Judges' Commentary: The Space Junk Papers

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Introduction

The number of teams choosing to participate in Problem B for the Mathematical Contest in Modeling continues to climb: In 2016, we judged more than 30 times the number of submissions compared to 1990. This year, for the first time, all of the winning papers were from teams in China.

The judges for Problem B have several observations to share that might aid teams in preparing for future competitions.

Suggestions

Answer the Question

Our main suggestion is to make sure that you answer the question(s) posed in the problem. In Problem B, you were asked to "develop a time-dependent model to determine the best alternative or combination of alternatives that a private firm could adopt as a commercial opportunity to address the space debris problem." This is your main goal!

While the problem statement went on to elaborate on what your model should include and be able to do, the judges understand that in the limited time allowed, you may not be able to comprehensively address each and every point in the problem statement. The MCM problems are intentionally open-ended and offer you the ability to expand your solution in interesting directions—but before you head off into unchartered territory, **please make sure that you have addressed the main elements of the problem statement**.

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The better papers thoroughly handled the main requirement to develop a time-dependent model and examined multiple alternatives—all with the goal of arriving at a commercially viable procedure for dealing with space debris. The better papers considered the mathematics and the economics in equal measure.

Use Sources but Be Original

Unlike many previous MCM problems, a tremendous amount of information on the topic of space debris was available on the Internet. The judges found this situation to be a bit problematic. Please realize that every team has access to the Internet and is very likely considering the same links that you found. This contest is not a report on all that the Internet says about a topic! We are seeking unique and creative new models, not an exhaustive report on existing information. Moreover, the judges noted identical charts and graphs in several papers—yet only some of the papers included the relevant citations from the Internet.

It is important to be very careful about what you use from other sources and that you reference them. The judges knew that some equations pertaining to space debris could also be found on the Internet—again, this is not interesting to us. **We would prefer to see your own equations that you derive based on your own logic and understanding of the problem.** If you do end up building your model from existing equations, you must cite them. This also applies to equations that you may have encountered in a textbook or math course. Cite, cite, cite!

But if all you are doing is citing, then your approach is misguided—we want you to be creative as you wrestle with an open-ended problem, so try not to get persuaded that the information that you track down is the best or only way to approach the problem. (Meritorious paper 47676 from Shanghai Jiao Tong University was the exemplar in regard to citations.)

Keep It Simple

This is a competition for undergraduate students, and although a handful of teams from high schools participate in the MCM, no students beyond the undergraduate level are permitted to participate. This means that **the judges are not looking to be wowed by advanced mathematical equations**. Neither are we interested in a list of variables and parameters that stretches over multiple pages. **It is okay to be simple and straightforward.** What is important is that you define your variables and parameters and that you explain the logic of your model. We are seeking creativity in the modeling process. Sometimes it may be appropriate for you to utilize an existing package or model in your work. If so, take some time to describe it for the judges and explain why you felt that it was an appropriate choice in this instance (and cite it!).

The careful analysis of your model and any solutions it generates is essential to the MCM. Be particularly attentive to its strengths and weaknesses. For any parameters, let the judges know where you found numerical values to use or how you estimated them. (This was particularly relevant in the Space Junk Problem if you used subjective approaches such as Analytic Hierarchy Process models.) An appropriate sensitivity analysis is essential, particularly if you are unable to obtain accurate values for any parameters in your problem. (This suggestion is relevant if you used a weighted matrix method in your model.)

In our view, the exemplar paper for the Space Junk Problem was the Outstanding paper from Zhejiang University. The main idea in this paper is to establish an insurance company and use the premiums collected to clean up some space debris, thereby reducing the overall risk of future claims. The team presented a very creative mathematical model with an economic perspective, which helped focus on the main task of developing a plan that would be commercially viable for a private company. The exposition was extremely clear; it was a pleasure to read. The scenarios to illustrate how the company could make money were solid. Although the Executive Summary discussed free riders, the judges felt it would have been helpful if the team had discussed the issue in greater detail in the body of the report and taken into account the potential for government involvement to require insurance of all satellite entities (companies or countries) in order to eliminate free riders. Another weakness in this paper was that the parameter choices for the decision-making matrix were not explained. The judges appreciated how the team used light humor, with comments such as "This page will not focus on this," and "Here comes the figure."

Conclusion

The judges feel that the better papers come from teams that do not rely too much on material from one mathematics course or from Internet sources. The better papers attempted to address all the points from the problem statement. They included a sensitivity analysis and a discussion of strengths, weaknesses, and next steps that illuminated a deeper understanding of the problem.

About the Author

Catherine Roberts is the Executive Director of the American Mathematical Society. Previously, she was the chair of Mathematics and Computer Science at College of the Holy Cross. She is also editor-in-chief of the journal *Natural Resource Modeling*. She has an A.B. from Bowdoin College in mathematics and art history, as well as a Ph.D. from Northwestern University in applied mathematics. She has been an Associate Editor of this journal.