Judge's Commentary: The Outstanding Emergency Power-Restoration Papers

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The Emergency Power-Restoration problem was truly challenging. The problem statement left many issues incompletely specified. These ambiguities, coupled with the very nature of the problem, allowed considerable latitude and hence demanded considerable modeling.

This open-ended character, which made the problem so interesting and so challenging for the participants, also made the problem interesting and challenging to judge. We clearly could not simply crown as winner the team whose schedule finished first, because there are multiple objectives and every team used its own relative weighting of these objectives. Furthermore, using different assumptions leads to different numerical results; it clearly would not be reasonable to compare directly the time to completion for a team that assumed crews traveled 60 mph with one that assumed crews traveled only 30 mph. Thus, there is no one "right" answer or single "optimal" solution.

Instead, the teams were evaluated based on how they approached the problem. We considered more factors than can possibly be detailed here, and every paper was judged individually; so it would be misleading to create the impression that winning teams simply needed to satisfy a checklist. Nevertheless, I will describe some characteristics that were associated with successful papers.

Perhaps the most important of these was *generality*. A power company would be unlikely to seek a schedule for one particular storm; by the time the consultants had the data for that storm, many (if not all) of the allocation decisions for that storm would have already been made. The power company is interested instead in objective criteria that it can use to schedule work crews during and after future storms and—as evidence of the viability of those criteria—wishes to see them applied to the given data. Teams that gave a schedule only for this one storm did not deliver as useful a product as did teams that gave a general procedure. Likewise, some teams implicitly or explicitly assumed that all storms would be similar to the one for which data are given; nature offers no such guarantees.

Since this was a contest in modeling, and models are simplified representations of reality, we also evaluated the reasonableness of the simplifying assumptions made and how well they were justified. Weaker papers simply asserted that a factor was unimportant, or worse, neglected even to identify the assumption. Stronger papers offered a rationale and discussed the implications of making or not making the assumption. Some papers distinguished themselves by performing sensitivity analyses and/or using bounding arguments to demonstrate quantitatively that the simplification made would not lead to substantially inferior solutions.

Another touchstone of quality was explicit recognition of the existence of multiple, often conflicting, objectives. Essentially every team recognized the choices to be made between different types of customers, but other factors that might enter into a priority calculation include the number of people affected and the elapsed time since the outage was reported. The "justice" of responding to calls in the order in which they are received must be balanced against the "efficiency" of dispatching crews to nearby locations (to minimize travel time) and the "wisdom" of giving priority to certain classes of customers. Since there are multiple objectives, and there is not one universally accepted way of converting the vector of "scores" on the corresponding attributes into a scalar measure of overall quality, it is expedient to report a variety of performance measures. The team from Oklahoma State University distinguished itself in this regard.

Another characteristic of a strong paper was the consideration of a variety of scheduling procedures. Many papers proposed a single approach, applied it, and reported the results in isolation. It is essentially impossible to ascertain whether such a procedure is good or bad. All the procedures could be labeled "bad," because at least a few customers were without power for a considerable time; likewise, all the procedures might be deemed "good," because they restored power to every customer eventually. Such statements are vacuous. It is only by comparing relative performance that one can hope to make useful statements about quality. Both the Washington University and the Oklahoma State University teams were outstanding in their use of five different approaches, including one (first come, first serve) that they inferred from the problem statement was likely to be similar to the power company's current practice.

Papers also varied with respect to the degree of sophistication of their scheduling algorithms. Many used a simple greedy heuristic that assigned the highest-priority not-yet-assigned job to a crew when the crew became available. Others were more clever. Some looked ahead before dispatching to see whether there were any crews closer to the destination who would become free shortly and hence be able to reach the scene first. Others used measures of shadow cost or opportunity cost to make assignments. One team even considered that working full 16-hr double-shifts can *extend* the completion time (the North Carolina School team's result not withstanding) if the crew cannot finish the final task that day, forcing additional travel time and delaying the earliest time at which the crew can be back on the job.

Likewise, some teams recognized that if the jobs are viewed as nonpreemptive, it may be prudent to leave a crew idle rather than immediately dispatch it, in case a higher priority call is received. The North Carolina School team considered an extreme version of this strategy, namely, holding back all crews for a certain amount of time. They performed a sensitivity analysis and calculated the optimal holding time for this storm; it is not zero. This team was also one of the relatively few that considered the possibility that the estimated repair times were only estimates, not universal constants cast in stone.

Finally, clarity of presentation is always important, particularly in this context, since the teams were instructed to play the role of consultants. This need for clarity placed a premium on having a concise, informative summary and on finding means of insightfully conveying the results. Verbal descriptions of algorithms and results are usually dry at best; but as the saying goes, a picture can be worth a thousand words. Teams that conveyed their results in well-designed tables or graphs typically made their point most effectively. All three of the outstanding teams distinguished themselves in this regard.

The Emergency Power-Restoration problem was difficult, and many excellent solutions were offered. In the end, however, three papers stood out from the others, and the members of those teams should feel proud of their accomplishments.

About the Author

Jonathan P. Caulkins did his undergraduate work at Washington University's School of Engineering and Applied Science, where he participated in the MCM. His teams' papers were rated Outstanding in the first two competitions, in 1985 and 1986.

Jon went on to earn a master's degree in electrical engineering and computer science and a doctorate in operations research from MIT. Now he is an assistant professor of operations research and public policy at Carnegie Mellon University's Heinz School of Public Policy and Management, where his research focuses on developing mathematical models of illicit drug markets.

Jon was an associate judge for the Emergency Power-Restoration Problem.