THE CONSORTIUM FOR
MATHEMATICS AND
ITS APPLICATIONS

2019 MCM Problem B
Triage Judging Guidelines

Purpose and Background

The Mathematical Contest in Modeling (MCM) and ***The Interdisciplinary Contest in Modeling (ICM)*** both rely on a Triage Judging and Final Judging process to identify seven classes of participant performance – Disqualified, Unsuccessful Participant, Successful Participant, Honorable Mention, Meritorious, Finalist, and Outstanding – based on the technical reports submitted under the MCM/ICM contest rules (http://www.comap.com/undergraduate/contests/mcm/instructions.php).

Final Judging is the culminating process whose purpose is to identify the papers that will be designated as Finalist or Outstanding. Prior to this event, Triage Judging in the United States and China efficiently ranks and categorizes each MCM/ICM submission based on desirable characteristics and content established over years of MCM/ICM operations, and upon the peculiarities of each problem.

Overall, the MCM/ICM supports and advocates an iterative mathematical modeling process consisting of major elements that include:

- Problem Restatement,
- Assumptions & Justifications,
- Model Construction and Application,
- Model Testing and/or Sensitivity Analysis,
- Analysis of Strengths & Weaknesses.

Papers that contain major elements in sufficient detail to address the problem posed receive higher recognition from judges.

The triage process relies on the professional expertise, experience, and judgment of academic faculty and industry professionals supporting the administration of the MCM/ICM to read and recognize key quality indicators in team papers – proper applications of mathematics and science, depth of exploration, completeness of a recognized modeling process, proper reliance upon and documentation of supporting research, innovative and insightful modeling approaches, and clear and concise exposition, among others. As noted frequently in UMAP Journal articles, elements such as these are universally valued among modelers, and are hallmark ingredients expected of top papers,.

While it is impossible to list all potential contributors to such quality, it is possible to note items that, if not present, will limit a paper's quality from the viewpoint of the MCM/ICM. While not claiming to be all-encompassing in its attempt to identify such limiting criteria, this memo will hopefully provide enough information to create a consistency in judgment despite extreme geographical and temporal separation of triage sites.

Triage Judging

In the Triage round we seek to cull out papers that do not have a chance at being Meritorious or Outstanding. In general we have percentage target levels we are planning to keep for final judging, but we always have to make some adjustments as we go through the process.

The judging of student team submissions uses seven paper classifications: Disqualified, Unsuccessful Participant, Successful Participant, Honorable Mention, Meritorious, Finalist, and Outstanding. The classification for each MCM/ICM paper is relative to the pool of papers received each year.

General guidelines and percentages for each category are as follows.

Disqualified (DQ) (% as warranted): the team's paper was found to be in violation of the contest rules. The rule violation should be noted in the comment column (e.g. "plagiarism," "same as paper xxx") and scored as 0. The MCM/ICM contest directors will review and verify all papers designated as disqualified (DQ).

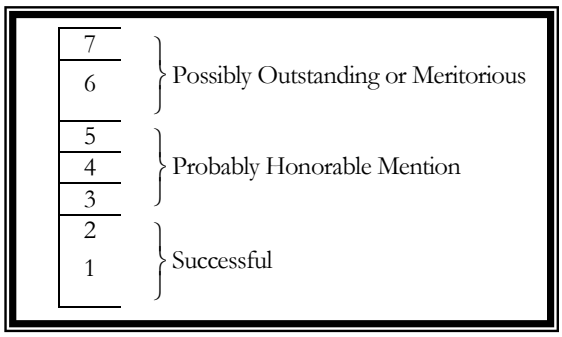
Unsuccessful Participant (UN) (% as warranted): the team's paper did not respond to any of the requirements of the contest problem, but did not violate any of the contest rules. A simple explanation of the failings should be noted in the comment column (e.g. "No modeling") and scored as 0. The MCM/ICM contest directors will review and verify all papers designated as unsuccessful (UN).

Successful Participant (P) (% as warranted): the team made an attempt at the problem and successfully submitted their paper. However, their overall paper is best described as fair to average, and possibly contains an incomplete modeling process or solution, and mathematical or logical errors. Scored as a 1 or 2.

Honorable Mention (HM) (% as warranted): the team submitted a complete, acceptable modeling approach and solution, but their solution contains at least one detractor, deficiency, or error that prevents it from being classified as Meritorious or Outstanding. Scored as 3, 4 or 5.

Meritorious (M) (10%): the team's paper represents an exemplary modeling approach, but their solution may contain minor errors or issues in logic, calculation, modeling, or assumptions. Scored as a 6 or 7.

Finalist (F)/Outstanding (O)(<1%): the team's paper represents an excellent modeling approach and a solid solution, including demonstrating an ability to clearly and concisely communicate their process, results, and conclusions. Scored as a 7.



Triage judging sessions are designed to accomplish a crude categorization of the papers. In the time allotted to each paper (no more than 15-20 minutes and 10-15 minutes on average), judges assess whether the required elements of the modeling process are addressed, and whether the teams have answered the questions posed in the problem statement. Judging during the triage sessions use a 7-point scale shown to the left to achieve the desired categorization. What makes this possible is the mindset of triage judges to primarily look for the very top papers and not try to fully evaluate every part of every paper. Don't be afraid to establish separations between quality levels with these numerical scores. Each paper is given 2 reads during the triage judging, so each judge is responsible for half the triage decision to have the paper forwarded to final judging or not.

The head judge culls approximately 60-80% of the papers after the triage round and take the remaining papers to final judging.

Triage Judging Notes

If you find a paper you are assigned to read is missing, damaged or incorrect, note the paper number and notify your head judge so that COMAP can check for the correct paper.

If you find that a team included any distinguishing information such as school name or student names, read the paper as normal and grade as normal, but add a note to the comment column (e.g. "includes school name on page xxx," "includes student name on page yyy").

If you find that a paper has gone over the assigned paged limit, read the paper as normal and grade as normal, but add a note to the comment column (e.g. "paper exceeded the assigned page limit").

Triage judges are encouraged, but not required, to include comments on their grading sheet. It could be as simple as a few words (e.g. "great assumptions"), or a sentence justifying the papers score (e.g. "fatal logic flaw on page zzz").

Problem Specific Guidance: Problem B (2019):

"Recommend a drone fleet and set of medical packages for the HELP, Inc. DroneGo disaster response system that will meet the requirements of the Puerto Rico hurricane scenario."

The core of the 2019 Problem B is a modeling problem attempting to design an aerial (rotary wing drones) relief response system capable of supporting the competing resource demands of a non-governmental organization attempting to provide emergency relief during a disaster. The intent of the problem is to have teams build a self-contained system (rotor wing drones and required medical packages) that can provide both deliveries of critical medical supplies to on-demand locations and to provide high-resolution aerial video reconnaissance of primary ground transportation routes in the disaster area.

- Teams that fail to link their fleet choice to the requirements of the provided scenario can score no higher than a 3 during triage judging.
- Teams that interpret any of the drones as fixed wing aircraft can score no higher than a 2 during triage as it significantly changes the nature of this modeling problem.
- Teams that fail to provide a drone fleet that will meet the medical requirements (identified in Attachment 4) and the reconnaissance requirement can score no higher than a 2 in triage.
- Teams that fail to make an assumption concerning the length of the relief effort, or simply assume that the relief effort will only last a couple of days can score no higher than a 2 in triage.
- Teams that fail to address the length of time Puerto Rico will be without electricity and its impact on relief operations can score no higher than a 3 in triage.

"Design the associated packing configuration for each of up to three ISO cargo containers to transport the system to Puerto Rico."

The core mathematical challenge of this problem is a set of two 3-dimensional bin packing problems, known to be non-polynomial (NP) hard in terms of computational complexity when some consideration of the packing is motivating an optimization. This optimization element appears by way of asking teams to design packing configurations that "minimize any need for buffer materials for unused space." This may be accomplished in a sensible heuristic approach described by the team, or by any number of known mathematical approaches.

The first bin packing problem arises after teams decide on the number and type of drones and the number and type of medical packages that will comprise "a complete system." Each drone and medical package has a different size shipping box. Once decided, they are required to define the 3-dimensional packing configuration of this system in one to three 20-foot standard dry ISO shipping containers.

- Teams that directly address the optimization consideration of this 3D packing problem should score higher in triage than those that do not.
- Teams that provide ISO container packing configurations that ignore the requirement to minimize (in some meaningful manner) the buffer material (hence the unused container space) needed can score no higher than a 3 during triage.
- Teams that fail to address this first 3D packing problem can score no higher than a 2 during triage.

Teams might consider all three containers as a single system, which would for example allow them to exclusively pack drones in one container and the medical packages in another container. This will cause problems if the situation is such that the NGO must send the containers to two or three sites. Puerto Rico is about 100 miles long and 35 miles across with roughly a 3500–4400 foot mountain range running down the middle. A single location will likely not meet all mission requirements without a team ignoring a substantial number of real considerations.

Teams may conclude it is not possible to design a DroneGo system that will meet all the requirements of the Puerto Rico scenario.

- In this case, teams that identify and apply some explicit tradeoff discussion or methodology should score higher in triage than those that do not.
- Teams that identified that the Puerto Rico scenario requirements exceed the capabilities of the drone fleet without addressing tradeoffs for these shortcomings can score no higher than a 3 during triage judging.

"Identify the best location or locations on Puerto Rico to position one, two, or three cargo containers of the DroneGo disaster response system to be able to conduct both medical supply delivery and video reconnaissance of road networks."

The subtle consideration that will make their choice of "complete system" non-trivial is the statement that between 1-3 containers could be "delivered to a single location, or up to three different locations" depending on the situation that the NGO encounters. We anticipate that most teams will recognize they need a complete system to fit into each of the three ISO containers, guaranteeing the NGO the most flexibility in responding to a disaster and reducing the first packing problem to a single container. Teams will also need to define "best" in some manner that allows them to distinguish between actual on-ground locations.

- Teams whose ISO container packing configurations ignore or assume away the possibility that each of the three containers could be positioned at geographically distant locations can score no higher than a 3 during triage.
- Teams that select multiple locations for the containers and fail to provide a **complete** disaster response system (drones and medical supplies) in an ISO container at a designated location can score no higher than a 2 in triage.
- Teams that base their location decisions based on some criteria defining "best" should score higher during triage judging than those that do not.

"For each type of drone included in the DroneGo fleet:

a. Provide the drone payload packing configurations (i.e. the medical packages packed into the drone cargo bay), delivery routes and schedule to meet the identified emergency medical package requirements of the Puerto Rico hurricane scenario."

This second 3D packing problem ask the teams to configure the three medical packages' packing in drone cargo bays ('containers') for delivery by the drones to relief locations throughout the island of Puerto Rico. Here, teams need to identify the number of each type of medical packages for each drone cargo bay used in their complete system, delivery routes and schedules. The "delivery routes" in this case are drone flight paths to and from relief locations.

- Teams that fail to address this second 3D packing problem can score no higher than a 3 during triage.
- Teams that fail to supply delivery routes and schedules for their drone fleet can score no higher than a 3 during triage.

"Provide a drone flight plan that will enable the DroneGo fleet to use onboard video cameras to assess the major highways and roads in support of the Help, Inc. mission."

This requirement for conducting video reconnaissance using on-board drone cameras should motivate teams to develop drone medical delivery flight paths as close to the target roads as possible, as the problem allowed for the medical relief and video reconnaissance missions to be conducted separately or simultaneously.

Teams will have to define what constitutes a "drone flight plan." Similarly, data regarding battery life, altitude restrictions, command and control (C2) limitations, video recording capacity versus streaming, and so on were deliberately <u>not</u> provided to teams, thereby requiring them to rely on the abundant literature available on the web.

COMAP received many questions from teams asking for clarification as to why drone H (tethered) was included in the set because it did not have video nor medical package carrying capabilities. As with the other drone characteristics, drone H is based on actual rotor UAV systems in operation today. Teams that asked this question most likely were not yet aware of C2 limitations such as line-of-sight communications between a base station and a rotor wing drone when fully autonomous flight was not being used. Drone H was included in this set to provide teams that were aware of such limitations to essentially provide a means for their C2 to rise above any terrain restrictions by placing retransmission communications capabilities on it. In doing so, teams would have greater flexibility as to the location(s) they identify to position the ISO containers.

In all, teams will need to make quite a number of assumptions regarding drones, drone operations, and video reconnaissance throughout their modeling effort.

- Teams that fail to provide drone flight plans that cover major transportation roads can score no higher than a 2 during triage.
- Teams that make modeling assumptions grounded in facts and conditions supported by research sources should score higher in triage than those that use unsupported ones.
- Teams that identify the possibility that the video reconnaissance mission is more than a one-time requirement should score higher in triage than those that do not.

Memo to the Chief Operating Officer: Write a 1–2 page memo to the Chief Operating Officer (CEO) of HELP, Inc. summarizing your modeling results, conclusions, and recommendations so that she can share with her Board of Directors.

- This element requires the students to summarize and interpret the results of their modeling effort for a relatively non-technical audience.
- The insights or results presented in the memo should follow from the team's answers to Part 1 A through D.
- Teams that fail to include this Memo can score no higher than a 2 in triage.

- Teams that fail to include their major results or recommended strategy can score no higher than a 3 in triage.
- Teams that suggest actions not related to their model should be scored lower than teams whose suggestions are supported by their modeling and analysis.
- Poorly written summaries should be scored lower than ones that are well written.

Required elements from Contest Instructions:

- One-page Summary Sheet

The contest instructions say: "…a summary should clearly describe your approach to the problem and, most prominently, you're most important conclusions. Summaries that are mere restatements of the contest problem or are a cut-and-paste boilerplate from the introduction are generally considered to be weak."

Besides the summary sheet as described each paper should contain the following mathematical modeling elements:

- Problem Restatement
- Assumptions & Justifications
- Model Construction and Application
- Model Testing and/or Sensitivity Analysis (This could include some sort of trade off analysis or testing that may not meet the formal definition of 'sensitivity analysis' but nonetheless represents a valid effort to test the parameter values used.)
- Model Revision
- An analysis of Strengths & Weaknesses.

These need not appear in stand-alone sections, but must be addressed somewhere in the paper for the team submission to be considered a complete modeling effort. Depending on a problem's difficulty, many good papers' modeling efforts are presented without Model Revision based on perhaps some type of verification assessment. Ideally, teams will revise their initial model by eliminating key assumptions or revising initial structural elements such as parameters.

- Teams that include Model Revision in their paper should score higher during triage than those that do not.
- Papers that omit any of the remaining five elements above can be scored no higher than a 4 during triage.

<u>The Final Judging Sessions (for information only for triage graders)</u>

The final judges develop a rubric for each problem and customize it to the problem being judged and the set of papers present. After the triage event, judges have a better idea of how the top papers they have read are addressing the problem and what elements are evolving to set papers apart from each other. This knowledge provides the basis for refining the rubric prior to the last judging session to pick the Outstanding papers. We usually have 4 or 5 rounds of final judging where approximately 50% of the papers are culled in each round.

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