

Resolving Conflicting Evidence in Photopolymer Engineering: State Mismatch, Measurement Bias and Decision Rules

A conflict-resolution framework that asks whether studies disagree about the same physical state before averaging, ranking or dismissing their results

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Abstract

Conflicting photopolymer evidence is often treated as a statistical disagreement when the underlying studies did not measure the same material state, process state or endpoint. This review proposes a staged conflict-resolution framework. It first tests state comparability, then measurement comparability, then bias and uncertainty, and only then considers synthesis. The framework distinguishes resolvable heterogeneity from genuine physical contradiction and defines decision rules for engineering use when evidence remains discordant. The objective is to prevent inappropriate averaging and to preserve useful boundary information contained in apparently incompatible results.

Keywords: conflicting evidence; heterogeneity; photopolymer; measurement bias; state mismatch; decision rule; qualification

1. Apparent conflict is not yet contradiction

Two studies can report different modulus, cure depth or ageing response without measuring the same physical question. Before invoking bias, the reviewer should compare formulation identity, cure history, temperature, specimen geometry, orientation, test method and endpoint definition. If these differ materially, the result is heterogeneity by state, not direct contradiction.

2. State mismatch is resolved by stratification

The first decision is whether a common target state can be defined. Evidence is stratified by material state and process history; only strata with a defensible bridge are compared. This is analogous to recognising clinical or methodological heterogeneity before pooling. Higgins and colleagues showed why inconsistency matters for synthesis [1], but engineering reviews often require an even earlier physical-state gate.

Table 1. Conflict-resolution sequence.

Stage	Question	If no
state	same material and process state?	stratify; do not pool
endpoint	same quantity and definition?	map or separate endpoints
method	measurement chains comparable?	quantify method effect
uncertainty	difference exceeds combined uncertainty?	treat as compatible
decision	conflict remains decision relevant?	record without escalation

3. Measurement systems can create structured disagreement

Bias may arise from calibration, fixture compliance, optical geometry, threshold definitions, sample preparation or data reduction. A conflict audit should compare the measurement chain, not only the nominal test standard. If one method measures an apparent property and another a local or corrected property, the difference may be expected rather than erroneous.

4. Weight evidence by relevance and uncertainty, not prestige

A recent or highly cited study is not automatically more transferable. Weight should reflect match to the target state, transparency of method, uncertainty characterisation, replication and independence. Ioannidis highlighted how design and bias influence the credibility of published findings [2]. In engineering qualification, the practical translation is to make evidence weights traceable rather than implicit.

Table 2. Typical structured biases.

Source	Mechanism	Diagnostic
optical exposure	nominal vs measured irradiance	calibration record
mechanical test	fixture/compliance or strain measurement	method comparison
post-cure	temperature and spectral mismatch	state reconstruction
conditioning	water/temperature history	mass or history record
selection	only successful prints tested	failure census

5. Genuine contradiction should narrow the claim

If comparable states and methods remain inconsistent beyond stated uncertainty, the correct outcome is not forced consensus. The claim should be narrowed to the region supported by both, or marked as unresolved. A qualification decision may then adopt a conservative bound, require confirmatory testing or reject transfer. The uncertainty itself becomes an engineering result.

6. Decision rules must be declared before seeing the preferred result

Post hoc selection of the study that matches expectations creates confirmation bias. Conflict-resolution rules should therefore define in advance what constitutes state equivalence, what level of method deviation is acceptable and how unresolved conflicts affect qualification. This does not eliminate judgement; it makes judgement auditable. Transparent review methods such as PRISMA reinforce the value of prespecified eligibility and synthesis rules [3].

Table 3. Allowed conflict outcomes.

Outcome	Engineering interpretation
reconciled	difference explained by state or method
compatible	difference within uncertainty
bounded	claim narrowed to common supported region
unresolved	additional discriminating evidence required
non-transferable	evidence cannot support target decision

7. Conflict registers improve future research

A structured conflict register records the competing claims, mismatch variables, measurement differences and the evidence needed to discriminate between explanations. Such registers turn disagreement into experimental design input rather than editorial friction. FAIR metadata principles are useful here because a conflict register should remain findable, reusable and linked to the evidence objects from which it was derived [4].

8. Scope boundary and neighbouring reviews

ER-396 owns the decision sequence for resolving apparently conflicting engineering evidence. ER-395 owns when a review should be updated, while ER-397 owns the reporting and engineering use of negative results and failed replication. ER-396 adjudicates comparability and conflict; it does not convert absence of replication into a negative-result policy.

9. Conflict diagnosis should follow a causal hierarchy

When two studies disagree, the first task is not to average them. The conflict should be decomposed through a causal hierarchy: identity mismatch, specimen-state mismatch, process mismatch, environmental mismatch, measurement-system mismatch, sampling variability, analysis choice and finally genuine mechanistic disagreement. Each level has a different remedy. Identity or state mismatch is handled by stratification; measurement-system mismatch may require recalibration or uncertainty reconciliation; sampling variability may be handled statistically; only after these explanations are exhausted should the disagreement be treated as evidence of competing mechanisms. This hierarchy reduces false contradictions created by incomplete metadata.

10. Measurement uncertainty defines an equivalence region

Two values are not meaningfully different merely because their point estimates differ. JCGM 100 establishes general rules for evaluating and expressing measurement uncertainty [5]. In ER-396, the practical consequence is to compare results with their uncertainty and method resolution before declaring conflict. Where uncertainties overlap strongly, the correct interpretation may be measurement equivalence rather than scientific disagreement. Where they do not overlap, the next question is whether the measurands are truly identical: same specimen state, geometry, conditioning, test speed, temperature and calculation convention. The uncertainty budget therefore becomes part of conflict diagnosis rather than an appendix to the final number.

11. Bias can be directional and state dependent

Measurement bias is especially dangerous when it correlates with the state variable under investigation. A surface-sensitive optical method may respond to cure gradients differently from a bulk mechanical test; a geometry-extraction algorithm may bias thin features more than thick ones; a thermal method may shift with sample mass or heating programme. These effects can create systematic disagreement that persists across replicates. The conflict register should therefore record not only a study-level risk label but the expected direction of each plausible bias and the states in which it operates. This permits targeted discriminating experiments instead of generic calls for more data.

12. Decision rules should predefine how conflict changes a claim

A conflict-resolution protocol needs an outcome vocabulary. A claim can be confirmed across comparable states, stratified into state-specific claims, downgraded in confidence, bounded to a narrower range, suspended pending new evidence or rejected. The choice should depend on relevance and uncertainty, not on journal prestige or the numerical result preferred by the reviewer. Predefining these outcomes before resolving a disputed literature set reduces post-hoc selection. Heterogeneity statistics can help describe inconsistency [1], but they do not replace engineering diagnosis of why the studies differ.

13. Discriminating experiments should target the competing explanations

The most informative follow-up test is one that separates hypotheses. If disagreement may arise from post-cure state, print matched specimens and vary only post-cure. If the suspected cause is machine irradiance, use a common material and independently characterise delivered exposure. If measurement systems disagree, test the same specimens with both methods under a traceable protocol. This logic converts conflicting evidence into an experimental-design problem. The endpoint is not forced consensus; it is a narrower, more defensible claim whose state variables and remaining uncertainty are explicit.

14. Interlaboratory evidence requires separation of site and method effects

When conflict occurs across laboratories, site effects should be treated as candidate causes rather than nuisance noise. Instrument calibration, environmental control, specimen preparation, operator choices and software reduction can each create persistent offsets. A

useful reconciliation study sends common specimens or common reference materials across sites and, where possible, cross-tests local specimens with a shared method. The design should permit site, specimen and method effects to be estimated separately. Without this structure, a pooled average can conceal a reproducible laboratory bias and falsely narrow uncertainty.

15. Conflict matrices make assumptions visible

For each disputed claim, a conflict matrix can list studies by material revision, specimen state, machine, process history, test method, environment, uncertainty and reported outcome. The matrix often reveals that supposedly contradictory studies occupy different cells. Only the residual disagreements within comparable cells need scientific resolution. The matrix should also capture missing fields explicitly because missingness itself limits the strength of reconciliation. This simple representation is valuable before formal meta-analysis because it tests the engineering comparability assumptions on which pooling would depend.

16. Robust decisions can proceed before complete consensus

Qualification sometimes cannot wait for perfect resolution. In that case the decision should be robust to the plausible interpretations of the conflict. A conservative boundary may be adopted, an uncertain material state may be excluded, or additional monitoring may be required. The selected action and the unresolved evidence should be recorded separately so that a pragmatic decision is not later mistaken for scientific consensus. ER-396 therefore distinguishes evidence resolution from decision resolution: the former explains the literature, while the latter chooses an action that remains acceptable under the residual uncertainty.

17. Quantitative reconciliation without false precision

Where multiple studies are sufficiently comparable, quantitative synthesis can support reconciliation, but pooling should follow rather than precede the state-matching exercise. Effect estimates should retain their measurement uncertainty and between-study heterogeneity. Sensitivity analysis can then test whether the decision changes when one laboratory, one material revision or one method family is removed. If the decision is unstable, the correct outcome is an uncertainty boundary or targeted discriminating experiment, not a more precise pooled number. This is particularly important in photopolymer engineering because small changes in cure, water uptake or specimen geometry can move the material into a different state even when nominal product names match. [1,5]

18. Decision table for conflict classes

ER-396 recommends a compact decision table. State mismatch leads first to stratification; measurement-system mismatch leads to method comparison or calibration; obvious bias leads to correction or exclusion with justification; sparse evidence leads to wider uncertainty; genuine contradictory evidence leads to a narrower claim or new experiment. Each row should specify what evidence is required before the conflict can be considered closed. This prevents teams from treating every disagreement as if it required the same response and makes it possible to audit why one study was separated, down-weighted or excluded.

19. Closure criteria for a disputed claim

A conflict is closed only when the engineering conclusion and the residual uncertainty are both recorded. Closure may mean convergence on one explanation, proof that the studies concern different states, adoption of a conservative bound, or explicit recognition that the claim remains unresolved. The closure record should identify the evidence considered, the decision rule, the rejected alternatives and the re-opening trigger. If later evidence changes a key state variable or measurement assumption, the claim returns to review. This avoids converting a temporary pragmatic decision into permanent scientific consensus.

20. Measurement-system analysis before literature reconciliation

If disagreement concerns a measured quantity, the measurement system should be examined before interpreting the material physics. Calibration state, resolution, fixture compliance, specimen alignment, signal processing and environmental control can produce structured offsets. Where reference artefacts or common specimens are available, a short measurement-system study can reveal whether laboratories disagree about the specimen or about the instrument. A reconciliation report should therefore document the measurement chain and its uncertainty, not only the final mean and standard deviation. [5]

21. Bayesian and interval reasoning as optional tools

Conflicting evidence does not require one universal statistical method. Bayesian models can represent prior information and laboratory effects; interval or uncertainty-budget approaches can be preferable when data are sparse but metrology is well characterised. The method should match the decision and the available evidence. What ER-396 requires is transparency about assumptions, sensitivity to plausible alternatives and separation of model uncertainty from observed material variability. A sophisticated model does not compensate for incompatible specimen states, and a simple bound can be more defensible than a precise posterior when the input studies are heterogeneous.

22. Worked closure logic

Suppose two studies report different tensile moduli for nominally the same resin. The first closure step compares formulation revision, post-cure, conditioning, orientation and test standard. If those differ, the studies are stratified rather than pooled. If state is matched, uncertainty intervals and calibration records are compared. If the difference remains larger than the combined measurement uncertainty, a crossed specimen or laboratory study is designed. Qualification can meanwhile use the conservative lower bound. The conflict is closed only when the record states whether the cause was state mismatch, measurement bias, genuine variability or unresolved contradiction.

23. Limitations and research priorities

Conflict-resolution methods can themselves introduce bias if analysts choose state variables, exclusions or models after seeing which result they prefer. Priorities are therefore preregistered conflict matrices, common-specimen interlaboratory exercises, measurement-system comparisons and discriminating experiments specified before reconciliation. Photopolymer research would benefit particularly from datasets in which material revision, cure, conditioning and test method are all controlled while one suspected source of disagreement is varied. Such studies can show whether apparent literature conflict is dominated by hidden state or genuine material variability. ER-396

also recommends reporting unresolved cases rather than forcing a consensus estimate; a bounded unresolved claim can be safer and more informative than an overconfident pooled number. [1-5]

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Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L.; ER-396 is a methodological engineering review and does not provide a comparative commercial recommendation.

Data availability

ER-396 is a literature-based engineering review; no new experimental dataset was generated.