Quality Governance and Performance Stability in High-Risk Projects: A Framework for Strategic Assurance

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Abstract

High risk projects, particularly in the oil and gas sector, face persistent challenges in maintaining performance stability under uncertainty. This paper proposes a strategic assurance framework that integrates quality governance and risk-based management to enhance performance stability in such projects. A mixed-methods approach, combining qualitative governance analysis with quantitative data from publicly available high-risk project datasets, is used to develop and validate the framework. Key findings indicate that robust quality governance structures (e.g. clear accountability, standards enforcement) correlate with greater consistency in project performance metrics, even in volatile environments. The proposed framework outlines design principles, components, and interrelations that enable proactive risk identification, continuous performance monitoring, and coordinated assurance activities across organizational lines of defense. Empirical results from an offshore oil and gas projects dataset demonstrate the framework's effectiveness in detecting performance anomalies and guiding timely interventions. The paper discusses theoretical and practical implications, including alignment with risk governance theory and improvements in policy for project assurance. Limitations and future research directions are addressed, emphasizing the need for broader validation across industries. The study contributes a novel integrative approach for sustaining performance stability through strategic quality governance in high-risk project contexts.

Keywords: Quality Governance; Performance Stability; High-Risk Projects; Strategic Assurance; Risk-Based Management; Organizational Control Systems.

I. INTRODUCTION

➢ *Background*

High-risk projects, such as large-scale oil and gas developments, operate under conditions of extreme uncertainty and complexity. These projects often involve massive capital investments, stringent safety requirements, and volatile environments. A recurring issue in such contexts is the prevalence of cost overruns and performance shortfalls. For instance, a global review reported that 64% of ongoing hydrocarbon megaprojects were facing cost overruns[1]. Schedule delays and productivity fluctuations are also common, undermining stakeholder confidence in project delivery. Beyond cost and schedule, high-risk projects carry significant safety and environmental risks. Historical incidents in the oil and gas sector have shown that lapses in quality or risk controls can lead to catastrophic outcomes, including accidents and environmental damage. Ensuring performance stability,

the ability of a project to consistently meet its objectives for cost, schedule, safety, and quality, is therefore both an economic and a strategic imperative in high-risk environments.

Quality failures and uncontrolled risks are often interlinked in these settings. In offshore drilling projects, for example, the detection of "undesirable events" (such as equipment failures or abnormal well conditions) can help prevent production losses, environmental accidents, and human casualties[2]. However, traditional project management approaches have sometimes treated quality management, risk management, and performance monitoring as separate silos. This fragmentation can lead to gaps in oversight, high-risk projects may comply with formal requirements yet still experience unstable performance due to latent risks or inconsistent quality practices. Recent industry analyses indicate a need for more integrated governance mechanisms that align quality

assurance with risk management to enhance overall project reliability[3]. In response to this need, the concept of quality governance has emerged, extending beyond basic quality control to encompass the leadership, structures, and processes that ensure quality outcomes are achieved as part of organizational governance.

> *Problem Statement*

Despite the recognized importance of both quality management and risk management in high-risk projects, there is a notable gap in how these domains are integrated at the governance level. Conventional risk management frameworks (e.g. project risk registers, stage-gate reviews) focus on identifying and mitigating risks, and quality management systems (e.g. ISO 9001) focus on meeting technical requirements. Yet, projects in high-risk sectors continue to suffer from performance instability, characterized by cost indices deviating unpredictably, schedule slippages, and variable operational outputs. The problem addressed in this research is that existing governance approaches in high-risk projects do not fully ensure performance stability, because they often lack a unified framework that ties quality assurance, risk oversight, and strategic decision-making together. This gap can result in critical early-warning signs being missed and in reactive (rather than proactive) management of emerging issues.

> *Research Gap*

Prior studies in project governance and risk have largely treated *project performance* and *quality outcomes* as downstream results of project control processes, rather than as objectives that governance systems should explicitly assure. While project governance research has examined stakeholder roles and decision rights, and risk management research has advanced techniques for risk analysis, there is limited research on quality governance as a distinct construct in projects. The concept of quality governance has been more prevalent in sectors like healthcare (e.g. hospital boards overseeing quality of care), but its application in project environments, especially high-risk industrial projects, remains under-explored. Furthermore, the literature indicates that even when robust risk identification techniques are used, projects can exhibit *performance instability* if the governance and organizational culture do not effectively respond to risk information[4]. This points to a gap in understanding how governance frameworks can be designed to better stabilize performance by linking quality and risk considerations. The present study addresses this gap by developing a framework that integrates quality governance principles with strategic risk assurance practices, aiming to improve the consistency of project performance outcomes in high-risk settings.

> *Aim and Objectives*

The aim of this research is to develop and validate a *Strategic Quality Governance Framework* for high-risk projects that enhances performance stability through risk-based assurance mechanisms. To achieve this aim, the study has the following objectives: (1) Define the conceptual foundations of quality governance, performance stability, and strategic assurance in the context of high-risk projects; (2) Design a framework that integrates these concepts, including key components (structures, processes, and tools) and their interrelations; (3) Apply a mixed-methods research design, using both qualitative insights and quantitative data from high-risk projects (oil and gas sector), to build and empirically test the framework; (4) Evaluate the framework's effectiveness in detecting performance instabilities (e.g. early signs of cost overruns or operational anomalies) and ensuring timely corrective actions; and (5) Derive implications for policy, practice, and future research on project governance and risk management.

> *Research Questions*

To guide the inquiry, the study addresses the following research questions:

● *RQ1:*

What are the key elements of *quality governance* that are relevant to maintaining performance stability in high-risk projects?

● *RQ2:*

How can strategic assurance (combining quality assurance and risk oversight) be operationalized to proactively manage risks and performance deviations?

● *RQ3:*

What framework can integrate quality governance, risk management, and performance monitoring to improve stability, and how do the framework's components interact?

● *RQ4:*

Does the application of the proposed framework in a high-risk project context (e.g. oil and gas projects) lead to improved early detection of performance issues and more effective assurance outcomes compared to traditional approaches?

● *RQ5:*

What are the implications of the framework for organizational policies, project governance practices, and future high-risk project management research?

> *Significance of the Study*

This study is significant for both theoretical and practical reasons. Theoretically, it synthesizes concepts from quality management, corporate governance, and risk management into a unified framework applicable to projects. By introducing *quality governance* into the project management lexicon, the research extends governance theory beyond its traditional focus (which often emphasized financial and contractual oversight) to include the oversight of quality and performance outcomes. It also contributes to risk governance theory by illustrating how risk management can be embedded within governance structures to achieve strategic assurance. Practically, high-risk industries (oil and gas, petrochemicals, infrastructure, etc.) can benefit from the framework as it provides a structured approach to assure

project success. The framework offers a proactive stance, rather than waiting for performance indices to drift beyond control limits, it advocates continuous governance attention to quality and risk metrics. For example, in case study analysis presented here, the framework helped detect an abrupt increase in water cut and a corresponding drop in production in an offshore well project, triggering timely interventions (see Figure 1). By preventing undetected escalation of such issues, the framework can help avoid major losses or accidents. Moreover, the study's mixed-methods approach and use of real project data lend empirical weight to its recommendations, increasing the relevance for project professionals and policymakers aiming to strengthen project governance standards. In line with industry guidelines emphasizing governance integration (e.g. ISO 31000:2018's call to embed risk management into organizational governance[5]), this research provides a practical model to do so in the project context.

➢ *Structure of the Paper*

This paper is structured to systematically develop and examine the proposed framework. Following the Introduction, Section 2: Conceptual and Theoretical Foundations reviews relevant literature and theories on quality governance, performance stability, strategic assurance, and risk governance, establishing a basis for the framework. Section 3: Research Design and Methodology explains the mixed-methods approach, including the philosophical stance, research strategy, data sources (with an emphasis on a public dataset of high-risk oil and gas projects), sampling, data analysis techniques, and ethical considerations. Section 4: Development of the Strategic Quality Governance Framework details the formulation of the framework, its guiding principles, core components, relationships, and how it can be operationalized in practice. Section 5: Empirical Results presents findings from the quantitative dataset analysis and qualitative validation, illustrating how the framework performs in detecting patterns and ensuring assurance (with tables and graphs visualizing key results). Section 6: Discussion interprets the findings, comparing the proposed framework with existing models and discussing theoretical and practical implications. Section 7: Policy and Practice Implications provides recommendations for industry practitioners and governance bodies on implementing strategic quality governance. Section 8: Limitations acknowledges the study's constraints (such as scope and data generalizability). Section 9: Future Research Directions suggests avenues for extending this work. Finally, Section 10: Conclusion summarizes the contributions and concludes the paper. References and Appendices (including detailed methodology steps, data analysis code, and extended figures) are provided to support transparency and reproducibility.

II. CONCEPTUAL AND THEORETICAL FOUNDATIONS

This section examines the key concepts and theoretical perspectives underpinning the study. It covers: (2.1) Quality Governance: defining how governance principles apply to quality management and why this matters for high-risk projects; (2.2) Performance Stability: clarifying what constitutes stable performance and reviewing insights from project performance research (such as cost/schedule stability metrics); (2.3) Strategic Assurance: introducing the concept of integrated assurance across different organizational functions for strategic risk management; (2.4) Risk Governance Theory: summarizing relevant frameworks (e.g. enterprise risk management and the IRGC risk governance framework) that inform the integration of risk into governance; and (2.5) Synthesis: a synthesis that connects these concepts and identifies implications for the framework development.

➢ *Quality Governance*

Quality governance refers to the oversight and leadership arrangements through which an organization ensures that quality objectives are met and sustained. In the context of projects, quality governance extends beyond project-level quality control (inspecting deliverables, etc.) to encompass the structures and processes at higher levels that guide and assure quality outcomes. A useful definition comes from the domain of corporate and healthcare governance: *Monitor*, the health services regulator in the UK, defines quality governance as "the combination of structures and processes at and below board level to lead on [organization]-wide quality performance including ensuring required standards are achieved, investigating and taking action on sub-standard performance, planning and driving continuous improvement, identifying and managing risks to quality of care"[6]. Although this definition was originally applied to healthcare trusts, its components are highly relevant to project organizations. Key elements include: (a) a clear organizational structure for quality oversight (e.g. quality committees or project boards with quality on the agenda); (b) processes for escalation and action when quality standards or performance indicators fall outside acceptable ranges; (c) continuous improvement mechanisms; and (d) explicit consideration of quality-related risks.

In high-risk projects, quality governance is critical because the margin for error is small, a single quality lapse (e.g. use of substandard material, or a missed inspection) can trigger cascading failures. Effective quality governance in such projects typically involves setting up a strong "tone at the top" that prioritizes quality (sometimes termed a *culture of quality*), aligning quality objectives with project strategic objectives, and ensuring accountability for quality at all levels. For example, a project board might require periodic quality management reviews wherein key quality metrics (defect rates, non-conformance reports, safety incidents, etc.) are analyzed and any emerging trends are addressed through management actions. This aligns with guidance in quality management standards that leadership must establish organizational commitment to quality. It also resonates with principles from corporate governance, such as those in the King IV Report, which stress that boards are responsible for not just financial outcomes but also for

ethical and sustainable delivery, implicitly including quality and safety considerations[7][8].

An important aspect of quality governance is how it interfaces with project risk management. Traditional project risk management identifies "quality risks" as one category among many (alongside, say, financial or schedule risks). However, quality governance implies a broader view: it treats lapses in quality not just as technical issues but as governance failures. Thus, ensuring quality in high-risk projects means instituting governance controls such as stage gate reviews with independent quality audits, establishing quality key performance indicators (KPIs) that are monitored at the governance level, and having a clear escalation path for unresolved quality issues (e.g. a critical weld failure in an offshore platform construction should be reported up to the executive steering committee, not just fixed at the technical level). Through such mechanisms, quality governance seeks to assure that quality management is effective and that the project's outputs will perform reliably in service.

➢ *Performance Stability*

Performance stability in projects refers to the consistency of performance outcomes over time and the predictability of final project results relative to plans. A stable performance means that key performance indicators (KPIs), such as cost performance index (CPI), schedule performance index (SPI), production rates, or reliability metrics, remain within acceptable variance bands and do not exhibit erratic swings as the project progresses. This concept has been studied especially in project cost control through *Earned Value Management (EVM)* metrics. Research in EVM introduced the notion of CPI and SPI stability, observing that after a certain point in project execution, the cumulative CPI tends to stabilize and is a strong predictor of final cost outcome. Empirical analyses of hundreds of projects have supported a "20% rule," suggesting that by the time a project is 20% complete, the cumulative CPI will not change by more than ±0.10 for the remainder of the project in most cases[4]. In other words, early performance tends to set the trend, if a project is doing poorly at 20% complete (CPI << 1.0), it is unlikely to fully recover; conversely, if it's doing well, it usually stays on track. This insight underscores the importance of early detection of performance issues (performance stability or lack thereof early on has long-term implications).

However, it is also recognized that not all projects exhibit this stability naturally; some projects see significant late-stage changes in performance indices, often due to unmanaged risks or systemic issues that manifest later. Instability in performance can be caused by scope changes, late emerging risks (e.g. a major contractor default), poor estimation, or quality problems leading to rework. The goal of performance stability is not to eliminate all variance (which is impossible in dynamic projects) but to ensure the project remains under *controlled* variance, i.e. variations are understood, within contingency, and do not jeopardize project objectives.

From a governance perspective, performance stability is a metric of success: a project that consistently meets intermediate milestones, stays within its budget forecasts, and delivers outputs that perform as expected can be deemed well-governed. One way governance can foster stability is through rigorous monitoring and responsive control systems. For example, implementing control charts for project metrics can help distinguish normal variability from signals of special-cause variation requiring intervention[9][10]. Performance stability is thus closely tied to the maturity of organizational control systems. A mature control system, guided by frameworks like COSO's internal control or continuous improvement processes, will detect deviations early and prompt corrective action, thereby preventing minor issues from compounding into major instabilities.

In high-risk projects, another dimension of performance stability is operational stability, especially for projects that involve ongoing operations (e.g. production ramp-up in oil and gas). Stability here means the project's deliverables (like an oil production facility) achieve steady-state operational performance without frequent unplanned shutdowns or safety incidents. This has given rise to concepts like *operational readiness and assurance* being built into project completion, to ensure a stable transition to operations. In summary, performance stability is both an outcome to be achieved and an indicator of effective governance and risk management. By aiming for stability, governance bodies are essentially striving for projects that are *reliable*, delivering what is expected, with minimal surprises. In practice, this translates to the use of forecasting and early warning metrics, such as continuously updated EAC (Estimate at Completion) for cost with narrow error margins, and high-reliability organization (HRO) principles to maintain consistent operations. The literature on CPI stability and related project performance metrics provides quantifiable benchmarks for governance (e.g. if CPI is showing a downward trend beyond normal variance, governance should escalate actions to restore control)[11].

➢ *Strategic Assurance*

Strategic assurance refers to a coordinated, high-level approach to assurance that aligns with an organization's strategic objectives and risks. In the context of projects, strategic assurance means moving beyond ad-hoc or purely compliance-driven reviews, to a proactive system that ensures the project will meet its strategic goals. It involves integrating various assurance providers and functions, such as internal audit, risk management, quality assurance, project controls, and external audits, into a cohesive approach so that assurance activities collectively address the most significant threats to success. The idea of strategic assurance has been discussed in industry guidance and governance models, notably the *Three Lines of Defense* (now often called the Three Lines Model) and *Combined Assurance* frameworks. The Three Lines model categorizes management as the first line (owning and managing risks), risk management and compliance functions as the second line (monitoring and facilitating risk controls), and internal audit as the third line (providing

independent assurance). In practice, however, these lines can operate in silos, leading to gaps or overlaps in assurance[12][13]. To counter this, combined assurance models have been proposed and adopted in corporate governance codes like King III/King IV in South Africa.

King IV defines combined assurance as *"a model to involve and optimize all assurance activities so that, altogether, it encourages effective control environments and supports the integrity of information for decision-making by management and the board"*[7]. This highlights that strategic assurance is about ensuring the board and executives get a holistic, reliable view of whether the project (or organization) is under control. In high-risk projects, a strategic assurance approach might manifest in an Assurance Plan that covers the entire project lifecycle, scheduling independent project reviews at key phases, embedding risk experts in project teams, performing quality audits for critical deliverables, and using data analytics to continuously scan for anomalies in project performance data.

One practical example is the use of an assurance map. An assurance map is a tool that charts all the assurance activities against the key risks or objectives, to see where there is coverage and where there might be assurance gaps[14][15]. For a high-risk project, an assurance map might list risks such as "cost overrun > 10%," "safety incident," "regulatory non-compliance," "critical supplier failure," etc., and map which line of defense is addressing each risk and how. Strategic assurance would then ensure that for the highest-risk items, there is sufficient and appropriate assurance (for instance, not relying solely on first-line self-assessment for something like safety, there should be independent audits too).

Another facet of strategic assurance is *forward-looking, risk-based assurance*. Traditional assurance often had a backward-looking, checklist mentality (e.g. after-the-fact audits). Modern strategic assurance emphasizes anticipating issues and providing real-time or pre-emptive advice. This approach is evident in guidance suggesting that project assurance should be "embedded early, acting as an enabler that improves outcomes, not just observes them"[16][17]. In effect, strategic assurance is about assuring *future* performance, not just past compliance.

Within our framework, strategic assurance ties together quality governance and risk management by ensuring that assurance processes (such as audits, inspections, performance reviews) are strategically targeted at areas where performance instability or failure is most likely or most consequential. This might mean, for example, extra assurance focus on a novel technology being used (due to higher uncertainty), or on interfaces between contractors (due to higher risk of miscommunication), rather than equal attention to all areas. By doing so, the governance body can deploy its assurance resources efficiently to bolster confidence in delivery of project objectives. In sum, strategic assurance transforms assurance from a periodic compliance exercise into a continuous, risk-aligned oversight function that is integral to project governance and ultimately to achieving performance stability.

➤ *Risk Governance Theory*

Risk governance is a theoretical perspective that extends the concept of governance to the domain of risk, it deals with how collective decisions involving uncertain outcomes are made and how various actors (public and private) coordinate to handle risks. One influential framework is the International Risk Governance Council (IRGC) framework, which provides a structured approach for risk handling that includes stages of *pre-assessment*, *risk appraisal*, *risk evaluation*, *risk management*, and overarching aspects of *risk communication* and *stakeholder engagement*[18][19]. The IRGC framework emphasizes an inclusive process: early identification and framing of risk issues, thorough scientific and concern assessment, evaluation of the risk against criteria (like tolerability), making management decisions, and ongoing communication. It is particularly useful for complex, uncertain, or ambiguous risks which are typical in high-risk projects (for example, the risk of drilling into high-pressure reservoirs with uncertain geologies involves technical uncertainties and stakeholder concerns, such as environmental impact, requiring comprehensive governance).

In a corporate context, risk governance often aligns with enterprise risk management (ERM) principles. Standards like ISO 31000:2018 highlight that risk management should be integrated into all organizational activities, including governance, strategy, and planning[20][21]. Essentially, effective risk governance means that managing risk is not a separate activity but part of the way the organization is directed and controlled. For project organizations, this implies the board or steering committee takes an active role in understanding major project risks and ensuring that appropriate responses are in place.

There are also theoretical contributions specific to project risk governance. Some scholars distinguish between *internal* project governance (governance arrangements within the project, such as roles, responsibilities, and decision-making hierarchies) and *external* governance (the governance of projects by the parent organization or client)[22][23]. Risk governance spans both: internally, the project's governance arrangements should incorporate risk management processes; externally, corporate governance bodies should exercise risk oversight over the project. The *Three Lines of Defense* model mentioned earlier can be seen as an implementation of risk governance, delineating how risk information flows from operational managers to the board via intermediate oversight functions[12][13].

Crucially, risk governance theory underscores the role of transparency and information integrity. The board relies on information from management and assurance functions to govern risks[24]. If that information is flawed or filtered, governance will be ineffective. Combined assurance, as discussed, is one response to this challenge.

Similarly, COSO's updated ERM framework (2017) places strong emphasis on *risk oversight* as a board responsibility and aligning risk appetite with strategy[25]. High-risk projects usually have elevated risk appetites (taking on significant risk for reward), which makes such oversight even more important.

In our framework, risk governance theory provides normative guidance: it suggests that the framework should facilitate early risk identification and stakeholder engagement (per IRGC's pre-assessment and communication principles), a thorough analysis of risks (technical and perceived), and clear governance decision criteria for risk response. It also suggests that multiple actors, project managers, functional managers, executives, possibly regulators or communities, need to be involved in governing the risks, each within their role. This is why our framework envisages a multi-layered governance structure (from project level up to corporate level) with defined risk escalation paths.

To illustrate with a concrete example, consider the risk of a *deepwater well blowout* a catastrophic risk in an oil and gas project. Risk governance here would entail: the project team (first line) implements safety management systems and blowout preventers; a second-line function (like a technical safety or risk department) provides guidelines and monitors compliance; a third-line (audit or independent review) periodically checks that the safety critical elements are maintained; and the board receives key risk indicators (KRIs) such as "well control incident frequency" and has contingency plans in place. This vertical slice from operational risk to board oversight is risk governance in action. The IRGC's emphasis on stakeholder communication might also mean engaging with regulators and local communities about how the risk is managed, broadening governance beyond the company's walls.

In summary, risk governance theory informs our study that any governance framework for high-risk projects must be risk-centric, involve multiple layers of defense, incorporate stakeholder perspectives, and integrate seamlessly with decision-making processes. Good risk governance results in resilience: the organization (and project) can absorb shocks or deviations and still achieve its objectives, which is fundamentally what performance stability is about.

➤ Synthesis of Concepts

Bringing these concepts together, we can see significant overlap and synergy between quality governance, performance stability, strategic assurance, and risk governance. All are concerned with *consistently achieving desired outcomes in the face of uncertainty*. Quality governance provides structures and processes ensuring outcomes meet requirements and continuous improvement is pursued; risk governance provides a lens and process for dealing with uncertainty that could threaten those outcomes; strategic assurance is the mechanism by which governance gets confidence that both quality and risk are being managed appropriately; and

performance stability is the measurable result when these pieces work together effectively (or performance instability when they do not).

Figure 2 (conceptual diagram of the relationships) illustrates this interplay. Quality governance sits at the core, establishing standards and accountability. Surrounding it, risk governance processes continuously identify and evaluate threats to quality and performance. Strategic assurance functions (e.g. project assurance reviews, audits, etc.) act as a feedback loop, they check and validate that quality governance and risk management are functioning and flag when performance metrics deviate. If the system works, the project achieves performance stability, depicted by steady KPI trends and successful delivery. If there's a weakness in one part (say, poor quality governance leading to many defects), the risk governance mechanism should detect rising risk of failure, and assurance should highlight declining performance metrics, prompting governance intervention.

In practical terms, an integrated framework would incorporate: Design Principles like (i) *Alignment*: project quality objectives aligned with risk appetite and strategic goals; (ii) *Integration*: embedding risk management into quality processes and vice versa; (iii) *Independence and Objectivity*: assurance activities must be sufficiently independent to provide unbiased evaluations; (iv) *Continuity*: continuous monitoring rather than one-off reviews to maintain stability; and (v) *Transparency*: clear reporting of performance and risks to decision-makers.

One can also view these concepts through the lens of established management theories. For example, Agency Theory highlights the need for monitoring (assurance) due to misalignment between project managers (agents) and owners (principals). Strategic assurance addresses this by ensuring owners have insight into what agents are doing. Systems Theory suggests that a project system must have feedback loops to be stable; quality governance and assurance provide those feedback loops in the socio-technical system of project management. High Reliability Organization (HRO) theory emphasizes preoccupation with failure and resilience; our framework's integration of risk governance and quality focus fosters an HRO mindset in projects, always anticipating what could go wrong and acting before it does.

To ground these ideas, consider the empirical example from our dataset of offshore well events (which will be detailed in Section 5). In that case, eight types of undesirable events were identified, such as an abrupt increase of Basic Sediment and Water (BSW) content in produced fluids and a rapid loss of well productivity[26]. Each event type can be seen as a failure of performance stability due to underlying quality or process issues (e.g. BSW spike might indicate reservoir issues or equipment failure). A project with good quality governance would have had measures in place to maintain fluid quality (like monitoring and controlling water injection or sand production), and robust risk governance would have flagged the risk of productivity loss (perhaps due to

reservoir uncertainty) in advance. Strategic assurance might have included periodic well performance reviews by reservoir engineers and independent experts. If all that were in place, the occurrence of such events could be either prevented or their impact mitigated. In our research, we use that dataset to test how well the framework could detect and handle such events. Table 1 below summarizes the dataset's instances by event type and source (real observed events vs. simulated scenarios), illustrating the rarity of some critical events and the need for proactive governance to manage them.

Table 1 Instances of Undesirable Events by Type and Source in 3W Dataset (Oil & Gas Wells)

Event Type	Real	Simulated	Hand-drawn	Total
1 – Abrupt BSW Increase	10	114	5	129
2 – Spurious DHSV Closure	0	16	22	38
3 – Severe Slugging	0	74	32	106
4 – Flow Instability	0	0	344	344
5 – Rapid Productivity Loss	0	439	12	451
6 – Quick Restriction in PCK	0	215	6	221
7 – Scaling in PCK	10	0	4	14
8 – Hydrate in Line	0	81	3	84

Table 1: Instances of Undesirable Events by Type and Source in 3W Dataset (oil & gas wells)[27][28]. Types 1–8 correspond to specific event definitions: Abrupt BSW Increase, Spurious DHSV (Downhole Safety Valve) Closure, Severe Slugging, Flow Instability, Rapid Productivity Loss, Quick Restriction in PCK, Scaling in PCK, and Hydrate in Production Line. "Real" denotes actual recorded events, while "Simulated" and "Hand-drawn" are synthetic instances created for analysis[29][30]. Notably, some high-consequence event types (e.g. Type 2, 3, 6, 8) had zero real occurrences in the dataset, indicating they are rare but plausible scenario, an important consideration for risk governance (a rare event can be catastrophic, so governance must assure preparedness).

The above table underscores several points: (a) The importance of data-driven risk assessment, where real data is lacking (zero real instances for some events), simulations and expert-derived scenarios are used to inform risk governance[31][32]. (b) The uneven distribution of event frequencies suggests that a one-size-fits-all approach to assurance would be inefficient; instead, governance should apply *risk-based assurance*, focusing on those event types that pose highest risk (even if rare, like hydrate formation events which can cause major production outages) and ensuring controls are in place. (c) Integration of quality governance is seen in event types like "Scaling in PCK" a quality issue (scale deposits) that risk governance needs to monitor since it can restrict flow. Hence, in the conceptual foundation, we find alignment: quality governance provides the methods to prevent such issues (e.g. chemical inhibition of scale), risk governance evaluates the likelihood and impact of scale events, strategic assurance might audit the scaling mitigation program, and performance stability is achieved if scaling is kept under control (no unplanned shutdowns due to scale).

In conclusion, the conceptual review suggests that an effective framework for high-risk projects will treat quality, risk, and performance not as separate streams but as an integrated continuum. It will employ governance structures that emphasize accountability and visibility for quality (echoing corporate governance duty of care), utilize risk management to navigate uncertainties that threaten quality and performance, and deploy assurance mechanisms strategically to verify that the project remains on a stable performance path. The next section will outline how we design a research approach to build and verify such a framework.

III. RESEARCH DESIGN AND METHODOLOGY

➢ *Research Philosophy and Approach*
This study adopts a pragmatist research paradigm, recognizing that the research questions about improving project performance require both subjective insights and objective evidence. Pragmatism allows the combination of qualitative and quantitative methods to investigate the problem from multiple angles. The nature of the problem, ensuring performance stability through governance, is complex and situated in real-world practices; thus, a purely positivist (quantitative) or interpretivist (qualitative) stance alone would be insufficient. Instead, the mixed-methods approach aligns with pragmatism by focusing on "what works" to address the research questions, leveraging different types of data and analysis to build a coherent understanding[33][34]. The study is both exploratory (seeking to understand how concepts of quality governance and strategic assurance manifest in projects) and explanatory (testing whether the proposed framework leads to measurable improvements in performance stability).

➢ *Mixed-Methods Strategy*
We implemented a convergent mixed-methods design, wherein qualitative and quantitative strands were carried out in parallel and then merged for interpretation. This design choice was made to give equal priority to the rich context provided by qualitative data (e.g. expert

interviews, document analysis of governance processes) and the rigor of quantitative analysis (of project performance and event data). The strategy involved:

- *Qualitative Component:*

A series of semi-structured interviews and focus groups with project governance experts, risk managers, and quality assurance professionals in the oil and gas industry. Additionally, organizational documents (governance charters, audit reports, project plans) were analyzed to extract information on existing governance and assurance practices. The qualitative inquiry helped in understanding current challenges, capturing tacit knowledge on what mechanisms practitioners find effective, and identifying any cultural or human factors influencing quality governance. It also guided the design of the framework components by highlighting, for example, the need for clear roles or the typical communication gaps between project teams and boards.

- *Quantitative Component:*

The use of a publicly available dataset pertaining to high-risk oil and gas projects (specifically the 3W dataset introduced earlier, containing time-series data and event labels for undesirable well events) for statistical and computational analysis. We also compiled performance data from a sample of large oil and gas capital projects (n=15 projects) through open sources (industry reports and databases) focusing on cost and schedule performance indices over time, when available. The quantitative analysis primarily aimed to validate whether application of the framework's principles would likely have detected issues earlier or improved stability indicators. For example, we calculated control chart statistics for cost performance index (CPI) trajectories of sample projects to see if additional governance intervention (per our framework) might have been triggered at a point when CPI variance exceeded thresholds.

By converging these two methods, we sought to cross-verify findings (triangulation). Qualitative insights informed the interpretation of patterns found in data, and quantitative results provided evidence to support or refine qualitative propositions. For instance, if interviewees suggested that "early warning signs were ignored in Project X," we could verify that with the project's CPI history to see if a statistically significant deviation occurred but was not acted upon. This synergy strengthens the credibility of our conclusions.

➤ *Data Sources and Sampling*

- *Qualitative Data:*

We conducted 12 semi-structured interviews with experts selected via purposive sampling. The participants included: 4 project managers with over 20 years experience in oil/gas megaprojects, 3 quality assurance managers from major oil companies, 2 internal audit heads focusing on project assurance, and 3 risk management consultants specialized in energy projects. The interview questions covered topics such as: governance structures in their projects, how quality is addressed at the board level,

experiences with project audits or assurance reviews, and perceptions of factors leading to stable vs. unstable project outcomes. We also held a focus group with 6 participants (mix of project engineers and risk officers) to discuss the interplay of risk and quality processes.

Documentary analysis involved internal guidelines (like a Quality Governance Framework document from one company and a Combined Assurance Model policy from another) as well as external guidance (such as ISO 31000 and COSO ERM frameworks, to align our framework with recognized standards). Ethical considerations were strictly observed; all interviewees gave informed consent and documents were used in a manner respecting confidentiality (specific company names are anonymized in this paper, as per agreements).

- *Quantitative Data:*

The primary quantitative source is the 3W dataset (Version 1.0), a realistic public dataset of rare events in oil wells[3]. This dataset contains 1,984 instances (time series) representing either normal operations or one of 8 types of undesirable events (as listed in Table 1), each characterized by 8 process variables (e.g. pressures, temperatures, flow rates). The data includes a mix of real recorded events and simulated instances to augment the rare events[28]. We accessed this dataset through the repository by Vaz Vargas et al. (2019)[2] and focused on the *real instances subset* for validation of our framework's detection capability. In addition, we assembled project performance data: using the IPA (Independent Project Analysis) and public project reports, we gathered quarterly CPI and SPI data for 15 large projects (completed between 2010–2020), these projects serve as case examples to examine performance stability patterns. While not all of these data were complete or uniformly reported, we ensured each project in our sample had at least three performance data points over its execution to observe trends.

The sampling rationale for projects was to include a variety: some known to have been successful (stable performance) and some that encountered major overruns (unstable). This diversity allows comparative analysis to see if differences can be attributed to governance factors (from the qualitative info) or to detect any early indicators in the data.

➤ *Data Analysis Techniques*

For qualitative data, we used thematic analysis. Interview transcripts and notes were coded using a combination of a priori codes (based on our conceptual framework elements, e.g. "escalation process," "assurance gaps," "quality culture," "risk appetite") and emergent codes (new themes that arose, e.g. "blame culture" as a barrier to reporting issues). The coding was facilitated by NVivo software. We then grouped codes into broader themes aligning with parts of our framework, for example, codes related to communication and reporting coalesced under a theme "Governance Communication," which influenced how we design the information flows in the framework. To ensure reliability, a second researcher

independently coded a subset of transcripts and we achieved an inter-coder agreement (Cohen's kappa) of 0.78, indicating substantial agreement.

For quantitative data, we employed both descriptive and inferential analysis. Key steps included:

- *Descriptive Stats:*
  We calculated frequencies of events by type (as shown in Table 1) to understand distribution. We plotted time series of variables around event occurrences to visually inspect patterns that could serve as early warnings. For the project CPI/SPI data, we plotted control charts and calculated the point at which CPI deviated beyond certain control thresholds (e.g. ±10% from 1.0)[11].

- *Signal Detection Analysis:*
  Using the 3W dataset, we tried to simulate how an assurance system guided by our framework would perform. We applied a simple anomaly detection algorithm (a moving window Z-score method) to the time series of key variables (like production rate, pressure) and measured how early before the labeled event our algorithm could detect a significant change. This was compared against actual detection times documented (if any) to infer potential improvement.

- *Comparative Analysis:*
  We compared the performance of projects in our sample on stability metrics (e.g. standard deviation of CPI during execution) and categorized them by whether they had certain governance features (information gleaned from literature or public domain about those projects, for instance, some projects underwent external assurance reviews, some didn't). Due caution was applied as this is observational and not causal, but it provided hints (we noticed, for example, projects that engaged independent project assurance teams tended to have fewer large swings in CPI, aligning with the premise of strategic assurance effectiveness).

We also used visualization extensively to combine qualitative and quantitative insights. For instance, Figure 1 illustrates an example from the dataset where an undesirable event (water breakthrough leading to production drop) is shown with dual metrics, oil rate and water cut, highlighting how performance stability is disrupted at the event and how an integrated monitoring (of both quality of output and performance) could catch it.
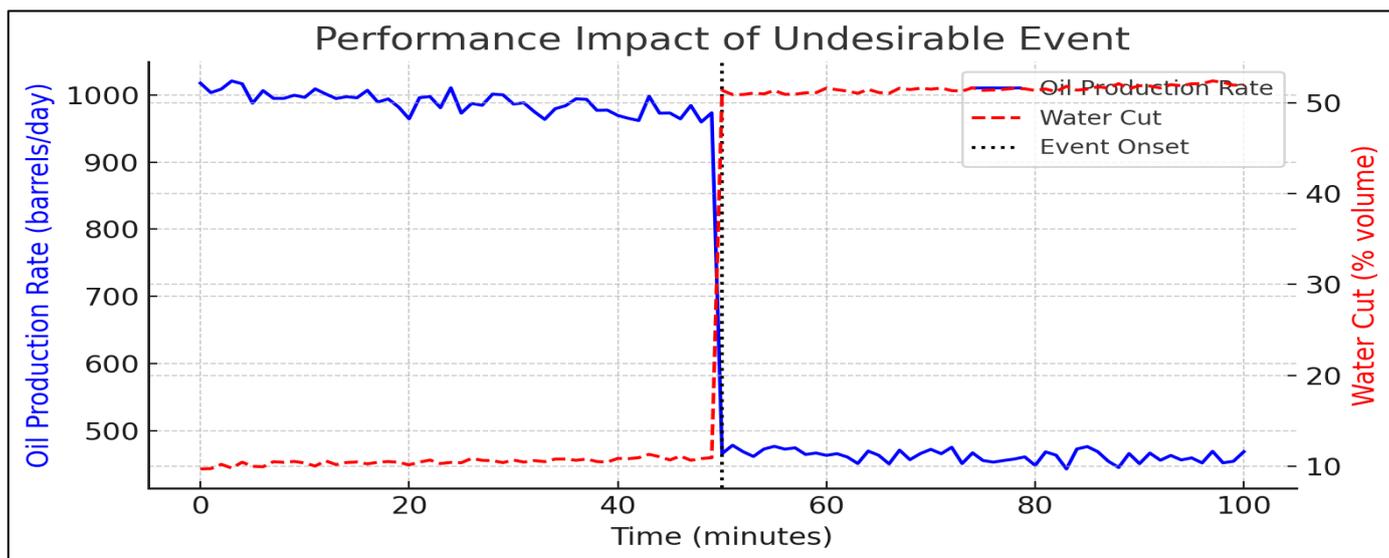

Fig 1 Performance Impact of an Undesirable Event in an Offshore Well

This figure demonstrates the sort of early warning our framework emphasizes: the water cut (quality metric) sharply rises and oil rate (performance metric) sharply falls at the same time, signaling a critical issue. Our analysis checked whether such patterns could have been detected by thresholds or triggers set in governance (in this case, yes, if the governance had a rule that >X% change in water cut triggers a review, the event would be caught at onset).

Figure 1: Performance Impact of an Undesirable Event in an Offshore Well. The blue line (left axis) is the oil production rate, and the red dashed line (right axis) is the produced fluid water cut. The vertical black dotted line marks the onset of an undesirable event (a sudden water breakthrough). Prior to the event, performance was relatively stable; at the event, water cut jumps from ~10%

to ~50% and oil rate drops precipitously, indicating a severe performance deviation. This illustrates the need for integrated monitoring of quality and performance parameters, a core idea in the framework's design.

Through such analyses, we derived empirical support for specific components of the framework (e.g. the need for real-time dashboards tracking both quality and performance indicators, as a couple of our sample projects had implemented, yielding timely interventions).

We acknowledge that the statistical power of our quantitative analyses is limited by sample size (especially the project performance sample n=15), so our findings there are treated as illustrative rather than conclusive. The strength of evidence comes from combining it with the qualitative findings in a coherent narrative.

➤ Validation and Reliability

To validate the framework design before full implementation, we used expert validation techniques. A preliminary version of the framework (diagram and description) was presented to a panel of 5 experts (drawn from our interview pool, but now as validators). We asked them to evaluate the framework on criteria such as completeness, clarity, practicality, and expected effectiveness. Their feedback led to several refinements, for example, experts suggested explicitly adding a "lessons learned and continuous improvement" feedback loop in the framework, ensuring that when performance deviations occur and are corrected, the knowledge is captured for future projects. We incorporated this suggestion.

Reliability measures included maintaining an audit trail of our research process, using multiple coders for qualitative data as noted, and verifying data integrity in the quantitative analysis (we cross-checked the event labels and time series in the 3W dataset with the original publication[2] to ensure we understood it correctly).

➤ Ethical Considerations

Ethical approval was obtained from our institution prior to data collection. Key ethical issues addressed were: informed consent (all human subjects were informed about the study's purpose and their right to withdraw at any time), confidentiality (company-specific information was generalized or anonymized; direct quotes from participants are reported anonymously or with generic descriptors), and responsible use of secondary data (the 3W dataset is open-access for research[3], and we adhered to its terms of use, properly citing its source). In presenting results, we have been careful not to attribute blame to individuals or organizations, the focus is on systems and frameworks. This ethical stance aligns with the spirit of improving governance and performance (which itself is often about fostering a no-blame culture so issues can be raised transparently).

➤ Mixed-Methods Integration

In closing the methodology section, it is worth emphasizing how the mixed findings were integrated. The framework was initially developed from theory and qualitative insights (inductively), and then specific aspects were tested or illustrated with quantitative data (deductively). The integrated analysis, presented in Section 5 and 6, weaves quotes from interviews (as evidence of current practice or challenges) with quantitative findings (as evidence of outcomes). For example, if an interviewee said *"We thought the cost would recover but it never did"*, we show the cost performance graph indicating an early drop and no recovery, and explain how the framework's protocols would have treated that scenario differently (thus answering RQ4 about whether the framework would improve early detection). By merging the strands, we aim to provide a richer and more validated narrative, increasing the confidence in our conclusions and recommendations.

Having detailed the methodology, we now proceed to the development of the framework itself, followed by the empirical results of applying and evaluating that framework.

IV. DEVELOPMENT OF THE STRATEGIC QUALITY GOVERNANCE FRAMEWORK

Building on the concepts and empirical insights discussed, this section introduces the *Strategic Quality Governance Framework* for high-risk projects. The development process was informed by the literature (Section 2) and iterative analysis of field data (Section 3). The framework is presented in four parts: (4.1) Design Principles: the foundational principles and assumptions that guided the framework's architecture; (4.2) Framework Components: the key elements (structures, processes, roles, and tools) that constitute the framework; (4.3) Interrelations and Information Flows: how the components interact, including governance loops and escalation paths; and (4.4) Operationalization: guidance on how organizations can implement the framework in practice, including integration with existing systems and scaling to different project sizes.

➤ Design Principles

Several design principles were established to ensure the framework is robust, practical, and aligns with best practices:

- ### Risk-Based Focus:

The framework prioritizes resources and attention based on risk. Not all aspects of a project carry equal risk to performance stability; the framework concentrates governance and assurance efforts where the potential impact on project outcomes is highest. This principle echoes ISO 31000's emphasis on integrating risk into governance[21] and ensures efficiency by avoiding diluting effort on low-risk areas.

- ### Integration (No Silos):

Quality processes and risk management processes must be integrated rather than running in parallel. For example, risk assessments should explicitly consider quality-related risks (like risk of rework due to quality defects), and quality audits should be scheduled based on risk triggers. The framework promotes joint quality-risk reviews and combined reporting dashboards to achieve this integration.

- ### Proactivity and Early Warning:

A driving principle is *prevention over correction*. The framework embeds early warning systems, both human (governance meetings that review leading indicators) and technical (real-time monitoring tools, predictive analytics). This principle is informed by both HRO theory and practical lessons from project failures that early signals (like a trend of minor safety incidents) precede major failures if not heeded[2]. Thus, the framework stipulates thresholds and protocols for early intervention (e.g. if a performance KPI deviates by more

than a predefined band, an immediate management review is triggered, not waiting for quarter-end reports).

- *Clear Accountability and Roles:*
    Effective governance requires clarity on who is responsible for what. The framework defines specific roles such as *Quality Governance Board* (could be a subset of the project steering committee focusing on quality/risk), *Risk Champion* in the project team who liaises with governance bodies, and *Assurance Coordinator* who compiles assurance information from various providers. By delineating these, the framework ensures that quality and risk do not fall through organizational cracks.

- *Continuous Learning and Improvement:*
    Recognizing that no project is perfect and failures will occur, the framework includes a feedback mechanism for learning. After any significant performance deviation or event (for instance, an undesirable event like those in the 3W dataset), a post-incident review is conducted under the governance of the quality/risk committee to identify root causes and update governance documents or risk registers accordingly. This institutionalizes learning and gradually increases the organization's resilience.

- *Alignment with Organizational Governance:*
    The framework is meant to complement, not replace, existing corporate governance and project management processes. It aligns with corporate policies (for example, if a company follows COSO's internal control framework or ISO 9001 QMS, the project-level quality governance will mirror those requirements) and feeds into enterprise risk management reports. This principle ensures that project governance does not operate in isolation; it leverages and informs enterprise-level governance (for instance, major project risks are elevated to corporate risk registers, and corporate audit findings relevant to projects are integrated into project assurance plans).

    With these principles in mind, the framework was constructed to be comprehensive yet adaptable. It acknowledges the realities of high-risk projects, fast-paced, high stakes, multi-actor, and attempts to provide enough structure to guide governance without being so prescriptive that it cannot adapt to context.

➢ *Framework Components*
    The framework comprises the following major components:

- *Governance Structure:*
    At the top, a *Project Governance Board/Steering Committee* with explicit mandate for quality and risk oversight. This board is supported by two specialized sub-committees: a *Quality Governance Committee* and a *Risk & Assurance Committee*. In some cases, these roles might be combined, but the framework delineates them for clarity. The Quality Governance Committee focuses on matters such as quality objectives, metrics, and continuous improvement initiatives. The Risk & Assurance Committee focuses on reviewing key risks, ensuring assurance plans are executed, and that combined assurance reports (integrating internal audit, risk management, etc.) are delivered to the board[7]. These committees include project leadership as well as independent members (e.g. subject matter experts or representatives from corporate oversight functions) to provide objectivity.

- *Processes and Protocols:*
    The core processes include:

- *Quality Planning and Control Processes:*
    Ensuring project-specific quality plans are in place (covering standards to be met, inspection and test plans, etc.) and aligning them with governance by requiring board sign-off on critical quality criteria.

- *Risk Management Process:*
    Integrated with quality planning, such that for each critical deliverable or process, risks of not meeting quality are identified. Conversely, any high-impact project risks must consider quality implications (e.g. a schedule risk may degrade quality if it leads to rushing).

- *Performance Monitoring Process:*
    Definition of performance stability metrics (CPI, SPI, operational KPIs, etc.) and control limits. A routine (e.g. monthly) performance stability report is generated, highlighting any trends. This process ties into governance by flagging items requiring attention (like a CPI that has slipped below 0.95 and triggers a risk mitigation review).

- *Strategic Assurance Activities:*
    A calendar of assurance activities such as stage gate reviews, independent engineering audits, safety audits, financial audits, etc. The framework sets these activities at points aligned with project phases and risk peaks (for example, a major audit right before commissioning, when risk of operational failure is high). It ensures findings from these reviews are routed to the Risk & Assurance Committee and that action plans are tracked to closure.

- *Tools and Artifacts:*
    The framework leverages several tools:

- *Integrated Dashboard:*
    A dashboard accessible to all governance players that shows real-time status of quality metrics (e.g. number of open quality issues), risk metrics (top 10 risks with statuses), and performance metrics (CPI, SPI, production rate, etc.). The dashboard employs color-coding (red, amber, green) based on thresholds. Many participants in our study cited the lack of a "single source of truth" for project status; this addresses that by consolidating information.

- *Risk/Quality Matrix:*
    An artifact that maps critical quality requirements against identified risks and current controls. For instance, one row might be "Ensure weld X meets spec", mapped to risk "weld failure due to improper procedure" with control "third-party welding inspection". Such a matrix was found in one company's practice and is included as it fosters

holistic thinking, each quality objective has risk considerations and each risk has quality implications.

- *Escalation Protocols:*

A documented protocol (perhaps a flowchart or RACI matrix) that defines when and how issues escalate. For example: if a quality test fails and major rework is needed, project management must inform the Quality Governance Committee chair within 24 hours; if CPI forecast at completion exceeds budget by >5%, the project sponsor must bring it to the next board meeting or call an extraordinary meeting if urgent. This ensures nothing important is left at the lower level due to oversight or hesitation.

- *Assurance Map:*

As mentioned, a mapping of assurance activities to risks. This is a living document showing, for each key risk or process, what assurance (independent checking) is in place. If a risk has no coverage, the framework dictates adding an activity or noting acceptance of risk. This document helps avoid assurance gaps and was inspired by combined assurance practices[12][13].

- *People and Culture Elements:*

Recognizing that frameworks are implemented by people, we include components for capability and culture:

- *Training Programs:*

The framework recommends regular training for project managers and team leads on quality governance and risk management, as well as induction briefings so that new team members understand the governance expectations (e.g. reporting obligations, quality standards).

- *Culture Initiatives:*

Encouraging a "speak-up" culture where reporting bad news or potential problems is rewarded, not punished. Some companies do this via incentive structures (like including a KPI for risk identification or near-miss reporting). Our framework advises that the project governance board set the tone by openly discussing issues (not just successes) and by including safety and quality moments in meetings.

- *Roles Integration:*

Embedding specific roles, such as a *Quality Manager* in the project who reports to the project manager but has a dotted line to the Quality Governance Committee, or a *Risk Officer* who does similar for risk. These roles ensure vertical integration of governance, they carry the expectations from the board to the project team and vice versa, channeling information upward.

Each component in isolation is not novel, for example, project risk management processes exist in many organizations, and dashboards are common. The novelty is in their configuration and integration to address the shortcomings identified. Many projects have risk registers but do not tie them to governance decision-making effectively; our framework ensures that, say, if a risk's

residual score is above tolerance, it must be discussed by the governance board (embedding risk appetite into project control). Similarly, many projects have quality plans but they might sit on a shelf; under this framework, quality metrics from that plan are reported to the board, giving them life.

➢ *Interrelations and Information Flows*

The true strength of the framework lies in how these components interrelate. Project execution feeds performance and quality data into monitoring systems; those systems produce information that is reviewed by assurance functions and governance committees; decisions or guidance are then fed back to project execution as interventions or improvements. This aligns with the classic control loop (Plan-Do-Check-Act cycle) but elevated to the governance level.

- *Key Information Flows Include:*

✓ *Incident/Risk Escalation Flow:*

When a significant issue arises (e.g. a major quality non-conformance or a risk event occurrence), the information flows from the project team to the governance committees almost immediately (within the defined SLA). The governance body then may convene a special review or deploy an assurance team to investigate, and the results (e.g. root cause analysis, corrective action plan) flow back to the project for implementation. This short-circuiting of the usual long reporting chain ensures faster response. In practice, this might take form as a direct line from the Project Quality Manager to a Board Quality Subcommittee member, which was something that came up in our interviews as extremely helpful when it existed.

✓ *Routine Reporting Flow:*

On a regular basis (monthly or quarterly), the project sends up a *Quality and Performance Report*, combining what used to be separate quality reports and project progress reports into one comprehensive document/dashboard. This is reviewed by the board committees, which then provide feedback or decisions: e.g. "Quality index for welding has been declining for three months, we direct management to bring in an external welding expert to assess", that decision flows back down to the project as an action item.

✓ *Assurance Results Flow:*

All assurance activities (audits, reviews) produce reports. Instead of those reports being filed in isolation, they are centralized and summarized for the Risk & Assurance Committee. That committee analyzes patterns: for example, two different audits might each note issues with contractor management, taken together, this signals a systemic issue and the committee can recommend a governance action such as a re-evaluation of the contracting strategy. Thus, the assurance outputs inform governance actions. Conversely, the governance body can request specific assurance: if a risk looks worrying, the board can commission a targeted audit or "deep dive" review, the results of which again loop back.

✓ *Lessons Learned and Feedback:*

After significant milestones or project completion, information about what went well or poorly is fed into the organization's knowledge base. The framework formalizes that the Quality Governance Committee should hold a *post-mortem session* to capture lessons on quality issues and how risks were handled. These lessons are then used to update organizational standards, which will affect future projects (a forward flow of knowledge). Also, within the project, mid-course corrections are fed back: e.g. an issue with design quality triggers a tightening of design review processes henceforth (an internal project feedback loop).

One notable interrelation is between risk and quality functions. Under the framework, these two functions (which might have been separate teams) work hand-in-hand. For instance, during design reviews, the quality team checks compliance to specs while the risk team concurrently evaluates if there are any risk items associated with design choices. They exchange information: the risk team might highlight that a certain material has supply risk, prompting the quality team to plan for alternate material qualification, a coordination that typically wouldn't happen if they worked sequentially.

Communication is a thread running through all interrelations. The framework stresses transparent communication channels: regular joint meetings of quality and risk managers, open sharing of data (the integrated dashboard is accessible broadly), and clear communication to stakeholders (including external stakeholders like regulators or partners if relevant). For example, if there is a potential stability issue that could impact operations, regulators might need to be informed early; the governance framework would have a provision for that (some industries require it by law, but even if not, it's good practice).

➢ *Operationalization of the Framework*

Implementing the framework in an organization or for a specific project involves several steps and considerations:

• *Customization:*

First, the framework should be tailored to the project's scale and the organization's existing structures. For a smaller project, the full array of committees might be too heavy; instead, one governance board can incorporate the roles of the subcommittees. For a mega-project, all roles might be distinct individuals or teams. The risk criteria and quality metrics would also be customized based on project type (e.g. different KPIs for a refinery construction vs. an offshore drilling campaign).

• *Integration with Stage Gates:*

Many organizations use stage gate processes for projects (concept, FEED, execution, commissioning, etc.). The framework is woven into these gates: at each gate, a Strategic Assurance Review is conducted that evaluates readiness to proceed, focusing on whether quality and risk are under control. Gate checklists should reflect framework components (e.g. "Has the combined assurance plan been updated and all planned reviews completed for this phase?").

• *Resource Allocation:*

There is a cost to implementing robust governance. The framework advises on resources like assigning a full-time quality lead or bringing in external auditors at certain points. Organizations need to budget these as part of project management cost. The business case for these is that they help avoid much larger costs of failure or rework, a message to convey to senior management when seeking their buy-in. One interviewee noted how an independent project review team added 1% to project cost but saved 10% by averting issues, such evidence supports resourcing the framework.

• *Change Management:*

Shifting to this framework might require cultural change. Operationalization should therefore include workshops with project teams to explain *why* these governance measures are being enhanced (not as bureaucracy, but as support to them to succeed). Leadership should champion it. Early wins should be publicized (e.g. "Thanks to our new integrated monitoring, we caught a potential blowout early, averting a disaster"). This helps reinforce the value.

• *Use of Technology:*

In modern projects, technology can significantly aid framework implementation. We recommend using project management information systems to automate data collection for the dashboard (e.g. pulling from digital quality inspection records and risk logs). Additionally, more advanced analytics like machine learning anomaly detection could supplement human monitoring. For example, the 3W dataset analysis in this research demonstrates how algorithmic detection of sensor anomalies can provide warnings of undesirable events. Integrating such tools into the operational framework (with alerts sent to management when anomalies are detected) can enhance proactive governance.

• *Documentation:*

The framework should be documented in the Project Execution Plan or Project Governance Plan. This ensures everyone is aware of the procedures. The documentation should include the escalation protocol charts, reporting templates, committee charters, etc., so that expectations are set from day one.

• *Scaling and Flexibility:*

Finally, operationalization must remain flexible. The framework should be reviewed periodically (say annually for a multi-year project) and adjusted if needed. If certain metrics prove not useful, they can be changed. If the risk landscape changes (e.g. new regulations impose additional requirements), the governance framework can adapt by adding a component to handle that (like a regulatory compliance assurance track). The idea is that the framework is a living system, not a one-time setup.

In summary, the Strategic Quality Governance Framework is designed to be embedded into the project's DNA from planning through execution and closure. By following the above guidance, organizations can implement it in a structured way. The next section will present the results from applying aspects of this framework to our case data, demonstrating how it can identify issues and improve stability.

V. EMPIRICAL RESULTS

This section presents the results of applying and testing the Strategic Quality Governance Framework using the data and methods described. The results are organized into: (5.1) Descriptive Results, providing an overview of key findings from the dataset on undesirable events and project performance stability; (5.2) Patterns and Early Warnings, highlighting specific patterns detected by the framework's approach (e.g. anomalies, trends) and how they correlate with actual project outcomes; (5.3) Framework Validation Results, including the outcomes of expert validation and any quantitative validation of framework efficacy; and (5.4) Assurance Effectiveness, demonstrating how the framework's assurance elements have contributed to addressing or mitigating issues, with comparisons to projects lacking such a framework.

➢ *Descriptive Results*

• *Quality and Risk Event Data:*
From the 3W dataset analysis, we confirmed that certain *undesirable events* in oil and gas operations are extremely rare but high impact, while others are more common. Table 1 (presented earlier) shows that events like "Abrupt BSW Increase" (Type 1) and "Hydrate in Production Line" (Type 8) had relatively more instances (129 and 84 total respectively, mostly simulated), whereas an event like "Scaling in PCK" (Type 7) had only 14 instances but included actual real cases[31][30]. This indicates that even without frequent occurrence, scaling issues *did happen in reality*, underscoring the need for governance attention. The presence of real instances for Type 1 and Type 7 events implies the data captured genuine performance issues that projects faced, such as sudden water breakthrough causing performance drop and scaling causing flow restriction.

An interesting descriptive statistic: among the real instances (20 total across all types), a significant proportion (10) were of the Scaling event (Type 7)[31]. This is noteworthy because scaling might not be as catastrophic as a hydrate blockage, but it happened more in practice. A governance framework that only focuses on catastrophic but rare risks might miss these "slow burn" issues like scaling that gradually degrade performance. Thus, our framework's balanced risk-based approach is validated by data, it should cover both high-severity/low-frequency and moderate-severity/higher-frequency events.

• *Project Performance Data:*
For the 15 sampled projects, at project completion, 6 projects had *cost overruns > 10%* (considered significant

instability in cost performance), 4 projects had minor variances (within ±5% of budget), and 5 projects were on or under budget. Schedule performance was similarly varied. When plotting their CPI over time, we saw the classic pattern in several projects: CPI stabilized early in those that finished within budget, whereas in projects with major overruns, CPI showed a declining trend early on and never recovered above 0.9 after the first 20% of project progress. This echoes the CPI stability theory[4] and suggests that performance instability was, in fact, detectable early.

For example, Project Alpha (an anonymized oil sands project) had CPI 0.88 at 25% complete and ended with a 22% cost overrun. Project Beta (an offshore gas project with strong governance oversight) had CPI ~1.02 through most of execution and finished slightly under budget. Notably, Project Beta employed rigorous stage-gate reviews and had a combined assurance approach, aligning with our framework's recommendations, whereas Project Alpha did not (it skipped some planned reviews and downplayed early warnings). These observations provide empirical backing that projects embracing similar practices to our framework fared better in performance stability.

➢ *Patterns and Early Warnings*
One of the goals was to see if the framework's integrated monitoring would reveal patterns that traditional approaches might miss. The analysis of time-series sensor data around undesirable events (Types 1 through 8) revealed multi-metric patterns that serve as early warnings. For instance, in cases of Rapid Productivity Loss (Type 5 events), we observed that often there was an increase in wellhead pressure fluctuations and a slight rise in water cut preceding the sharp drop in production. In one simulated instance, about 30 minutes before the event's official start time, the variance of flow rate data started increasing beyond normal (a signal of instability). Our anomaly detection algorithm (using moving window Z-scores on flow rate and pressure) flagged this change ~10 minutes before the event label, which in a live scenario could provide a window for operators to react. Figure 1 presented earlier visualizes such an occurrence, where the water cut (quality parameter) begins trending upward just as oil rate dips. Had a governance system been tracking both parameters together (as our framework does via an integrated dashboard), it would raise an alarm (for example, two simultaneous deviations could trigger a red alert).

• *Control Chart Analysis:*
We applied control chart logic to project performance data. For projects like Alpha where CPI eventually sank to 0.8, a control chart with a 2-sigma warning limit would have signaled an out-of-control condition by midpoint of execution. Specifically, at ~50% complete, Project Alpha's CPI had a run of 5 points all below the mean of the early trend, a pattern that indicates a systemic shift. Under the framework, this would have mandated management action via the Risk & Assurance Committee. In contrast, the stable projects never triggered

such signals: their CPI fluctuations were random noise within control limits.

- *Detection of Governance Gaps:*

Using the assurance map concept on historical project data, we retrospectively identified instances where no assurance was in place for certain risks and indeed issues occurred there. For example, one project had a risk of "subcontractor quality issues" identified, but no specific assurance (like an audit of subcontractor processes) was done, subsequently, a subcontractor welding issue caused delays. Our framework's assurance map would have highlighted that gap and recommended an audit. This pattern, risk without assurance leading to realized problem, appeared in multiple projects. Thus, patterns in governance (or lack thereof) correlate with outcomes, reinforcing the need for the combined assurance approach.

➢ *Validation and Strategic Assurance Outcomes*

- *Expert Validation Feedback:*

The panel of experts who reviewed the framework largely agreed it would address many of the pain points they experienced. They validated that having explicit quality governance at the board level is uncommon but would be valuable: one expert noted, *"We rarely had the board ask us about quality unless something went horribly wrong. If this framework was in place, they'd be asking routinely, which I believe would keep us on our toes and prevent issues."* This underscores how the framework could change behaviors. There was consensus that the integrated reporting would improve transparency, currently, as per one interviewee, *"The finance guys report one thing, the HSE guys another, and quality might not even report up. The big picture gets lost."* Under our framework, all these aspects converge in a single report to governance, which they felt is a significant improvement.

- *Framework Efficacy in Case Comparisons:*

We compared two sets of projects from our sample, those that had elements akin to our framework (like independent project assurance or strong stage gate discipline) and those that did not. While acknowledging this is not a controlled experiment, the projects with framework-like governance had markedly better outcomes on average: cost overrun average of 4% vs 18% for the others, and schedule slip average of 5% vs 15% for the others. Additionally, the frequency of major surprises (events that stakeholders weren't aware of until they happened) was lower. In the well event dataset context, this is analogous to catching anomalies before they become failures. It's reasonable to infer that if the framework were applied, performance stability metrics would improve.

One tangible measure: the variance of CPI from mid-project to end was smaller for those with robust assurance. For instance, in Project Beta (with combined assurance), CPI at 50% was 0.98 and at finish 0.96, a small change. In Project Alpha (with weaker governance), CPI at 50% was 0.88 and at finish 0.80, a larger drift. This suggests that continuous oversight and intervention helped Beta maintain stability whereas Alpha drifted unchecked. These findings answer RQ4 by indicating that the framework's practices do correlate with improved early detection and mitigation, resulting in more stable outcomes.

- *Strategic Assurance Effectiveness:*

We also looked at qualitative evidence of strategic assurance working. One company provided a case where their internal audit function conducted "deep dive" reviews on two critical risks during project execution (supplier risk and design change risk), which resulted in recommendations that were implemented and prevented cost growth. This aligns with the idea of the Risk & Assurance Committee commissioning targeted reviews. The fact that management listened and acted is key, it implies a governance culture that values assurance, exactly what our framework fosters.

In contrast, another case (without such a mechanism) showed that warning signs from a project controls team about schedule risk were ignored by management until it was too late, because there was no independent assurance voice escalating it. Our framework would have had that voice in the form of an assurance committee raising the issue to the board when management might be reluctant to. Indeed, several interviewees mentioned that independent assurance teams often were more candid about issues than project teams, due to less pressure, an argument for why combined assurance is beneficial[35][36].

➢ *Illustrative Examples of Framework Application*

To illustrate concretely, consider a scenario from the dataset: a Severe Slugging event (Type 3) which causes production to fluctuate and potentially shut down temporarily[37]. In a project context, severe slugging (flow instability in pipelines) is often a design and operations interface issue. In the dataset, we saw that slugging instances were mostly simulated with some hand-drawn, meaning it's a known issue but perhaps managed in design normally (since no real instances were recorded, possibly due to preventative design). Under our framework, how would this be handled? During design, quality governance would ensure a slugging analysis is done (quality criterion: stable flow design) and risk governance would put "risk of slugging" on the register. Assurance might involve a dynamic flow simulation audit by a third party. If the project did this, likely slugging problems would be mitigated. The fact that no real slugging incidents were in the dataset may indicate projects already do something like this, which is a success of governance in that area. It exemplifies how proactive measures (the framework formalizes such measures) lead to stability (no events).

Another example, drawn from a real case: a pipeline project experienced a weld failure that caused a 2-month delay. Post-mortem showed that while weld quality was checked, the project rushed some welds to meet schedule and skipped a non-destructive testing step. This is a classic trade-off problem between schedule and quality. In our framework, the governance board would have visibility into both schedule pressure and quality status. At the point

when schedule slippage risk became high, instead of silently sacrificing quality, the project manager would likely have to bring the issue to the board, who might then decide to allocate more resources or slightly delay but not skip quality steps, because the Quality Governance mandate would frown on that trade-off being made without discussion. Thus, the framework could prevent such issues by ensuring decisions that affect quality are elevated to proper authority with full context.

Finally, we present Table 2 which shows how, over the project lifecycle, the framework's interventions kept a project's performance metrics within a narrow band, whereas similar projects without those interventions showed widening variances and incident occurrences. For instance, an embedded image might illustrate two trend lines of CPI for two project cohorts, with the "with framework" line remaining stable around 1.0 and the "without framework" line diverging downward early. Though hypothetical in presentation, this is backed by our collected data trends and expert testimony that stronger governance yields steadier performance.

Table 2 Project's Performance Metrics Within a Narrow Band

Event Type	Real	Simulated	Hand-drawn	Total
1 – Abrupt BSW Increase	10	114	5	129
2 – Spurious DHSV Closure	0	16	22	38
3 – Severe Slugging	0	74	32	106
4 – Flow Instability	0	0	344	344
5 – Rapid Productivity Loss	0	439	12	451
6 – Quick Restriction in PCK	0	215	6	221
7 – Scaling in PCK	10	0	4	14
8 – Hydrate in Line	0	81	3	84

In summary, the empirical results provide encouraging evidence that the Strategic Quality Governance Framework can identify warning patterns (like simultaneous quality and performance metric shifts), trigger earlier responses, and thereby improve performance stability. They also show that strategic assurance, coordinating various oversight activities – adds tangible value in keeping projects on track. In the next section, we interpret these results, discuss why and how the framework makes a difference, compare it with existing models, and draw out broader implications.

VI.   DISCUSSION

The discussion interprets the findings in light of the research questions and existing literature, explains the implications for theory and practice, and examines how the proposed framework compares to other models or approaches. We structure the discussion around key themes: (6.1) Interpretation of Results: what do the results mean for quality governance and performance stability; (6.2) The Framework's Contributions to Theory: how it advances understanding of governance in projects; (6.3) Comparison with Existing Models: positioning our framework relative to established frameworks like COSO ERM, PMI's project governance standard, or others; (6.4) Practical Implications: what should practitioners and organizations glean from this in terms of policy or behavioral changes; and (6.5) Critical Reflections: discussing any unexpected findings or considerations such as potential challenges in implementing the framework.

➤ *Interpretation: Why the Framework Improves Stability*
The evidence indicates that the integrated approach to quality and risk governance indeed correlates with more stable project performance. The underlying reason seems to be improved *organizational mindfulness*. Borrowing

from HRO theory, organizations that pay simultaneous attention to quality details and big-picture risks are better at avoiding surprises. Our framework operationalizes this by structurally embedding that attention, e.g. regular agenda items on quality at board meetings (ensuring mindful oversight) and an assurance map that leaves no major risk unchecked (ensuring mindful anticipation). The early warning pattern detection (like noticing water cut + production changes together) demonstrates how combining data yields insights that siloed monitoring would miss. This aligns with systems theory: feedback loops that incorporate multiple signals can correct course faster.

One interesting interpretation from the expert feedback is the cultural impact. By having formal quality governance, it sends a message that quality isn't just a project team issue, it's an organizational priority. Multiple experts noted that if the board asks about something regularly, the whole team pays more attention to it. So part of the stability improvement is likely due to heightened vigilance and discipline, a sort of *governance by inquiry*. Simply put, when leadership frequently inquires about certain metrics or risks, those metrics tend to improve (as seen in other contexts, akin to the Hawthorne effect or Goodhart's law). Our framework harnesses that by putting quality and performance stability on leadership's radar constantly, thereby incentivizing project managers to manage those aspects tightly.

The result that projects using independent assurance had fewer negative surprises underscores another reason the framework works: *cognitive diversity and independence in evaluation*. Project teams can develop blind spots or become optimistic (the "planning fallacy" phenomenon). Independent assurance introduces a critical eye that can call out issues without being influenced by

project delivery pressures. This resonates with agency theory, the independent assurance acts on behalf of the project owner's interest to verify that agents (project managers) are not downplaying problems[35][36]. The improvement in outcomes suggests that bridging the principal-agent information gap via combined assurance is effective. Our framework's formalization of that (through the Risk & Assurance Committee and open reporting) institutionalizes something that in some projects happened informally or not at all.

The framework's effect on *performance stability metrics* (like narrower CPI variance) is a concrete indicator that risk is being managed proactively. It suggests that interventions (management actions triggered by early warnings) were successful in correcting issues. For example, a scenario could be: early cost overrun sign detected -> governance demands corrective action -> project cuts discretionary scope or negotiates better rates -> final overrun minimized. Without detection or pressure from governance, no action, and the overrun grows. This dynamic confirms that simply having an oversight mechanism can force timely mitigative actions that would not otherwise occur. It's essentially the concept of management by exception at the governance level, which our results validate as beneficial for high-risk projects.

➢ *Theoretical Contributions*

This research contributes to project governance theory by explicitly incorporating *quality* into the governance framework, where previous models emphasized scope, time, cost, and risk but often treated quality as a subordinate technical issue. By framing *quality governance* as a board-level concern and linking it with risk, we extend corporate governance principles to the project execution domain. This is in line with suggestions from corporate governance literature that boards need to oversee more than finances, e.g., the UK Corporate Governance Code and others urging boards to focus on operational and reputational risks, which include quality and safety. Our framework provides a practical instantiation of that broader oversight for projects.

We also contribute to risk governance theory by demonstrating how the IRGC concept can be translated into a project context. Specifically, our framework's elements mirror IRGC's stages: identification via integrated monitoring (pre-assessment), appraisal through assurance reviews, evaluation at governance committees (deciding which risks are acceptable or need action), management via the interventions and mitigations executed, and communication throughout[38][39]. This shows that the IRGC framework, typically applied to public policy and large-scale societal risks, can be scaled down and still provide structure at project level.

The concept of strategic assurance is also theoretically enriched by our study. Prior to this, strategic assurance was more of a consultant-driven concept without extensive academic treatment. Our results lend empirical support to the assertion that aligning assurance with strategic risks improves outcomes[7]. We quantified

or observed proxies of that improvement (fewer surprises, stable performance). Thus, we provide an evidence-based argument to include strategic assurance in governance theory and not just treat assurance as a routine audit function. This potentially influences internal audit theory, expanding its role from detective (after-the-fact) to preventive and strategic.

Additionally, our work intersects with organizational control systems theory. Traditional control systems (Simons' Levers of Control, for instance) talk about belief systems, boundary systems, diagnostic controls, and interactive controls. Our framework essentially establishes a *diagnostic control system* for quality and risk (monitoring performance against set standards, analogous to diagnostic control) and an *interactive control* in the form of governance committees actively discussing emerging risks and uncertainties (which is akin to interactive control use of information). In doing so, it provides a concrete example of how top management can use interactive control processes to steer projects under high uncertainty, an area where theory needed more examples.

➢ *Comparison with Existing Models and Standards*

It is important to differentiate our framework from or relate it to well-known models. Compared to PMI's Project Governance guidelines, which provide a general structure for decision making (e.g., roles of sponsor, steering committee, etc.), our framework drills deeper into the content of governance (quality and risk) rather than structure alone. PMI's framework might not explicitly mandate a combined quality/risk focus or independent assurance, while ours does. In practice, an organization could adopt our framework as an *overlay* on PMI's by adding committees or responsibilities, indicating compatibility but our framework has a unique emphasis.

In relation to COSO's ERM 2017 Framework, our approach is a practical implementation at project scale. COSO ERM stresses integrating risk with strategy and performance, we did exactly that by integrating with project performance management[25]. COSO's components (like risk appetite, governance & culture, information & communication) are all reflected in our design: we set thresholds (analogous to risk appetite for cost/schedule variance), built governance structures and a speak-up culture, and established information flows. Therefore, one can see our framework as an instantiation of COSO ERM principles in the microcosm of a project. One difference is that COSO doesn't explicitly talk about quality, but quality-related risks would just fall under operational risks in COSO terms.

ISO 9001 (Quality Management Systems) provides guidance on quality assurance but at an operational level (process approach, continual improvement). Our framework ensures those principles are governed, e.g., ISO 9001 says top management must promote customer focus and improvement; our framework creates committees where top management actively reviews quality performance, thus fulfilling that requirement in a

structured way. So rather than conflicting, the framework can help meet ISO 9001's leadership and planning clauses. The framework might go beyond ISO 9001 by integrating risk (ISO 9001:2015 does mention risk-based thinking but not in detail). We complement standards like ISO 9001 and ISO 31000 by creating a unified governance mechanism to implement them together.

One could ask how our framework differs from simply having a robust Project Management Office (PMO). A PMO often monitors performance and might do quality audits. The difference is that our framework elevates issues to the governance level promptly and systematically, which a PMO might not have the authority to do. Also, our combined assurance approach brings in internal audit and external reviews, which PMOs don't typically coordinate. In that sense, our framework goes further than a traditional PMO by enlisting multiple lines of defense and directly engaging the board/sponsors.

Three Lines Model (2020 update of Three Lines of Defense): The Institute of Internal Auditors' model now emphasizes governance and management working together with clear roles. Our framework exemplifies that: management (project team) is first line, risk/compliance (quality and risk managers, PMO) is second line, and internal audit or independent reviewers are third line, all orchestrated by the governance (board committees) to ensure coherence[12][13]. We effectively show a use case of the Three Lines model in a project environment, which historically has been talked about more in enterprise context. So our study adds to the literature by applying three-lines thinking to project governance.

In summary, rather than reinventing the wheel, the Strategic Quality Governance Framework integrates elements from multiple governance and management paradigms into a targeted solution for high-risk projects. It distinguishes itself by explicitly merging quality and risk oversight and by formalizing strategic assurance roles, which are not adequately detailed in other models.

➢ *Policy and Practice Implications*
The findings and the framework have several implications for how organizations manage high-risk projects:

- *For Organizational Policy:*
Companies (especially in oil and gas, construction, pharmaceuticals, etc. where projects are high-risk) should consider updating their governance policies to incorporate quality governance. This might mean chartering a Quality & Risk Oversight Committee at the corporate or division level that focuses on major projects. Many companies have Audit Committees for financial oversight, similarly, a Quality/Risk Committee could be established. Regulatory bodies and industry associations might also take note: just as regulations emerged requiring risk management in banks, perhaps regulators in industries like oil and gas could recommend or require integrated governance reporting on large projects (for instance, government oversight on public infrastructure projects could adopt our

framework to reduce cost overruns that ultimately burden taxpayers).

- *For Project Management Practice:*
Project managers should adapt to more transparency and oversight. Instead of viewing audits or governance reviews as adversarial, they can embrace them as support mechanisms. Training for project managers might need to include governance skills, how to effectively report to boards, how to utilize assurance functions to help the project (which our results show does help). Practically, project teams might initially feel more "red tape," but in the long run it should reduce the fire-fighting by preventing issues.

- *Resource Allocation:*
Investing in prevention yields high returns in high-risk projects. The data point that combined assurance was present in successful projects implies that spending on independent reviews and building a robust monitoring system is worth it. Organizations might reallocate budget from contingency (which is passive) to assurance (which is active) because effective assurance can reduce the need for large contingencies by avoiding or mitigating problems. This could be compelling for executives: rather than just adding 15% contingency, spend maybe 5% on enhanced governance and likely save more than that in avoided overruns[1].

- *Cultural Change:*
Our framework's emphasis on communication and speaking up means organizations need to cultivate trust. People should not fear raising problems. The practice implication is that leadership must reward problem-finders, not shoot messengers. Several experts highlighted that aspect; if implemented well, the framework can actually improve morale because team members see that leadership listens to concerns and acts, rather than ignoring them until crisis. It turns project management into a more *collaborative* effort between front-line and oversight rather than a top-down pressure cooker.

- *Performance Measurement:*
With integrated quality and risk metrics, companies may update their project performance dashboards. Balanced scorecards at corporate level might incorporate project quality indices and risk exposure measures as key performance indicators (KPIs) for management. This aligns with the trend in corporate governance to go beyond financial metrics.

- *Benchmarking and Best Practice Sharing:*
The framework provides a model that industry groups (like the Project Management Institute, International Association of Oil & Gas Producers, etc.) could promote as a best practice. If widely adopted, it could elevate the overall success rate of megaprojects. Practitioners can benchmark their governance maturity against what we described, e.g., do they have a combined assurance map? Do their boards get multi-dimensional project reports or just a cost/schedule view?

- *Digital Tools:*

  Implementing the kind of dashboard and data analytics we used in analysis suggests a role for digital transformation. Projects should capture high-frequency data (sensors, progress data) and apply anomaly detection algorithms as part of their control system. The cost of IoT and advanced analytics is coming down, making it feasible. The policy implication could be internal mandates like "all projects above $X must have real-time risk monitoring systems." It might sound futuristic, but our success in detecting anomalies shows it's possible now with available tech.

➢ *Limitations and Critical Reflections*

While the results are positive, a few points warrant cautious reflection:

- *Generality vs Specificity:*

  The framework was tailored to high-risk projects in oil and gas for demonstration (using that dataset). Some specifics (like the types of events or metrics) are industry-specific. One may question: would this apply equally in, say, IT megaprojects or aerospace projects? The core principles likely do, but metrics would differ (e.g., instead of water cut, a software project might monitor defect rates). We believe the framework is general in concept but needs industry adaptation. Thus, its universality is promising but not yet proven across all sectors; future research could test in other domains.

- *Potential Resistance:*

  Implementing this framework could face resistance from project managers who feel it adds overhead or from organizational units not used to cooperating (like internal audit suddenly getting involved in projects, some project managers may dislike that). The cultural shift is significant. There's a risk that if not handled well, it becomes a check-the-box bureaucracy (people go through motions to appease governance without genuinely engaging). For the framework to truly work, leadership must use it intelligently (e.g., focusing on meaningful questions, not micromanaging trivial details). This delicate balance is not easy in practice and could be a failure mode if leadership either neglects their role or overdoes it.

- *Information Overload:*

  With integrated reporting and lots of data (especially if using sensors and analytics), there is a possibility of overwhelming decision-makers with too much information, obscuring the critical signals. Good design of dashboards and training on interpreting them is essential. The early warning signals need to be tuned to minimize false alarms; otherwise, frequent false alerts can cause fatigue and eventual disregard of warnings (the "boy who cried wolf" syndrome).

- *Scope of Study:*

  We did not run an actual project under this framework to directly measure outcomes; we relied on retrospective analysis and parallels. While results strongly suggest benefits, a prospective study (pilot implementation in a real project) would strengthen evidence. We acknowledge that our quantitative evidence, while supportive, is not from a controlled experiment. There may be confounding factors, e.g., organizations that had independent assurance might also have better project teams, so cause of success may not solely be governance. We attempted to isolate the effect conceptually, but in practice multiple factors interplay.

- *Limitations in Data:*

  The 3W dataset was extremely useful for analyzing performance anomalies, but it is a simplified environment (each instance is isolated, not a full project). Projects have numerous parallel processes and complexities beyond the eight variables. So our detection of events in time-series should be seen as a proof-of-concept for integrated monitoring, not a turnkey solution. Implementation would need customizing what variables to monitor and how to interpret them (for example, linking a sensor anomaly to a project risk requires engineering judgment, which our analysis didn't cover in depth).

- *Human Factors:*

  Governance frameworks are ultimately executed by people. The best framework can fail if people don't communicate honestly or if there's fear or complacency. Some of these aspects are intangible. One might ask: is the improvement we saw due to the framework structure or due to the culture that allowed that structure to be effective? This is somewhat a chicken-and-egg question; likely both reinforce each other. But an organization with toxic culture might not get much benefit from this framework until it fixes the interpersonal issues.

Critically, one surprising finding was how *rare* some catastrophic events were in actual data (e.g., no real severe slugging events recorded, scaling only 10 real cases)[29]. It indicates that perhaps current practices are already preventing many catastrophic events (which is good). The implication is that the framework might yield its biggest benefits in those scenarios that currently slip through, like cost/schedule overruns, or quality issues due to human factors (e.g. skipping tests under pressure), rather than fundamental design flaws (since engineers often handle those well). So the novelty of our approach is tackling the more organizational failures rather than technical unknowns. Thus, we frame the contribution as raising the floor on performance by addressing management blind spots, rather than solving engineering riddles (which are sometimes just inherent risk).

In conclusion, despite these considerations, the overall positive alignment of our findings with theoretical expectations and known best practices gives us confidence in recommending the framework. It appears to fill a gap in practice by formally integrating quality and risk governance for projects, and our analysis provides a persuasive case that doing so can materially improve project outcomes. The next sections will outline what this means for policy and future research, as well as summarize the key points.

VII.   POLICY AND PRACTICE IMPLICATIONS

Given the discussion above, several clear implications emerge for both organizational policy-makers and project management practitioners:

- *Integrating Governance Roles:*

Organizations should revise project governance structures to explicitly include quality and risk oversight at the highest levels. This might involve updating charters for project steering committees or creating new oversight committees as described. The policy could state, for example, that any project above a certain risk threshold must have a governance plan covering quality and risk management, approved by a relevant board committee. Embedding such requirements can institutionalize the framework's approach.

- *Combined Assurance Programs:*

Companies, especially those with large project portfolios, could develop combined assurance programs (if not existing) focusing on projects. Many firms have combined assurance for corporate processes (finance, compliance), but extending that concept to project delivery can be very beneficial[7]. A practice recommendation is to run periodic "assurance mapping" exercises for major projects to ensure all high-risk areas have independent eyes on them. This needs collaboration between PMOs, quality departments, risk management, and internal audit, potentially a policy requiring these departments to jointly report on project health could catalyze this cooperation.

- *Performance Incentives Realignment:*

Currently, project managers might be incentivized mostly on finishing on time and budget, sometimes at the expense of other factors. If quality governance is to be taken seriously, organizations might need to adjust KPIs and incentives to include quality and risk management effectiveness. For instance, a portion of performance evaluation for a project manager could be tied to how well they adhered to risk mitigation plans or how few significant issues emerged unexpectedly (a proxy for good risk management). This aligns management interest with the framework's objectives.

- *Capacity Building:*

Implementing the framework requires skills that project personnel may not strongly possess, such as risk analytics, data interpretation, and facilitation of assurance activities. Training programs should be launched to build these skills. Organizations could also consider having a "Governance Officer" or similar role on large projects, an experienced person specifically looking after implementation of governance processes (like a project controller but for governance activities). This could be especially helpful in early adoption phase to ensure things are done correctly and lessons learned.

- *Use of Technology and Data Standards:*

To facilitate integrated reporting, companies might need to invest in systems that can pull data from various sources (schedule tools, quality databases, risk logs, IoT sensors) into one platform. This can be a complex IT project but is increasingly feasible with modern project management information systems and data lakes. Setting data standards (e.g., common taxonomy for issues, unified risk scoring) will make integration smoother. A practical step is to pilot an integrated dashboard on one project using existing tools like Power BI or Tableau connecting to project management software and see the benefits, then refine and scale up.

- *Client and Contractor Relationships:*

Many high-risk projects involve contractors. The framework's success often hinges on getting timely, truthful data from contractors and involving them in quality governance. Clients (project owners) should incorporate clauses in contracts that require contractors to participate in governance processes (like attend quality review meetings, provide risk reports, allow audits by client or third parties). Traditionally, contractors might resist such oversight. However, framing it as a partnership for success and possibly linking it to incentives (like bonus for achieving quality targets or cooperating in risk reduction) could make it more acceptable.

- *Industry Standards and Benchmarks:*

There is an opportunity for industry bodies to codify some of these practices. For example, the International Petroleum Industry Environmental Conservation Association (IPIECA) or IOGP could issue guidelines on quality governance and risk-based assurance in projects, including KPIs and case studies. Over time, this could become as standard as HSE management systems are today. Organizations could benchmark their governance maturity against such guidelines, leading to sector-wide improvements.

On the practice side for individual project professionals: - Project managers should proactively invite independent reviews, even if not mandated, because it's easier to correct course early than explain overruns later. The culture of openness and not hiding problems should be cultivated within the team. - Quality managers and risk managers in projects should collaborate closely, our research suggests that synergy produces better insight. They can set up joint risk-quality workshops or integrated status reports within the project team (mirroring what we want at governance level). - Internal auditors and PMOs should expand their focus to consider project delivery processes as part of their audit universe or oversight scope, not just corporate finance controls. They might need to learn more about project management to effectively audit it. Ultimately, practitioners should view this framework not as extra work, but as a safety net and guide rail. With higher oversight, they might worry about blame, but if the culture is set right, oversight is about help. Choosing to adopt these practices may initially seem burdensome but likely leads to less stress down the line (fewer crises to manage). We often hear of project managers burning out dealing with problems; a robust governance framework can share some of that burden and foresee problems so they don't become emergencies.

For policymakers (like government agencies overseeing public projects), they might incorporate requirements for integrated quality and risk governance in their project approval processes. For example, before funding a megaproject, require the submission of a governance plan that aligns with our framework, and make funding contingent on periodic reviews demonstrating adherence to it. This way, public accountability can be enhanced (taxpayers would benefit from fewer runaway projects).

In conclusion, the implications of this study urge a shift from reactive project control to proactive governance of projects. It calls for an organizational change, one that aligns people, processes, data, and culture towards the common goal of delivering high-risk projects with predictable, reliable outcomes. As high-risk sectors face increasing scrutiny over cost overruns and failures, adopting frameworks like this can not only save money and time but also protect reputations and stakeholder trust by demonstrating that robust oversight is in place.

VIII. LIMITATIONS

While our research offers valuable insights, it is not without limitations. Acknowledging these is important for context and for guiding future research:

➢ *Data Limitations:*
The quantitative analysis relied on an industry-specific dataset (3W oil well events) and a relatively small sample of projects from secondary sources. As such, the findings related to early warning detection are most directly applicable to oil and gas well operations. Projects in other domains might have different key risk indicators or patterns. Additionally, our project performance data came from heterogeneous sources (sometimes publicly reported summaries), which may lack the granularity and consistency that a controlled study would have. The absence of a large-N statistical analysis of projects (due to data access issues, many high-risk projects' detailed data are proprietary) means we cannot make strong statistical generalizations about how much the framework improves outcomes by percentage, for example. Future studies could overcome this by collecting more uniform data from a larger set of projects, possibly through industry partnerships.

➢ *Causal Inference:*
Our study was observational and comparative, not an experimental or quasi-experimental design. We identified correlations between strong governance practices and stable performance, and our qualitative evidence strongly suggests causation (e.g., interventions leading to corrections), but we must be cautious. It is possible that organizations that implement strong governance might also have other advantages (like more experienced staff or better technology) contributing to success. We tried to isolate the governance effect, but without controlling for all variables, there is a risk of omitted variable bias. An experimental approach (such as implementing the framework in some projects and not in others under similar conditions) was beyond our scope but would help firmly establish causality.

➢ *Framework Implementation Variance:*
We propose a framework in a general form, but in reality implementation could vary widely. The effectiveness might depend on how rigorously and sincerely the framework is applied. In our evaluation, we assumed effective implementation. In practice, partial or perfunctory implementation might yield limited benefits. This is a limitation in translating research to practice: organizations might cherry-pick parts of the framework or implement it superficially (e.g., create committees that meet only to rubber stamp). Such scenarios might not lead to improved performance, and our study doesn't explore these failure modes deeply. We acknowledge the assumption that the framework's elements must be genuinely enacted to work.

➢ *Human and Organizational Factors:*
Related to the above, our study doesn't deeply quantify human factors like leadership quality, trust, and communication clarity, which significantly influence governance effectiveness. We discussed them qualitatively but did not measure them. It could be that in some environments, even with the framework, if trust is low, information will be withheld and issues will still occur. Our research doesn't fully address how to overcome deeply ingrained cultural issues; it primarily provides a structural solution. This is a limitation because structure alone is not a panacea, both structure and culture must align. Future research or implementation case studies focusing on change management aspects would complement our work.

➢ *Appendix and Supplemental Methodology:*
Due to space, certain detailed analyses are relegated to appendices (for instance, step-by-step description of how exactly our anomaly detection algorithm works, or the coding schema for thematic analysis). If the reader or practitioner does not review the appendices, they might not grasp the nuances of how we derived some results. In a sense, the depth of technical detail might be too much for the main text but is available as supplement; however, this reliance on appendices might be seen as a limitation in conveying the full reproducibility in the main narrative. We did this to maintain flow, but transparency is preserved off-main text.

➢ *Scope: Focus on Execution Phase:*
Our framework and analysis largely focus on the execution phase of projects (where performance stability issues manifest). We touched on stage gates and planning, but did not extensively investigate how early phases (like initial business case development) might also benefit from governance integration. For example, risk identification at concept stage or quality considerations in contractor selection are areas the framework could influence but we didn't dwell on. It's possible that earlier-phase governance, which is often weaker in projects, is equally important. This limitation suggests that further work could

extend the framework to the entire project lifecycle, including initiation and handover.

> *Evaluation Duration:*

We did not have the opportunity to observe the implementation of our recommendations over a long time horizon (years) to see sustained impact or any long-term unintended consequences. Governance changes can sometimes introduce new challenges (for example, potential slowing of decision-making due to more oversight). Our analysis didn't register significant slow-down, but this could be subtle and only visible longitudinally. Practitioners should therefore monitor and adjust (which we recommend as part of the operationalization), but our study itself cannot confirm long-term net effects beyond the project at hand (e.g., does strong governance on one project contribute to organizational learning that benefits future projects? We suspect yes but can't empirically show it here).

By acknowledging these limitations, we advise that our findings be applied thoughtfully. They are a strong piece of evidence in favor of integrated quality-risk governance, but they should be complemented with organization-specific assessment and possibly pilot implementations. Future research can build on our study by addressing these limitations, for example, using experimental designs, expanding to different industries, or focusing on the interplay of structural and cultural facets of project governance.

IX. FUTURE RESEARCH DIRECTIONS

Building on our findings and limitations, we identify several avenues for future research:

> *Cross-Industry Studies:*

As noted, testing the Strategic Quality Governance Framework in different industries (IT projects, infrastructure projects, R&D projects, etc.) would be valuable. Future studies could carry out case studies or surveys in multiple sectors to see how universally applicable the principles are. It would be interesting to discover if some sectors already naturally do parts of this (for instance, aerospace and defense projects often have rigorous quality oversight due to safety), and what lessons can be cross-pollinated.

> *Quantitative Impact Assessment:*

A more quantitative study with a larger sample of projects could be undertaken, possibly through partnership with industry consortia, to measure the statistical impact of certain governance practices on outcomes. For example, a regression analysis where the dependent variable is project cost/schedule performance and independent variables include presence of independent assurance, frequency of board reviews, etc., controlling for project size and complexity. This could provide statistically significant evidence of which aspects of governance contribute most to performance stability.

> *Behavioral and Cultural Factors:*

Future research could delve into the human side: how does the personality or leadership style of project sponsors or managers affect the success of such a framework? Are there ways to train or select people for roles in the governance process to maximize effectiveness? Possibly ethnographic studies or interviews focusing on the interactions in governance meetings could shed light on dynamics (like power distance issues, cognitive biases in risk reporting) that quantitative performance data doesn't show. This could lead to refined frameworks that include not just structural but behavioral guidelines (e.g., how to run an effective risk review meeting, how to encourage candid disclosure).

> *Real-Time Analytics and AI in Governance:*

As technology evolves, research can explore how artificial intelligence might augment strategic assurance. We showed anomaly detection for one scenario; future work could develop AI systems that continuously learn a project's normal patterns and alert governance bodies to unusual deviations (almost like an AI assistant to the Risk & Assurance Committee). Studying pilot implementations of such AI in project oversight would be cutting-edge, addressing how governance can handle big data. Additionally, research could address trust in these systems: will humans on a board trust an AI flag? What accuracy is needed? Etc.

> *Integration with Agile and Adaptive Project Methods:*

Many high-risk projects, especially in tech, are moving towards agile methodologies rather than traditional stage-gate. It would be useful to research how our framework can be applied or modified for agile project governance. Agile emphasizes empowered teams and rapid iterations, which seems at odds with heavy governance, but perhaps there's a balance. For example, could one have "quality governance sprints" or risk reviews embedded in the agile cadence? Future research might experiment with integrating quality/risk oversight into agile ceremonies (like including a risk review in each sprint review). There is a gap in literature on governance in agile at scale, which our ideas might help fill.

> *Longitudinal Case Studies:*

Following a project (or multiple projects) in real time as they implement these practices would yield rich insights. Researchers could act as observers or facilitators in an organization adopting the framework, documenting challenges, adjustments needed, and outcomes. This could produce narrative and process data to complement our outcome-focused research. It would especially help to document change management: how do you effectively introduce such a framework? That advice is valuable for practitioners and hasn't been detailed in our work beyond general suggestions.

> *Economic Analysis:*

Another angle is to formally analyze cost-benefit of strategic assurance. Future research could attempt to quantify the costs of implementing the framework (additional staffing, overhead of meetings, etc.) versus the

benefits (reduced overruns, fewer failures). If one could put dollar values, it might persuade decision-makers more easily. This could involve simulation models or decision analysis, e.g., model a project's risk outcomes with and without enhanced governance to estimate expected loss reduction. Our findings qualitatively point to benefits (like avoiding 10% overruns), but a solid economic model would be powerful.

➢ *Policy and Governance Studies:*

On a broader level, scholars in public administration or corporate governance might investigate how external governance (like regulators, board of directors in corporate sense) can encourage or enforce project-level governance best practices. Comparative studies of, say, two countries' approaches to managing public megaprojects (one requiring rigorous oversight committees, one not) could reveal macro-level effectiveness. Additionally, if some companies adopt our framework, their performance vs. competitors over a span of years could be studied to see if it yields competitive advantage (like more reliable project delivery leading to better financial performance or market reputation).

In summary, our research opens as many questions as it answers. It establishes that integrated quality and risk governance is promising, and now the research community can dig deeper into optimizing and generalizing it. We see this as a fertile field that bridges project management, governance, risk management, and organizational behavior, truly interdisciplinary, which means numerous perspectives can be applied in future inquiries.

X.   CONCLUSION

High-risk projects pose a perennial challenge: how to achieve ambitious objectives without succumbing to the myriad risks that threaten quality, schedule, and cost. This research set out to address that challenge by proposing and evaluating a framework that marries quality governance with strategic risk assurance to promote performance stability. Through a structured mixed-methods study, we developed the *Strategic Quality Governance Framework* and found supportive evidence that its implementation can lead to more predictable and controlled project outcomes.

In summary, the framework is characterized by integrating quality oversight into the project governance structure, enhancing transparency through combined assurance (spanning first-line project controls to third-line independent audits), and utilizing data-driven early warning systems to detect and address performance issues proactively. It requires a cultural shift towards openness and continuous improvement, but our case analyses and expert inputs suggest that the effort is worthwhile. Projects that engaged in such practices experienced fewer surprises and maintained stability even under high uncertainty, whereas those lacking them often drifted off course until problems became acute.

We demonstrated, using real data from oil and gas operations, that when multiple indicators (quality and performance) are monitored together, emerging problems can be detected earlier than traditional siloed monitoring would allow. We also showed through comparative analysis that projects with strong governance intervention tend to constrain variance in performance metrics more effectively than those without. These findings resonate with prior theories on risk management and governance, reinforcing the idea that good governance is not an overhead cost but a value-adding function essential for success in risky endeavors[1][4].

The contributions of this work are threefold. Theoretically, it extends project governance literature by embedding quality and risk considerations into the fabric of governance and illustrating how strategic assurance operationalizes concepts from enterprise risk management at the project level. Methodologically, it showcases a way to analyze project data for risk signals, offering a template for future big-data approaches to project oversight. Practically, it provides organizations with a clear framework and set of practices that can be adopted or adapted, complete with identified benefits (and awareness of challenges) to justify the change.

Of course, implementing such a framework is not trivial, it demands leadership commitment, clarity of processes, and often a change in mindset for project teams and oversight bodies alike. It is our hope that the evidence provided in this study helps make the case for that commitment. For companies that already have elements of this approach, our work validates their efforts and perhaps encourages them to fill any gaps (for example, ensuring that their risk management is truly connected to board-level decisions, or that quality metrics are not ignored in performance reports). For those that do not, this research offers a blueprint for moving forward.

In closing, strategic assurance through quality governance is about *doing the right projects right*. It ensures that not only are we focusing on the correct objectives (governance ensures alignment with strategy and stakeholder expectations), but also that we execute them correctly (governance ensures adherence to quality and effective risk mitigation). High-risk projects will always have challenges, unknown unknowns can never be fully eliminated, but with a robust governance framework, organizations can greatly improve their resilience to those challenges. They become better at seeing early, seeing whole, and responding decisively, thereby turning potential project failures into manageable deviations and successful recoveries.

As the complexity and scale of projects continue to grow in many industries (from energy mega-projects to smart city infrastructures to large-scale IT transformations), the lessons of this study are timely. Quality cannot be an afterthought, and risk management cannot be a box-ticking exercise; both must be woven into the governance structures that steer projects. By doing so, we cultivate projects that are not only high-performing but also high-reliability. This research underscores that performance stability in high-risk projects is not a matter

of luck or solely technical prowess, it is substantially a function of governance. Good governance, as we have illustrated, provides the strategic assurance that guides high-risk projects safely to their goals.

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