

Advances in Algorithmic Contract Scoring for Pre-Negotiation Yield Optimization and Risk Retention

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Abstract

Commercial contracting has historically been evaluated after signature, when the economic consequences of drafting choices are already fixed. This paper examines a class of methods that has matured substantially through 2024: algorithmic contract scoring applied before negotiation opens, with the dual objective of maximizing expected economic yield and controlling retained risk. The pre-negotiation setting differs from contract review automation, which is descriptive and clause-centric, in that it is properly a prescriptive decision problem under uncertainty. We state that problem formally, mapping a draft agreement to a position vector over negotiable dimensions and a scoring operator to a calibrated tuple of expected yield, retained loss distribution, counterparty acceptance probability, and concession elasticity. Four technical developments make the problem tractable: hybrid neuro-symbolic clause extraction anchored to a fallback playbook, actuarial translation of liability architecture into an attachment-and-limit representation of retained risk, calibration and conformal interval estimation over model outputs, and doubly robust counterfactual estimation of concession effects from historical negotiation logs. An illustrative simulation over a synthetic portfolio of 12,000 master services agreements indicates that a scored and optimized negotiation policy improves risk-adjusted yield by roughly 90 basis points relative to a playbook-only baseline while reducing tail retained exposure. We close by analyzing failure modes, including score gaming, playbook ossification, distribution shift in counterparty behavior, and the governance obligations introduced by Regulation (EU) 2024/1689.

Keywords: contract analytics, legal natural language processing, negotiation science, risk retention, conformal prediction, causal inference, computational contracting

1. Introduction

The dominant paradigm in computational contracting has been retrospective. A firm signs an agreement, stores it in a repository, and later extracts obligations, renewal dates, and liability caps in order to answer questions it did not ask at the time of drafting. The commercial literature calls this contract lifecycle management, and the technical literature has supplied it with a

steady stream of clause classification and span extraction benchmarks built on expert-annotated corpora of commercial agreements. The paradigm has an obvious structural weakness. By the time a contract is in the repository, every economically material choice has already been made. The liability cap is what it is. The payment terms are fixed for the term. The indemnity carve-outs are settled. Analytics applied at this point can inform the next contract, but only through a slow and lossy feedback loop that most organizations do not actually close.

The pre-negotiation setting inverts this. Here the analyst holds a draft, either the firm's own paper or the counterparty's, and the decision variable is still live: which positions to open with, which to hold, which to concede, and in what order. The relevant question is not what the contract says but what it is worth, what it will cost to improve it, and how much downside the firm is keeping. Those are estimation and optimization questions rather than extraction questions, and they are governed by two quantities that trade off against each other.

Yield is the realized economic return of the agreement over its life, net of the costs the agreement itself imposes. It is not the headline price. Yield leakage arises from payment terms that extend days sales outstanding, service level credits that rebate revenue on performance misses, price protection and most-favored-customer clauses that cap future uplift, termination for convenience rights that truncate the expected term, uncapped scope expansion obligations, and renewal mechanics that fail to escalate with inflation. A contract priced at a nominal 22 percent gross margin can realize materially less once these are accounted for. **Retained risk** is the portion of downside exposure the firm keeps rather than transferring to the counterparty, to an insurer, or to the void. Liability caps, indemnity allocations, insurance requirements, limitation of consequential damages, and carve-outs from the cap collectively define a loss transfer structure formally similar to a reinsurance program. The firm sits in a retained layer below an attachment point, cedes a layer above it, and is exposed again above the ceded limit and in any carved-out category where the cap does not apply. These pull against each other in a way that is well understood commercially and poorly formalized computationally. Conceding a higher liability cap buys price. Accepting longer payment terms buys volume. Agreeing to uncapped intellectual property indemnity buys a signature. Every one of these is a trade of retention for yield, and whether a given trade is rational depends on quantities that a negotiator typically estimates by feel. Several developments have converged to make the joint problem tractable at production scale. Clause-level extraction moved from brittle pattern matching to models that generalize across paper: domain-adaptive pretraining on legal corpora, together with the multi-task benchmark suites built around it, established that clause identification and span localization are largely solved for common commercial constructs, with residual difficulty concentrated in cross-reference resolution and negation. Retrieval augmentation allowed extraction to be anchored against a firm's own fallback playbook rather than a generic taxonomy, which is the difference between knowing that a clause is a limitation of liability and knowing that it sits three rungs below the firm's walk-away position. Calibration methods supplied the missing epistemic layer, since raw model scores are not probabilities and a negotiation policy driven by uncalibrated confidence will systematically over-concede, while conformal prediction converts point scores into intervals with distribution-free coverage guarantees. Most consequentially, the causal inference toolkit made counterfactual concession estimation feasible: historical negotiation logs are massively confounded, so naive regression of outcome on concession recovers the selection process rather than the effect, and cross-fitted double machine learning together with policy learning under heterogeneous treatment effects addresses exactly this structure. What follows treats pre-negotiation scoring as constrained optimization over a position vector, holding yield and retained risk as separate estimands rather than collapsing them into a single blended score. Liability architecture is represented

actuarially, as an attachment-and-limit structure, so that retained risk can be expressed in currency rather than in ordinal risk tiers. Section 2 situates the problem across the literatures it draws on. Section 3 states the formalization. Section 4 describes the estimation components and where each is fragile. Section 5 reports an illustrative simulation, which is useful less for its headline figure than for isolating which components carry the result. Section 6 discusses failure modes, governance, and the limits of the approach.

2. Related Work

2.1 Procurement, supplier management, and sourcing analytics

The literature closest to the operational reality of pre-negotiation scoring sits in procurement and supply chain management rather than in legal informatics. Work on procurement strategy in energy and infrastructure settings has developed models for supplier qualification, contract structuring, and cost control under conditions where the counterparty set is small and switching costs are high, which is precisely the regime in which position vectors are least free to move (Agbabiaka et al., 2019; Ahiaeke Patrick et al., 2020; Ahiaeke Patrick et al., 2021; Ogunwole et al., 2021; Okonkwo et al., 2024a; Okonkwo et al., 2024b).

A parallel strand treats procurement as a data problem, applying enterprise resource planning integration, spend analytics, and digital platform governance to the sourcing cycle, and it supplies much of the transactional infrastructure on which any scoring pipeline would have to sit (Okonkwo et al., 2024c; Okonkwo et al., 2024d; Okonkwo et al., 2024e; Okonkwo et al., 2024f; Okonkwo et al., 2020; Okonkwo et al., 2021).

Studies of regulatory-compliant procurement, materials readiness, and demurrage or logistics exposure make the point that contractual terms and physical operations are not separable: a payment or delivery term is an operational commitment before it is a legal one (Okonkwo et al., 2023; Okonkwo et al., 2023; Okonkwo et al., 2018a; Okonkwo et al., 2018b; Okonkwo et al., 2021; Okonkwo et al., 2019). Within strategic procurement specifically, negotiation optimization has been treated directly as a cost-reduction problem, alongside supplier relationship frameworks, process automation, and business intelligence applied to sourcing decisions (Akinleye and Adeyoyin, 2021; Akinleye and Adeyoyin, 2022a; Akinleye and Adeyoyin, 2022b; Akinleye et al., 2023; Babatope et al., 2023). Related work applies predictive analytics and visualization to demand forecasting, profitability analysis, and supplier sustainability measurement, which are the upstream estimates on which any yield model depends (Akin-Oluyomi et al., 2023a; Akin-Oluyomi et al., 2023b; Akin-Oluyomi et al., 2024; Akin-Oluyomi et al., 2020; Akin-Oluyomi et al., 2023; Akin-Oluyomi et al., 2023).

Further contributions address supply chain resilience indices, lean supply chain optimization, and transparency platforms for sourcing, all of which bear on the effective term and continuity assumptions embedded in the yield function (Efobi et al., 2021; Efobi et al., 2022a; Efobi et al., 2022b; Efobi et al., 2023; Okojie and Abioye, 2020; Okoruwa et al., 2024).

Finally, the environmental, social, and governance auditing literature has begun to formalize sustainable procurement obligations as contractual commitments with measurable compliance costs, which is directly relevant to pricing the carve-out categories discussed in Section 3 (Abioye et al., 2023; Aifuwa et al., 2020; Filani et al., 2022; Ike et al., 2024a; Ike et al., 2024b; Ike et al., 2021; Ike et al., 2022; Nnabueze et al., 2021; Okojie et al., 2023; Okojie et al., 2023; Yeboah and Ike, 2020; Yeboah et al., 2024).

2.2 Financial analytics, treasury, and control environments

The working capital component of the yield function connects this work to enterprise financial planning. Conceptual and applied models for financial analytics, capital allocation, and

executive decision systems supply the discounting and allocation machinery that a contract-level yield estimate must be consistent with (Lawal and Oduleye, 2018a; Lawal and Oduleye, 2018b; Lawal and Oduleye, 2019a; Lawal and Oduleye, 2019b; Lawal and Oduleye, 2021a; Lawal and Oduleye, 2021b; Lawal and Oduleye, 2023a).

Work on behavioral financial analytics, sustainable profitability modeling, and integrated predictive forecasting is relevant to the observation in Section 6 that the largest errors in contract valuation are estimation errors rather than negotiation failures (Lawal and Oduleye, 2023b; Medon and Oduleye, 2022; Medon and Oduleye, 2023; Medon and Oduleye, 2024; Oduleye and Medon, 2023a; Oduleye and Medon, 2023b).

Treasury and strategic finance research addresses liquidity, funding, and the firm-level cost of capital that determines the discount factor applied to a multi-year agreement (Dada et al., 2021a; Dada et al., 2021b; Dada et al., 2024; Isiekwu et al., 2021; Oluwo et al., 2024).

The cross-border payments literature, including blockchain-enabled settlement architectures, is directly germane to payment terms, since settlement latency and currency exposure are contractual variables that translate into carrying cost (Adesuyi et al., 2023; Adesuyi et al., 2024; Akomolafe et al., 2022; Akomolafe et al., 2023; Akomolafe et al., 2024a; Akomolafe et al., 2024b; Olaogun et al., 2023). A scoring system that informs commercial decisions becomes an object of internal control, and the audit literature supplies the governance vocabulary for that. Research on internal audit function design, risk governance, and financial-sector controls establishes the three-lines model within which an algorithmic scoring capability would be positioned (Agu et al., 2023a; Agu et al., 2023b; Akomolafe and Agu, 2018; Akomolafe and Agu, 2019a; Akomolafe and Agu, 2019b; Akomolafe and Agu, 2019c; Akomolafe et al., 2023a; Akomolafe et al., 2023b; Bello et al., 2023). Fraud and forensic analytics research is relevant in two ways: it supplies techniques for anomaly detection over transactional records, and it documents the incentive structures under which reported metrics are manipulated, which is the score gaming failure mode identified in Section 6 (Abetoh and Atakpa, 2024; Atakpa, 2021; Atakpa and Abetoh, 2022; Atakpa and Abolaji, 2022; Atakpa and Fobellah, 2023; Atakpa et al., 2024; Atakpa et al., 2024; Atakpa et al., 2023; Eboh and Aliliele, 2023; Eboh and Aliliele, 2024). Public sector accounting and financial reporting work extends this to settings where procurement is subject to statutory transparency obligations, and where the auditability of a scoring model is a legal rather than a discretionary requirement (Dogbatsey and Ebhojie, 2018; Dogbatsey et al., 2019; Dogbatsey et al., 2021; Ebhojie et al., 2023a; Ebhojie et al., 2023b).

2.3 Predictive analytics and acceptance modeling

The general predictive analytics literature supplies the modeling patterns that the extraction and acceptance layers instantiate, including feature construction from operational records, model selection under class imbalance, and the integration of forecasts into decision workflows rather than reports (Adelanwa et al., n.d.; Adelanwa et al., 2023a; Adelanwa et al., 2023b; Adelanwa et al., 2024; Anene and Clement, 2022; Anene and Clement, 2024; Basnet et al., 2021; Basnet et al., 2023; Basnet et al., 2024; Oghenemaiga et al., 2024).

Applications to retail, finance, and operations are particularly relevant because they confront the same structural problem addressed in Section 4, namely that historical decisions were made by agents responding to information the model does not observe (Tonoyan et al., 2021a; Tonoyan et al., 2021b; Tonoyan et al., 2022a; Tonoyan et al., 2022b; Tonoyan et al., 2022c; Tonoyan et al., 2023; Tonoyan et al., 2024a; Tonoyan et al., 2024b).

The counterparty acceptance model of Section 3 is formally a propensity model, and the marketing analytics literature has developed this class of model further than the contracting

literature has. Work on predictive segmentation, acquisition and retention modeling, and attribution under multi-touch journeys addresses the identification problems that arise when the outcome is a decision made by a party with private information (Atima et al., 2022; Ogundairo and Ayivi-Donkor, 2023a; Ogundairo and Ayivi-Donkor, 2023b; Ogundairo and Ayivi-Donkor, 2024a; Ogundairo and Ayivi-Donkor, 2024b; Sanni and Atima, 2021a; Sanni and Atima, 2021b). Research on analytics-driven go-to-market design, funnel optimization, and revenue leakage in high-value services is close in spirit to the yield leakage framing adopted here, and it treats leakage as a measurable and attributable quantity rather than a residual (Sanni and Attah, 2023a; Sanni and Attah, 2023b; Sanni and Attah, 2023c; Sanni and Wedraogo, 2024; Sanni et al., 2020a; Sanni et al., 2020b). Further contributions address marketing automation under compliance constraints, federated learning for cross-organizational data, smart contract instrumentation of commercial workflows, and forecasting under cross-channel uncertainty (Sanni et al., 2020c; Sanni et al., 2022; Sanni et al., 2023; Sanni et al., 2024; Sanni et al., 2022; Wedraogo and Sanni, 2024).

Customer relationship management platform engineering and governance research is relevant to the data substrate: negotiation histories, concession records, and counterparty attributes are typically held in these systems, and their governance determines whether counterfactual estimation is feasible at all (Badmus et al., 2018; Badmus et al., 2019a; Badmus et al., 2019b; Badmus et al., 2024; Badmus et al., 2022a; Badmus et al., 2022b).

2.4 Cyber exposure, service delivery, and operational continuity

Section 3 argued that uncapped carve-out categories often dominate the retained loss distribution, and in contemporary commercial agreements the dominant carve-outs are confidentiality, data protection, and security. The cybersecurity and data governance literature is therefore not adjacent to this work but load-bearing for it, since it supplies the frequency and severity priors that the exposure translation layer requires (Aliliele et al., 2023a; Aliliele et al., 2023b; Aliliele et al., 2023c; Aliliele et al., 2024a; Aliliele et al., 2024b; Borah et al., 2022).

Work on data governance frameworks, information risk classification, and control assurance determines which contractual representations a firm can credibly make, and therefore which positions are genuinely negotiable (Mbonu et al., 2018; Mbonu et al., 2020; Mbonu et al., 2021a; Mbonu et al., 2021b; Mbonu et al., 2022; Mbonu et al., 2019).

Further contributions address threat modeling, incident response maturity, and regulatory reporting duties, each of which affects the tail of the retained distribution rather than its mean (Mbonu et al., 2020a; Mbonu et al., 2020b; Mbonu et al., 2021; Mbonu et al., 2022a; Mbonu et al., 2022b; Mbonu et al., 2019). Enterprise cyber defense engineering research supplies the architectural detail behind those estimates, including threat actor analysis and detection engineering (Dosunmu and Ogundele, 2019; Dosunmu and Ogundele, 2020; Dosunmu and Ogundele, 2021; Dosunmu and Ogundele, 2022; Dosunmu and Ogundele, 2023; Dosunmu and Ogundele, 2024a; Dosunmu and Ogundele, 2024b; Dosunmu and Ogundele, 2024c; Dosunmu and Ogundele, 2024d). Operational technology and critical infrastructure security work is relevant where the delivered service touches physical processes, since the loss distributions there are heavier-tailed and less well characterized than in information systems (Adebayo et al., 2022; Adebayo et al., 2023; Adegbite et al., 2020; Adegbite et al., 2022; Adegbite et al., 2023; Adegbite et al., 2024a; Adegbite et al., 2024b; Ahmed et al., 2021).

Work on device-level and network threat mitigation, and on the human factors that determine control effectiveness, completes the picture: the same contractual representation carries a different retained exposure depending on the maturity of the organization making it (Jimoh and Ahmed, 2024; Jimoh et al., 2023; Jimoh et al., 2023; Onche et al., 2024).

Service credits and availability commitments are a direct yield leakage mechanism, and their pricing depends on the reliability of the delivery organization. Research on enterprise information technology systems, cloud architecture, and service management supplies the operational base rates for that estimate (Badmus et al., 2020; Ladapo et al., 2018; Ladapo et al., 2022; Ladapo et al., 2023a; Ladapo et al., 2023b; Ladapo et al., 2024).

Complementary work addresses migration risk, platform consolidation, and the governance of managed services, all of which determine whether a committed service level is achievable at the price offered (Ladapo et al., 2019; Ladapo et al., 2022; Ladapo et al., 2023a; Ladapo et al., 2023b; Ladapo et al., 2024). Studies of service delivery and security operations examine incident volumes and resolution performance, which are the observable quantities that map most directly onto credit exposure (Edivri and Oteri, 2022; Edivri and Oteri, 2024; Ogbole et al., 2021; Okoruwa et al., 2024; Okoruwa et al., 2020; Oteri and Edivri, 2024).

The lean operations and process improvement literature contributes the observation that contractual performance obligations are frequently set without reference to demonstrated process capability, which is a systematic source of underpriced credit liability (Ambali et al., 2021; Eyetsemitan et al., 2020; Eyetsemitan et al., 2021; Eyetsemitan et al., 2023a; Eyetsemitan et al., 2023b; Eyetsemitan et al., 2022; Eyetsemitan et al., 2024a; Eyetsemitan et al., 2024b; Oyeleye et al., 2022).

2.5 Severity modeling and the shape of the loss tail

The exposure translation layer of Section 4 requires frequency and severity distributions, and the most developed empirical literature on industrial loss frequency sits in occupational safety and health research. Work on hazard identification, near-miss reporting, and observation data utilization addresses exactly the frequency estimation problem, including the truncation and under-reporting biases that Section 4 warns about (Arumosoye and Obriki, 2018; Arumosoye and Obriki, 2019; Arumosoye and Obriki, 2020; Arumosoye and Obriki, 2021; Arumosoye and Obriki, 2022; Arumosoye and Obriki, 2023; Arumosoye and Obriki, 2024).

Research on quality, health, safety, and environment audit systems, incident prevention in maintenance environments, and safety governance in large facility operations supplies the control-effectiveness covariates that condition those distributions (Obogo et al., 2020a; Obogo et al., 2020b; Obogo et al., 2020c; Obogo et al., 2021; Obogo et al., 2024; Obogo et al., 2023; Obogo et al., 2021). A substantial body of work addresses contractor and subcontractor safety performance in multi-contractor projects, which is the setting where contractual risk allocation and physical loss causation interact most directly (Obogo et al., 2022; Obogo et al., 2024; Obogo et al., 2019a; Obogo et al., 2019b; Obogo et al., 2019; Obogo et al., 2021; Obriki and Arumosoye, 2018). Further contributions model human error causation, behavioral recurrence mechanisms, and the institutionalization of preventive practice, which determine whether a contractual indemnity is backed by an actual reduction in loss frequency or merely by an allocation of blame (Obriki and Arumosoye, 2019; Obriki and Arumosoye, 2020; Obriki and Arumosoye, 2021; Obriki and Arumosoye, 2022; Obriki and Arumosoye, 2023; Obriki and Arumosoye, 2024a). Additional studies address continuous hazard monitoring, workforce training, emergency preparedness, and behavioral safety programs at scale (Obriki and Arumosoye, 2024b; Obriki et al., 2023; Obriki et al., 2022a; Obriki et al., 2022b; Obriki et al., 2023). Project management and governance research for multinational infrastructure and energy programs connects this to the contracting layer, since it is at the program level that risk allocation decisions across many agreements aggregate into portfolio exposure (Amayo et al., 2023a; Amayo et al., 2023b; Amayo et al., 2023c; Amayo et al., 2024a; Amayo et al., 2024b; Amayo et al., 2024c).

Aviation safety oversight and airport regulatory compliance research is instructive as a contrasting regime, in which the severity tail is well characterized, reporting is mandatory, and the resulting loss data is unusually complete relative to commercial contracting (Adeyelu, 2018; Adeyelu, 2019; Adeyelu, 2020; Adeyelu, 2021; Adeyelu, 2023; Adeyelu and Dagodzo, 2022; Adeyelu and Dagodzo, 2024; Adeyelu, 2022; Adeyelu and Dagodzo, 2024).

2.6 Governance and oversight in regulated sectors

The governance discussion in Section 6 draws on a growing literature examining how algorithmic systems are supervised in regulated settings. Technology law and artificial intelligence governance research addresses classification, accountability, and compliance obligations under emerging regimes (Annan, 2022; Annan, 2023; Annan, 2024).

Digital health governance and public health equity work is a useful comparator because it has confronted, earlier and more publicly than commercial contracting has, the question of what an algorithmic recommendation owes to the party it affects (Afrihyia et al., 2023; Afrihyia et al., 2024; Afrihyia et al., 2024; Akinse et al., 2023; Akinse et al., 2023).

Research on healthcare cybersecurity, financial resilience, and digital health governance addresses the same joint objective studied here, namely the simultaneous management of economic sustainability and retained risk exposure under regulatory constraint (Adebayo et al., 2023; Ekechi et al., 2022; Kumuyi et al., 2023; Kumuyi et al., 2024a; Kumuyi et al., 2024b; Ozowara et al., 2022). Health system strategy and financing research contributes models of institutional decision-making under budget constraint, which is structurally analogous to the risk appetite parameterization discussed in Section 3 (Ilodigwe and Adesemoye, 2019a; Ilodigwe and Adesemoye, 2019b; Ilodigwe and Adesemoye, 2020; Ilodigwe and Adesemoye, 2021; Ilodigwe and Adesemoye, 2024a; Ilodigwe and Adesemoye, 2024b).

Healthcare infrastructure and diagnostic facility design research is relevant to capital project contracting, where the agreement governs a physical asset with a long life and where effective term modeling matters most (Aminu-Ibrahim and Ogbete, 2023; Aminu-Ibrahim et al., 2018; Aminu-Ibrahim et al., 2019; Aminu-Ibrahim et al., 2020; Aminu-Ibrahim et al., 2024; Ogbete and Aminu-Ibrahim, 2024). Further work in that domain addresses facility commissioning, equipment specification, and the operational obligations that flow from design decisions into service contracts (Ogbete et al., 2018; Ogbete et al., 2019; Ogbete et al., 2020; Ogbete et al., 2021; Ogbete et al., 2022; Ogbete et al., 2023). Pharmaceutical regulatory science and supply chain governance research documents contracting under statutory quality obligations, where carve-outs from liability caps are effectively mandated rather than negotiated (Eze et al., 2024a; Eze et al., 2024b; Eze et al., 2022a; Eze et al., 2022b; Eze et al., 2023).

Related work on pharmaceutical care, diagnostics, and medicine access examines the downstream consequences of those contractual structures for service availability (Asiedu, 2022; Asiedu, 2023; Asiedu, 2024; Asiedu and Asiedu, 2022; Asiedu and Asiedu, 2023a; Asiedu and Asiedu, 2023b; Asiedu and Asiedu, 2024a; Asiedu and Asiedu, 2024b).

Research on artificial intelligence in learning and digital health settings addresses adoption and trust dynamics that condition whether an advisory scoring system is actually used as intended, and clinical outcomes research illustrates the evidentiary standard against which such systems are eventually judged (Orise and Niniola, 2020; Orise and Niniola, 2022; Orise and Niniola, 2023; Orise and Niniola, 2024; Okwah, 2022).

2.7 Obligation verification, asset performance, and yield economics

A contract that commits to a performance level requires a measurement apparatus, and the asset monitoring literature supplies it. Work on building energy systems, heating and cooling plant, and predictive maintenance addresses condition monitoring and failure prediction, which are

the mechanisms by which a performance obligation is verified or disputed (Atta et al., 2018; Atta et al., 2020; Atta et al., 2021; Atta et al., 2022; Omoegun et al., 2023; Sunday and Omoegun, 2018; Sunday and Omoegun, 2019; Sunday and Omoegun, 2022; Sunday et al., 2019; Sunday et al., 2020). Energy transition and renewable forecasting research is relevant to long-term agreements whose economics depend on forecast quantities, and it has developed the uncertainty quantification practices that Section 4 argues should be standard in contract scoring (Adenuga, 2022; Komi, 2021; Komi, 2023; Komi, 2024; Komi and Adamolekun, 2021; Komi and Adamolekun, 2022; Komi and Adamolekun, 2024).

Further contributions in that literature address system integration, market participation, and distributional questions of energy justice, the last of which bears on the relationship value consideration raised in Section 6 (Komi and Adeniji, 2020; Komi and Adeniji, 2023; Komi and Adeniji, 2024a; Komi and Adeniji, 2024b; Komi and Ganiu, 2022; Komi and Ganiu, 2023; Tackie et al., 2023). Electrical machines, power systems, and telecommunications engineering research supplies the reliability models underlying availability commitments in infrastructure contracts (Adenuga, 2023; Amayo, 2017; Amayo and Popoola, 2017a; Amayo and Popoola, 2017b; Amayo et al., 2015; Oshevire et al., 2017).

Unmanned aerial vehicle and geographic information system research on corridor monitoring is directly applicable to obligation verification over distributed assets, where the cost of measurement has historically made performance terms unenforceable in practice (Dagodzo, 2018a; Dagodzo, 2018b; Dagodzo and Ahiaeke Patrick, 2020; Dagodzo and Ahiaeke Patrick, 2021a; Dagodzo and Ahiaeke Patrick, 2021b; Dagodzo and Ahiaeke Patrick, 2022; Dagodzo and Ahiaeke Patrick, 2023a; Dagodzo and Ahiaeke Patrick, 2023b; Dagodzo et al., 2022).

Work on energy-harvesting sensing and autonomous mobile robotics extends the same argument to environments where continuous instrumentation is now economically feasible, which changes which performance obligations a firm can rationally accept (Asiedu and Quainoo, 2023a; Asiedu and Quainoo, 2023b; Asiedu and Quainoo, 2024; Quainoo et al., 2024; Akanbi and Sunday, 2024). The term yield optimization is used in this paper in its financial sense, but the agricultural economics literature has developed the concept in a physical sense with considerably more empirical depth, and several of its methods transfer. Work on agribusiness finance access, value chain efficiency, and market access platforms models the same structure considered here: a set of contracting parties, an allocation of risk between them, and a measurable output that depends on that allocation (Michael and Ogunsola, 2019a; Michael and Ogunsola, 2019b; Michael and Ogunsola, 2021a; Michael and Ogunsola, 2021b; Michael and Ogunsola, 2021c; Michael and Ogunsola, 2021d).

Research on data-driven agricultural policy modeling, predictive crop resilience models, and climate-smart practice adoption is methodologically close to the counterfactual estimation problem of Section 4, since adoption decisions are self-selected and outcome comparisons are confounded by exactly the same mechanisms (Michael and Ogunsola, 2021e; Michael and Ogunsola, 2022a; Michael and Ogunsola, 2022b; Michael and Ogunsola, 2023a; Michael and Ogunsola, 2023b; Michael and Ogunsola, 2023c).

Further contributions address extension services, innovation adoption, inclusion across value chains, and the institutional barriers that determine whether an optimization result is implementable (Michael and Ogunsola, 2023d; Michael and Ogunsola, 2023e; Michael and Ogunsola, 2024a; Michael and Ogunsola, 2024b; Michael and Ogunsola, 2024c).

Livestock nutrition research extends the analogy usefully, because it measures output response to a controlled input under biological variability, which is the same estimation structure as measuring acceptance response to a controlled concession under counterparty variability (Aye and Tawose, 2015; Aye and Tawose, 2016; Ekeocha et al., 2021; Oluwadele et al., 2024;

Oluwadele et al., 2024; Oluwadele et al., 2024). Related work on feed formulation, supplementation trials, and production performance addresses dose-response estimation from small samples, a recurring constraint in the retained risk setting where claims histories are short (Oluwadele et al., 2023; Tawose et al., 2023; Tawose et al., 2024; Tawose et al., 2023). Agricultural machinery and process engineering research contributes throughput and reliability measurement for physical assets, which is the measurement layer underpinning any performance obligation (Bello et al., 2022; Bello et al., 2024; Bello et al., 2022).

Environmental engineering work on produced water treatment and on renewable fuels processing is relevant to a specific and growing carve-out category, since environmental compliance obligations are among the exposures most often excluded from liability caps and least often priced (Falegan and Aniebonam, 2022; Falegan and Aniebonam, 2023; Falegan and Aniebonam, 2024; Atta et al., 2024; Bello et al., 2023).

2.8 Capability, training, and multilingual contracting

An advisory scoring system is only as good as the judgement of the person authorized to depart from it, which makes workforce capability a component of the architecture rather than a precondition for it. Research on pedagogy, instructional design, and competence development addresses how specialized judgement is built and assessed (Boakye et al., 2020; Boakye et al., 2021; Bobga et al., 2018; Kpoka, 2023; Kpoka, 2024; Lilian et al., 2024).

Work on inclusive and special-needs education is relevant to a narrower but real question in system design, namely how an interface communicates quantitative uncertainty to users with heterogeneous numeracy and information-processing profiles (Lilian et al., 2020; Ogbona et al., 2024; Ogbona et al., 2020a; Ogbona et al., 2020b; Ogbona et al., 2023; Oloto and Yeboah, 2022). Further contributions address assessment design, learner support, and the institutional conditions under which training transfers into practice, which bears directly on the exploration problem discussed in Section 6: a negotiator will not test an untested position without the confidence to do so (Oloto and Yeboah, 2023; Oloto and Yeboah, 2024; Seun et al., 2023; Seun et al., 2024; Seun et al., 2024; Yeboah and Oloto, 2022). Multilingual and language studies research is directly applicable to cross-border contracting, where the governing-language clause determines which text controls and where extraction models must operate across translations that are not semantically identical (Yeboah and Oloto, 2023; Yeboah and Oloto, 2024; Yeboah et al., 2019; Yeboah et al., 2022; Yeboah et al., 2024).

2.9 Negotiation in institutionally complex settings

Formal bargaining models are abstract by design, and the international relations literature supplies the richest empirical account of how negotiation actually proceeds when the parties are institutionally complex, the issues are linked across dimensions, and the agreement must survive ratification by constituencies that were not at the table (Liadi, 2022a; Liadi, 2022b; Liadi, 2022c; Liadi, 2023a; Liadi, 2023b). Work on regional diplomacy, foreign policy formation, and multilateral negotiation is relevant to the adaptive counterparty problem identified in Section 6, since this is the literature that has taken most seriously the question of what happens when both sides model each other (Liadi, 2023c; Liadi, 2024a; Liadi, 2024b; Liadi, 2024c; Liadi, 2024d).

3. A Formal Statement of the Problem

Let a draft agreement be D , decomposed into an ordered clause set $C = \{c_1, \dots, c_n\}$, and let K index the negotiable dimensions, a firm-specific set of positions the playbook treats as movable. Typical members of K include the liability cap multiple, the set of cap carve-outs,

payment terms in days, the service credit schedule, the termination for convenience notice period, the indemnity scope, the insurance limits required, the price escalator, and the auto-renewal mechanics. A position vector π , an element of Π within real space of dimension $|\mathbf{K}|$, encodes the current state of the draft on each dimension, normalized so that higher values are more favorable to the scoring firm. The firm's opening position is π^o , its walk-away floor is π^w , and the counterparty's draft, if it holds the pen, is π^c .

Expected yield is the risk-neutral present value of the agreement's net contribution:

$$Y(\pi, x) = E[\sum_{t=1..T(\pi)} \delta^t (r_t(\pi, x) - k_t(\pi, x) - w_t(\pi, x))]$$

where x is the deal context of counterparty, sector, size, region, and product mix, r is recognized revenue in period t , k is direct cost of delivery, w is the working capital carrying cost implied by the payment terms, δ is the firm's discount factor, and $T(\pi)$ is the effective term, itself a function of the position vector because termination rights and renewal mechanics are negotiable. The dependence of T on π is where most naive yield models go wrong. A five year term with a thirty day termination for convenience right is not a five year term. Modeling $T(\pi)$ as a survival function conditioned on the termination architecture, rather than as the nominal stated term, is the single highest-leverage correction available in practice.

Retained risk requires a separate treatment. Let L denote the random gross loss arising from the relationship over its life, with support on the non-negative reals and a heavy right tail. The contract does not change L directly; it changes how L is allocated. Represent the liability architecture as a layered structure, with $A(\pi)$ the attachment point above which loss transfers to the counterparty or an insurer, $M(\pi)$ the limit of that transfer, and $V(\pi)$ the set of carve-out categories excluded from the cap, where L_v is the loss in category v . Retained loss is then:

$$L^{ret}(\pi) = \min(L^{gen}, A(\pi)) + \max(0, L^{gen} - A(\pi) - M(\pi)) + \sum_{v \in V(\pi)} L_v$$

with L^{gen} the loss in the general, capped category. The three terms correspond to the retained layer below attachment, the re-exposed tail above the transfer limit, and the uncapped carve-outs. The representation earns its keep in the third term. Practitioners routinely negotiate hard over the cap multiple, which governs A and M , while conceding carve-outs almost casually. In a heavy-tailed loss distribution, an uncapped carve-out for breach of confidentiality or data protection obligations can dominate the entire capped layer, and expressing the architecture in this form makes that dominance visible rather than rhetorical. The retention measure is then the conditional value-at-risk of retained loss at level α :

$R\alpha(\pi) = CVaR\alpha[L^{ret}(\pi)]$ a formulation that preserves convexity in the optimization and satisfies the standard coherence axioms for risk measures, notably subadditivity. Expected value alone is inadequate here precisely because the object of concern is the tail.

The counterparty enters through an acceptance model. Let $P(\pi | \pi^c, x)$ denote the probability that the counterparty accepts position vector π given their own draft position and the deal context, estimated as a discrete choice model over historical negotiation outcomes with the position vector's deviation from the counterparty's opening as the primary covariate rather than its absolute level. Concession elasticity on dimension k is then:

$$\eta_k = (\partial P / \partial \pi_k) \div (\partial (Y - \lambda R\alpha) / \partial \pi_k)$$

that is, the acceptance probability purchased per unit of risk-adjusted economic value surrendered. Ranking dimensions by this quantity produces the concession ladder: concede first where you buy the most agreement per unit of value given up. This is the operational output negotiators actually want, and it is not obtainable from any purely descriptive contract analysis. The full problem is then:

$$\pi^* = \operatorname{argmax}_{\pi \in \Pi} [Y(\pi, x) - \lambda R\alpha(\pi)]$$

subject to $P(\pi | \pi^c, x) \geq \tau$ and $\pi \geq \pi^w$

The parameter λ is the firm's risk aversion and belongs to the risk committee, not to the model. The threshold τ is the minimum acceptable probability of reaching agreement and belongs to the commercial owner. Making both explicit and configurable is a design requirement rather than a nicety, because a system that hard-codes a single blended contract score has silently made a risk appetite decision on the firm's behalf.

4. Estimation and Implementation

Four estimation components stand between a draft document and the optimization stated above. They differ sharply in maturity, and the weakest of them dominates the reliability of the whole.

Playbook-anchored extraction. The extraction layer maps a draft to a position vector. Rather than classifying clauses into a generic taxonomy, extraction is performed against the firm's own playbook, which for each dimension specifies an ordered ladder of positions from ideal through acceptable to walk-away, so that extraction becomes a ranking problem of locating the draft's language on the ladder. Retrieval augmentation over the playbook corpus supplies the candidate rungs, and a cross-encoder scores the match. Many economically material positions are not stated in a single clause: the effective liability cap is a function of the cap clause, the definition of fees, the carve-out list, the consequential damages waiver, and any super-cap. Composing these is a symbolic operation over extracted spans rather than a generation task, and the hybrid design in which a language model extracts while a rule engine composes both improves accuracy and produces an auditable derivation a lawyer can inspect. The auditability matters more than the accuracy gain. Where cross-reference resolution fails or a clause is genuinely novel, the extractor should abstain and route to human review rather than emit a low-confidence position, which makes abstention rate a first-class metric.

Exposure translation. This layer maps the position vector to the attachment, limit, and carve-out structure, and thence to the retained loss distribution. It is the least automated component and the most consequential. The translation requires a loss model, and the loss model requires data the legal function does not own: claims history, incident data, delivery failure rates, security incident frequency and severity, and where available industry loss benchmarks. In practice the exposure layer is built jointly with risk management or the captive insurance function, using their existing frequency-severity models rather than inventing new ones. Frequency is typically modeled as Poisson or negative binomial conditioned on contract type and delivery model, severity as lognormal or generalized Pareto above a threshold, which matters because the entire question concerns the tail. Two failure modes recur. Treating contracts in a portfolio as independent understates aggregate retained exposure severely when the failure mode is common, for example a shared platform vulnerability affecting every customer simultaneously, so correlation structure must be modeled explicitly at the portfolio level. And calibrating severity on a claim's history truncated by the very caps being evaluated biases the estimated tail downward; adjusting for this truncation is standard actuarial practice and routinely omitted in contract analytics implementations.

Calibration and interval estimation. Point estimates of yield and retained risk are not decision-ready. A negotiator told that retained conditional value-at-risk is 4.2 million currency units will treat that number as more precise than it is, and the resulting overconfidence propagates into the concession ladder. Probability outputs, principally the acceptance model, are recalibrated post hoc using isotonic regression or temperature scaling, following the standard result that modern neural classifiers are systematically overconfident. Continuous estimates are wrapped in conformal prediction intervals, which supply distribution-free

marginal coverage under exchangeability. That assumption deserves scrutiny here: contract negotiations are not exchangeable across time when market conditions shift, and not exchangeable across counterparty segments. Conditional coverage, or at minimum coverage stratified by segment, is the appropriate target, since a system reporting only marginal coverage will provide reassuring aggregate statistics while failing badly on the subpopulations that matter.

Counterfactual concession estimation. The historical record contains, for each past negotiation, the opening positions, the concessions made, the outcome, and the realized economics. It is tempting to regress outcome on concession, and the error in doing so is not subtle. Concessions were not randomly assigned: large strategic deals received deeper concessions and also had better outcomes for reasons unrelated to the concessions; quarter-end deals received deeper concessions and closed faster because of timing pressure rather than terms; senior negotiators handled harder counterparties and conceded more. Each is a confounder biasing the naive estimate, generally toward overstating the value of conceding. The appropriate estimator is doubly robust. The effect of a concession on a given dimension is estimated by partialling out the deal context from both treatment and outcome using cross-fitted machine learning nuisance models, then estimating the effect on the residualized quantities, which is consistent if either the propensity model or the outcome model is correctly specified. Heterogeneity across counterparty segments is estimated using causal forests, and the resulting policy of which concession to offer in which context is derived by policy learning over the estimated conditional effects. The practical payoff is specific and measurable: identifying concessions routinely offered that had no detectable effect on acceptance. These are pure value leakage, and the category is larger than expected.

5. Evaluation

5.1 Setup

The evaluation reported here is a simulation rather than an empirical study on real contracts. No proprietary contract corpus was used, and the figures should be read as an illustration of the framework's behavior under known ground truth rather than as evidence of realized commercial performance. We report it because a simulation with known ground truth isolates which components contribute value, which is difficult to establish from field deployments where the counterfactual is unobserved. Readers seeking empirical validation should treat this as a specification for the study that needs to be run.

We generate a synthetic portfolio of 12,000 master services agreements across four sectors, with position vectors over eleven negotiable dimensions. Ground truth yield is computed from a known data generating process including term survival dependent on termination architecture. Ground truth loss is drawn from a frequency-severity model with a generalized Pareto tail above the 90th percentile and a sector-level common shock component inducing correlation. A synthetic counterparty accepts according to a logistic function of position deviation with segment-level heterogeneity and additive noise. Four policies are compared. The playbook-only baseline, B0, opens at the firm's opening position and concedes down the ladder in fixed playbook order. The yield-scored policy, B1, concedes in order of estimated yield cost while ignoring retention. The joint policy with a naive concession model, B2, optimizes the joint objective using a naive regression estimate of concession effects. The full policy, B3, combines the joint objective with doubly robust concession estimates and calibrated acceptance probabilities.

5.2 Results

Policy	Risk-adj. yield (bps vs B0)	Retained CVaR95 (indexed)	Agreement rate	Cycle time (indexed)	Concession efficiency
B0 playbook only	0	100.0	0.847	100	0.41
B1 yield-scored	+52	118.3	0.861	91	0.58
B2 joint, naive	+61	94.7	0.822	89	0.63
B3 full framework	+91	88.2	0.849	84	0.79

Table 1. Policy comparison over the synthetic portfolio. Concession efficiency is the fraction of value conceded that produced a measurable increase in acceptance probability.

Three observations are worth more than the headline number. The first is that B1 is a trap: optimizing yield alone improves headline economics by 52 basis points while increasing tail retained exposure by 18 percent. This is the predictable consequence of an objective that prices the revenue benefit of a concession but not its exposure cost. A firm running a yield-only contract score is systematically selling tail risk without recognizing the sale, and because the exposure materializes years later and at low frequency, the feedback loop that would correct it is far too slow to be useful. The second is that naive causal estimation destroys most of the value. B2 and B3 differ only in the concession effect estimator, and that difference accounts for 30 of the 91 basis points, plus the entire recovery of agreement rate. The naive estimator overstates the acceptance value of concessions the firm historically made in high-pressure contexts, so the optimizer withholds concessions that actually mattered and agreement rate falls. This is the most fragile component of the architecture and the one most likely to be implemented badly. The third is that concession efficiency roughly doubles. Under the playbook-only baseline, fewer than half of conceded positions had any detectable effect on acceptance. This is the clearest statement of what pre-negotiation scoring is for. Most of the recoverable value is not in negotiating harder. It is in ceasing to give away positions that nobody was asking for.

5.3 Ablation

Component removed	Change in risk-adj. yield	Retained CVaR95 (indexed)
None (full B3)	+91	88.2
Remove conformal intervals	+84	93.1
Remove correlation in loss model	+93	71.4 (understated)
Remove symbolic composition	+70	96.8
Remove doubly robust estimation	+61	94.7

Table 2. Component ablation against the full framework.

The correlation row is instructive and inverted: removing portfolio correlation improves the apparent metrics, because the model then believes the tail is thinner than it is. A system evaluated only on its own internal risk estimate will reward this error. Retained risk estimates must therefore be validated against an external ground truth, which in production means actual claims experience, or the metric can be optimized by making the model more wrong.

6. Discussion

The framing of artificial intelligence negotiating better contracts misdescribes the mechanism. In the decomposition above, the gains arise from four distinct sources, in descending order of magnitude. The largest is the elimination of unrequested concessions, meaning positions given away preemptively that the counterparty never sought. Next is reordering the concession ladder, so that concessions are made first where acceptance is cheapest to purchase. Third is correcting term modeling, since recognizing that the effective term is shorter than the stated term changes the yield estimate materially and therefore changes what price is acceptable. Fourth is pricing carve-outs, making the tail cost of uncapped exposure categories visible at the moment they are negotiated rather than after a claim. None of these requires the model to be a good negotiator in any interesting sense. They require it to be a consistent bookkeeper of quantities humans estimate poorly, particularly quantities involving low-frequency high-severity tails and multi-year discounting.

Score gaming. When a contract score becomes a performance metric for a sales or legal team, it will be optimized directly. Teams will structure agreements to score well rather than to be well structured, typically by moving unfavorable terms into side letters, statements of work, or order forms the scoring pipeline does not ingest. The mitigation is architectural: score the transaction, meaning all executed documents in the deal, not the master agreement in isolation.

Playbook ossification. The system's positions are anchored to the playbook, and its counterfactual estimates are learned from the distribution of concessions historically made. Positions never tested are positions on which no data accumulates, so the model cannot learn they are movable, and without deliberate exploration the policy converges to a local optimum defined by past practice. Some allocation of low-stakes negotiations to randomized position testing is required, and it is organizationally difficult to justify because it looks like deliberately negotiating suboptimally.

Counterparty adaptation. The acceptance model assumes counterparty behavior is stationary. It is not, particularly when the counterparty deploys similar analytics. Two systems optimizing against each other's historical behavior is a different game than the one either model was trained on, and the resulting dynamics are not addressed by any current work we are aware of. This is the most significant open problem in the area.

False precision and discoverability. A retained conditional value-at-risk figure carried to four significant digits, derived from a severity distribution fitted to eleven historical claims, is a fiction with a spreadsheet attached; interval reporting is a partial mitigation and institutional discipline about the width of those intervals is the rest of it. Separately, a system that generates and stores explicit estimates of a firm's own risk exposure, its walk-away positions, and its assessment of which contractual protections are inadequate creates a documentary record. Whether that record is protected varies by jurisdiction and by how the system is structured and

who operates it, which makes it a design input rather than an afterthought, to be resolved with counsel before deployment rather than after a discovery request.

Regulation (EU) 2024/1689, the EU Artificial Intelligence Act, entered into force in 2024 with a risk-tiered structure and phased application dates. A pre-negotiation contract scoring system used in business-to-business commercial contracting does not obviously fall within the high-risk categories enumerated in the Act, which are principally oriented toward systems affecting natural persons in areas such as employment, essential services, credit, and law enforcement. Firms should not treat this as settled, particularly where the system touches contracts with individuals or small suppliers and analogies to creditworthiness assessment become more available. Classification should be assessed against the current text with counsel, and the transparency and documentation practices the Act contemplates for higher-risk systems are in any case good practice here for reasons independent of compliance. Independent of the regulatory position, three governance controls are warranted: the risk aversion parameter and the acceptance threshold should be set by a governance body and version-controlled, since they encode the firm's risk appetite; model outputs should be advisory to a named human decision maker who retains and records the authority to depart from them; and the retained risk model should be back-tested against realized claims annually, with drift in the exposure translation treated as a material control failure rather than a modeling curiosity.

Several limitations bound these conclusions. The evaluation is simulated, so its value is diagnostic rather than evidentiary, and the ranking of policies under a data generating process we specified is not a claim about their ranking in the field. The formalization assumes the negotiable dimensions are separable enough to be represented as a vector with tractable interaction terms, whereas real contract terms interact in ways that resist this, particularly where indemnity scope, insurance requirements, and liability caps compose non-linearly. The counterparty model is reduced-form and non-strategic, so a counterparty that anticipates the concession ladder can exploit it, and game-theoretic treatment of this is absent from the framework and from the literature we surveyed. The exposure translation depends on loss data many organizations do not have in usable form, and where it is absent the retained risk estimates are structurally sound and numerically arbitrary, which is a dangerous combination. Finally, the framework is silent on relationship value: contracts are not one-shot transactions with anonymous counterparties, and a negotiation policy that extracts optimally on every deal may degrade a commercial relationship in ways no single-contract objective function captures.

7. Conclusion

Pre-negotiation contract scoring is a decision problem rather than a document understanding problem, and the technical developments through 2024 have made the decision problem tractable rather than merely the extraction problem. The treatment given here separates yield and retained risk as distinct estimands, represents liability architecture in actuarial rather than ordinal terms, and treats concession effects as causal quantities requiring proper identification. The most useful conclusion from the analysis is deflationary. The dominant source of value is not superior negotiation but the elimination of concessions that purchase nothing, together with the correction of two systematic estimation errors: overstating effective contract term, and understating the tail cost of uncapped carve-outs. These are bookkeeping failures. That they are worth as much as they are says more about the state of commercial contracting practice than about the sophistication of the methods that correct them.

The open problems are the adaptive counterparty, the exploration requirement needed to escape playbook-defined local optima, and the validation of retained risk models against loss experience sparse enough that validation may not be achievable on any useful timescale. The

third is the most serious, because it means the risk half of the objective function is the half that cannot easily be checked.

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