

Judges' Commentary: The Outstanding River Problem Papers

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Problem Overview and General Remarks

This year's problem dealt with scheduling variable-length river trips down a 225-mile stretch of a particular river, using either oar-powered rubber rafts (at 4 mph) or motor boats (at 8 mph). A fixed starting point and a fixed ending point were specified for all trips, with campsites distributed fairly uniformly down the river corridor. Minimal contact between groups of visitors was desired, and no two groups could share the same campsite. The goal was to maximize the number of trips over a six-month period, utilizing both types of transportation and allowing for trip lengths of 6 to 18 nights on the river. In addition to the executive summary, teams were required to write a memo to the managers of the river trips, advising them on the optimal scheduling of trips of various lengths over the six-month period, and taking the carrying capacity of the river into account.

The teams' approaches varied greatly, especially regarding the number of campsites available—a factor that had a significant impact on the number of trips that could be scheduled. Many teams found that the “Big Long River” greatly resembled a stretch of the Colorado River in the Grand Canyon, and some used that as a case study for their models. Simulations are available for scheduling trips on that river, but teams had to address all of the issues raised in the problem statement and come up with a solution that demonstrated their own creativity. The judges looked for that and for carefully-explained mathematical model-building with sensitivity analysis that went beyond what is found in the literature.

Executive Summary and Memo

The executive summary is of critical importance, especially in early judging. It should

- motivate the reader;
- be polished, with a good synopsis of key results;
- give an overview of the model(s) used, together with the rationale for using such a model and the primary results obtained from that model; and
- state specific results obtained for the optimal solution.

Teams were also asked to write a memo appropriate for the manager of the Big River boat tours. Whereas the executive summary usually contains technical details, this memo was intended for a nontechnical person who wanted to know how best to schedule trips. Hence, the memo was supposed to give specifics on how to schedule trips of various types to best accommodate as many groups as possible. Vague generalizations were of little or no value.

Documentation

In comparison with previous contests, the judges were pleased to observe a noticeable improvement in how references were identified and in the specific precision of their documentation. Considering the online resources available, proper documentation was an especially important factor in this year's problem. Despite the improvement, many papers contained charts and graphs from Web sources with no documentation.

All graphs and tables should

- have labels and/or legends;
- provide information about what is discussed in the paper;
- be "called out" in the text of the paper, so as to refer the reader to them; and
- be explained in the text, including their significance.

The best papers used graphs to help clarify their results, and those papers also documented trustworthy resources whenever used.

Assumptions

Teams made many assumptions about travel along the river. Some were appropriate and played integral roles in the models used; others were

superfluous. Some teams assumed that there would always be enough customers to fill any trips scheduled; other teams used probability distributions to describe the demand for different trips at different times of the season. Either approach could be used, but each led to different results. The carrying capacity of the river was dependent on the number of campsites available and the types of trips to be scheduled.

Since this is a modeling contest, much weight is put on whether or not the model could be used (with modification) in the real world. Therefore, assumptions required for simplification could not be totally unrealistic. Also, clear writing and exposition is essential to motivate and explain assumptions, and to derive and test models based on those assumptions.

The Model(s)

One can arrive at a fairly complete solution to this problem with pencil and paper alone. Problem solvers should at least consider this possibility before launching a simulation! Some teams began with a simple model, then improved it to accommodate the requirements better. Teams should be aware that it is not the quantity of models considered that is important, but rather the quality of the model selected and its applicability to the case at hand.

At a minimum, the solutions should try to come up with a mix of trips that seem reasonable. Most teams recognized that for a 225-mile river, a motor boat could run the entire distance in 6 to 8 nights, whereas a raft powered by oars would need 12 to 18 nights. While it is true that requiring only the shortest trip lengths would permit the most boats to get down the river, it was important to consider that not all groups would choose to travel that way.

Some teams considered a profit incentive when scheduling trips of varying duration on the river and used selected numbers from the Grand Canyon boat trips as a guide. For example, the cost of the trip might be a constant fixed cost plus an amount based on the number of nights on the river. In that case, shorter trips might allow more boats to launch and be optimal in terms of profit. Or perhaps it would be more valuable to people to get more time in this pristine wilderness, so they would pay a premium for the longer trips—in which case it might be worth sending fewer boats down the river. Many teams ignored cost/profit issues.

Teams assigned campsites so as to ensure that no two sets of campers occupied the same site at the same time. At the end of each night, the teams had to be sure that all crafts camped in reasonable locations and that the model did not require a boat to travel too far in any one day. Many teams measured the percentage of campsites occupied each night as a help in determining an optimal number of campsites and how good the solution was from a manager's perspective.

In addition to having no two groups at the same campsite, minimum contact between groups also implies minimizing crafts passing one another on the river. Teams that took this into account showed true diligence. Some teams even measured the average number of such contacts. Although neglecting this aspect was not a fatal flaw, proper consideration of the crossings gave the model added value.

Testing the Model—Simulations and Sensitivity Analysis

MCM teams are getting better at carrying out simulations, and this technique was of great value for the Big River problem. However, to carry out a simulation properly, criteria had to be specified for scheduling trips of varying length. A good flowchart with examples was very powerful in clarifying how a simulation was to be carried out. Some teams used a well-defined prioritization scheme that assured that no two groups stayed at the same campsite on any given night and rejected assignments that violated that criterion.

Sensitivity analysis was an essential ingredient. The better papers considered how their solution was impacted by changing the number of campsites and by changing the types of trips. This included varying the ratio of motor boats to oar-powered rafts and varying the ratio of trip durations. The graphical demonstration of the results of such sensitivity analysis was a powerful way to communicate the outcomes and to check for patterns of optimality.

Although sensitivity analysis could have included issues associated with boating accidents, inclement weather, and flash floods, most papers only alluded to such possibilities. Few teams considered anything but constant speeds for the river flow and the boats. Some teams considered extending the hours of travel.

Strengths and Weaknesses

A strong paper must assess its strengths and its weaknesses. One of the greatest strengths of any model is how well it reflects the real world situation. Hence, using a case study to validate a model is a powerful means to make that case. Most papers recognized the limitations of their models in failing to consider weather, river, and individual camper issues. A strong solution might mention among weaknesses that assigning campsites is something of a limitation, because an accident that prevents a boat from reaching its assigned campsite could mess up the model. A more realistic model would say that a given boat will go at most—rather than exactly— n

miles per day; and a flexible model would ensure that a boat could find an open campsite if it didn't make it to its goal campsite.

Concluding Remarks

Mathematical modeling is an art. It is an art that requires considerable skill and practice in order to develop proficiency. The big problems that we face now and in the future will be solved in large part by those with the talent, the insight, and the will to model these real-world problems and continuously refine those models. The judges are very proud of all participants in this Mathematical Contest in Modeling and we commend you for your hard work and dedication.

About the Author

Marie Vanisko is a Mathematics Professor Emerita from Carroll College in Helena, Montana, where she taught for more than 30 years. She was also a Visiting Professor at the U.S. Military Academy at West Point and taught for five years at California State University, Stanislaus. She chairs the Board of Directors at the Montana Learning Center on Canyon Ferry Lake and serves on the Engineering Advisory Board at Carroll College. She has been a judge for the MCM for 17 years and for the HiMCM for eight years.