Writing Classes for Mathematical Modeling Competitions

W1: Paper Architecture and Judge Navigation

Kenneth Sok Kin Cheng

Revised 20 August 2026

Learning goals

By the end of this two-hour writing class, students should be able to:

- distinguish contest rules from writing folklore and verify the correct rule set before submission;
- explain the job of each major section in a modeling report;
- organize a report so that a judge can locate the answer, assumptions, evidence, and limitations quickly;
- connect problem requirements to models, results, validation, and conclusions through a **traceability map**;
- evaluate a paper using evidence-based questions rather than invented score percentages;
- rewrite weak assumptions using the pattern *what – why – effect – test*;
- build a complete section blueprint for a competition problem before drafting prose;
- conduct a short **judge-navigation audit** of a draft.

1 The paper is the model's interface

A team may have correct mathematics, useful code, and a sensible recommendation. None of these helps unless the report allows a reader to reconstruct the reasoning. A competition paper is therefore not a diary of what the team did. It is a designed path from the question to a defensible decision.

Launch activity: the 60-second search test

Imagine that you are judging an unfamiliar 20-page report. You have sixty seconds to locate:

1. the main recommendation;
2. the central model equation or algorithm;
3. the most important assumption;
4. one validation result;
5. one limitation.

What visual or structural features would help you find each item? List at least four: section headers, result tables, equation references, captions, bold conclusions, or a task-to-section map.

The evidence chain

A strong report makes the following chain visible:

$$\text{question} \longrightarrow \text{assumptions and data} \longrightarrow \text{model} \longrightarrow \text{results} \longrightarrow \text{checks} \longrightarrow \text{decision}.$$

Every arrow is a claim that must be explained. For example, an assumption should affect the model; a numerical result should answer a task; a validation check should change how confidently the recommendation is stated.

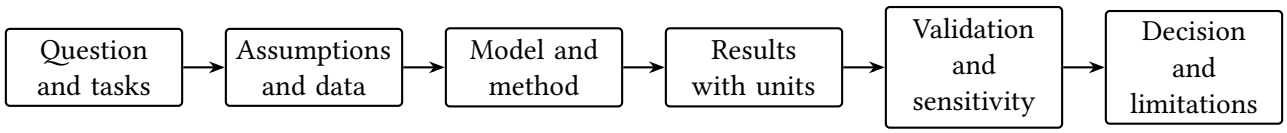


Figure 1: A modeling report is an evidence chain. A missing link is more damaging than a missing decorative section.

Model criticism: A paper is not the chronological story

Teams often write in the order they worked: failed attempt, code debugging, new idea, another failed attempt, final model. The judge needs the logical order instead. Failed approaches may be mentioned briefly when they justify a design choice, but the main narrative should present the clearest defensible route.

2 Rule snapshot: verify before writing

Formatting rules are part of the problem. They change by contest and year, so a team should create a one-page compliance sheet before writing. The table below records the official 2026 rules relevant to report design; always re-check the current official instructions before a future contest.

2026 report-format comparison

	HiMCM 2026	IM^{2}C International 2026
Team and work window	Up to four students; teams may work during the published 14-day contest window.	Up to four students from the same school; one consecutive five-day period.
First pages	Page 1 is the Summary Sheet. A table of contents is encouraged.	One-page Summary Sheet, one-page Table of Contents, then the solution.
Page accounting	Summary plus up to 24 further pages: 25 pages total. TOC, references, notes, and appendices count.	Solution maximum 24 pages; the one-page summary and one-page TOC are separate. References and appendices at the end do not count toward the 24-page solution limit.
Typography	English PDF; readable font of at least 12 point.	English; A4 with margins at least 1.5 cm or Letter equivalent; at least 12 point.
Identification	Control number and page number in the header; no student, advisor, or school names.	Control number and page number in the header; no student, advisor, or school names.
AI documentation	Use of LLMs or other AI tools must be identified and cited; a separate AI-use report is appended after the 25-page solution and is not counted in that limit.	Follow the current IM^{2}C and regional instructions; do not assume that HiMCM's AI-report format transfers automatically.

Checkpoint: Checkpoint: which statements are unsafe?

Mark each statement as safe or unsafe, then repair the unsafe ones.

1. "All modeling contests allow 25 pages."
2. "The Summary should be the first page."
3. "Appendices never count toward the page limit."
4. "A 10-point font is acceptable if the paper is long."
5. "The team should verify the current rules before creating the template."

Model criticism: Compliance layer versus writing layer

A contest rule tells you what must be submitted. A writing principle tells you how to make the reasoning easy to follow. For example, HiMCM requires a Summary Sheet, but the rule does not guarantee that a summary is informative. Compliance is necessary; communication quality still has to be designed.

3 A reader-first paper architecture

The original draft treated one section order as compulsory. That is too rigid. Good papers share recognizable functions, but adjacent functions may be merged when the logic is clearer. The test is not "Did

we use exactly these headings?" The test is "Can the reader find every necessary piece of evidence?"

Recommended architecture

Layer	Typical sections	Reader's question
Front matter	Summary; Table of Contents	What did the team do and find? Where is everything?
Orientation	Problem restatement; objectives; assumptions; notation; data	What exactly is being answered, under what interpretation?
Model core	Baseline model; refined model; algorithms; derivations	Why this model, and how does it work?
Results	Numerical or analytical results; figures; decision table	What is the answer, with units and context?
Evidence	Verification; validation; uncertainty; sensitivity	Why should the reader trust the result, and when does it change?
Decision	Recommendation; strengths; limitations; conclusion	What action follows, and how cautious should we be?
Back matter	References; appendices; required disclosures	Where did information come from, and where are supporting details?

Model criticism: Useful flexibility

- Results may follow each model immediately instead of appearing in one distant "Results" section.
- Validation may be integrated beside a model when the check is essential to understanding it.
- Strengths and limitations may sit in the conclusion if they are specific and visible.
- A separate literature-review section is often unnecessary; cite the relevant source where the modeling choice is introduced.

What should not disappear is the function: assumptions, results, checks, limitations, and references must remain findable.

Card-sort activity: build the logical order

Arrange the following cards into a coherent paper route for a school-bus routing problem:

distance data | route algorithm | final routes | problem tasks | assumptions | benchmark | sensitivity to travel time | recommendation

There may be more than one defensible order. For every adjacent pair, write one sentence explaining why the second follows from the first.

Worked example 1: a coherent queue-paper skeleton

For a school canteen queue problem, a concise section plan might be:

1. **Problem interpretation.** Define the performance measures: average wait, 90th-percentile wait,

and staffing cost.

2. **Data and assumptions.** Explain how arrival and service times are estimated and when a Poisson model is plausible.
3. **Baseline capacity check.** Compare arrival rate λ and service capacity $c\mu$ before simulation.
4. **Discrete-event simulation.** State events, state variables, algorithm, warm-up, and replications.
5. **Results by staffing level.** Present one table containing wait, queue length, utilization, and cost.
6. **Validation.** Compare the one-server simulation with an analytical M/M/1 result under matching assumptions.
7. **Sensitivity.** Vary peak arrival rate and service-time distribution.
8. **Recommendation.** Choose the smallest staffing level meeting the service target; state the limitation during exceptional peaks.

The structure mirrors the evidence chain rather than the team's work diary.

4 Rubric decoded as an evidence map

Official HiMCM descriptions emphasize modeling and problem solving, analysis, conclusions, communication, clarity, support, and organization. IM^{2}C guidance asks for variables, assumptions, justified model design, testing, sensitivity, and strengths or weaknesses. These sources do not publish the percentage weights used in the original draft. Therefore, use the following as a *teaching lens*, not as an official scoring formula.

Five questions a strong report answers

1. **Task coverage:** Did the team answer every requirement in the problem statement?
2. **Model reasoning:** Are assumptions, data choices, and methods appropriate and justified?
3. **Mathematical execution:** Are equations, algorithms, calculations, and interpretations correct?
4. **Evidence and robustness:** Is the model checked against data, theory, benchmarks, limiting cases, or alternative assumptions?
5. **Communication and compliance:** Can a reader follow the argument, locate results, verify sources, and confirm that the rules were followed?

Evidence map

Question	Strong visible evidence	Weak signal
Task coverage	Task list, matching subsections, final answer table	One task is answered only implicitly or not at all
Model reasoning	Assumption rationale; baseline-to-refinement logic; method choice	A fashionable method appears with no comparison or need
Execution	Defined symbols; derived equations; reproducible algorithm; units	Final formula appears without explanation or dimensions
Evidence	Benchmark, data comparison, residuals, sensitivity table, uncertainty	"The model is accurate and robust" with no numerical check
Communication	Informative captions, result callouts, cross-references, consistent notation	Walls of text, hidden answer, unlabeled figures, notation drift
Compliance	Correct format, anonymity, citations, disclosure, file checks	Team names in paper, wrong page count, missing source documentation

Evidence hunt

Read a two-page excerpt from any modeling paper. For each of the five questions above, highlight one sentence, equation, figure, or table that supplies evidence. If you cannot find evidence, write the exact addition that would repair the gap.

Checkpoint: Checkpoint

A paper uses an advanced genetic algorithm and reports a very low objective value. Which evidence questions remain unanswered? Name at least three specific checks the paper still needs.

5 Assumptions are design decisions

An assumption is not a ceremonial sentence. It changes the feasible model, the interpretation of parameters, and the strength of the recommendation.

The four-part assumption pattern

For each important assumption, state:

1. **What:** the precise simplification or claim;
2. **Why:** evidence, domain reasoning, or a clearly stated practical necessity;
3. **Effect:** what becomes possible, and what distortion may be introduced;
4. **Test:** how the assumption will be checked or varied later.

Not every minor assumption needs four separate paragraphs, but every high-impact assumption should make these four ideas recoverable.

Worked example 2: weak and improved assumption

Weak: "We assume customer arrivals are Poisson."

Improved: "During the 20-minute peak interval, we model customer arrivals as a Poisson process with constant rate λ. This is plausible when arrivals are approximately independent and the observed counts show no strong trend within the interval. The assumption permits exponential inter-arrival sampling and comparison with queueing formulas. Because student arrivals may occur in groups after a bell, we also rerun the simulation using burst arrivals and compare the staffing recommendation."

Rewrite studio

Rewrite two of the following assumptions using *what – why – effect – test*:

1. "Traffic speed is constant."
2. "The population does not migrate."
3. "All customers behave the same."
4. "The data are accurate."

Underline the sentence that admits a possible weakness. A strong assumption section does not pretend that simplification has no cost.

Model criticism: Do not separate assumptions from their consequences

A long list at the beginning is easy to forget. Refer back to assumptions when they enter an equation: "Under Assumption A2, the arrival rate is constant, so..." Later, sensitivity analysis should identify which assumptions were actually tested. This creates traceability instead of a decorative list.

6 Results, validation, and sensitivity must be visible

A result is more than a number. A useful result unit contains a question, a metric, a value with units, a comparison, and a decision implication.

Answer-first result unit

Use the pattern:

$$\text{task} \longrightarrow \text{metric} \longrightarrow \text{result} \longrightarrow \text{comparison} \longrightarrow \text{decision}.$$

Example: "To keep the 90th-percentile wait below 6 minutes, three counters are required. The simulation estimate is 5.4 minutes (95% interval 5.1–5.7), compared with 8.9 minutes for two counters. We therefore recommend three counters during the peak period."

Worked example 3: compact evidence table

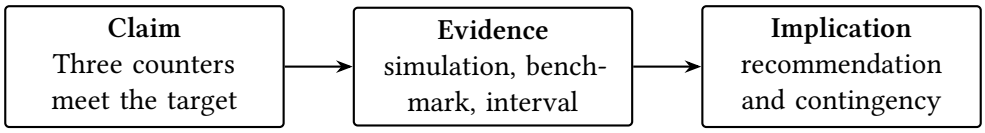
Scenario	Counters	Mean wait (min)	90th percentile	Utilization
Baseline	2	4.8	8.9	0.91
Recommended	3	2.1	5.4	0.64
Arrival rate $+20\%$	3	3.6	7.2	0.77
Slower service -10%	3	3.0	6.4	0.71

The table does not merely show output. It reveals that the recommendation misses the target when demand rises by 20%, so the conclusion should include a peak-demand contingency.

Validation and sensitivity are different

- **Verification**: Did we solve or code the model correctly? Examples: hand calculation, conservation check, unit test, convergence test.
- **Validation**: Does the model represent the real system well enough? Examples: held-out data, external benchmark, expert expectation, observed trend.
- **Sensitivity analysis**: How does the conclusion change when inputs or assumptions change?
- **Uncertainty analysis**: How uncertain is the reported output because inputs or simulation are uncertain?

A paper may use different section names, but it should not confuse these jobs.



A caption or paragraph should explain the relation among the three boxes; the reader should not have to infer it from a figure alone.

Figure 2: A result becomes persuasive when the claim, supporting evidence, and decision implication are linked explicitly.

Checkpoint: Caption test

Which caption is stronger, and why?

1. "Figure 4. Sensitivity analysis."
2. "Figure 4. Increasing peak arrival rate by 20% raises the 90th-percentile wait above the 6-minute target even with three counters; the recommendation therefore requires an overflow plan."

7 Traceability and judge navigation

A report should make it possible to trace every problem requirement to a result and every recommendation to evidence.

Task-to-evidence matrix

Before drafting, construct a table like this:

Problem task	Model / method	Result location	Check / limitation
Estimate current performance	Queue simulation	Table 3, Section 5.1	Compare with observed sample
Choose staffing level	Cost-service trade-off	Figure 6, Section 5.2	Arrival-rate sensitivity
Plan exceptional peaks	Scenario model	Table 5, Section 6	Peak timing is uncertain

If one row has an empty cell, the paper is not ready.

Judge-navigation audit

Exchange blueprints or drafts. The reviewer has 90 seconds and may not ask the author questions. Record the page or section where you found:

1. each problem task;
2. the primary model;
3. the main numerical answer;
4. the strongest validation check;
5. the most decision-changing sensitivity result;
6. the final recommendation and limitation.

Anything not found within 90 seconds needs a structural repair, not merely a grammar edit.

Model criticism: Navigation is not decoration

A table of contents, numbered equations, descriptive headings, captions, and cross-references reduce the reader's search cost. Decorative colour, complex diagrams, and excessive boxes do not automatically improve navigation. Use visual hierarchy only when it reveals the logical hierarchy.

8 Integrated blueprint workshop

Workshop: design the paper before solving it

A school wants to reduce congestion at one entrance between 7:30 and 8:00. Students arrive by foot, car, and bus. The school may change lane allocation, staff deployment, and arrival guidance. The goal is to reduce delay without creating an unsafe queue outside the gate.

In teams, produce a one-page report blueprint containing:

1. a three-sentence problem interpretation with measurable outputs;
2. a task list and task-to-evidence matrix;
3. three high-impact assumptions in *what – why – effect – test* form;
4. a baseline model and one justified refinement;
5. a proposed results table with column headings and units;
6. one verification check, one validation check, and two sensitivity scenarios;
7. a section outline with one-sentence purpose statements;
8. a final recommendation sentence template containing a condition and limitation.

Do not calculate the final answer. The product is the architecture of a defensible paper.

Differentiated routes

- **Core route:** use a deterministic arrival-flow model and a simple capacity comparison.
- **Challenge route:** add time-varying arrivals and a discrete-event simulation.

- **Extension route:** define a multi-objective score balancing delay, cost, and safety; explain how weights would be justified and tested.

All routes must preserve the same evidence chain and task traceability.

9 What to carry into W2

Class W1 takeaways

1. Rules are contest- and year-specific. Build the template only after checking the official instructions.
2. A standard architecture is useful, but section names and placement should serve the logical evidence chain.
3. Do not treat unofficial percentage weights as an official rubric. Evaluate visible evidence instead.
4. Every major assumption should reveal what is assumed, why, its effect, and how it will be tested.
5. Results must be easy to locate and must connect a number to a comparison and a decision.
6. Verification, validation, sensitivity, and uncertainty answer different questions.
7. A task-to-evidence matrix and a 90-second navigation audit expose structural gaps early.

Checkpoint: Exit ticket

In no more than four sentences:

1. name one structural change you will make to your next report;
2. identify one assumption you would test rather than merely state;
3. explain the difference between validation and sensitivity;
4. state what W2 must teach you about the one-page Summary.

In **W2: Writing the Summary**, we will construct the first page through four functions: problem, method, quantitative results, and decision insight. Students will diagnose weak summaries and draft progressively shorter versions without losing evidence.

Appendix A: Paper-architecture checklist

Audit question	Evidence to locate
Does the paper answer every task?	Task list, matching result sections, task-to-evidence matrix
Can the reader understand the model?	Defined symbols, assumptions, derivation or algorithm, units
Can the reader find the answer?	Summary, highlighted result table, explicit conclusion
Was the implementation checked?	Hand case, unit test, conservation or convergence check
Was the representation of reality checked?	Data comparison, benchmark, held-out case, expected trend
Is the recommendation robust?	Parameter and structural sensitivity; uncertainty interval
Are limitations decision-relevant?	Conditions under which the recommendation may fail
Is the document compliant?	Current page limit, font, anonymity, headers, citations, disclosure
Can a judge navigate it quickly?	Descriptive headings, captions, cross-references, consistent notation

Appendix B: Independent paper-reading task

Choose one recent Outstanding HiMCM paper or published IM^{2}C solution. Do not begin by judging the mathematics. First produce:

1. its section map;
2. a task-to-evidence matrix;
3. the first location of each main numerical answer;
4. one example of a strong assumption, caption, validation check, and limitation;
5. one structural decision you would copy and one you would change.

Then compare the report against the five evidence questions in this class.

Appendix C: Official sources checked for this lesson

- COMAP, 2026 HiMCM/MidMCM Contest Instructions and Rules.
- COMAP, HiMCM/MidMCM Tips Article.
- IM^{2}C challenge overview and modeling expectations.

Rules may change. Verify the current official documents immediately before a contest.

Model audit card

Audit before trusting or communicating a model

Purpose	What question or decision does the model support?	**Data**	Which inputs are observed, derived, or simulated?
Assumptions	Which simplifications may change the answer?	**Units**	Are dimensions and scales consistent?
Verification	Were equations, code, constraints, and limiting cases checked?	**Validation**	Is performance tested against independent evidence?
Uncertainty	How do measurement, parameter, solver, and structural errors affect conclusions?	**Ethics**	Who benefits, who bears risk, and what fairness criterion matters?
Reproducibility	Are data provenance, versions, seeds, and transformations recorded?	**Communication**	Are claims conditional, traceable, and decision-relevant?

Further reading

- HiMCM / MidMCM Contest Instructions (COMAP)
- IM²C challenge overview and modeling expectations (International Mathematical Modeling Challenge)
- GAIMME: Guidelines for Assessment and Instruction in Mathematical Modeling Education (SIAM / COMAP)

Sources, provenance, and licence

These notes follow the iterative modeling and assessment perspective in the SIAM/COMAP GAIMME report. Competition-specific remarks are a snapshot checked on 20 August 2026 against the official COMAP HiMCM instructions; readers should verify current rules before submission. Unless a source is explicitly identified, classroom datasets and numerical scenarios are synthetic or simulated teaching examples and are not empirical claims about a real institution. Third-party references retain their own terms.

Student response guide and checking criteria

For closed calculations, show the definition, substitution, units, and at least one independent check; the worked examples in this unit are method hints, but you must complete the arithmetic yourself. Open modeling responses are checked on five dimensions: a clear purpose and output; stated data and provenance; defensible assumptions and scope; traceable computational verification and model validation; and alignment among uncertainty, limitations, and the recommendation. Support each dimension with concrete evidence rather than writing only "completed."