

Article

Risk Allocation at Engineering Interfaces in Construction Contracts: A Case Study of the Taiwan High Speed Rail Project

Teng-Che Lu ^{1,*} and Tsung-Chieh Tsai ²¹ Graduate School of Engineering Science and Technology, National Yunlin University of Science & Technology, Douliu 64002, Taiwan² Department of Civil and Construction Engineering, National Yunlin University of Science & Technology, Douliu 64002, Taiwan; tsaitc@yuntech.edu.tw

* Correspondence: a5478890@ms7.hinet.net or d11110208@yuntech.edu.tw

Abstract

Large-scale infrastructure projects routinely divide construction responsibilities across several specialized contractors whose scopes are simultaneously independent and mutually reliant, producing boundary zones where design changes, remedial obligations, and contractual disputes repeatedly emerge. This study examines how interface-related risks are distributed between civil construction contractors and core system contractors, drawing on fieldwork conducted within the Taiwan High Speed Rail (THSR) project. Questionnaire surveys were administered to 38 practitioners who held direct THSR involvement or comparable experience in analogous multi-party infrastructure projects, yielding a valid response rate of 63.3%. Using a weighted influence scoring approach, 37 risk factors grouped into seven interface categories were evaluated. Results show that Variation (top-ranked item A07, score 290/300), Care of Works (B01, 284/300), and Cooperation and Coordination (D04, 285/300) represent the three most consequential risk domains. Analysis of risk-initiation patterns indicates that project owners are the predominant source of variation-related risks, while core system contractors most frequently trigger care-of-works incidents. Structured comparison of FIDIC (1995), AIA/A201 (1997), NEC/ECC (1995), ENAA (1996), and THSR contractual documents uncovers a shared shortcoming: no examined standard form contains explicit provisions tying risk liability to the party whose conduct gave rise to the risk. Evidence from three documented THSR dispute cases is consistent with the survey data and illustrates the real-world consequences of this drafting gap. On this basis, the study proposes a risk-trigger principle as a potential framework for improving interface risk allocation in future multi-party infrastructure contracts.

Keywords: risk allocation; core system contract; interface risk; contract comparison; Taiwan High Speed Rail; multi-party contracts



Academic Editor: Yasser Mohamed

Received: 31 May 2026

Revised: 23 June 2026

Accepted: 25 June 2026

Published: 26 June 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

1.1. Background and Research Motivation

Infrastructure procurement practices in Taiwan have shifted markedly over recent decades, moving away from conventional single-contractor delivery toward arrangements in which several independent entities share project responsibilities. This transition has generated a category of risk that single-contract frameworks were never designed to address: interface risk, understood here as the cost overruns and schedule disruptions that arise wherever one contractor's scope ends and another's begins, and which cannot be

adequately governed under a unified contractual arrangement [1]. Today's major infrastructure undertakings involve layered networks of long-duration agreements that span the entire project lifecycle from initial planning through post-construction handover. Faced with this complexity, owners have commonly sought to shift project uncertainties onto contractors by embedding broadly worded risk clauses in contract documents [2]. Yet this approach has inherent limits. Where two or more principal contractors—civil construction contractors and core system contractors in particular—must deliver interdependent scopes under separate agreements with the same owner, the question of who bears responsibility for interface-zone risks becomes genuinely difficult to resolve.

Uncertainty is an unavoidable feature of complex infrastructure delivery. Scope revisions, unforeseen ground conditions, and delayed owner instructions are practical realities that no contract can fully anticipate in advance [3]. When owners push an excessive share of these uncertainties onto contractors through broadly drafted risk provisions, contractors protect themselves by building risk premiums into their bids—costs that ultimately return to the owner in the form of higher contract prices. When, conversely, contractors misjudge the risks they have accepted, disputes and claims multiply, eroding the collaborative relationships that effective project delivery requires [4]. The boundary between civil construction and core system installation in high-speed rail projects illustrates this tension with particular clarity. Civil contractors are responsible for the structural fabric of the project—tunnels, viaducts, and station structures—while core system contractors install the operating infrastructure: tracks, signaling, electrification, and rolling stock. Each party's ability to complete its scope depends critically on what the other delivers, yet their obligations are set out in separate contracts that may contain inconsistent or conflicting risk provisions [5].

The Taiwan High Speed Rail (THSR) project offers a well-documented setting in which to examine these interface risk allocation problems. Opened for revenue service in 2007, THSR was Taiwan's first high-speed rail system, delivered through a Build–Operate–Transfer (BOT) arrangement under which a private consortium financed, built, and now operates a 345-kilometre corridor between Taipei and Kaohsiung [6]. During construction, responsibility was divided among twelve separate civil contracts and a single comprehensive core system contract, generating numerous interface zones where scope boundaries, technical requirements, and scheduling interdependencies converged [7]. Post-construction review established that interface-related claims accounted for a disproportionately large share of total contractual disputes, with scope changes, care-of-works obligations, and coordination breakdowns appearing repeatedly as sources of conflict [8]. The contractual structure of the THSR project—in which the owner holds separate agreements with the civil contractor and the core system contractor but no direct contract links the two contractors—is illustrated in Figure 1.

1.2. Research Objectives and Scope

Three interrelated objectives guide this investigation:

1. Empirical identification and ranking of interface risk factors through a structured survey targeting practitioners with direct THSR involvement or comparable experience in analogous multi-party infrastructure projects;
2. Comparative analysis of risk allocation provisions across five internationally recognised standard-form contracts (FIDIC, AIA, NEC/ECC, ENAA) and THSR-specific documentation;
3. Formulation of a risk-trigger principle as a practical basis for improving interface risk allocation in future multi-party infrastructure contracts.

The study concentrates on the boundary between civil construction contractors and core system contractors, intentionally setting aside other interface categories—such as design–construction, owner–contractor, or contractor–subcontractor interfaces—to keep the analysis focused. A sequential mixed-methods design is employed, combining quantitative survey data, qualitative contract document analysis, and illustrative case study analysis [9].

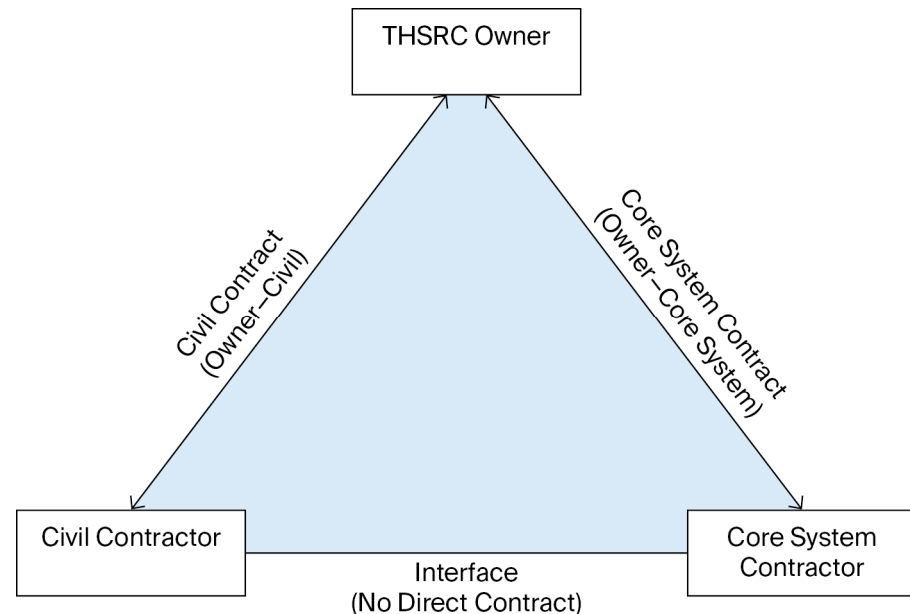


Figure 1. THSR Contractual Relationship and Interface Zone. The shaded triangle represents the interface zone in which risks arise from the interaction of both contractors’ scopes, yet no direct contractual link governs their relationship. Note: No direct contractual link exists between the Civil Contractor and the Core System Contractor; interface risks arise within the shaded zone and must be governed through owner-mediated provisions.

To operationalise these objectives, the study addresses the following research questions:

- RQ1: Which interface risk factors are regarded as most critical by practitioners with experience in high-speed rail projects involving separate civil and core system contracts?
- RQ2: What are the predominant risk-initiation patterns for each interface risk category—that is, which party (owner, civil contractor, or core system contractor) most frequently triggers each type of risk?
- RQ3: How do internationally recognised standard-form contracts (FIDIC, AIA, NEC/ECC, ENAA) and THSR-specific documentation allocate interface risks, and do any of them explicitly link risk responsibility to the party whose conduct initiated the risk?
- RQ4: Can documented THSR dispute cases illustrate the survey findings and demonstrate the practical applicability of a risk-trigger allocation principle?

1.3. Research Gap

Prior THSR-related studies—most notably Yu (2006) [7]—established a foundational taxonomy of interface risk factors and demonstrated that interface risk management requires dedicated contractual attention. However, that work and subsequent investigations share a common limitation: they characterise what interface risks exist without examining who initiates them or how standard form contracts allocate them. Specifically, three gaps remain unaddressed in the existing literature:

1. No trigger analysis. Existing studies rank interface risks by severity or frequency but do not systematically attribute each risk to its originating party (owner, civil contractor,

or core system contractor). Without this attribution, it is impossible to assess whether conventional risk allocation clauses assign responsibility to the correct party.

2. No cross-contract comparison. Previous THSR research relies primarily on project-specific contract documents without benchmarking their provisions against internationally recognised standard forms (FIDIC, AIA, NEC/ECC, ENAA). This leaves open the question of whether the allocation deficiencies observed in THSR contracts are idiosyncratic or systemic across the industry.
3. No principle-level synthesis. Existing work documents allocation problems but stops short of proposing a governing principle that could guide future contract drafting. The risk-trigger principle advanced in this study fills that gap.

Unlike previous THSR studies, this research not only identifies interface risk factors but also examines risk-initiation patterns, compares international standard forms, and supports the findings through documented dispute cases. The study thereby extends existing knowledge from risk identification toward trigger-based risk allocation and contract governance—a progression that directly addresses unresolved questions in the existing literature.

1.4. Significance and Contribution

The study responds to a meaningful gap in construction contract research. Although risk allocation in single-contract settings has attracted sustained scholarly attention [10–12], the specific problem of interface risk allocation in multi-party frameworks—where two or more principal contractors deliver interdependent scopes under separate agreements with a shared owner—has received comparatively little systematic treatment. Three contributions follow from this investigation:

Conceptual contribution: A risk-trigger principle is advanced, grounded in causal accountability rather than in a party's capacity to absorb losses. This challenges the dominant allocation logic, which assigns risks to whoever is best placed to control or mitigate them [13], by showing that interface risks frequently originate with parties other than those contractually designated to bear the consequences. The study does not claim to introduce a new legal doctrine but rather develops a practical contract-governance framework for interface-risk attribution.

Methodological contribution: A weighted influence methodology is developed and applied for evaluating interface risk factors, combining practitioner assessments of both occurrence probability and consequence severity. This produces more actionable risk rankings than approaches that consider frequency alone [14].

Practical contribution: The contract comparison reveals structural weaknesses in standard form provisions covering interface risks, and the risk-trigger principle provides concrete guidance for drafting improved interface risk allocation clauses in future multi-party contracts.

1.5. Organization of the Paper

The paper is structured as follows. Section 2 surveys the literature on risk allocation principles, legal context, interface management, and contract governance. Section 3 articulates the study's distinct contributions. Section 4 presents the mixed-methods research design, covering survey instrument construction, contract selection, and case study protocol. Section 5 reports findings from the practitioner survey and contract comparison. Section 6 analyses three documented THSR disputes that are consistent with and help contextualise the survey results. Section 7 discusses theoretical, practical, and contract drafting implications. Section 8 states the principal conclusions, acknowledges limitations, and identifies directions for future research.

2. Literature Review

2.1. Risk Allocation Principles in Construction Contracts

Risk allocation sits at the heart of construction contract design, shaping project costs, schedule reliability, and the frequency of disputes [15]. The economic rationale for deliberate risk allocation draws on transaction cost theory: well-designed contracts place each risk with the party that can control, mitigate, or absorb it most cheaply [16]. This logic, which underpins both academic guidance and the drafting conventions of standard-form contracts, rests on three premises: that risks can be reasonably anticipated before work begins; that different parties possess distinct capacities to manage particular risk categories; and that the risk premiums embedded in contract prices reflect rational estimates of expected loss [17].

In practice, however, these premises break down in complex multi-party environments. Research on integrated risk response frameworks for EPC+PPP arrangements shows that conventional allocation principles often fail when contractors must coordinate interdependent scopes under separate agreements [18]. Three specific failure modes are documented. First, many interface risks cannot be controlled by either contractor acting alone; they arise from the interaction of two parties' activities and therefore require joint management [19]. Second, the contractor best placed to limit a risk's consequences may not be the one whose conduct triggered it [7]. Third, contractors who carry disproportionate risk loads respond either by padding their bids with large contingency allowances or by under-investing in risk management once a contract is awarded—both outcomes increasing total project cost [20].

A growing body of scholarship explores alternative frameworks that emphasise shared accountability, collaborative problem resolution, and incentive alignment [21,22]. Relational contracting models, most prominently the NEC/ECC family, embed mechanisms such as pain-share/gain-share arrangements, early warning obligations, and joint risk registers that distribute interface risks more evenly [23]. Nonetheless, these instruments remain uncommon in practice, particularly in civil-law jurisdictions where contractual interpretation prioritises textual precision over relational norms [24].

2.2. Legal Basis for Risk Allocation

In Taiwan, risk allocation in construction contracts operates within the framework of the Civil Code, which governs contractual obligations, breach remedies, and force majeure provisions. Parties retain wide latitude to apportion risks through explicit contractual terms, subject to public policy constraints and doctrines prohibiting unconscionable clauses. For BOT infrastructure projects, the Private Participation in Infrastructure Act (PPI Act) provides supplementary statutory guidance, directing that risks should be assigned to the party better able to manage them while preserving adequate protection for the public interest [25].

Four specific legal doctrines are particularly relevant to interface risk allocation in multi-party infrastructure projects under Taiwan law.

First, causation. Under Articles 216 and 227 of the Civil Code, a party claiming compensation for breach of contract must establish a causal link between the other party's act or omission and the loss suffered. In multi-contractor environments, causation is frequently contested because the same damage may result from the sequential or concurrent acts of several parties. The risk-trigger principle proposed in this study operationalises the causation requirement by directing contract drafters to identify, *ex ante*, which party's conduct is most likely to initiate each category of interface risk, thereby reducing post-dispute causation disputes.

Second, owner instruction liability. Under the Civil Code framework, owner-supplied instructions and materials may affect the allocation of contractual responsibility. Article 508 of the Civil Code provides a statutory basis for attributing responsibility to the owner where defects or additional costs arise from owner-supplied materials or instructions, offering a legal foundation for the risk-trigger principle in the Taiwanese contractual context. The THSR dispute cases examined in this study illustrate how ambiguous variation instructions generated interface conflicts between civil and core system contractors.

Third, contractual liability allocation. Taiwan law grants parties substantial freedom to allocate risks through explicit contractual terms, subject to the good-faith principle (Article 148 of the Civil Code) and the prohibition on unconscionable clauses (Article 247-1). In practice, BOT and large-scale infrastructure contracts routinely employ broadly worded risk-transfer clauses that attempt to shift all foreseeable and unforeseeable risks onto the contractor. Taiwanese legal scholarship has increasingly recognised concerns regarding such clauses, particularly where the transferred risk is one that the owner—by reason of its instructions or decisions—was better placed to prevent.

Fourth, delay responsibility. Construction delay claims in Taiwan are governed by the general principles of contractual breach (Articles 226–229 of the Civil Code) and, for public projects, by the Government Procurement Act. Under Taiwan law, where delay results from the concurrent acts of multiple contractors, responsibility may be allocated according to each party's causal contribution—an approach consistent with, and reinforcing, the risk-trigger principle developed in this study.

This causation-based approach to delay responsibility finds support in Taiwan arbitration practice. Published CAAI commentary indicates that proportional fault analysis is commonly adopted in multi-contractor delay disputes, attributing schedule liability to the party whose act or omission constituted the proximate cause of the delay [26]. Taiwan court decisions have similarly recognised that, where an owner's instruction directly precipitates a contractor's non-performance, the owner bears corresponding responsibility under the Civil Code [27]. These precedents reinforce the doctrinal foundation of the risk-trigger principle and suggest that its adoption in standard contract forms would be consistent with established Taiwanese legal practice.

2.3. Interface Management in Multi-Party Projects

Interface management has developed into a recognised sub-field of project management, concerned with the coordination problems that arise when multiple organisations must deliver interdependent work packages [28]. Interfaces are conventionally classified as technical (physical connections between components), organisational (coordination between project teams), or contractual (allocation of responsibilities between parties) [29]. High-speed rail projects bring all three types into contact simultaneously: civil contractors must produce structural platforms that satisfy geometric tolerances set by the core system contractor; project teams must align design reviews, material approvals, and construction sequencing; and contracts must clearly attribute responsibility for interface-related risks [30].

Empirical research consistently identifies breakdowns in interface management as a leading cause of cost growth and schedule slippage in complex infrastructure projects [31,32]. Recurring failure modes include: ambiguous scope boundaries that leave gaps or overlaps in responsibility; inconsistent technical specifications across separate contracts; inadequate mechanisms for managing schedule interdependencies; and vague risk allocation provisions that produce disputes when interface problems materialise [33]. Effective interface management calls for both formal governance instruments—interface control documents, coordination meetings, dispute resolution procedures—and informal

relational mechanisms such as trust, open communication, and a shared commitment to problem resolution [34].

2.4. Interface Risk Management and Stakeholder Integration

Interface risks in megaprojects occupy a distinctive category: they emerge from the interaction of multiple contractors' activities rather than from any single party's conduct, making unilateral risk management strategies inherently insufficient. Recent scholarship underscores the importance of integrating risk management with stakeholder coordination in complex multi-party environments. Malek and Bhatt show that risk reduction in megaprojects must directly address interface coordination mechanisms, finding that projects employing systematic interface risk identification and mitigation protocols outperform those relying on conventional risk transfer in both cost and schedule outcomes [33]. Their evidence suggests that interface risks cannot be governed effectively through one-sided contractual allocation; they require collaborative governance structures that align incentives and enable joint problem resolution.

Castelblanco et al. extend this perspective through a multilayer network analysis framework that models stakeholder relationships and risk interdependencies simultaneously in complex megaprojects [35]. Their findings reveal that interface risks propagate through stakeholder networks in ways that conventional risk registers cannot capture: a risk event initiated by one contractor can cascade across multiple interfaces, affecting parties with no direct contractual link to the originating party. This network perspective carries significant implications for contract design, pointing toward interface risk allocation clauses that account for both direct and indirect risk transmission pathways.

2.5. Contract Governance Mechanisms

Contract governance refers to the formal and informal arrangements through which contracting parties monitor performance, resolve disputes, and adapt to circumstances that were not foreseen when the contract was signed [16,36]. Luo et al. distinguish three primary governance dimensions in megaprojects: formal control mechanisms (detailed specifications, monitoring systems, penalty clauses), relational mechanisms (trust, open communication, collaborative problem resolution), and adaptive mechanisms (variation procedures, dispute resolution protocols) [37]. Their work shows that effective governance requires a balanced combination of all three dimensions; over-reliance on formal controls can erode trust and reduce flexibility, while exclusive dependence on relational mechanisms may leave accountability gaps.

Zhang et al. examine how contract design, enforcement, and inter-organisational trust interact to shape megaproject outcomes, concluding that these three elements function as complements rather than substitutes [36]. High-performing projects in their configurational analysis typically combine detailed contractual provisions with robust enforcement mechanisms and strong inter-organisational trust—a finding that challenges the assumption that detailed contracts signal distrust and crowd out relational governance. Clear contract provisions, this evidence suggests, can actually reinforce trust by reducing ambiguity and aligning expectations.

Alqershy and Shi's systematic review of governance mechanisms in megaprojects synthesises evidence from 87 empirical studies, identifying contract completeness, incentive alignment, and dispute resolution procedures as the three most consequential governance elements [38]. Their analysis shows that interface-related disputes account for approximately 30% of all megaproject claims, with ambiguous risk allocation provisions cited as the primary contributing factor in 65% of those cases.

3. Research Contributions

Table 1 positions the present study against the most closely related prior work on THSR interface risk management. The comparison highlights the distinctions between the present study and previous THSR-related research.

Table 1. Comparison of the present study with Yu (2006) [7] and related prior THSR research. (Yu (2006) [7] was selected as the primary comparator because it remains the only dedicated empirical study of interface risk management specific to the THSR project; no subsequent study has replicated or extended its scope with the same project focus).

Research Element	Yu (2006) [7]	Present Study
Interface risk factor identification	✓	✓
Weighted influence ranking (probability × severity)	Partial	✓ (full 37-factor ranking)
Risk-trigger attribution (who initiates each risk)	✗	✓
Cross-contract comparison (FIDIC/AIA/NEC/ENAA)	✗	✓
THSR dispute case illustration	Limited	✓ (3 documented cases)
Risk-trigger principle formulation	✗	✓

Note: Yu (2006) [7] is the foundational THSR interface risk study. “Partial” indicates that ranking was performed but without systematic trigger attribution.

The table makes clear that the present study does not merely replicate prior work: it extends the field from risk identification toward trigger-based risk allocation and contract governance—a progression that none of the examined prior studies has undertaken.

This study makes three distinct contributions to construction contract scholarship and practice:

3.1. Empirical Contribution: Interface Risk Identification and Ranking

The study develops and deploys a comprehensive survey instrument that identifies and ranks interface risk factors based on practitioner assessments of probability and consequence severity. Where earlier work has addressed interface management challenges in general terms [39,40], this investigation provides granular empirical data on specific risk factors—delayed variation orders, inadequate temporary works protection, and insufficient coordination meetings—and their relative importance in high-speed rail construction. The weighted influence methodology employed here produces more actionable risk rankings than frequency-based approaches by explicitly capturing both the likelihood and the impact of each risk factor [41].

3.2. Analytical Contribution: Systematic Contract Comparison

The study conducts a structured comparative analysis of interface risk allocation provisions across five internationally recognised standard form contracts (FIDIC Red Book 1995, AIA A201 1997, NEC/ECC 1995, ENAA Model Form 1996) and THSR contract documentation. A consistent analytical framework examines seven risk categories across all contract forms, revealing systematic patterns in how different contractual traditions approach interface risk allocation. The comparison exposes a shared shortcoming: no examined standard form contains provisions that explicitly link risk responsibility to the party whose conduct initiated the risk event—a finding with significant implications for contract drafting practice in multi-party infrastructure projects.

3.3. Conceptual Contribution: Risk-Trigger Principle

The study advances a risk-trigger principle as an alternative framework for allocating interface risks in multi-party contracts. The principle holds that interface risks should be

borne by the party whose actions or omissions set the risk event in motion, rather than by the party conventionally deemed best placed to control or mitigate it. Grounded in causal accountability and considerations of fairness, the principle addresses a recurring inequity in multi-party contracting: when Party A's delayed instruction or defective work generates additional costs for Party B, Party A should carry those costs regardless of whether Party B might theoretically have been better positioned to reduce them. The principle is illustrated through three anonymised THSR dispute narratives that demonstrate how conventional allocation approaches produce inequitable outcomes and adversarial dynamics in multi-party settings.

Figure 2 illustrates the operational logic of the risk-trigger principle as a six-step decision framework applicable to interface risk events in multi-party infrastructure contracts.

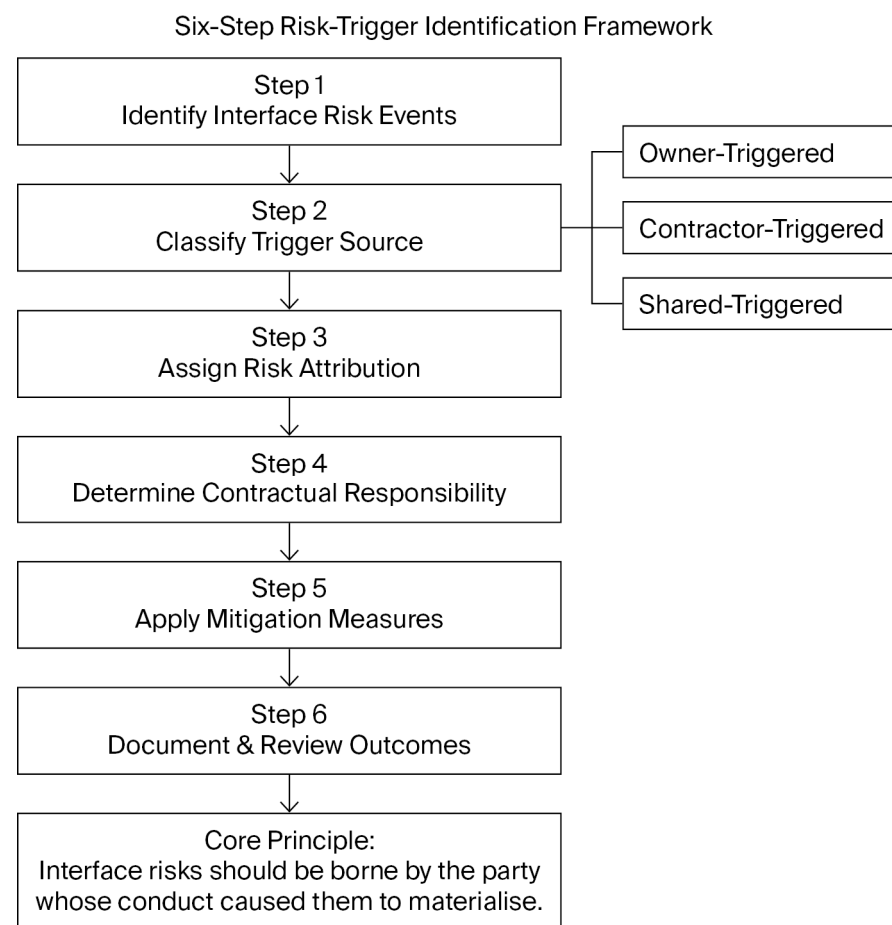


Figure 2. Conceptual Framework of the Risk-Trigger Principle. The framework presents a structured six-step process for identifying risk-triggering parties and allocating interface risks according to causal responsibility in multi-party infrastructure projects.

4. Research Methodology

4.1. Research Design Overview

The study adopts a sequential mixed-methods design that draws on three complementary sources of evidence: (1) a quantitative practitioner survey to identify and rank interface risk factors; (2) qualitative analysis of contract documents to compare risk allocation provisions across standard forms and THSR-specific agreements; and (3) case study investigation to illustrate survey findings and examine practical consequences [42]. Triangulating across these three methods strengthens the credibility and transferability of the conclusions by

combining the quantitative rigour of survey data with the contextual depth that qualitative inquiry provides [43].

4.2. Survey Methodology

4.2.1. Survey Instrument Development

The survey instrument was constructed through a staged process. An initial pool of interface risk factors was assembled by reviewing THSR contract documents, dispute records, and published literature on interface management [44,45]. This draft list was subsequently refined through semi-structured interviews with five senior practitioners—two project managers, two contract administrators, and one claims consultant—each with direct THSR involvement. The interviews identified additional risk factors not apparent in documentary sources and removed items considered redundant or insufficiently specific. The finalised instrument contained 37 discrete risk factors distributed across seven categories:

- Category A: Variation (7 factors): scope modifications, design changes, and variation order administration.
- Category B: Care of Works (6 factors): protection of completed work, temporary works, and work-in-progress.
- Category C: Suspension (4 factors): work stoppages, demobilisation, and remobilisation.
- Category D: Cooperation and Coordination (6 factors): information exchange, joint planning, and collaborative problem resolution.
- Category E: Indemnity (5 factors): third-party claims, intellectual property, and liability distribution.
- Category F: Delay (5 factors): schedule impacts, critical path disruption, and time extension entitlement.
- Category G: Force Majeure (4 factors): unforeseeable events, natural disasters, and regulatory changes.

For each factor, respondents rated: (1) probability of occurrence (1 = very low to 5 = very high); (2) consequence severity if the risk materialises (1 = negligible to 5 = catastrophic); and (3) the party most likely to initiate the risk event (owner, civil contractor, core system contractor, or shared).

4.2.2. Sampling and Data Collection

The target population comprised construction professionals with direct or comparable experience in high-speed rail projects involving separate civil construction and core system contracts. Because such projects are globally limited in number, the sampling frame was broadened to include practitioners experienced in analogous multi-party infrastructure settings—metro systems, airport terminals, and power plants—where comparable interface challenges occur. Potential respondents were identified through professional networks, industry associations, and snowball referrals. Of 60 invitations distributed, 38 usable responses were received, giving a 63.3% response rate. Although the sample size is modest, it represents a specialised expert population with direct or comparable experience in high-speed rail megaprojects. The respondent profile was as follows:

- Organisational affiliation: 14 owner representatives, 13 civil contractors, 11 core system contractors.
- Professional role: 16 project managers, 12 contract administrators, 10 claims and dispute resolution specialists.
- Experience: Mean 18.3 years in the construction industry; mean 8.7 years on multi-party infrastructure projects.

4.2.3. Data Analysis

Survey responses were analyzed using a weighted influence methodology that combines probability and consequence assessments into a composite risk score. For each risk factor, the weighted influence score was calculated as:

$$\text{Weighted Influence} = \Sigma(\text{Probability} \times \text{Consequence}) / \text{Number of Respondents}$$

This approach yields scores ranging from 1 (very low probability $\times$ negligible consequence) to 25 (very high probability $\times$ catastrophic consequence). To illustrate: for a risk factor assessed by all 38 respondents, the raw sum $\Sigma(P \times C)$ ranges from a minimum of 38 (each respondent scoring 1×1) to a maximum of 950 (each respondent scoring 5×5). Dividing by 38 yields a mean score in the range 1–25. To facilitate comparison with prior interface-risk studies and to produce more intuitive rankings, scores were then normalized to a 0–300 scale. The normalization factor is 12, because $25 \times 12 = 300$ —that is, a perfect mean score of 25 maps exactly to 300 on the normalized scale. The resulting formula is therefore

$$\text{Normalized Score} = [\Sigma(P \times C) / 38] \times 12$$

As a worked example: factor A07 (delayed or ambiguous variation orders) received a raw sum of $\Sigma(P \times C) = 920$ across 38 respondents, yielding a mean of $920 / 38 = 24.21$, and a normalized score of $24.21 \times 12 \approx 290 / 300$. The normalized 0–300 scale was adopted solely for comparative ranking purposes; it does not represent an absolute measure of risk magnitude. Risk factors were then ranked in descending order of weighted influence score. Risk-trigger analysis was conducted by calculating the percentage of respondents attributing each risk factor to each party (owner, civil contractor, core system contractor, shared). It is important to note that the terms “critical” or “highly ranked” as used throughout this study refer exclusively to weighted ranking results derived from practitioner assessments; they do not imply statistical significance in the inferential statistical sense, as no hypothesis testing was performed on the ranking outcomes.

To maintain table readability, risk-trigger attribution results are presented as percentages. Raw respondent counts are reported in Table 2 and additional survey materials are provided in Appendix A.

Where the leading attribution category remained below 50%, the result should be interpreted as a plurality attribution rather than a majority attribution.

4.3. Contract Document Analysis

4.3.1. Contract Selection

These historical editions were selected because they correspond to the contractual environment that existed during the procurement and implementation period of the THSR project. The comparison is therefore historically anchored in the THSR contractual context rather than intended as a full analysis of contemporary standard forms such as FIDIC 2017 or NEC4.

Five internationally recognised standard-form contracts were chosen for comparative analysis, selected to represent both their widespread use in infrastructure procurement and the diversity of contractual traditions they embody:

- (1) FIDIC Red Book (1995)—Conditions of Contract for Construction—widely used in international infrastructure projects and representative of civil-law drafting traditions.
- (2) AIA A201 (1997)—General Conditions of the Contract for Construction—predominant in North American projects and representative of common-law drafting conventions.

- (3) NEC/ECC (1995)—New Engineering Contract/Engineering and Construction Contract—the leading relational contracting model, increasingly adopted in UK and Commonwealth projects.
- (4) ENAA Model Form (1996)—Model Form of International Contract for Process Plant Construction—widely used in the power and industrial sectors.
- (5) THSR Contract Documentation—The actual civil construction and core system contracts used in the Taiwan High Speed Rail project.

Table 2. Interface risk factor rankings.

Rank	Code	Risk Factor	Category	Weighted Score	Primary Risk Trigger
1	A07	Delayed or ambiguous variation orders	Variation	290	Owner (30/38, 78%)
2	D04	Insufficient coordination meetings	Cooperation and Coordination	285	Shared (20/38, 52%)
3	B01	Inadequate protection of completed works	Care of Works	284	Core System (26/38, 68%)
4	A03	Inconsistent specifications across contracts	Variation	278	Owner (27/38, 71%)
5	F02	Cascading delays across interfaces	Delay and Disruption	276	Shared (18/38, 48%)
6	D01	Late provision of interface control documents	Cooperation and Coordination	273	Owner (24/38, 64%)
7	B04	Damage to temporary works	Care of Works	268	Core System (22/38, 59%)
8	A05	Scope gaps at interface boundaries	Variation	265	Owner (26/38, 69%)
9	D06	Conflicting schedule assumptions	Cooperation and Coordination	262	Shared (21/38, 55%)
10	E03	Ambiguous liability for interface defects	Indemnity	258	Owner (23/38, 61%)
11	F04	Disputed entitlement to time extensions	Delay and Disruption	255	Shared (18/38, 47%)
12	B06	Inadequate site access coordination	Care of Works	251	Civil (21/38, 54%)
13	A02	Variation order pricing disputes	Variation	248	Shared (19/38, 51%)
14	C01	Unilateral suspension by owner	Suspension	245	Owner (31/38, 82%)
15	D03	Inadequate early warning mechanisms	Cooperation and Coordination	242	Shared (19/38, 49%)
16	E01	Third-party claims at interfaces	Indemnity	238	Shared (17/38, 46%)
17	B03	Contamination of works by adjacent activities	Care of Works	235	Core System (22/38, 57%)
18	F01	Critical path disputes	Delay and Disruption	232	Shared (20/38, 53%)
19	A06	Cumulative impact of minor variations	Variation	228	Owner (25/38, 66%)
20	D05	Language and cultural barriers	Cooperation and Coordination	225	Shared (17/38, 44%)
21	C03	Demobilization cost disputes	Suspension	221	Owner (28/38, 74%)
22	E05	Intellectual property disputes	Indemnity	218	Core System (24/38, 63%)
23	B05	Inadequate temporary utilities	Care of Works	215	Civil (22/38, 58%)
24	A01	Unauthorized variations	Variation	212	Civil (20/38, 52%)
25	F05	Concurrent delay attribution	Delay and Disruption	208	Shared (24/38, 62%)
26	G02	Regulatory changes affecting interfaces	Force Majeure	205	Owner (21/38, 56%)
27	C02	Prolonged suspension impacts	Suspension	201	Owner (26/38, 68%)
28	E04	Professional indemnity gaps	Indemnity	198	Owner (22/38, 59%)
29	D02	Inadequate dispute escalation procedures	Cooperation and Coordination	195	Owner (22/38, 57%)
30	B02	Inadequate site security	Care of Works	192	Civil (23/38, 61%)
31	F03	Float ownership disputes	Delay and Disruption	188	Shared (22/38, 58%)
32	A04	Variation valuation methodology disputes	Variation	185	Shared (19/38, 49%)
33	G01	Force majeure definition disputes	Force Majeure	182	Owner (20/38, 53%)
34	C04	Remobilization delays	Suspension	178	Shared (17/38, 45%)
35	E02	Insurance coverage gaps	Indemnity	175	Owner (24/38, 62%)
36	G03	Pandemic or epidemic impacts	Force Majeure	168	Shared (27/38, 72%)
37	G04	Political risk and expropriation	Force Majeure	162	Owner (31/38, 81%)

4.3.2. Analytical Framework

Contract documents were examined using a structured content analysis protocol [46]. For each of the seven risk categories identified in the survey, relevant clauses were extracted and coded according to: (1) which party bears the risk (owner, contractor, shared, or unaddressed); (2) the conditions under which that allocation applies; (3) the remedies available to the risk-bearing party; and (4) whether any provision links risk allocation to the conduct that caused the risk. Two researchers coded independently; inter-coder reliability was measured using Cohen's kappa ($\kappa = 0.87$, indicating strong agreement).

Disagreements were resolved through discussion and reference to authoritative contract commentaries [47,48].

4.4. Case Study Methodology

4.4.1. Case Selection

Three documented THSR disputes were chosen for in-depth analysis on the basis of: (1) their relevance to the interface risk categories identified in the survey; (2) the availability of detailed supporting documentation (arbitration awards, court judgments, or published case summaries); and (3) their coverage of different risk-initiation patterns (owner-initiated, contractor-initiated, and ambiguous causation). The three cases involved:

- Case 1: A variation-related dispute arising from owner-directed design changes affecting both civil and core system scopes.
- Case 2: A care-of-works dispute arising from alleged inadequate protection of completed civil structures by the core system contractor.
- Case 3: A coordination dispute arising from conflicting schedule assumptions embedded in the civil and core system contracts.

4.4.2. Data Collection and Analysis

The three cases were reconstructed from project correspondence, dispute records (including arbitration awards and court judgments), published THSR documentation, and interviews with practitioners who participated in the relevant events. Case data were compiled from multiple sources, including arbitration awards, court judgments, contract documents, project correspondence, and interviews with parties involved in the disputes (where accessible). Each case was analyzed using a structured protocol that examined: (1) the factual circumstances giving rise to the dispute; (2) the contractual provisions governing risk allocation; (3) the parties' arguments regarding risk responsibility; (4) the tribunal's or court's reasoning and decision; and (5) the alignment between the case outcome and the risk-trigger principle proposed in this study. Cross-case synthesis identified common patterns and supported the survey findings regarding the most critical interface risk factors [49].

4.5. Validity and Reliability

Several strategies were employed to strengthen the credibility and consistency of the findings:

- Construct validity: The survey instrument was developed with direct practitioner input and pilot-tested to confirm that risk factors were clearly defined and pertinent to interface management challenges.
- Internal validity: Convergence across the survey data, contract analysis, and case studies provided multiple independent lines of evidence supporting the principal findings.
- External validity: Including respondents with experience across project types beyond THSR improves the applicability of findings to other multi-party infrastructure contexts.
- Reliability: Structured analytical protocols, independent coding by two researchers, and inter-coder reliability assessment ensure consistency in the contract document analysis.

5. Results

5.1. Survey Findings: Interface Risk Rankings

Table 2 summarises the weighted influence scores and rankings for all 37 interface risk factors. Three factors stand out as the most consequential:

1. A07—Delayed or ambiguous variation orders (Variation): weighted score 290/300.

2. D04—Insufficient coordination meetings and information exchange (Cooperation and Coordination): weighted score 285/300.
3. B01—Inadequate protection of completed civil works during core system installation (Care of Works): weighted score 284/300.

These results point consistently to variation management, care-of-works obligations, and coordination quality as the dominant interface risk domains in multi-party high-speed rail delivery.

5.2. Risk-Trigger Analysis

Examination of risk-initiation attributions reveals three distinct patterns.

Owner-initiated risks. Variation-related factors (A07, A03, A05, A06) are strongly attributed to owner conduct: between 66% and 78% of respondents identified the owner as the primary initiating party. This reflects the owner's authority over design changes, specification development, and variation order issuance.

Contractor-initiated risks. Care-of-works factors (B01, B03, B04) are predominantly attributed to core system contractor conduct, with 57–68% of respondents pointing to that party as the primary initiator. These attributions reflect the core system contractor's responsibility for protecting completed civil structures during installation operations.

Shared-initiation risks. Cooperation and coordination factors (D04, D06, D03) and delay-related factors (F02, F04, F01) attract shared attribution, with 44–62% of respondents distributing responsibility across multiple parties. These risks arise from the interaction between two contractors' activities rather than from any single party's unilateral conduct.

Taken together, the data confirm that interface risks do not follow a single causal pattern: some are consistently traceable to one party's decisions, while others emerge from the cumulative effect of several parties' behaviour. Figure 3 visualises this distribution across all seven risk categories.

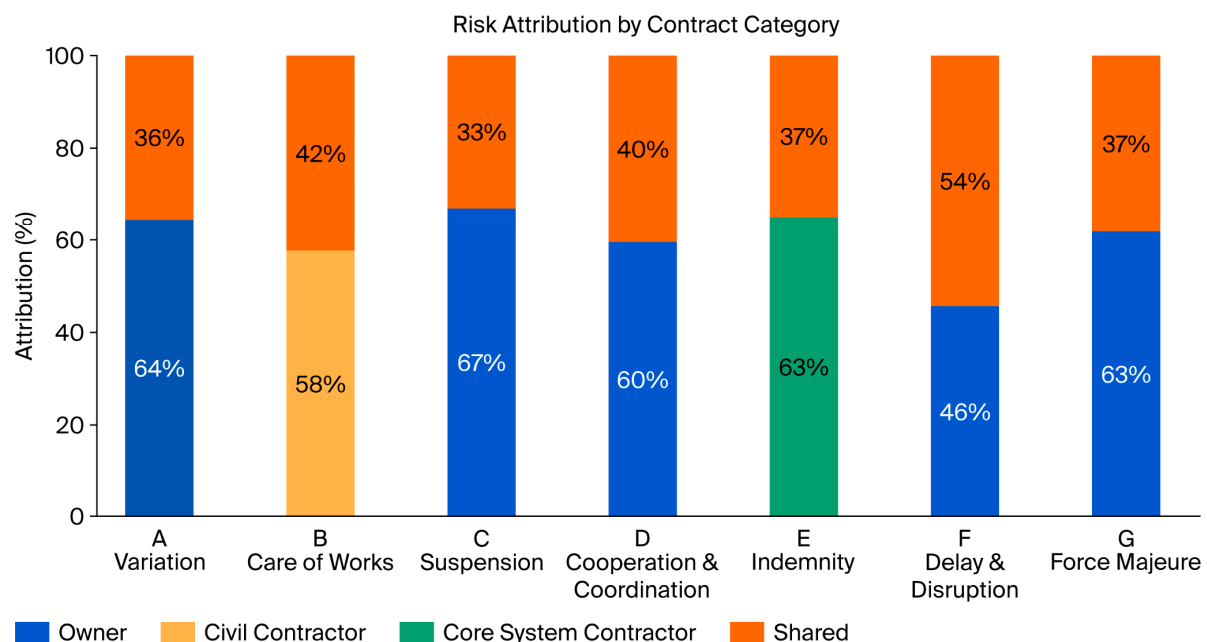


Figure 3. Distribution of Interface Risk Initiators Across Seven Risk Categories (%). Values represent respondent attributions of the party most likely to initiate each risk category, including owner, civil contractor, core system contractor, and shared attribution. Percentages were calculated from survey responses ($n = 38$). Detailed attribution percentages for all parties are reported in Table 2 and Appendix A. Each bar displays only the dominant attribution party for that risk category.

5.3. Comparative Contract Analysis

To preserve readability, Tables 3–6 summarise only the principal clause-level findings. Detailed clause-level analysis is available from the authors upon reasonable request and may be further expanded during production if required.

Table 3. Variation risk allocation provisions.

Contract	Variation Definition	Owner's Right to Order	Contractor's Obligation	Valuation Method	Risk-Trigger Link
FIDIC 1995	Clause 51: Any change to design, quantity, quality, or sequence	Broad discretion (Clause 51.1)	Must execute unless unreasonable (Clause 51.1)	Rates & prices, or reasonable cost (Clause 52)	No explicit link
AIA A201 1997	Article 7.1: Changes in Work authorized by Change Order	Unilateral right (Article 7.2.1)	Must proceed promptly (Article 7.3.1)	Mutual agreement or cost-plus (Article 7.3.3)	No explicit link
NEC/ECC 1995	Clause 44: Instruction changing Scope of Work	PM may instruct (Clause 44.1)	Contractor must comply (Clause 27.3)	Compensation Events (Clause 60–65)	Partial: CE triggered by PM instruction
ENAA 1996	Article 23: Variation of Contract	Owner may order (Article 23.1)	Contractor must execute (Article 23.2)	Agreed rates or actual cost (Article 23.3)	No explicit link
THSR Civil	Section 8: Variations	Owner's discretion	Contractor must comply	Schedule of rates or negotiation	No explicit link
THSR Core	Section 9: Changes	Owner may direct	Contractor must implement	Cost-plus with markup	No explicit link

Table 4. Care-of-works risk allocation provisions.

Contract	Care Obligation	Scope of Care	Exceptions	Remedial Work	Risk-Trigger Link
FIDIC 1995	Clause 20: Contractor responsible for care until Taking-Over	All Works, including temporary works	Owner's risks (Clause 20.4)	Contractor must rectify at own cost	No explicit link
AIA A201 1997	Article 10.2: Contractor protects Work	Work and materials at site	Owner's fault or separate contractor	Contractor bears cost unless Owner caused	Partial: exception for Owner fault
NEC/ECC 1995	Clause 80: Contractor cares for Works	Until Completion Certificate	Compensation Events	Contractor corrects defects	Partial: CE mechanism
ENAA 1996	Article 17: Care of Works	Until Taking-Over	Force majeure, Owner's risks	Contractor repairs at own cost	No explicit link
THSR Civil	Section 12: Care of Works	Until handover to Core System	Owner-caused damage	Contractor responsible unless Owner fault	Partial: exception for Owner
THSR Core	Section 11: Protection	Core System works and civil interface	Civil contractor's negligence	Core System repairs unless Civil caused	Partial: exception for Civil

Table 5. Cooperation and coordination risk allocation provisions.

Contract	Cooperation and Coordination Duty	Coordination Mechanisms	Information Exchange	Joint Planning	Risk-Trigger Link
FIDIC 1995	Clause 4.6: Co-operation with other contractors	General duty to cooperate	As reasonably required	Not specified	No explicit link
AIA A201 1997	Article 6.2: Mutual responsibility	Coordinate with separate contractors	Timely information	Not specified	No explicit link
NEC/ECC 1995	Clause 25: Early warning; Clause 10: Mutual trust	Early warning system, risk register	Open communication	Collaborative planning	Partial: early warning obligation
ENAA 1996	Article 6: Cooperation and Coordination	Cooperate with other contractors	Provide necessary information	Not specified	No explicit link
THSR Civil	Section 5: Coordination	Interface meetings, ICDs	Monthly reports	Interface schedule	No explicit link
THSR Core	Section 6: Interface Management	Joint coordination committee	Weekly updates	Integrated schedule	No explicit link

Table 6. Delay risk allocation provisions.

Contract	Delay and Disruption Definition	Excusable Delays	Compensable Delays	Time Extension	Cost Recovery	Risk-Trigger Link
FIDIC 1995	Clause 44: Extension of time for completion	Variations, exceptional events	Variations, Owner delays	Clause 44	Clause 52 (if variation)	Partial: links to cause
AIA A201 1997	Article 8.3: Delays and extensions	Owner-caused, force majeure	Owner-caused only	Article 8.3.1	Article 15.1.6	Partial: distinguishes causes
NEC/ECC 1995	Clause 60: Compensation Events	CE events (Clause 60.1)	CE events	Clause 62	Clause 63	Yes: CE mechanism links cause to compensation
ENAA 1996	Article 28: Extension of time	Owner delays, force majeure	Owner delays	Article 28.2	Article 28.3	Partial: links to cause
THSR Civil	Section 14: Time Extensions	Variations, Owner delays, force majeure	Variations, Owner delays	Section 14.2	Section 14.3	Partial: links to cause
THSR Core	Section 15: Schedule Relief	Owner changes, Civil delays	Owner changes	Section 15.2	Section 15.3	Partial: links to cause

Tables 3–6 map the risk-allocation provisions of the five examined contract forms against the four highest-ranked interface risk categories: Variation, Care of Works, Cooperation and Coordination, and Delay.

5.4. Key Findings from Contract Comparison

The cross-contract mapping yields five recurring observations:

1. Variation provisions. Every examined contract confers broad discretionary authority on the owner to direct variations and imposes a corresponding duty on the contractor

to comply. Yet none explicitly addresses the interface scenario in which an owner-ordered variation to one contractor's scope generates consequential disruption to a co-located contractor's scope. The NEC/ECC Compensation Event mechanism approaches this gap most closely by providing a structured process for quantifying time and cost consequences of owner instructions, but it does not extend automatically to secondary contractors.

2. Care-of-works provisions. Standard forms typically impose blanket care obligations without distinguishing damage attributable to the responsible contractor's own operations from damage caused by a co-located contractor's activities. The AIA A201 and THSR-specific contracts carve out partial exceptions for owner-caused or separate-contractor-caused damage, but the burden of proving causation falls on the affected party—a demanding standard in complex interface environments.
3. Cooperation provisions. General cooperation duties appear in all five contracts; however, most offer limited operational guidance regarding specific coordination mechanisms, information exchange protocols, or joint programme management. The NEC/ECC early-warning obligation (Clause 16) represents the most developed approach, requiring parties to proactively surface and jointly address foreseeable risks. THSR contract documents specify interface control documents and coordination meetings, but do not clearly apportion liability for coordination breakdowns.
4. Delay provisions. The majority of examined contracts distinguish excusable delays (time extension without cost recovery) from compensable delays (time extension plus cost recovery), with compensable events generally confined to owner-initiated causes. Guidance on attributing delays in multi-contractor interface scenarios—where concurrent activities interact—remains limited. The NEC/ECC Compensation Event mechanism again provides the most structured pathway by tethering relief to identifiable triggering events.
5. Risk-trigger principle gap. Across all five instruments, no provision systematically allocates interface risks to the party whose conduct initiated the risk event. Partial mechanisms exist—owner-fault exceptions, Compensation Events triggered by owner instructions—but these are fragmented and do not constitute a coherent risk-trigger framework applicable to multi-contractor interface situations.

6. Case Study Analysis

The three cases presented below were reconstructed from documented THSR dispute records and arbitration materials held by the project participants. Identifying details—including station designations, contract numbers, and party names—have been anonymised in accordance with confidentiality requirements agreed with the project participants. Due to these confidentiality obligations, arbitration reference numbers and court judgment citations cannot be disclosed in this publication; the authors retain the underlying documentation and can make it available to the editors or reviewers in confidence upon request. The cases were selected because they correspond directly to the three highest-ranked risk categories identified in the survey (Variation, Care of Works, and Cooperation and Coordination) and because their documented outcomes provide the clearest evidence for or against the risk-trigger principle.

6.1. Case 1: Variation-Related Dispute (Owner-Triggered Risk)

6.1.1. Factual Background

At THSR Station C, the owner issued a variation instruction to the civil contractor directing modifications to the platform structure in order to accommodate a revised core system configuration. The instruction specified updated geometric tolerances and addi-

tional structural reinforcement. After completing the modified works, the civil contractor submitted a claim for extra time and cost. The variation, however, had knock-on consequences for the core system contractor: the revised platform geometry necessitated a redesign of the track support arrangement, relocation of signalling equipment, and a revised installation sequence. The core system contractor accordingly lodged a separate claim for these secondary effects. The owner rejected that claim on the ground that the variation instruction had been addressed solely to the civil contractor and that the core system contractor's contractual scope was unaltered.

6.1.2. Contractual Provisions

The civil contract contained a standard variation clause granting the owner discretion to direct changes and requiring the civil contractor to comply subject to equitable adjustments of time and price. The core system contract contained an analogous clause but made no provision for secondary consequences arising from variations directed at a different contractor. Neither instrument incorporated language linking risk responsibility to the party whose conduct gave rise to the risk event.

6.1.3. Dispute Resolution

The core system contractor commenced arbitration, contending that the owner's instruction to the civil contractor constituted a constructive variation to the core system scope and entitled it to time extension and cost recovery. The owner maintained that no variation instruction had been issued to the core system contractor and attributed any disruption to the core system contractor's inadequate coordination with the civil contractor. The tribunal found in favour of the core system contractor on three grounds:

1. The owner's variation instruction to the civil contractor produced foreseeable and unavoidable consequences for the core system contractor's scope.
2. The core system contractor bore no contractual obligation to absorb costs attributable to owner-initiated design changes.
3. The absence of a direct variation instruction to the core system contractor did not bar recovery for secondary consequences flowing from the owner's own conduct.

The tribunal awarded the core system contractor both a time extension and cost recovery measured against the actual scope of the disruption.

6.1.4. Alignment with Risk-Trigger Principle

The outcome of this dispute is consistent with the risk-trigger principle: the risk event—secondary disruption to the core system scope—was set in motion by the owner's decision to issue a variation instruction, and the tribunal allocated responsibility to the owner even in the absence of express contractual language to that effect. The case exposes a structural shortcoming of conventional variation clauses: by focusing exclusively on the direct recipient of the variation instruction, they leave the consequential impacts on co-located contractors unaddressed and create avoidable disputes.

6.2. Case 2: Care-of-Works Dispute (Contractor-Triggered Risk)

6.2.1. Factual Background

Following completion of a viaduct structure in THSR Section D, the civil contractor handed the structure over to the core system contractor for track installation. During installation operations, a heavy plant operated by a core system subcontractor caused surface damage to the viaduct deck, necessitating concrete remediation. The civil contractor submitted a claim for the cost of those repairs. The core system contractor rejected the claim on three grounds: the damage was minor and within acceptable tolerances; the civil

contractor had not installed adequate protective measures; and the civil contract imposed a continuing care obligation that persisted until project completion.

6.2.2. Contractual Provisions

The civil contract contained a care-of-works clause requiring the civil contractor to maintain and protect all completed works until formal Taking-Over by the owner. The core system contract included a general obligation to avoid damage to existing works but was silent on the specific question of who bore responsibility for damage inflicted on civil structures during core system installation. Neither contract resolved this interface damage scenario with precision.

6.2.3. Dispute Resolution

The civil contractor commenced arbitration, arguing that the core system contractor's plant and operations had caused the damage and that the core system contractor should therefore bear the remediation cost. The core system contractor maintained that the civil contractor's continuing care obligation encompassed protection against damage from subsequent contractors' activities. The tribunal found in favour of the civil contractor on three grounds:

1. The damage was directly attributable to the core system contractor's plant and operations.
2. The civil contractor's care obligation did not extend to protecting completed works against damage caused by another contractor's negligence.
3. The core system contractor owed an independent duty to conduct installation activities in a manner that avoided harm to existing structures.

The tribunal awarded the civil contractor recovery of remediation costs together with associated delay-related losses.

6.2.4. Alignment with Risk-Trigger Principle

This dispute illustrates the risk-trigger principle from the opposite direction: the risk event—physical damage to completed civil works—was initiated by the core system contractor's operations, and the tribunal assigned responsibility accordingly, notwithstanding the civil contractor's continuing care obligation. The case illustrates that broadly worded care-of-works clauses should not be construed to exempt a subsequent contractor from liability for harm it directly causes.

6.3. Case 3: Coordination Dispute (Shared-Trigger Risk)

6.3.1. Factual Background

In THSR Section E, the civil and core system contractors held conflicting assumptions about the handover sequence for completed tunnel sections. The civil contract specified that sections would be released sequentially from south to north as each achieved substantial completion. The core system contract, by contrast, assumed simultaneous release of all sections to permit uninterrupted track installation. Neither assumption was codified in the interface control documents. When the civil contractor began releasing sections in sequence, the core system contractor objected that this approach would disrupt its planned installation programme and cause delay. The civil contractor countered that simultaneous release was operationally impractical and would require it to maintain incomplete sections for an extended period.

6.3.2. Contractual Provisions

Both contracts imposed general coordination duties and referenced interface control documents, but those documents did not specify a handover sequence. The civil contract

entitled the civil contractor to a time extension for owner-caused delays. The core system contract contained a parallel entitlement and an additional provision allowing a time extension for delays caused by other contractors, provided such delays were not reasonably foreseeable at contract execution.

6.3.3. Dispute Resolution

Both contractors submitted time-extension claims together with associated cost recovery. The owner rejected both, taking the position that the contractors should have resolved the handover sequence through the contractually required coordination process. The parties proceeded to mediation, where they agreed on a compromise: the civil contractor would release sections in batches of three, providing sufficient continuity for track installation while avoiding the burden of maintaining large areas of incomplete work. Both contractors withdrew their time-extension claims in exchange for the owner's commitment to expedite certain owner-furnished equipment deliveries.

6.3.4. Alignment with Risk-Trigger Principle

This case highlights the boundary conditions of the risk-trigger principle. Neither party unilaterally initiated the coordination failure; the problem arose from the interaction of two independently reasonable but mutually incompatible planning assumptions. The negotiated settlement—a brokered compromise rather than a tribunal-imposed allocation—reflects the practical reality that genuinely ambiguous interface risks resist clean causal attribution and benefit from collaborative resolution. At the same time, the case is consistent with the survey finding that coordination risks are predominantly shared: 52% of respondents attributed insufficient coordination to joint responsibility, consistent with the ambiguous causation pattern observed here.

6.4. Cross-Case Synthesis

The three cases collectively are consistent with the survey findings and underscore the practical relevance of the risk-trigger principle:

1. Variation risks are predominantly owner-initiated. Case 1 confirms that variation-related interface risks typically originate from owner decisions—design changes, specification revisions—and should be allocated to the owner regardless of which contractor's scope is directly affected by the instruction.
2. Care-of-works risks are predominantly contractor-initiated. Case 2 confirms that care-of-works interface risks typically originate from a contractor's own operations and should rest with the contractor whose activities caused the damage, notwithstanding any continuing care obligation held by the affected party.
3. Coordination risks frequently involve shared initiation. Case 3 confirms that coordination interface risks often arise from the interaction of multiple parties' conduct rather than from any single party's unilateral decision, making collaborative resolution more appropriate than unilateral risk transfer.
4. Standard contract provisions are structurally deficient. All three disputes exposed gaps in conventional risk allocation clauses that fail to connect risk responsibility to risk causation in interface settings, generating avoidable disputes and inefficient outcomes.

7. Discussion

7.1. Theoretical Implications: The Risk-Trigger Principle

The survey results and illustrative evidence converge on a single core insight: conventional risk allocation logic—which directs risks to the party best placed to control or

mitigate them—produces inequitable and economically inefficient outcomes in multi-party interface settings. The risk-trigger principle offers an alternative framework grounded in causal accountability. Under this principle, interface risks should be borne by the party whose conduct—whether action or omission—sets the risk event in motion, irrespective of whether another party might have been better positioned to limit the consequences.

The principle carries three theoretical advantages. First, it aligns risk-bearing with fairness: parties should answer for the costs of risks they create, not merely for risks they happen to be well-placed to manage [50]. Second, it strengthens prevention incentives: knowing that they will carry the costs of risks they initiate, parties have a direct financial motive to avoid risk-triggering behaviour in the first place [51]. Third, it curtails moral hazard: under conventional allocation, the risk-bearing party may under-invest in mitigation because the party whose conduct triggered the risk faces no corresponding financial exposure [52].

Recent empirical work reinforces these theoretical arguments. Malek and Bhatt find that projects in which risk allocation clauses explicitly link responsibility to causation achieve markedly better cost and schedule outcomes [33]. Wang et al.'s integrated risk response framework for EPC+PPP arrangements similarly concludes that effective multi-party risk allocation requires clear attribution of risks to their originating sources rather than blanket downstream transfer to contractors [18]. Alqershy and Shi's systematic review identifies causal attribution as a critical yet under-developed element of megaproject governance [38].

Two additional theoretical benefits deserve attention. First, the risk-trigger principle helps correct the information asymmetry inherent in interface risk situations: the party initiating a risk event typically has better knowledge of its timing and probability than the party left to bear the consequences. Second, clear causal attribution reduces transaction costs by narrowing the scope of disputes over risk responsibility and enabling more efficient claim resolution.

7.2. Practical Implications

The findings carry direct implications for both owners and contractors. Owners should recognise that attempting to shift all interface risks onto contractors through broadly worded allocation clauses is self-defeating: contractors price those risks into their bids, and disputes multiply when risks materialise. A more productive approach involves three steps: (1) explicitly identifying interface risks during contract preparation; (2) allocating those risks in accordance with the risk-trigger principle; and (3) establishing collaborative governance mechanisms—interface control documents, regular coordination meetings, early warning systems—that support joint risk management throughout construction. Contractors, for their part, should scrutinise interface risk provisions at bid stage, explicitly price the risks they accept, and document risk-initiating events as they occur to support any subsequent claims.

Ambiguities in cooperation and coordination clauses may also have indirect safety implications that extend beyond the immediate contractual dispute. In multi-party infrastructure projects, unclear boundaries of responsibility for joint activities—such as temporary works protection, access coordination, and shared utility management—can create conditions in which each contractor assumes the other has taken precautionary measures. This assumption gap has been identified as a contributing factor in several infrastructure incidents internationally. Contract clauses that explicitly assign responsibility for each coordination task to a named party, consistent with the risk-trigger principle, reduce this ambiguity and thereby contribute not only to equitable risk allocation but also to safer project execution.

The multilayer network analysis framework developed by Castelblanco et al. provides a practical instrument for acting on these recommendations [35]. By mapping stakeholder relationships and risk interdependencies simultaneously, project teams can pinpoint the interface zones where risk-trigger provisions require the most careful drafting and where enhanced coordination mechanisms will deliver the greatest benefit.

7.3. Contract Drafting Implications

The contract comparison and case study analysis reveal structural weaknesses in standard form provisions covering interface risks. Three targeted drafting recommendations emerge.

7.3.1. Variation Clauses

Standard variation clauses should be extended to address consequential impacts on other contractors' scopes explicitly. Recommended language:

"Where a Variation instructed to one Contractor produces foreseeable impacts on another Contractor's scope, programme, or cost, the Owner shall compensate the affected Contractor for those consequential effects, irrespective of whether a separate Variation instruction has been issued to that Contractor. The affected Contractor shall give prompt notice of such impacts and shall cooperate in limiting the consequences."

This formulation implements the risk-trigger principle by placing consequential variation costs on the owner—the party who initiated the variation—rather than on the affected contractor. Zhang et al.'s work on contract design and trust in megaprojects shows that explicit provisions of this kind reinforce rather than undermine relational governance by reducing ambiguity and establishing clear mutual expectations [36].

7.3.2. Cooperation Clauses

Standard cooperation clauses should be strengthened to specify concrete coordination mechanisms and to allocate responsibility for coordination failures in accordance with the risk-trigger principle. Recommended language:

"The Parties shall manage interface risks collaboratively through: (1) monthly interface coordination meetings; (2) joint preparation and maintenance of interface control documents; (3) early warning of emerging interface issues; and (4) cooperative problem resolution. Where a coordination failure results from one Party's failure to provide information on time, attend coordination meetings, or comply with agreed interface procedures, that Party shall bear the time and cost consequences of the failure."

This provision pairs procedural coordination requirements with a risk-trigger allocation rule for coordination failures.

8. Conclusions

8.1. Key Findings

This study examined interface risk allocation in multi-party construction contracts through an empirical investigation informed by the Taiwan High Speed Rail project and expert assessments from professionals with direct or comparable multi-party infrastructure experience. Four principal findings emerge:

1. Interface risk rankings: Survey data from 38 practitioners identified delayed or ambiguous variation orders (A07, weighted score 290/300), inadequate protection of completed civil works (B01, 284/300), and insufficient coordination meetings (D04, 285/300) as the three most consequential interface risk factors.

2. Risk-initiation patterns: Analysis of who triggers each risk revealed clear systematic tendencies: variation-related risks are predominantly owner-initiated (66–78% attribution); care-of-works risks are predominantly contractor-initiated (57–68% attribution); and coordination risks are predominantly shared (44–62% attribution).
3. Contractual deficiencies: Comparative analysis of five standard form contracts (FIDIC, AIA, NEC/ECC, ENAA, THSR) revealed a common structural weakness: none incorporates explicit provisions linking interface risk responsibility to the party whose conduct gave rise to the risk.
4. Illustration of the risk-trigger principle: Three anonymised THSR dispute narratives are consistent with the proposed risk-trigger principle and show how causal responsibility may help explain interface-risk allocation in practice.

8.2. Practical Recommendations

For project owners: (1) identify interface risks explicitly during contract preparation; (2) allocate those risks in accordance with the risk-trigger principle; (3) establish collaborative governance mechanisms to support joint risk management; and (4) resist the temptation to transfer all interface risks to contractors through broadly worded clauses. For contractors: (1) scrutinise interface risk provisions at bid stage; (2) explicitly price accepted risks; (3) document risk-initiating events as they arise; and (4) engage proactively in interface coordination processes. For contract drafters: enhance standard form provisions governing variations, care of works, and cooperation to incorporate the risk-trigger principle explicitly and to specify concrete coordination mechanisms.

8.3. Limitations and Future Research

The survey included practitioners with either direct THSR involvement or comparable experience in major infrastructure projects. However, this distinction was not recorded as a separate demographic variable during data collection and is therefore acknowledged as a limitation of the study.

Three limitations qualify the findings. First, the survey sample, though achieving a strong response rate (63.3%), comprised 38 respondents drawn from a single project context. The findings should therefore be interpreted with caution given the relatively small sample size ($n = 38$) and the specialized nature of the THSR project environment, which may limit generalisability to other high-speed rail or infrastructure contexts. Larger samples drawn from multiple projects and jurisdictions would improve the robustness and transferability of the risk rankings and trigger-attribution patterns reported here. Second, the contract comparison covered five standard forms; extending the analysis to more recent editions (FIDIC 2017, NEC4) and jurisdiction-specific variants would yield broader insights. Third, the illustrative evidence was drawn from three THSR disputes; examining additional cases from other multi-party infrastructure projects would further strengthen illustration of the risk-trigger principle.

Future research should: (1) test the risk-trigger principle across diverse project types and legal systems; (2) develop operational guidance for drafting and implementing risk-trigger provisions; (3) investigate how risk-trigger allocation interacts with relational governance mechanisms; and (4) assess the long-term performance outcomes of projects adopting risk-trigger principles compared with those relying on conventional risk allocation approaches.

Author Contributions: Conceptualization, T.-C.L. and T.-C.T.; methodology, T.-C.L. and T.-C.T.; validation, T.-C.L.; formal analysis, T.-C.L.; investigation, T.-C.L. and T.-C.T.; data curation, T.-C.L.; writing—original draft preparation, T.-C.L.; writing—review and editing, T.-C.T.; supervision, T.-

C.T.; project administration, T.-C.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. The APC was funded by the corresponding author.

Data Availability Statement: The data presented in this study are available from the corresponding author upon reasonable request. The data are not publicly available due to confidentiality restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Survey Questionnaire

The following questionnaire was administered to practitioners with direct THSR involvement or comparable experience in analogous multi-party infrastructure projects ($n = 38$). Respondents evaluated: (1) the probability of the risk event occurring, (2) the severity of its consequence, and (3) the party most likely to initiate the risk.

Appendix A.1. Category A: Variation

The wording below represents the questionnaire items used to operationalise the 37 risk factors reported in Table 2.

- A01. The owner issues a formal variation order that changes the scope of civil works.
- A02. The owner-directed scope change requires the civil contractor to coordinate with the core system contractor.
- A03. The owner modifies the design specification after civil works have commenced.
- A04. The owner orders acceleration of civil works to meet a revised programme milestone.
- A05. The owner instructs a suspension of civil works pending design clarification.
- A06. The owner-issued variation creates an interface conflict between civil and core system works.
- A07. The owner fails to issue a timely variation order despite a known scope change.

Appendix A.2. Category B: Care of Works

- B01. The civil contractor fails to protect completed works from damage during ongoing construction.
- B02. The civil contractor's operations cause physical damage to the core system contractor's installed equipment.
- B03. The civil contractor does not maintain adequate site security, resulting in theft or vandalism.
- B04. The civil contractor's subcontractor causes damage to shared infrastructure.
- B05. The civil contractor fails to comply with temporary works requirements, causing structural damage.
- B06. Damage to works occurs during the defects liability period due to the civil contractor's inadequate maintenance.

Appendix A.3. Category C: Suspension

- C01. The owner suspends civil works due to unresolved design issues originating from owner-supplied information.
- C02. The owner orders a suspension to allow the core system contractor to complete prior works.
- C03. The owner suspends the contract due to funding or regulatory approval delays.
- C04. The owner issues a partial suspension affecting only certain sections of the civil works.

Appendix A.4. Category D: Cooperation and Coordination

- D01. The civil contractor and core system contractor fail to agree on a shared construction programme.
- D02. Interface meetings between the civil and core system contractors are inadequate or infrequent.
- D03. The owner fails to facilitate timely resolution of interface disputes between contractors.
- D04. Ambiguity in the contract documents creates uncertainty about which party is responsible for interface coordination.
- D05. The core system contractor's late delivery of technical data delays civil works.
- D06. The civil contractor's late completion of structural works prevents the core system contractor from commencing installation.

Appendix A.5. Category E: Indemnity

- E01. The core system contractor's plant or equipment causes damage to the civil contractor's completed works.
- E02. The core system contractor's operations result in personal injury to the civil contractor's workers.
- E03. The core system contractor's activities cause environmental damage within the project site.
- E04. The core system contractor fails to indemnify the owner against third-party claims arising from its operations.
- E05. The core system contractor's negligence causes delay to the overall project completion.

Appendix A.6. Category F: Delay and Disruption

- F01. The owner's late approval of shop drawings causes delay to the civil contractor's works.
- F02. Concurrent delays caused by both the owner and the civil contractor make it difficult to apportion responsibility.
- F03. The owner's failure to hand over the site on time disrupts the civil contractor's planned programme.
- F04. The civil contractor's inefficiency contributes to delay, but the owner's instructions also cause disruption.
- F05. Force majeure events affect the project programme, but the extent of impact is disputed between the parties.

Appendix A.7. Category G: Force Majeure

- G01. A typhoon causes physical damage to partially completed civil works and delays the construction programme.
- G02. An earthquake results in ground movement that affects both civil and core system works.
- G03. A pandemic-related restriction prevents workers from accessing the site, causing project delay.
- G04. An unforeseen subsurface condition is encountered that was not identifiable from the owner-provided site investigation data.

References

1. Love, P.E.D.; Ackermann, F.; Smith, J.; Irani, Z.; Edwards, D.J. Making Sense of Rework Causation in Offshore Hydrocarbon Projects. *Proj. Manag. J.* **2016**, *47*, 16–28. [\[CrossRef\]](#)
2. Kumaraswamy, M.M.; Thorpe, D.A.S. Systematizing Construction Project Evaluations. *J. Manag. Eng.* **1996**, *12*, 34–39. [\[CrossRef\]](#)
3. Lowe, D.; Leiringer, R. *Commercial Management of Projects: Defining the Discipline*; Blackwell Publishing: Oxford, UK, 2006.
4. Doloi, H. Understanding Impacts of Time and Cost Related Construction Risks on Operational Performance of PPP Projects. *Int. J. Strateg. Prop. Manag.* **2012**, *16*, 316–337. [\[CrossRef\]](#)

5. Tah, J.H.M.; Carr, V. Towards a Framework for Project Risk Knowledge Management in the Construction Supply Chain. *Adv. Eng. Softw.* **2001**, *32*, 835–846. [\[CrossRef\]](#)
6. Chiang, Y.H.; Cheng, E.W.L. Construction Loans and Industry Development: The Case of Hong Kong. *Constr. Manag. Econ.* **2010**, *28*, 959–969. [\[CrossRef\]](#)
7. Yu, C.C. Risk Allocation of Interfaces between Construction and Core System Contractors: A Case Study on Taiwan High Speed Railroad Project. Master's Thesis, National Yunlin University of Science and Technology, Yunlin, Taiwan, 2006. Available online: <https://ndltd.ncl.edu.tw/cgi-bin/gs32/gswweb.cgi?o=dncldr&s=id=%22094YUNT0028001%22> (accessed on 15 June 2026).
8. Tsai, T.-C.; Yen, C.-C. Risk Allocation of Interfaces between Construction and Core System Contracts: A Case Study on Taiwan High Speed Railroad Project. In Proceedings of the 23rd International Symposium on Automation and Robotics in Construction (ISARC 2006), Tokyo, Japan, 3–5 October 2006; pp. 454–459. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; SAGE Publications: Thousand Oaks, CA, USA, 2017. Available online: <https://us.sagepub.com/en-us/nam/designing-and-conducting-mixed-methods-research/book241842> (accessed on 15 June 2026).
10. Cheung, S.O.; Pang, K.H.Y. Anatomy of Construction Disputes. *J. Constr. Eng. Manag.* **2013**, *139*, 15–23. [\[CrossRef\]](#)
11. Tiong, R.L.K. CSFs in Competitive Tendering and Negotiation Model for BOT Projects. *J. Constr. Eng. Manag.* **1996**, *122*, 205–211. [\[CrossRef\]](#)
12. Akintoye, A.; MacLeod, M.J. Risk Analysis and Management in Construction. *Int. J. Proj. Manag.* **1997**, *15*, 31–38. [\[CrossRef\]](#)
13. Lam, K.C.; Wang, D.; Lee, P.T.K.; Tsang, Y.T. Modelling Risk Allocation Decision in Construction Contracts. *Int. J. Proj. Manag.* **2007**, *25*, 485–493. [\[CrossRef\]](#)
14. Wang, S.Q.; Dulaimi, M.F.; Aguria, M.Y. Risk Management Framework for Construction Projects in Developing Countries. *Constr. Manag. Econ.* **2004**, *22*, 237–252. [\[CrossRef\]](#)
15. Ng, A.; Loosemore, M. Risk Allocation in the Private Provision of Public Infrastructure. *Int. J. Proj. Manag.* **2007**, *25*, 66–76. [\[CrossRef\]](#)
16. Williamson, O.E. Transaction Cost Economics: The Governance of Contractual Relations. *J. Law Econ.* **1979**, *22*, 233–261. [\[CrossRef\]](#)
17. Rooke, J.; Seymour, D.; Fellows, R. Planning for Claims: An Ethnography of Industry Culture. *Constr. Manag. Econ.* **2004**, *22*, 655–662. [\[CrossRef\]](#)
18. Wang, J.; Yu, J.; Gu, X.; Xie, M.L.; Ma, W.B. Integrated Risk Response Decision-Making Frameworks for EPC+PPP Projects: A Consideration of the Dual Status of the Private Sector. *Eng. Constr. Archit. Manag.* **2025**, *ahead of printing*. [\[CrossRef\]](#)
19. Ford, D.N. Achieving Multiple Project Objectives through Contingency Management. *J. Constr. Eng. Manag.* **2002**, *128*, 30–39. [\[CrossRef\]](#)
20. Bajari, P.; Tadelis, S. Incentives versus Transaction Costs: A Theory of Procurement Contracts. *Rand J. Econ.* **2001**, *32*, 387–407. [\[CrossRef\]](#)
21. Mosey, D. *Collaborative Construction Procurement and Improved Value*; Wiley-Blackwell: Oxford, UK, 2009.
22. Eriksson, E.; Westerberg, M. Effects of Cooperative Procurement Procedures on Construction Project Performance: A Conceptual Framework. *Int. J. Proj. Manag.* **2011**, *29*, 197–208. [\[CrossRef\]](#)
23. Broome, D.; Hayes, J. A Comparison of the Clarity of Traditional Construction Contracts and of the New Engineering Contract. *Int. J. Proj. Manag.* **1997**, *15*, 255–261. [\[CrossRef\]](#)
24. Beale, H.; Dugdale, T. Contracts between Businessmen: Planning and the Use of Contractual Remedies. *Br. J. Law Soc.* **1975**, *2*, 45–60. [\[CrossRef\]](#)
25. Act for Promotion of Private Participation in Infrastructure Projects. Promulgated 2000, Last Amended 2022. Available online: <https://law.moj.gov.tw/ENG/LawClass/LawAll.aspx?pcode=D0060001> (accessed on 19 June 2026).
26. Chinese Arbitration Association, International (CAAI). *Arbitration Practice in Construction Disputes: Selected Awards and Commentary*; CAAI: Taipei, Taiwan, 2018.
27. Taiwan High Court. Civil Judgment No. 108-Jian-Shang-2 (2019). In *Construction Law Review of Taiwan*; Taiwan Construction Law Association: Taipei, Taiwan, 2020; Volume 12, pp. 45–58.
28. He, Q.; Tian, Z.; Wang, T. Performance Measurement Methods in Megaprojects: An Analytical Review. *Int. J. Proj. Manag.* **2022**, *40*, 634–645. [\[CrossRef\]](#)
29. Shen, Q.; Li, H.; Chung, J.; Hui, P.-Y. A Framework for Identification and Representation of Client Requirements in the Briefing Process. *Constr. Manag. Econ.* **2004**, *22*, 213–221. [\[CrossRef\]](#)
30. Shen, L.C.; Chan, A.P.C.; Akintoye, A. Comparative Study of Public Private Partnership Schemes in Hong Kong and the United Kingdom. *J. Surv. Built Environ.* **2007**, *18*, 71–81.
31. Flyvbjerg, B.; Holm, M.S.; Buhl, S. Underestimating Costs in Public Works Projects: Error or Lie? *J. Am. Plan. Assoc.* **2002**, *68*, 279–295. [\[CrossRef\]](#)
32. Merrow, E.W. *Industrial Megaprojects: Concepts, Strategies, and Practices for Success*; Wiley: Hoboken, NJ, USA, 2011.

33. Malek, M.S.; Bhatt, V. Investigating the effect of risk reduction strategies on the construction of mega infrastructure project (MIP) success: A SEM-ANN approach. *Eng. Constr. Archit. Manag.* **2023**, *30*, 3831–3852. [[CrossRef](#)]
34. Pryke, S. Towards a Social Network Theory of Project Governance. *Constr. Manag. Econ.* **2005**, *23*, 927–939. [[CrossRef](#)]
35. Castelblanco, G.; Fenoaltea, E.M.; De Marco, A.; Demagistris, P.; Petruzzi, S.; Zeppegno, D. Combining Stakeholder and Risk Management: Multilayer Network Analysis for Complex Megaprojects. *J. Constr. Eng. Manag.* **2024**, *150*, 04023161. [[CrossRef](#)]
36. Zhang, L.; Fu, Y.; Lai, J. Complements or Substitutes? Recipes of Contract Design, Contract Enforcement, and Trust for Megaproject Performance. *Int. J. Proj. Manag.* **2024**, *42*, 102587. [[CrossRef](#)]
37. Luo, L.; Liu, Y.; Yang, Y.; Xie, J.; Wu, G. Interactive Roles of Megaproject Governance Mechanisms and Their Effects on Governance Performance. *Eng. Constr. Archit. Manag.* **2025**, *32*, 5943–5964. [[CrossRef](#)]
38. Alqershy, M.T.; Shi, Q.; Zhang, F. Exploring Governance Mechanisms in Megaprojects: A Mixed-Methods Systematic Review. *Eng. Manag. J.* **2025**, *37*, 90–113. [[CrossRef](#)]
39. Patel, M.; Robinson, H. Impact of Governance on Project Delivery of Complex NHS PFI/PPP Schemes. *J. Financ. Manag. Prop. Constr.* **2010**, *15*, 216–234. [[CrossRef](#)]
40. Davies, A.; Gann, D.; Douglas, T. Innovation in Megaprojects: Systems Integration at London Heathrow Terminal 5. *Calif. Manag. Rev.* **2009**, *51*, 101–125. [[CrossRef](#)]
41. Aven, T. Risk Assessment and Risk Management: Review of Recent Advances on Their Foundation. *Eur. J. Oper. Res.* **2016**, *253*, 1–13. [[CrossRef](#)]
42. Yin, R.K. *Case Study Research and Applications: Design and Methods*, 6th ed.; Sage Publications: Thousand Oaks, CA, USA, 2018; Available online: <https://us.sagepub.com/en-us/nam/case-study-research-and-applications/book250150> (accessed on 15 June 2026).
43. Denzin, N.K. *The Research Act: A Theoretical Introduction to Sociological Methods*; Transaction Publishers: New Brunswick, NJ, USA, 2009.
44. Davis, P.R. A Relationship Approach to Construction Supply Chains. *Ind. Manag. Data Syst.* **2008**, *108*, 310–327. [[CrossRef](#)]
45. Merschbrock, C.; Munkvold, B.E. Effective Digital Collaboration in the Construction Industry: A Case Study of BIM Platform Use in a Hospital Construction Project. *Comput. Ind.* **2015**, *73*, 1–7. [[CrossRef](#)]
46. Krippendorff, K. *Content Analysis: An Introduction to Its Methodology*, 4th ed.; Sage Publications: Thousand Oaks, CA, USA, 2018. Available online: <https://us.sagepub.com/en-us/nam/content-analysis/book258450> (accessed on 15 June 2026).
47. Murdoch, J.; Hughes, W. *Construction Contracts: Law and Management*, 4th ed.; Taylor & Francis: London, UK, 2008. Available online: <https://centaur.reading.ac.uk/35469/> (accessed on 15 June 2026).
48. Eggleston, B. *The NEC 3 Engineering and Construction Contract: A Commentary*, 2nd ed.; Blackwell Publishing: Oxford, UK, 2006.
49. Miles, M.B.; Huberman, A.M.; Saldaña, J. *Qualitative Data Analysis: A Methods Sourcebook*, 3rd ed.; SAGE Publications: Thousand Oaks, CA, USA, 2014.
50. Cao, M.; Zhang, Q. Supply Chain Collaboration: Impact on Collaborative Advantage and Firm Performance. *J. Oper. Manag.* **2011**, *29*, 163–180. [[CrossRef](#)]
51. Holmström, B. Moral Hazard and Observability. *Bell J. Econ.* **1979**, *10*, 74–91. [[CrossRef](#)] [[PubMed](#)]
52. Ostrom, E. Collective Action and the Evolution of Social Norms. *J. Econ. Perspect.* **2000**, *14*, 137–158. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.