from Clemson University. He taught at the US Military Academy for 12 years, until retiring from active military service, and at Francis Marion University, where he was the chair of mathematics for 8 years. He has many publications and scholarly activities including 20+ books, 22 chapters of books and technical reports, 150 journal articles, and more than 150 conference presentations and mathematical modeling workshops. He has directed several international mathematical modeling contests through COMAP, the HiMCM and the MCM. His interests include applied mathematics, optimization (linear and nonlinear), mathematical modeling, statistical models, models for decision making in business, industry, medical and government, and computer simulations. He is a member of INFORMS, the Military Application Society of INFORMS, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics, and in several of these societies he has held numerous positions.