Strategies for Balanced Risk Flow-Down in International Nuclear Power Plant Construction under Localization Requirements

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Research background

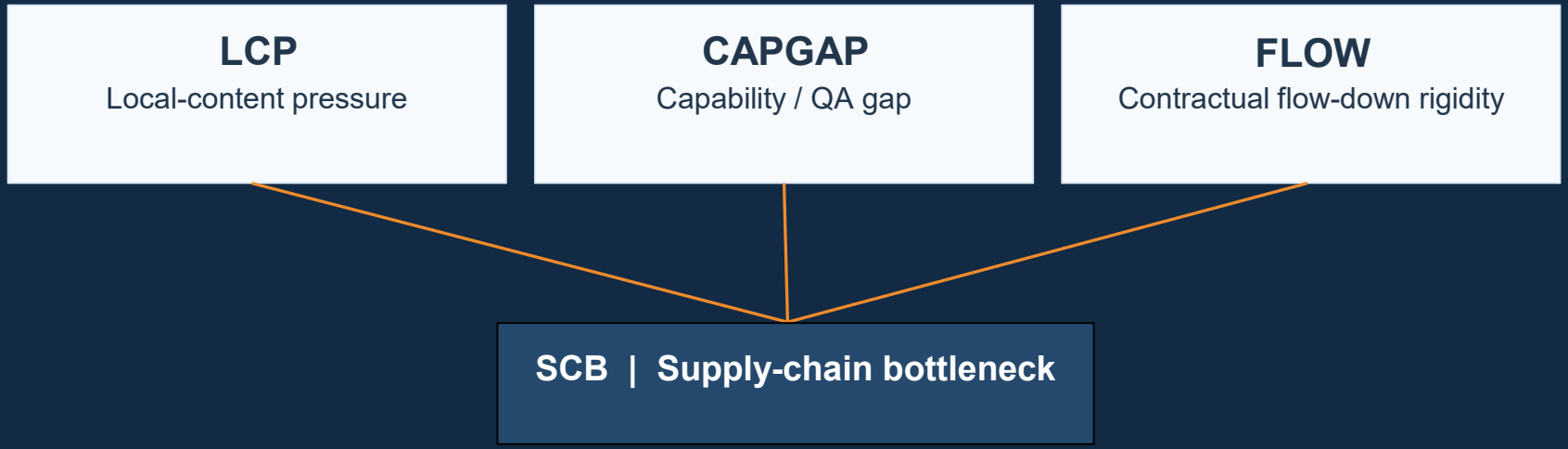
Why contractual risk flow-down matters

- New nuclear projects use local-content requirements to build domestic industry, employment and technology transfer. Local participation therefore becomes a project-delivery constraint.
- Under EPC/LSTK contracts, the prime contractor remains accountable to the owner and passes selected performance, schedule and liability obligations to subcontractors.
- A local supplier may accept back-to-back clauses without the nuclear QA maturity, cash flow, insurance, bonding or contract-management capacity needed to absorb them.

Legal transfer does not eliminate project risk: an unmanageable subcontract exposure may reappear as distress, rework or delay.

Research aim and conceptual model

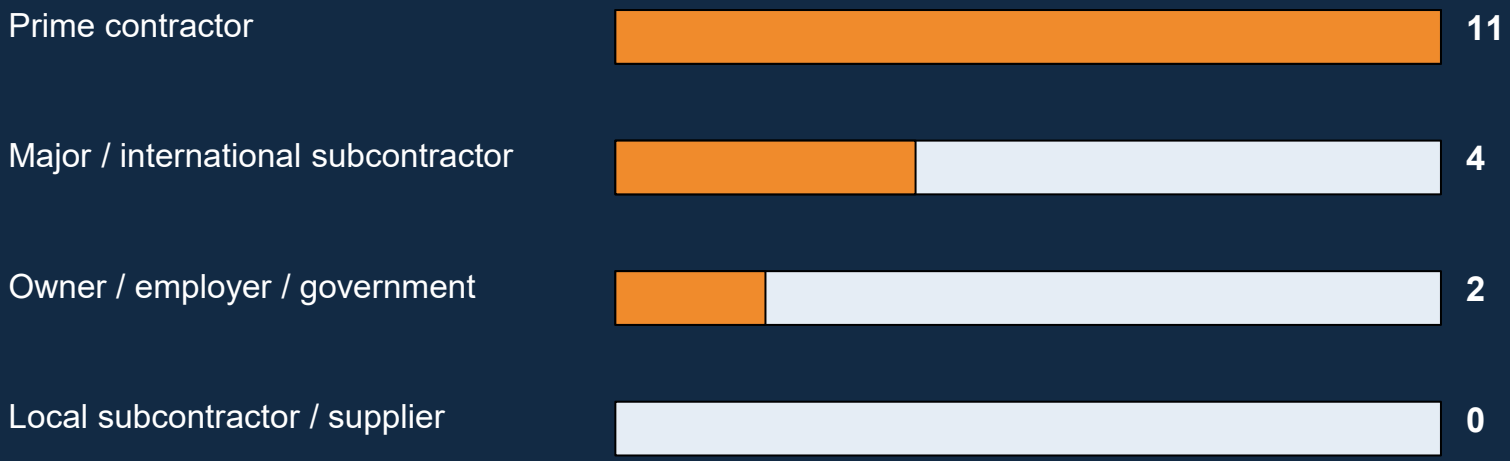
Research questions: which combinations lead to bottlenecks or prevent them, and what contract mechanisms do experts prefer?



- RQ1–RQ2: assess LCP, CAPGAP and FLOW as configurations for both SCB and ~SCB, including necessity and sufficiency. RQ3: analyse liability caps, equivalent relief and dispute arrangements through separate expert-judgement questions; REG and MACRO are robustness conditions.

Data and methodology

Expert questionnaire: 17 responses, with 15 complete respondent–project assessments in the main fsQCA model.



SCB is the mean of five 1–7 ratings: schedule delay, EPC intervention, supplier distress, QA rework and overall delivery difficulty. No direct local-supplier responses.

Calibration: scores 2 / 4 / 6 (non-member / crossover / member), logistic fuzzy sets.
Truth-table frequency ≥1; sufficiency consistency ≥0.85 and PRI ≥0.75; α = 0.777–0.906.

fsQCA: no sufficient pathway to a bottleneck

Primary outcome: supply-chain bottleneck (SCB), N = 15.

What the observed cases show

- Only C01, C05 and C16 have SCB membership above 0.5; C11 lies exactly at 0.5 and the other eleven cases are below the crossover.
- Only four of eight possible LCP–CAPGAP–FLOW rows are observed: 000 (1 case), 001 (4), 011 (5) and 111 (5). The other rows are logical remainders.
- None of these observed rows meets the joint SCB sufficiency thresholds (consistency ≥0.85; PRI ≥0.75), partly because high-SCB outcomes are rare.

No sufficient failure pathway was identified here; this does not prove that such a pathway cannot exist in other projects.

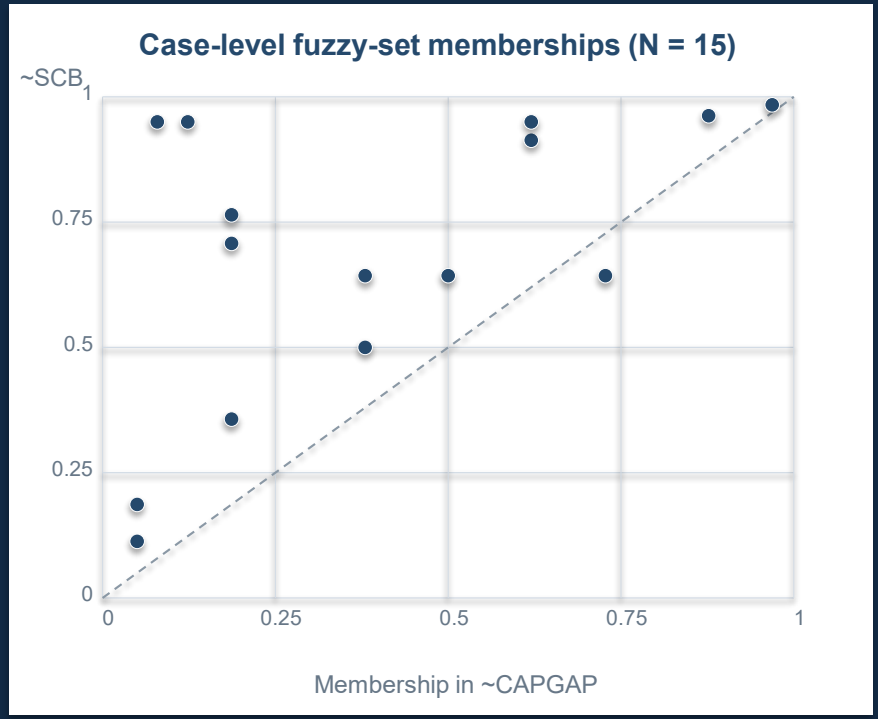
fsQCA: observed protective configuration

Conservative and intermediate solution for avoiding SCB in the 15 observed cases.

~LCP × ~CAPGAP → ~SCB

0.985	0.533	0.974
Consistency	Coverage	PRI

- Sufficient rows 000 and 001 differ only in FLOW, which drops out when they are minimized.
- Five cases directly support this solution. Here, ~CAPGAP is core and ~LCP peripheral.
- The simpler ~CAPGAP term (consistency 0.986) additionally relies on unobserved high-LCP / low-CAPGAP configurations.



Case patterns: where the fsQCA evidence is strongest

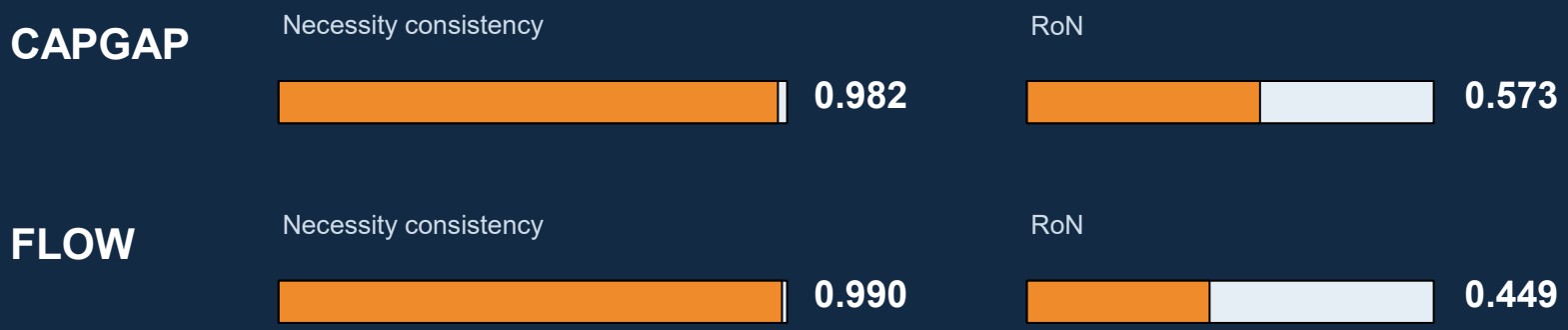
Observed configurations in the primary model (N = 15); 1 = presence, 0 = absence after crossover assignment.

LCP–CAPGAP–FLOW	Cases	Cons. SCB	Cons. ~SCB	PRI ~SCB	Interpretation
000	1	0.555	1.000	1.000	Protective
001	4	0.478	0.983	0.967	Protective
011	5	0.620	0.841	0.698	Mixed cases
111	5	0.685	0.835	0.652	Mixed cases

Rows 000 and 001 support the protective solution; rows 011 and 111 contain contradictory outcomes.
No observed row passes the chosen SCB sufficiency thresholds (consistency ≥ 0.85; PRI ≥ 0.75).

What about rigid contractual flow-down?

Necessity is about inclusion of outcome cases—not proof that a condition causes the outcome.



- CAPGAP and FLOW both exceed the 0.90 necessity-screening threshold, but their modest RoN values show that both are also common in cases without severe SCB.
- CAPGAP × FLOW is not sufficient for SCB (consistency 0.605; PRI 0.353). The data do not identify a distinct causal FLOW effect.

Robustness and sensitivity checks

Does the protective configuration hold under alternative specifications?

Model / sensitivity check	N	Consistency	Coverage	PRI
Primary: ~LCP × ~CAPGAP	15	0.985	0.533	0.974
Without SCB QA-rework item	15	0.975	0.537	0.957
Strict-QA subgroup (proxy)	8	0.960	0.432	0.910
MACRO alternative model	15	0.911	0.680	0.863
REG alternative model	14	0.984	0.573	0.973

All results above concern ~SCB, but MACRO and REG models use different condition sets and solution expressions.

Sensitivity: crossover 4.2 changes the conservative term; “strict QA” is not an exclusively nuclear-project subset.

Expert judgement: risks not suitable for automatic flow-down

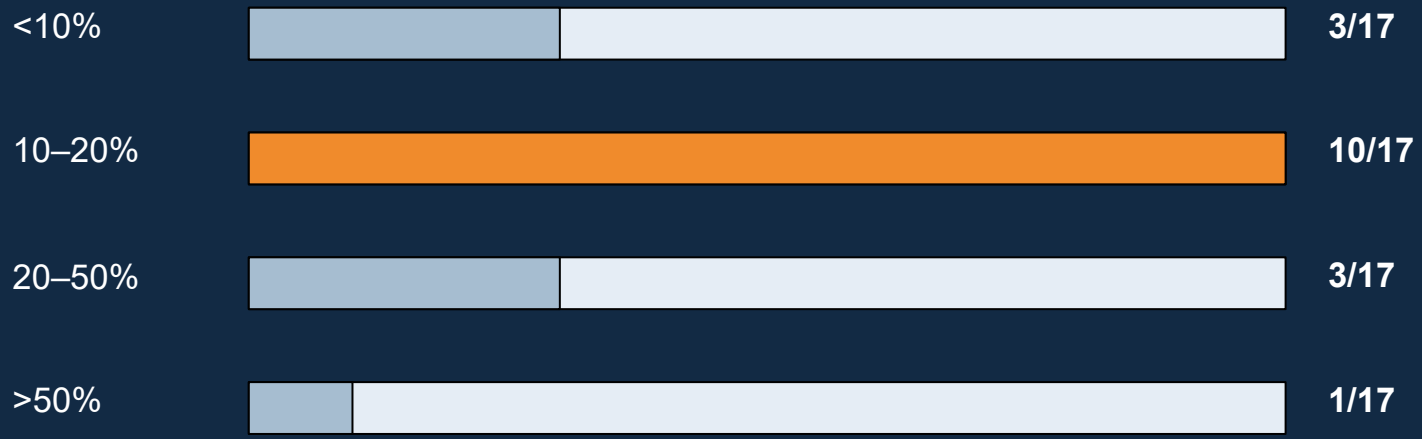
Number of respondents selecting each risk (multiple responses; N = 17).



Q12 allowed multiple answers. Other selected risks: strict time bars and excessive bonds / guarantees (5/17 each).

Liability limits and bankability

Q17: upper-tier experts' estimates of the maximum insurable overall liability cap for a typical local subcontract (N = 17).



- Ten of 17 respondents (58.8%) selected 10–20% of subcontract value; this was the most common response band.

Q16 Delay LD bands: <5% (3), 5–10% (5), 10–15% (5), >15% (4). Neither question establishes a verified market-wide limit.

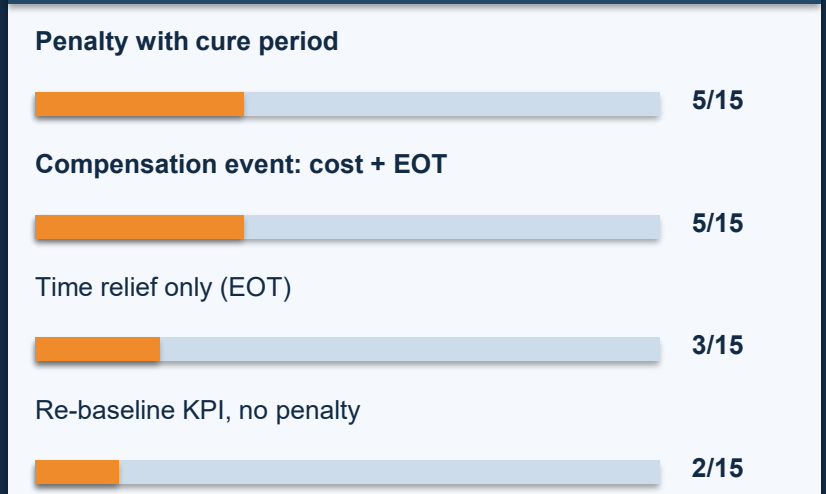
Expert preferences: contractual remedies and liability design

Professional-judgement questions Q13 and Q14; these results describe preferences, not tested project outcomes.

Q13: overall-liability structure (N = 17)



Q14: missed local-content target (N = 15*)



*Two Q14 responses marked multiple choices and were excluded from the single-choice distribution.

Equivalent Balance framework

Empirical input: capability-readiness configuration; contractual recommendations: expert judgement and literature.

1 Supplier readiness

Check comparable technical references, nuclear-grade QA routines, qualified staff, traceability, working capital and guarantees. Use development milestones for weak packages.

2 Proportionate liability

Set LDs, caps, carve-outs and bonds by controllable package exposure and actual insurance or banking capacity—not by automatic prime-contract percentages.

3 Equivalent relief

Bridge owner approvals, regulatory change and other non-attributable events through proportionate time/cost relief, with notice, evidence and mitigation duties.

4 Contract governance

Align notices, claims evidence, escalation channels and dispute forums across tiers, or bridge differences where local law must govern the subcontract.

Q15 preferences: aligned governing law / forum 7/17; local-law subcontract with equivalent-relief bridge 6/17. No single approach dominated.

Implications for nuclear EPC projects

Apply localization and risk allocation package by package, based on readiness and criticality—not only a project-wide percentage.

Recommended contract and supply-chain practices

- Segment work packages by safety classification, critical-path exposure, interfaces, technical difficulty and alternative qualified suppliers.
- Check actual supplier QA and documentation routines, references, qualified staff and finances; phase localization with qualification gates.
- Check proposed LDs, liability caps, carve-outs, insurance and bonds with the local supplier, banks and insurers before contract award.
- Map owner approvals, regulatory change, nominated suppliers and interface events to EOT / cost relief, notices and evidence requirements.

Monitor supplier and contract health during execution; adjust development support and escalation before a critical package fails.

Conclusions

Exploratory findings from 17 expert responses (15 complete cases in the main fsQCA model).

Key messages

- No observed configuration is sufficient for SCB at the chosen thresholds; only three cases lie above the SCB crossover.
- For ~SCB, ~LCP × ~CAPGAP is sufficient within the observed solution (consistency 0.985), supported directly by five cases.
- FLOW is common and shows high necessity consistency, but it does not show a separate sufficient effect on SCB in these data.
- Contract recommendations focus on supplier readiness, insurable liability, equivalent relief and aligned governance.

Limits: small and unbalanced sample; no local-supplier respondents; strict QA is not nuclear-only; project independence unverified.

Thank you for your attention

Questions?

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