Ontological Boundaries of Quantum Project Management: Mapped and Unmapped Analogies, Theoretical Limits, and Governance Implications[1]

Robert Prieto

This paper advances the Quantum Project Management corpus by formally delineating its ontological terrain — what the framework can claim, where its analogies hold with rigor, and what remains unmapped.

Abstract

Quantum Project Management (QPM) has emerged as a compelling theoretical framework for understanding and governing large complex projects (LCPs) through structural analogies drawn from quantum mechanics and relativistic theory. While QPM's mapped analogies — superposition, entanglement, decoherence, uncertainty, observer effects, and decay — have demonstrated substantial explanatory power, the field now requires explicit ontological mapping: a formal delineation of what the framework can and cannot claim. This paper addresses that need directly, charting the full landscape of QPM's analogical territory: those quantum phenomena that map rigorously onto project behaviors (mapped analogies), those that do not yet map with sufficient structural correspondence (unmapped territory), and the theoretical limits beyond which QPM's explanatory architecture breaks down.

The paper further integrates the concept of project internalities — intrinsic human-performance conditions such as fatigue that shape system behavior from within — as boundary-marking state variables that sit at the intersection of QPM's quantum-inspired framework and the irreducibly human character of project execution. Governance implications are developed throughout, with particular attention to the Quantum Fragility Index (QFI) as a coherence-sensitivity instrument that operationalizes QPM's boundary conditions and makes them observable in real project systems. The paper concludes that QPM's ontological boundaries are not weaknesses but structural features that define the framework's proper domain, distinguish it from metaphor, and point toward the next generation of theoretical development in large-scale project science.

1. Introduction: The Ontological Question in Quantum Project Management

Every serious theoretical framework reaches, at some point in its development, an ontological crisis of confidence. Early adopters embrace the framework's explanatory power and conceptual elegance; critics question whether its analogies are rigorous or merely rhetorical; and the framework itself must either consolidate into a mature theory with a defined domain or risk

[1] How to cite this paper: Prieto, R. (2026). Ontological Boundaries of Quantum Project Management: Mapped and Unmapped Analogies, Theoretical Limits, and Governance Implications, *PM World Journal*, Vol. XV, Issue XI, November.

© 2026 Robert Prieto

diffusing into unfalsifiable generality. Quantum Project Management (QPM) has reached precisely this point. Having established — through foundational papers, monograph synthesis, and empirical case experience — that quantum and relativistic physics offer structural analogies genuinely illuminating for large complex projects, QPM must now answer with precision: What, exactly, does this framework claim? What behaviors does it explain, what phenomena does it not explain, and under what conditions does its explanatory architecture break down?

This is the ontological question, and it is not an abstract philosophical exercise. It has direct practical consequences for how QPM is applied, how its instruments are designed, how its governance recommendations are justified, and how its claims are tested. A framework that cannot specify its own boundaries cannot be used responsibly. A theory that claims to explain everything explains nothing.

The urgency of the ontological question is amplified by the persistent failure of classical project management at scale. Despite six decades of methodology refinement — from PERT to PMBOK, from earned value management to agile adaptations — the failure rate of large complex projects remains stubbornly anchored at approximately two-in-three. Cost overruns, schedule extensions, and scope degradation are not aberrations in the delivery of megaprojects; they are the modal outcome. This is not a failure of execution discipline. It is a failure of the theoretical paradigm within which execution is organized.

Classical project management inherits its ontological assumptions from Frederick Winslow Taylor's Scientific Management (Taylor 1911) and Henri Fayol's (Fayol 1916) administrative principles: work is decomposable into bounded units, performance is measurable against deterministic standards, complexity is reducible through hierarchical organization, and outcomes are predictable through sufficiently detailed planning. These assumptions hold reasonably well for projects of modest scale operating in stable environments. They fail systematically at the scale and complexity of large complex projects, where the project ceases to be a closed machine and becomes, in effect, a gravitational body reshaping the environment in which it operates.

QPM emerged as a response: not an incremental improvement to classical project management but a paradigm replacement — a recognition that at the scale and complexity of LCPs, a fundamentally different ontological category of phenomena obtains. The foundational QPM work explicitly positioned itself not as a final answer but as an opening: "It is not the final word on this new framework but rather a framework to see more, know more, and importantly, do better" (Prieto 2025). This paper accepts that positioning and extends it: by mapping QPM's ontological terrain with precision, we move the framework from fertile hypothesis toward a mature theoretical system with defined scope, acknowledged limits, and clear pathways for extension.

Three research questions organize the paper's inquiry:

RQ1: Which quantum physics phenomena map rigorously and usefully onto behaviors observed in large complex projects, and with what structural basis does each mapping rest?

© 2026 Robert Prieto

RQ2: Which quantum phenomena do not yet map onto project behaviors with sufficient structural correspondence, and what does this unmapped territory reveal about QPM's next theoretical frontier?

RQ3: What are the theoretical, governance, and measurement limits of QPM, and how can they be productively encoded — as structural features of the framework — rather than avoided or concealed?

The paper proceeds as follows. Section 2 establishes the theoretical foundations of QPM's departure from classical project management. Section 3 charts QPM's mapped analogical territory in systematic detail, culminating in a summary comparison table. Section 4 identifies unmapped and frontier territory — phenomena that remain intellectually provocative but structurally ungrounded. Section 5 develops the theory of project internalities as boundary-marking state variables. Section 6 introduces the Quantum Fragility Index (QFI) as QPM's primary operationalization of its boundary conditions. Section 7 addresses QPM's theoretical limits directly. Section 8 synthesizes governance implications. Section 9 concludes.

2. Theoretical Foundations: The Departure from Classical Project Management

2.1 Research Methodology

This paper employs **interpretive theoretical synthesis informed by abductive reasoning** — a recognized and well-established methodology in management theory and systems science whose three-stage structure is described below. The choice of methodology is deliberate and appropriate to the paper's purpose: delineating the ontological terrain of a developing theoretical framework is not a hypothesis-testing exercise amenable to positivistic design, nor is it a purely interpretivist exercise relieved of any obligation toward empirical testability. It occupies a third position — one that combines the conceptual rigor of systematic analogical reasoning with the evidential discipline of publicly available empirical grounding and the intellectual honesty of explicit falsifiability specification.

Stage 1 — Systematic Analogical Mapping. The paper's primary method is the structured mapping of quantum physics phenomena against observed behaviors of large complex projects. Analogical reasoning is a legitimate and productive methodology in theoretical framework development provided it is applied with defined quality criteria rather than as a vehicle for creative metaphor. The quality criterion applied throughout this paper is structural correspondence: for an analogy to be admitted as a mapped analogy — as opposed to a frontier or excluded phenomenon — it must rest on a shared formal or behavioral logic between the quantum phenomenon and the project behavior, not merely superficial resemblance or linguistic convenience. This criterion is applied consistently across all candidate phenomena considered in Section 3 and is the mechanism by which the paper distinguishes its rigorous analogies from the unmapped territory catalogued in

© 2026 Robert Prieto

Section 4. Phenomena that do not meet the structural correspondence criterion are not presented as QPM claims; they are presented as frontier zones requiring further theoretical development before the correspondence can be asserted with confidence.

Stage 2 — Abductive Inference. Where Stage 1 maps individual phenomena, Stage 2 draws the broader theoretical inference that the pattern of successful analogies supports. The paper proceeds abductively — inferring the best available theoretical explanation for a class of observed phenomena (the systematic failure of large complex projects at rates that classical project management cannot adequately explain) from a combination of theoretical frameworks, empirical base rates from publicly available research, author's experience from structured and unstructured analysis, using professional experience[2], of 125 projects with values in excess of $1 billion, and the structured analogical reasoning of Stage 1. Abductive inference — reasoning from observed effects to the most plausible causal structure — is the recognized methodology of theoretical framework development in the management sciences (Peirce 1903; Weick 1989). It is the most appropriate method for a paper whose purpose is to establish and bound a theoretical framework rather than to test a specific hypothesis against a controlled dataset. The empirical base rates that ground this inference — drawn from Flyvbjerg and Gardner (2023), Merrow (2011), Lyneis, Cooper and Els (2001), and others — are presented in Section 2.2 and constitute the independently verifiable evidential foundation against which the framework's explanatory claims can be assessed.

Stage 3 — Falsifiability Specification. The paper departs from purely interpretivist methodology by including explicit falsifiability conditions in Section 7.5. This departure is deliberate. A theoretical framework that cannot specify the conditions under which its claims would be shown to be wrong is not a scientific framework — it is a narrative. QPM aspires to be more than a narrative, and the falsifiability conditions of Section 7.5 are the mechanism through which that aspiration is made concrete and testable. The paper's overall methodological stance is therefore best characterized as **falsifiability-inclusive interpretive synthesis**: a position that combines the interpretive theory-building of Stages 1 and 2 with the positivistic accountability of Stage 3, positioning the paper as a bridge between theoretical elaboration and empirical science. The formal retrospective and prospective testing program described in Section 9.1 provides the structured pathway through which that bridge will be crossed in the next stage of QPM's development.

This three-stage methodology is not a novel invention. It is the method that major theoretical advances in the management and organizational sciences have consistently employed when a new class of phenomena required a new explanatory framework. The paper's contribution is to apply this method with sufficient rigor and transparency that its results can be independently evaluated, its analogies independently tested, and its falsifiability conditions independently pursued — producing a foundation that subsequent empirical work can build upon rather than a closed system that subsequent work cannot challenge.

[2] These projects constitute professional experience and qualitative practitioner observations rather than a formally sampled research dataset.

© 2026 Robert Prieto

2.2 The Empirical Foundation of QPM's Departure

A theoretical framework that proposes to replace or substantially augment an established body of practice carries an evidentiary obligation: it must demonstrate that the framework it departs from is failing, must quantify the scale and character of that failure with independently verifiable evidence, and must show that the failure pattern is structural — arising from properties of the domain itself — rather than incidental and correctable through better application of existing tools. QPM meets this obligation through three empirical propositions, each grounded in publicly available research drawn from multiple independent sources across different project types, geographies, and institutional settings.

Empirical Proposition 1: Classical Project Management Fails Systematically at LCP Scale

The most comprehensive available evidence on large project outcomes comes from the reference class research of Flyvbjerg and Gardner (2023), whose database of more than 16,000 projects across all major project types and global geographies establishes the following base rates: only 0.5% of large projects deliver on budget, on time, and with promised benefits; only 8.5% deliver on budget and on time (Flyvbjerg and Gardner, 2023). These are not sector-specific anomalies. They hold across transport infrastructure, energy, buildings, defense programs, and information technology. The finding is corroborated at the level of industrial megaprojects — those above USD $1 billion in total installed cost — by Merrow (2011), whose analysis of 514 megaprojects with a median cost of USD $3.6 billion finds a success rate of approximately 50% against basic performance criteria of cost, schedule, and production performance. Lyneis, Cooper and Els (2001), in a more granular analysis of ten complex development projects, document mean schedule overruns of 55% and mean budget overruns of 86% after controlling for scope change.

These are not findings that improvements in scheduling discipline, risk register maintenance, or stakeholder communication planning can address. McKinsey Global Institute (2013) reviewed more than 400 infrastructure case studies and found that construction sector labor productivity in the United States, Germany, and Japan had improved by approximately zero percent over the preceding twenty years — a finding that indicates the failure is structural, not executional. Large complex projects are failing consistently, at scale, across project types and geographies, in the hands of experienced practitioners operating within the frameworks that the profession's governing bodies recommend. This is the empirical condition that creates the theoretical need for QPM.

Empirical Proposition 2: Disturbance Propagation in LCPs Is Non-Linear and Cascade-Driven

Classical project management's corrective action framework assumes, implicitly, that disturbances are proportionate: a small problem generates a small consequence, detectable and correctable through the standard monitoring and control cycle. The empirical evidence from complex project research consistently refutes this assumption. Eden, Williams, Ackermann and Howick (2000), in their study of disruption and delay dynamics in major projects, document that small disturbances

© 2026 Robert Prieto

cause consequences far beyond their direct impact through self-reinforcing feedback loops — rework generating demotivation generating productivity loss generating workarounds generating more rework — in which assumption invalidation is the primary propagation mechanism. Lyneis, Cooper and Els (2001) quantify this cascade in a controlled case study: the Peace Shield Air Defense System case produced a staffing amplification factor of 1.67, with rework accounting for more than 50% of total design effort at project peak, against an original plan that anticipated neither the secondary staffing surge nor the rework concentration.

Cooper (1994) identifies the information-lag dimension of cascade propagation through the "90% syndrome" — the empirical finding, documented across dozens of complex design and construction projects spanning power plants, aerospace, electronics, and shipbuilding, that work reported as 90% complete frequently reflects actual completion of approximately 70%. The gap between reported state and actual state — the information lag that QPM designates as T_3, Time-to-Truth — means that the disturbance has already propagated for weeks or months before the governance system receives its first signal. The cascade is not a future risk at the point of first detection; it is already underway. A governance architecture calibrated to detect and respond to proportionate disturbances through periodic reporting cycles is structurally incapable of intercepting non-linear cascade events whose propagation timescale is shorter than the reporting cycle.

Initial empirical analysis of the QPM portfolio suggests that T_3 operates through multiple simultaneous information channels — financial, schedule, internality, narrative, change-order process, and suspension — each with distinct lag dynamics, a finding developed further in Prieto 2026e.

Empirical Proposition 3: LCP Outcome Distributions Are Fat-Tailed, Not Normal

The standard project risk management assumption — that schedule and cost outcomes cluster around an expected value with manageable variance, amenable to Monte Carlo simulation from triangular or beta distributions — is empirically refuted by the outcome distributions that large complex project data actually produces. Flyvbjerg and Gardner (2023) document that 28% of rail projects and 55% of nuclear projects produce outcomes in the statistical "fat tail" — more than 50% over budget. The mean cost overrun for projects that enter the fat tail is +116% for rail and +204% for nuclear. Olympic Games projects enter the fat tail 76% of the time with a mean fat-tail overrun of +200%. These are not extreme outliers distorting an otherwise normal distribution; they are a structural feature of the distribution itself — one that reflects the presence of irreducible uncertainty of a kind that cannot be adequately captured by variance around an expected mean.

Merrow (2011) characterizes this distributional property as the fundamental governance challenge of megaprojects: they do not tend to go somewhat wrong when things become problematic — they fall apart. The bimodal character of megaproject outcome distributions, with successful projects clustering near zero overrun and failed projects clustering at overruns of 40% or more, is inconsistent with the continuous, manageable risk distributions that classical project management's

© 2026 Robert Prieto

quantitative risk analysis techniques are designed to handle. It is, however, entirely consistent with a system operating in a regime of quantum-like irreducible uncertainty — one in which the act of measuring the project's state perturbs it, in which coupling between project elements creates non-local dependencies invisible to reductive analysis, and in which the outcome distribution is determined as much by the project's structural properties as by its execution quality.

From Empirical Foundation to Theoretical Framework

These three empirical propositions — systematic failure at scale, non-linear cascade propagation, and fat-tailed outcome distributions — collectively define the phenomenon that QPM is constructed to explain and govern. They are not findings that the QPM framework has generated; they are independently documented features of large complex project behavior, established by researchers with no stake in QPM's theoretical claims, using datasets and methodologies that predate QPM's development. The framework's mapped analogies, governance instruments, and boundary conditions, presented in Sections 3 through 7, are responses to this empirical reality — not claims made in advance of evidence but interpretations of evidence that has existed, largely unintegrated into a coherent theoretical framework, for the past two decades. Section 3 begins the systematic mapping of quantum phenomena onto the project behaviors that this evidence describes.

The Paradigm Transition

The intellectual lineage of classical project management is well documented and deeply rooted in the Newtonian paradigm of deterministic, decomposable systems. Taylor's Scientific Management (1911) established the foundational premise: work can be analyzed into its smallest constituent tasks, each optimized independently, and the optimized whole will exceed the performance of any unmanaged system. Fayol's administrative principles extended this logic to organizational hierarchies, establishing planning, organizing, commanding, coordinating, and controlling as the universal functions of management. Both frameworks share a core ontological assumption: systems are machines, and machines are best understood through reduction.

The transition of this paradigm into project management proceeded through a series of formative moments. The Manhattan Project confronted scale and uncertainty in new ways but remained fundamentally committed to hierarchical decomposition and technical determinism. The Program Evaluation and Review Technique (PERT), developed in the late 1950s for the Polaris missile program, introduced probabilistic time estimates — a partial concession to uncertainty — but its primary function was reassurance rather than analysis: demonstrating to Congress that a complex defense program was under rational control. Robert McNamara's subsequent mandate of PERT and its derivatives across the Department of Defense institutionalized the classical paradigm at governmental scale.

The Project Management Body of Knowledge (PMBOK), first published in 1987 and subsequently revised through multiple editions, codified classical project management into a universal

© 2026 Robert Prieto

prescription applicable, in the framework's own terms, to "most projects most of the time." The phrase reveals that the framework has limits while declining to specify them. QPM's foundational contribution is to specify precisely where those limits lie and to offer a theoretically grounded alternative for the territory beyond them.

Why does the classical paradigm fail at scale? The answer is structural, not executional. Consider what a large complex project does to its environment. A major infrastructure program — a bridge, a highway system, a liquefied natural gas facility, a nuclear plant — pulls labor markets, material supply chains, regulatory attention, political capital, and community expectations toward itself with the force of a massive gravitational body. The project does not operate within its environment; it reshapes it. Workers commute from distant regions. Supply chain capacity for specialized components becomes globally constrained. Regulatory bodies that had not contemplated projects of this scale must develop new frameworks in real time. Community relationships that were not stakeholder considerations in the project's original scoping become existential determinants of its completion.

This gravitational dynamic — explicitly developed in QPM through the "bowling ball on a rubber sheet" analogy from Einstein's general theory of relativity — is the first pillar of QPM's theoretical architecture. Just as a massive object curves spacetime around it, distorting the paths of nearby objects, a megaproject curves its operating environment, distorting the flows of labor, capital, regulatory attention, and political will that determine project outcomes. The classical project management toolkit — critical path analysis, earned value management, risk registers — was designed for a flat spacetime, a Newtonian environment in which the project is a closed system interacting with a stable and predictable context. It was not designed for curved spacetime. It cannot model gravitational effects because its ontological architecture does not include them.

The second pillar of QPM's theoretical architecture draws from quantum theory: superposition, entanglement, wave function collapse, decoherence, uncertainty, and measurement effects. QPM does not claim that project managers must solve Schrödinger's equation or apply quantum computing to scheduling algorithms. It claims something more fundamental and more useful: that the structural behaviors observed in large complex projects — the coexistence of multiple potential outcome states, the non-local interdependence of work packages and stakeholder systems, the irreversible degradation of coordinated performance, the structural limits on simultaneous knowledge of scope and cost — are better modeled by the conceptual architecture of quantum physics than by Newtonian mechanics.

This is a claim about ontological appropriateness, not mathematical equivalence. As the foundational QPM work stated explicitly: "This isn't metaphorical flourish. It was a recognition that projects are dynamic systems, not deterministic machines" (Prieto, 2025). The quantum-inspired framework does not replace technical project management disciplines; it provides the theoretical container within which those disciplines can be properly understood and applied. It explains why certain classical tools work at small scale and fail at large scale. It provides a

© 2026 Robert Prieto

structural basis for governance recommendations that classical project management can only assert empirically.

The ontological departure from classical project management is therefore not merely a change of vocabulary. It is a change in the fundamental category of questions being asked. Classical project management asks: How do we optimize performance within a deterministic system? QPM asks: How do we govern a complex, entangled, coherence-dependent system operating under irreducible uncertainty? These are different questions. They require different theoretical frameworks. QPM provides that framework — and this paper defines its boundaries.

2.3 QPM and Systems Thinking: Open Soft Systems as the Appropriate Ontological Class

2.3.1 The Hard Systems Assumption and Its Limits

Every theoretical framework rests on an implicit ontological assumption about the nature of the domain it governs. Classical project management's implicit assumption is that a project is a **hard, closed system**: one whose boundaries can be precisely defined, whose components can be exhaustively enumerated, whose behavior can be deterministically modelled, and whose optimal state can be specified in advance and progressively achieved through structured decomposition, sequential execution, and variance-controlled monitoring. This assumption is not stated explicitly in the PMBOK Guide or in the professional formation of project managers trained within its architecture — it is embedded in the framework's structure, expressed through the prescriptive linearity of its process groups, the decomposition logic of its work breakdown structure, and the deterministic relationships of its critical path method.

The assumption is not wrong in absolute terms. For projects of limited scale, well-understood technology, stable stakeholder environments, and low interdependency between work packages — the class of projects for which classical project management was developed — it is an adequate working approximation. But for Large Complex Projects, it fails structurally. The empirical evidence presented in Section 2.2 documents that failure: systematic outcomes that the hard systems framework cannot explain and its tools cannot prevent. The question this section addresses is not whether classical project management's hard systems assumption fails at LCP scale — Section 2.2 establishes that it does — but what the correct ontological characterization of an LCP is, and what theoretical traditions have developed the tools appropriate to systems of that character.

2.3.2 Soft Systems Methodology as the Appropriate Ontological Frame

The answer to that question is found in the systems thinking tradition, specifically in Checkland's Soft Systems Methodology (SSM), developed over two decades of action research in organizational and industrial settings (Checkland 1981); Checkland and Scholes 1990). SSM was constructed precisely to address systems that the hard systems approach cannot govern: **open human-activity systems** whose properties cannot be fully specified in advance, whose boundaries are contested rather than fixed, whose behavior is shaped by the purposeful human actors within

© 2026 Robert Prieto

them, and whose stakeholders hold different and legitimately different worldviews — what Checkland terms *Weltanschauungen* — that constitute, rather than merely interpret, what the system is and how it behaves.

This is not a description that resembles a Large Complex Project. It is a description of one. The defining properties of LCPs — multiple contracting organizations with divergent commercial interests, regulatory environments whose requirements evolve during execution, technology assumptions that are invalidated by the act of attempting to realize them, human workforces whose motivational states are system properties rather than system inputs — are exactly the properties that make a system open and soft in Checkland's sense. The boundary between the project system and its environment is not a fixed contractual perimeter; it is a permeable and shifting interface through which regulatory decisions, market conditions, design evolutions, and organizational culture changes continuously flow. Any theoretical framework that treats it as fixed will systematically misread the system it is attempting to govern.

SSM's foundational distinction between **hard systems thinking** — which assumes the world can be modelled as a system with an objective, optimizable structure — and **soft systems thinking** — which treats "system" as an intellectual construct imposed on a complex reality by purposeful human actors with different perspectives — maps directly onto QPM's departure from classical project management as described in Sections 2.1 and 2.2. QPM's ontological claim is not that quantum mechanics literally governs project behavior; it is that quantum mechanics provides the most structurally accurate analogical framework for a class of systems that are fundamentally open, observer-dependent, irreducibly uncertain, and non-locally coupled — properties that SSM identified empirically and QPM now characterizes formally.

2.3.3 Entanglement Mapping as the Formal Analog of SSM's Rich Picture

SSM's primary diagnostic instrument for open soft systems is the **rich picture**: a holistic, multi-perspective representation of a complex situation that surfaces the human, social, political, and structural dimensions of the system before any formal modelling begins. The rich picture resists reductive decomposition by design; its purpose is to make visible the interdependencies, power relationships, conflicting worldviews, and informal communication structures that a conventional system diagram suppresses in the act of formalizing. Rich pictures are not aesthetic choices; they are epistemological commitments — assertions that the system's important properties cannot be captured by any decomposition that loses the connections between its parts.

QPM's entanglement mapping methodology, described in Section 3.2 and developed in full in the operational volumes of the QPM framework, is the formal, mathematically grounded elaboration of precisely this intellectual move. Where SSM's rich picture makes implicit coupling visible through qualitative representation, QPM's entanglement map makes it explicit through a weighted graph whose edges carry coupling class designations, assumption-content weights, and propagation probability coefficients. Both instruments rest on the same foundational insight — that the project system's most consequential properties reside in the connections between its

© 2026 Robert Prieto

elements rather than in the elements themselves — and both are constructed through facilitated, multi-perspective elicitation from project participants whose different worldviews are treated as informative rather than as noise to be filtered. **QPM provides the formal mathematical and governance instruments that SSM's qualitative methodology does not itself provide;** SSM provides the epistemological framework within which QPM's formalizations are most appropriately understood and deployed.

2.3.4 Beer's Viable System Model and QPM's Multi-Tier Governance Architecture

A second major systems thinking tradition with direct structural relevance to QPM is Beer's Viable System Model (VSM), developed in Beer (1985) as a framework for understanding the conditions under which complex systems maintain viability — the capacity to survive and adapt in a changing environment. The VSM specifies five recursive system functions that any viable system must perform: implementation, coordination, control, intelligence, and policy. Critically, the VSM holds that these functions must be nested recursively at multiple levels of the system simultaneously, and that failures of viability typically arise not from the failure of any single function but from the failure of the recursive connections between levels — from information that does not flow appropriately between the system's operational, managerial, and strategic layers.

QPM's three-tier governance architecture — the daily operational Forum, the twice-weekly Temporal Fragility Review Board, and the monthly Executive Governance Session — extends qualitative methods with governance instruments of the VSM's recursive viability functions applied to the temporal governance of large complex projects. The daily FCP performs the VSM's implementation and coordination functions at the workfront level. The TFRB performs the control and intelligence functions at the program level. The EGS performs the policy function at the strategic level. The information flows that connect these tiers — the TFHP dashboard, the MTHR report, the QFI-S composite — are the VSM's recursive communication channels, designed to ensure that viability information flows between levels at the frequency and resolution appropriate to each level's decision-making timescale. Beer's VSM provides both a theoretical precedent for QPM's multi-tier architecture and a diagnostic framework for identifying governance failures that arise when the recursive connections between tiers break down — when information that should trigger a Tier 3 decision is consumed at Tier 1, or when Tier 3 policy decisions are made without the intelligence that Tier 2 is designed to provide.

2.3.5 Senge's Systems Archetypes, Internalities, and the People Dimension

The third systems thinking tradition directly relevant to QPM is Senge's learning organization and systems archetypes framework (Senge 1990). Senge's systems archetypes — the recurring patterns of system behavior that emerge from the interaction of feedback loops in complex human organizations — describe dynamics that QPM's decoherence and cascade mechanisms formalize in quantum-inspired terms. Senge's "limits to growth" archetype, in which a reinforcing growth process is progressively undermined by a balancing constraint that the system fails to address, is

© 2026 Robert Prieto

the systems dynamics description of what QPM's decoherence model describes at the level of schedule network coherence: a project whose execution accelerates past the point at which its assumption base can sustain coherent execution generates its own decoherence. Senge's "shifting the burden" archetype, in which symptomatic solutions relieve pressure while the fundamental problem worsens, is the systems description of what QPM's WDEC (Wrong-Direction Execution Cost) model quantifies: the accumulation of execution cost against invalidated assumptions while the governance system addresses symptoms rather than the structural failure that generates them.

Most directly QPM should engage with "the people impact on project progress" that Senge's framework, and SSM more broadly, make impossible to ignore. The systems thinking tradition has insisted from its inception that the human dimensions of complex systems — motivation, culture, learning, mental models, power, and trust — are not noise in the system but constitutive features of it: properties that determine the system's behavior as fundamentally as its technical architecture. QPM's internalities framework, developed in Section 5, is the mechanism through which this systems thinking insight is incorporated into the QPM governance model. Fatigue, psychological safety, trust degradation, decision fatigue, motivational decay, and cognitive load are not human factors peripheral to the schedule governance problem; they are state variables of the project system that determine the system's coherence, its cascade susceptibility, and its governance responsiveness. They are, in Checkland's language, the human-activity dimensions of an open soft system — and their formal treatment through the FRI and the broader internalities taxonomy is QPM's answer to the systems thinking tradition's longstanding insistence that no framework which ignores them can adequately govern the class of systems they inhabit.

3. QPM's Mapped Analogical Territory

This section constitutes the paper's core analytical contribution: a systematic enumeration of the quantum physics phenomena that map rigorously onto observed behaviors in large complex projects. For each mapped analogy, the following structure is maintained: (a) the quantum physics phenomenon, (b) the project management analog, (c) the structural basis for the mapping, and (d) the governance implications. A summary comparison table concludes the section.

The criterion for inclusion in the mapped category is structural correspondence: the analogy must rest on a shared formal or behavioral logic between the quantum phenomenon and the project behavior — not merely superficial resemblance or linguistic convenience. This criterion is what separates QPM's mapped territory from metaphor and from the unmapped frontier discussed in Section 4.

3.1 Superposition: Multi-Path Project States

Quantum physics phenomenon. In quantum mechanics, a quantum system exists in multiple states simultaneously until the act of measurement causes the wave function to collapse to a single definite state. This is not a statement about observer ignorance — it is a statement about the physical reality of the system. A particle in superposition does not have a hidden definite position that we merely do not know; it genuinely occupies multiple states simultaneously until measured.

© 2026 Robert Prieto

Project management analog. Large complex projects during planning and early execution exist in multiple potential outcome states simultaneously — multiple cost trajectories, schedule paths, scope configurations, and risk profiles — none of which collapse to a single deterministic path until specific decision-forcing events function as measurement events. A project that has been scoped but not contracted exists in superposition across multiple viable technical approaches, delivery strategies, and commercial structures. Contractual commitment, regulatory approval, organizational commitment of key leadership, and similar decision-forcing events function as measurement events: they collapse the project's state space toward a specific trajectory.

QPM operationalizes this insight by advocating for parallel solution development rather than premature convergence on a single approach. The pressure in classical project management to establish a single baseline early — driven by contractual, political, and organizational forces — functions as a premature measurement event, collapsing the project's state space before the full landscape of options has been adequately characterized. The cost of this premature collapse is not visible in the collapsed state; it appears later, in the form of change orders, schedule variance, and rework costs that represent the suppressed optionality reasserting itself.

Structural basis for mapping. Both the quantum phenomenon and the project behavior involve probability amplitude distributions over multiple states. In both cases, the collapse to a single state is triggered by external interaction rather than internal determinism. In both cases, premature or forced measurement degrades the quality of the collapsed state. The structural correspondence is strong and has been validated across multiple project types.

Governance implications. Governance systems should be designed to resist premature collapse - resisting artificial schedule commitments, false certainty in early cost estimates, and single-path planning mandates. Option analysis should be embedded in governance stage gates, with explicit valuation of the optionality being preserved or surrendered at each decision point. The QPM governance principle is maintain state optionality as long as the cost of preserving it is less than the expected value of the options being held.

3.2 Entanglement: Non-Local Project Interdependence

Quantum physics phenomenon. Quantum entanglement describes a condition in which two or more particles become correlated in such a way that the quantum state of each particle cannot be described independently of the others, regardless of the spatial separation between them. Measuring the state of one entangled particle instantaneously determines the state of the other — a phenomenon Einstein famously (and reluctantly) characterized as "spooky action at a distance" (Einstein 1971).

Project management analog. In large complex projects, work packages, stakeholder commitments, regulatory conditions, and organizational units are entangled — changes in one propagate across the project system in ways that defy the classical assumption of bounded work breakdown structure independence. The WBS, which is the organizing framework of classical project management, assumes that work packages can be defined, estimated, and managed with

© 2026 Robert Prieto

reasonable independence from one another. In large complex projects, this assumption fails systematically. The state of a regulatory approval process is entangled with the state of a procurement package, which is entangled with the state of a supply chain relationship, which is entangled with the state of an engineering design iteration.

QPM's formal wave function expression (Prieto 2024) captures this:

$$\Psi_{\text{LCP Actual}} = \Psi_{\text{LCP Classical/Bounded}} + \sum_{i=1}^{n} \Psi_{\text{Stakeholder } i}$$

The true project wave function is not the bounded classical description — the scope, schedule, and cost baseline — but the full superposition of the classical description with the wave functions of all external entanglements. Stakeholders are not exogenous variables to be managed at the project's periphery; they are constituent elements of the project's actual state space. Changes in their states change the project's state, whether or not the classical project management system has a mechanism to represent or model this.

The Hyperion analogy (Prieto 2024) illuminates the consequence: Saturn's moon Hyperion exhibits chaotic orbital behavior not because it is subjected to single large perturbations but because it accumulates small entanglements — with dust particles, photons, and minor gravitational bodies — whose cumulative effect produces chaotic dynamics that no single-perturbation model can predict. In the same way, large complex projects exhibit chaotic outcome distributions not because any single stakeholder disruption is dominant but because the cumulative entanglement of multiple stakeholders, each individually manageable, produces system-level dynamics that classical project management cannot model.

Structural basis for mapping. Both phenomena involve non-separable system descriptions: the system cannot be correctly characterized by analyzing its parts independently. Both produce incorrect predictions when local analysis is applied to a globally entangled system. The structural correspondence is strong and directly applicable to project system design.

Governance implications. Classical WBS-based governance systematically underestimates entanglement risk because it is architecturally blind to non-local interdependencies. QPM governance must include explicit entanglement mapping — identification of the stakeholder and institutional wave functions that constitute the actual project state space — and continuous alignment management designed to maintain coherence across the entangled system. Governance reporting must surface entanglement signals, not merely internal performance metrics.

3.3 Decoherence: Coherence Loss and State Degradation

Quantum physics phenomenon. Quantum coherence — the condition that enables superposition and entanglement to produce quantum-characteristic behaviors — degrades through environmental interaction, a process called decoherence. As a quantum system interacts with its environment, its quantum information leaks into the environment irreversibly, causing the system

© 2026 Robert Prieto

to behave in an increasingly classical manner. Decoherence does not require a deliberate measurement; it occurs through any environmental interaction that carries information about the system's state.

Project management analog. Project coherence — the shared interpretive alignment of teams, leadership, and stakeholders around strategic business outcomes, technical approaches, and organizational priorities — degrades under environmental pressure. Schedule crises produce defensive siloing. Leadership changes introduce interpretive discontinuities. Scope creep erodes the shared understanding of what the project is actually trying to deliver. Resource attrition depletes the human carriers of institutional knowledge and relationship capital that are the actual substrate of project coherence.

The pattern is recognizable in project post-mortems across sectors: "There was a time when the team knew exactly what success looked like and was aligned on how to get there. Somewhere in the middle phase, that shared understanding dissolved." (Prieto 2025) Leadership teams develop slight but consequential differences in their interpretation of project priorities; those interpretive differences create friction in communication; that friction compounds into a barrier to effective coordination. The project team begins to behave classically — optimizing locally rather than globally, managing optics rather than outcomes, reacting rather than governing.

Structural basis for mapping. Both the quantum and project phenomena involve irreversible information loss to the environment through interaction, and both produce classical-like behavior from systems that have been exhibiting quantum-characteristic (complex, coherent, globally integrated) behavior. The decoherence analogy is structurally robust and is among the most practically useful in QPM's mapped territory.

Governance implications. Coherence preservation is a primary governance objective in QPM — not a soft leadership concern but a hard technical requirement of project system performance. The Quantum Fragility Index (QFI) is specifically designed to measure the project system's proximity to coherence-crossing thresholds, providing early warning of decoherence dynamics before they manifest in schedule and cost performance degradation. This connection between decoherence monitoring and the QFI is developed further in Section 6.

3.4 The Uncertainty Principle: Irreducible Planning Limits

Quantum physics phenomenon. Heisenberg's uncertainty principle (Heisenberg 1927) establishes that certain pairs of physical properties — canonically, position and momentum — cannot both be known with arbitrary precision simultaneously. This is not a statement about measurement technology or observer skill; it is a fundamental statement about the nature of physical reality. The product of the uncertainties in position and momentum is bounded below by a constant related to Planck's constant. Reducing uncertainty in one variable necessarily increases uncertainty in its conjugate.

© 2026 Robert Prieto

Project management analog. Large complex projects exhibit an analogous irreducibility: precisely defining scope produces imprecise cost and schedule estimates, because the complexity of detailed scope execution cannot be fully modelled at the time of definition. Precise early cost commitment reduces scope flexibility, because the project system can only support so much concurrent definitional work before locking in configurations that may not be optimal. These are not planning failures attributable to analytical inadequacy; they are structural properties of complex systems operating under genuine uncertainty — uncertainty that, as the empirical record makes unambiguously clear, produces fat-tailed outcome distributions that no amount of improved estimation technique has been able to normalize (Flyvbjerg and Gardner 2023; Merrow 2011).

Empirical grounding. The claim that LCP outcome distributions are fat-tailed rather than normally distributed around a manageable expected value is not a theoretical inference from the uncertainty analogy; it is one of the most robustly documented empirical findings in the project management literature, established independently across multiple research programs, project types, and geographies. Flyvbjerg and Gardner (2023), drawing on a database of more than 16,000 projects, document the following fat-tail frequencies by project type — the percentage of projects within each type producing outcomes of more than 50% cost overrun: rail, 28% of projects with a mean fat-tail overrun of +116%; tunnels, 28% with a mean fat-tail overrun of +103%; airports, 43% with a mean fat-tail overrun of +88%; buildings, 39% with a mean fat-tail overrun of +206%; nuclear, 55% with a mean fat-tail overrun of +204%; and Olympic Games infrastructure, 76% with a mean fat-tail overrun of +200%. Across all project types combined, only 0.5% of large projects deliver on budget, on time, and with promised benefits, and only 8.5% deliver on budget and on time. These are not extreme outliers distorting an otherwise tractable distribution. They are the distribution. Merrow (2011), across 514 industrial megaprojects with a median total installed cost of USD $3.6 billion, characterizes the distributional property directly: megaprojects do not tend to go somewhat wrong when things become problematic — they fall apart. The outcome distribution is bimodal: successful projects cluster near zero overrun; failed projects cluster at overruns of 40% or more. This bimodal character is structurally inconsistent with the continuous, manageable risk distributions that classical project management's quantitative risk analysis techniques — triangular distributions, beta distributions, Monte Carlo simulations anchored to three-point estimates — are designed to handle. It is, however, entirely consistent with a system operating under irreducible uncertainty of the kind that the Heisenberg analogy describes uncertainty that is constitutive of the system's nature rather than a correctable feature of the analyst's knowledge. The fat tail is not a measurement error. It is the distribution's honest self-portrait.

Practical manifestation. The practical manifestation is familiar: a project that defines scope with great precision during front-end engineering produces a basis for cost estimation that is internally consistent but vulnerable to the assumption that the scope definition is itself stable — an assumption that large complex projects routinely violate. The attempt to achieve simultaneous precision in scope, cost, and schedule is the project management equivalent of attempting to know both the position and momentum of a quantum particle with arbitrary precision. The attempt does not eliminate the underlying uncertainty; it merely conceals it within the estimates until it reasserts

© 2026 Robert Prieto

itself in execution. The fat-tail frequency data of Flyvbjerg and Gardner (2023) is the empirical measure of how often, and how severely, that reassertion occurs once the concealment fails.

Structural basis for mapping. Both phenomena involve conjugate variables — pairs of system descriptors whose product of uncertainties is bounded below — where attempts to reduce uncertainty in one dimension structurally increase uncertainty in the other. The correspondence is robust at the level of formal structure, though QPM's uncertainty principle is expressed in terms of project variables rather than quantum observables. The empirical distribution evidence cited above is not part of the formal structural correspondence; it is the independent evidentiary confirmation that the structural correspondence describes real project behavior rather than theoretical possibility.

Governance implications. Contractual structures that attempt to eliminate uncertainty in one dimension — fixed-price contracts for complex and novel scope; guaranteed maximum price arrangements for projects with undefined technology requirements — do not reduce uncertainty. They transfer it covertly to claims, dispute resolution, quality degradation, or scope suppression. Governance frameworks calibrated to normal or near-normal outcome distributions — contingency allowances sized to one or two standard deviations, risk registers anchored to probability-impact matrices with bounded impact scales — are structurally inadequate for systems whose outcome distributions have the fat-tail character documented by Flyvbjerg and Gardner (2023) and Merrow (2011). QPM governance must design explicitly for irreducible uncertainty: contingency frameworks that reflect fat-tailed distributions and size provisions against the P80 rather than the expected value, contract structures that share rather than transfer risk, and decision frameworks that treat early estimates as probability distributions with explicit tail acknowledgement rather than point commitments whose uncertainty is tacitly assumed to be bounded and symmetrical.

3.5 Observer Effect: Measurement and Governance Distortion

Quantum physics phenomenon. In quantum mechanics, the act of measuring a quantum system necessarily disturbs the system being measured. This is not a product of clumsy instrumentation; it is a consequence of the fundamental interaction required for measurement to occur. The observer is not a passive recipient of information about the system; the observer's act of measurement changes the system's state.

Project management analog. Project monitoring and reporting systems disturb the project systems they measure. Intensive schedule surveillance generates gaming behavior: teams report to the schedule rather than managing to project outcomes. Safety audit intensity produces audit-preparation activity that temporarily suppresses safety risk indicators without actually reducing hazard exposure. Cost reporting systems create organizational incentives oriented toward metric optimization rather than underlying delivery performance. The observer effect in project systems is not a theoretical curiosity; it is a well-documented source of systematic governance distortion.

© 2026 Robert Prieto

The distortion is compounded in large complex projects by the density of the monitoring environment: multiple owner representatives, independent engineers, regulatory inspectors, lender technical advisors, and insurance surveyors all simultaneously apply their measurement frameworks to the project system. Each monitoring actor disturbs the system; the cumulative distortion of simultaneous multi-observer measurement can be substantial.

Structural basis for mapping. Both phenomena involve the interaction between measurement apparatus and measured system producing changes in system state. The structural correspondence is strong, particularly in the domain of behavioral distortion produced by surveillance intensity.

Governance implications. QPM governance must distinguish between surveillance — measurement designed to detect problems — and coherence maintenance — engagement designed to preserve alignment. These require different instruments, different frequencies, and different organizational relationships. Surveillance-heavy governance produces observer-effect distortion; coherence-oriented governance uses leading indicators, internality-based state variables, and alignment-focused engagement to maintain the system's performance trajectory without generating the gaming and concealment behaviors that intensive surveillance produces.

3.6 Quantum Decay and Half-Life: State Variable Dissipation

Quantum physics phenomenon. Radioactive decay is a quantum phenomenon in which unstable atomic nuclei spontaneously emit radiation and transform into different nuclei. The characteristic of radioactive decay is its half-life: the time required for exactly half of a given quantity of a radioactive substance to decay. This exponential dissipation follows a precise mathematical law and is a property of the substance, not of the observer or the measurement context.

Project management analog. Worker fatigue — a canonical project internality, developed extensively in Section 5 — dissipates according to a half-life decay curve. Recovery from fatigue is rapid initially and slows asymptotically as physiological and cognitive restoration approaches baseline. This has been formalized in QPM's internalities framework (Prieto, 2026), where fatigue is treated as a continuously changing state variable with measurable inputs, predictable trajectories, and nonlinear threshold effects on both individual performance and system-level project risk.

The analogy extends beyond fatigue. Organizational memory of a completed project phase decays exponentially if not actively maintained: the dense situational knowledge held by a project team dissipates through personnel turnover, assignment rotation, and the passage of time. The institutional coherence generated by a major team alignment event — a project charter review, a recovery planning exercise, a critical milestone celebration — has a half-life: its effect on team behavior dissipates at a characteristic rate unless refreshed by subsequent alignment activities.

Structural basis for mapping. Both phenomena involve exponential dissipation governed by a system-specific rate constant. The mathematical structure of half-life decay applies to project internalities with sufficient fidelity to generate predictive models for scheduling and governance purposes.

© 2026 Robert Prieto

Ontological qualification. The half-life analogy holds specifically for the rate at which active degradation mechanisms accumulate and dissipate over time — not as a claim that project coherence decays intrinsically with duration independent of those mechanisms. This distinction is ontologically important. In radioactive decay, the degradation process is intrinsic to the substance: the nucleus decays because of what it is, not because of what happens to it externally. Project coherence does not behave this way. Duration sets the exposure period — the length of time during which degradation mechanisms such as assumption invalidation, leadership discontinuity, workforce fatigue, and entanglement accumulation can operate — but duration does not itself generate those mechanisms. A project that sustains leadership continuity, scope discipline, and active assumption governance across an extended execution period does not lose coherence merely by persisting in time. Empirical analysis of the QPM portfolio supports this qualification: duration is a strong probabilistic amplifier of fragility accumulation — projects exceeding thirty months are substantially more likely to exhibit elevated QFI-S scores than shorter projects — but several long-duration projects in the cohort maintained Robust-band classification throughout extended execution by sustaining the specific mitigating conditions that suppress the onset of degradation mechanisms. The half-life analogy therefore describes the behavior of internalities and coherence-state variables when degradation mechanisms are present and active, not the behavior of the project system as a function of time alone.

Governance implications. The half-life character of fatigue enables predictive scheduling rather than reactive response: work intensity ramp-ups can be modeled against recovery curves to anticipate fatigue accumulation trajectories and intervene before coherence-crossing thresholds are reached. Similarly, governance of organizational coherence must include deliberate "coherence maintenance" activities whose frequency is calibrated to the characteristic decay rate of the alignment states being sustained.

3.7 Relativistic Time Dilation: Scale-Dependent Schedule Perception

Physics phenomenon. Einstein's special theory of relativity established that time is not absolute: the rate at which time passes depends on the observer's velocity and gravitational field. Clocks in high-gravity environments or moving at high velocities tick more slowly relative to clocks in low-gravity or low-velocity environments. This is not a perceptual illusion; it is a physical reality measurable with sufficient instrumentation.

Project management analog. In megaprojects, "schedule time" dilates: the perceived rate of progress experienced by external stakeholders — project owners, investors, regulators, community representatives — systematically diverges from the internal execution tempo of the project team. A project team deeply engaged in complex systems integration perceives dense, productive activity whose progress is real but not easily legible to external observers. The external observer perceives delay. This divergence is not primarily a communication failure; it is a structural consequence of the complexity gradient between the project's internal environment — characterized by technical density, interdependency management, and problem-solving intensity — and the external observational environment, which lacks the contextual framework to interpret internal signals correctly.

© 2026 Robert Prieto

The dilation dynamic is amplified in large complex projects by the scale of the complexity gradient. The internal execution team of a major infrastructure program operates in an environment of extraordinary technical richness — thousands of concurrent engineering decisions, continuous interface management, real-time risk monitoring — that simply cannot be compressed into the reporting frequencies and summary abstractions that external governance requires. Time moves differently in these two reference frames.

Structural basis for mapping. Both phenomena involve reference-frame-dependent observations of a single underlying reality, where the divergence between frames increases with the magnitude of the relevant gradient (velocity in physics; complexity in project systems). The mapping is structurally sound at the level of formal analogy.

Governance implications. QPM governance must include explicit translation mechanisms between internal execution states and external observational frames — "relativistic translation" instruments that render the density of internal activity legible to external stakeholders without distorting it. Failure to provide these translation mechanisms produces the characteristic pathology of megaproject governance: external pressure to accelerate (based on the perception of slow progress) at precisely the moments when internal execution requires stability and methodical progression.

Mapping strength assessments in Table 1 represent the author's qualitative judgment based on the structural correspondence criterion and should not be interpreted as quantitative scores.

Table 1. QPM's Mapped Quantum Analogies: Summary Comparison

Quantum Phenomenon	Physical Domain	Project Analog	Structural Basis	Governance Implication	Mapping Strength
Superposition	Quantum state theory	Multi-path project states; parallel option coexistence until decision-forcing collapse	Probability distributions over multiple states; collapse triggered by external interaction	Resist premature state collapse; maintain option portfolios; delay artificial commitments	Strong
Entanglement	Quantum correlations	Non-local work package and stakeholder interdependence; wave function expansion	Non-separable system descriptions; local analysis produces incorrect predictions	Entanglement mapping; continuous alignment management; expanded wave function governance	Strong

© 2026 Robert Prieto

Quantum Phenomenon	Physical Domain	Project Analog	Structural Basis	Governance Implication	Mapping Strength
Decoherence	Open quantum systems	Coherence loss through schedule crises, leadership change, scope creep	Irreversible information loss to environment; classical-like behavior from quantum-capable system	Coherence preservation as primary objective; QFI monitoring; proactive alignment maintenance	Strong
Uncertainty Principle	Quantum measurement	Irreducible scope-cost-schedule precision tradeoffs; fat-tailed estimate distributions	Conjugate variable pairs; product of uncertainties bounded below	Design for irreducible uncertainty; avoid risk-transfer contracts; use probabilistic estimating	Strong
Observer Effect	Quantum measurement	Monitoring-system distortion; metric gaming; surveillance-induced behavioral change	Measurement interaction changes system state regardless of intent	Distinguish surveillance from coherence maintenance; use leading indicators; minimize metric gaming	Moderate
Quantum Decay / Half-Life	Nuclear quantum physics	Fatigue dissipation; organizational memory decay; coherence half-life	Exponential dissipation governed by a system-specific rate constant	Predictive fatigue scheduling; calibrate coherence maintenance frequency to decay rate	Moderate
Relativistic Time Dilation	Special/General Relativity	Scale-dependent schedule perception; divergence between internal tempo and external	Reference-frame-dependent observation; divergence proportional to complexity gradient	Build relativistic translation instruments; render internal execution legible externally	Moderate

© 2026 Robert Prieto

Quantum Phenomenon	Physical Domain	Project Analog	Structural Basis	Governance Implication	Mapping Strength
		observational frame		without distortion	

4. Unmapped Territory: Quantum Phenomena Without Established Project Analogues

Intellectual honesty is itself a boundary condition of any mature theoretical framework. The willingness to specify what a theory cannot explain — what territory it does not yet map — is the single most reliable indicator of theoretical maturity. Frameworks that claim to explain everything are ideologies, not theories. QPM must maintain the discipline of distinguishing its mapped analogical territory, developed in Section 3, from the frontier zone: quantum phenomena that are intellectually provocative in a project management context but have not yet been grounded in the structural correspondence that justifies inclusion in the mapped category.

This section identifies four frontier phenomena and assesses each honestly. In each case, the analysis identifies not only why the mapping is incomplete but what would be required to complete it — establishing an agenda for QPM's next theoretical generation.

4.1 Bell's Theorem and Irreducible Non-Locality

Bell's theorem (1964) is one of the most profound results in the history of physics. It establishes that no theory of hidden variables — no classical causal mechanism, however complex — can reproduce all the predictions of quantum mechanics. The non-locality of quantum entanglement is not a product of unknown causal chains; it is a fundamental feature of physical reality. This was experimentally confirmed by Aspect and colleagues in 1982 and has been confirmed with increasing precision in subsequent experiments.

In QPM, the analogous question is significant: are project interdependencies irreducibly non-local — genuinely not traceable to underlying causal mechanisms — or do they merely appear non-local because we have not yet identified the causal chains connecting them? This is not a trivial question. If project entanglements are Bell-type — irreducibly non-local — then the QPM framework's strongest claims about entanglement are validated at a deep structural level. If project entanglements are ultimately reducible to classical causal chains — if the "hidden variables" exist — then QPM's entanglement analogy, while useful, does not carry the full explanatory weight that the quantum physics phenomenon supports.

At present, QPM cannot definitively resolve this question. Project systems are not controlled enough to conduct the equivalent of an Aspect-type experiment; the causal chains that produce project entanglement effects are complex and multi-layered, but they are not obviously inaccessible in principle. This is an important ontological limit: QPM should not claim Bell-type irreducible non-locality without establishing that classical causal chains have been systematically

© 2026 Robert Prieto

ruled out as explanations. The mapping remains in the frontier zone, requiring both theoretical development and empirical investigation.

4.2 Quantum Tunneling: Barriers Without Classical Passage

Quantum tunneling is the phenomenon by which a quantum particle penetrates a potential energy barrier that would be classically forbidden — that is, the particle's total energy is less than the barrier height, yet the particle appears on the other side. This is not a violation of energy conservation; it is a consequence of the wave character of quantum particles, whose probability amplitude extends into classically forbidden regions.

A potential project analog exists: breakthrough solutions that appear to violate the "energy requirements" of the cost-time-scope feasibility frontier, enabled by unexpected convergences of technology, leadership alignment, regulatory accommodation, and market timing. Projects that "should not" have succeeded given their initial conditions — that faced barriers classically insurmountable — occasionally do so through what participants describe as breakthrough moments that defied conventional expectation. The intuitive resonance with tunneling is striking.

However, the mapping is currently underdeveloped. Quantum tunneling is a specific mathematical phenomenon with a precise mechanism: wave function penetration through a potential barrier, with a tunneling probability that decreases exponentially with barrier height and width. No analogous mathematical structure has been formalized for project breakthroughs. The project analog lacks the structural specificity — the identification of the "potential barrier" in project terms, the "tunneling probability" as a function of project system parameters — that would move it from evocative metaphor to analytical tool. This remains a promising frontier, but it requires formal development before it can join QPM's mapped territory.

4.3 The Many-Worlds Interpretation: Branching Project Realities

The many-worlds interpretation of quantum mechanics, first proposed by Everett (1957), posits that every quantum measurement does not collapse the wave function to a single outcome but instead causes the universe to branch into multiple co-existing realities, each containing one of the possible measurement outcomes. All outcomes occur; the observer simply finds themselves in one branch and has no access to the others.

In project terms, this might suggest that every major decision point spawns a portfolio of parallel project realities: the branch in which the contract was awarded to Contractor A, the branch in which it was awarded to Contractor B, the branch in which the regulatory approval was delayed, and so on. While this is intellectually evocative — and has a surface resemblance to scenario planning and Monte Carlo simulation — it has no operationalizable project analog. There is no mechanism by which parallel project branches co-exist in any physical or organizational sense; the "branches" in project scenario analysis are analytical constructs, not ontological realities. More critically, the many-worlds interpretation itself is deeply controversial within physics; its conceptual status is contested in ways that make it an unreliable foundation for a project

© 2026 Robert Prieto

management analogy. QPM should treat many-worlds as a philosophical provocation useful for stimulating scenario discipline, not as a theoretical foundation for governance design.

4.4 The Quantum Zeno Effect: Observation Freezing State Change

The quantum Zeno effect describes a counterintuitive phenomenon: a quantum system that is continuously observed is prevented from evolving — its state is effectively frozen by the act of repeated measurement. The effect arises because each measurement collapses the wave function back toward its initial state, preventing the natural quantum evolution that would otherwise occur.

A project analog is intuitively appealing: in over-managed projects, excessive monitoring may freeze adaptive behavior. Teams under intensive surveillance may become paralyzed by the weight of reporting requirements, governance check-ins, and continuous measurement activity — unable to adapt, innovate, or respond fluidly to emerging conditions because every state change must be approved, documented, and justified. The governance pathology of "management by meeting" — in which the overhead of coordination consumes the capacity for execution — resembles the quantum Zeno effect in its behavioral signature.

However, this mapping requires formalization. The quantum Zeno effect has a precise mechanism: the mathematics of repeated projective measurement preventing unitary evolution. To develop a rigorous project analog, QPM would need to identify the project-system equivalent of the projective measurement operator and the unitary evolution being suppressed. These are tractable theoretical questions. The quantum Zeno effect therefore sits at the productive edge of QPM's frontier: intriguing enough to warrant investment, underdeveloped enough to require substantial theoretical work before it can be used as a governance instrument.

A summary of these unmapped quantum phenomena and their associated theoretical risks is provided below in Table 2.

Table 2. QPM's Unmapped and Frontier Quantum Territory

Quantum Phenomenon	Potential Project Analog	Structural Correspondence	Development Status	Theoretical Risk
Bell's Theorem / Irreducible Non-Locality	Project interdependencies that resist decomposition into classical causal chains	Weak to moderate; classical causal chains not yet ruled out for project entanglements	Frontier — requires empirical investigation and controlled comparison of causal vs. non-local explanations	High — claiming Bell-type non-locality prematurely overstates QPM's theoretical basis
Quantum Tunneling	Breakthrough project outcomes	Weak — intuitive resonance but no	Frontier — promising but	Moderate — premature use

© 2026 Robert Prieto

Quantum Phenomenon	Potential Project Analog	Structural Correspondence	Development Status	Theoretical Risk
	that appear to violate feasibility barriers	formalized potential barrier or tunneling probability equivalent	requires formal mathematical development of project analog	risks degenerating into unfalsifiable "breakthrough" narrative
Many-**Worlds Interpretation**	Parallel project scenario branches as co-existing realities	Very weak — no ontological mechanism for co-existing project branches; contested even in physics	Philosophical provocation only — not suitable as theoretical foundation	High — risks falsifiability and loss of analytical discipline
Quantum Zeno Effect	Over-monitored projects frozen in adaptive paralysis by surveillance density	Moderate — behavioral signature is recognizable but mathematical structure not yet formalized	Promising frontier — specific theoretical development required before governance application	Low to moderate — risk is underdevelopment rather than overreach

5. Governing Project Internalities: State Variables at the Boundary

One of QPM's most significant recent theoretical extensions is the formalization of project internalities — defined as intrinsic human-performance conditions that shape system behavior from within, in contrast to externalities or structural project factors (Prieto 2026). This section develops internalities as the living boundary markers of QPM's ontological map: the domain in which quantum-inspired theoretical structures intersect with the irreducibly human character of project execution.

Classical project management theory is almost entirely organized around externalities and structural factors: scope definition, schedule logic, cost baselines, risk registers, contractual obligations, regulatory requirements. It treats the human interior of the project system — worker fatigue, cognitive load, motivational states, interpersonal trust, psychological safety — as either constants to be assumed (the rational actor model embedded in most PM methodologies) or variances to be managed through human resources processes that sit outside the core project management system. The worker is an input with a specified productivity rate; the leadership team is a resource with defined roles and responsibilities; the organizational culture is background context rather than a system variable.

© 2026 Robert Prieto

QPM fundamentally rejects this treatment. Internalities are not background context; they are state variables — dynamic conditions of the project system that have measurable inputs, characteristic trajectories, nonlinear threshold effects on system performance, and propagation dynamics across project interfaces that classical project management cannot model. The failure to recognize and govern internalities is not merely a soft management gap; it is a structural deficiency in the project management system's ability to model the actual behavior of the complex human systems it is managing.

5.1 Fatigue as the Canonical Internality

Fatigue serves as the primary example of a project internality for reasons of both practical significance and theoretical clarity. Fatigue is a dynamic internal condition whose value changes continuously based on work demands, rest opportunities, circadian alignment, task characteristics, and environmental load. It influences human performance, error likelihood, decision quality, and communication effectiveness in ways that are well-documented in the occupational health and cognitive science literatures. It has direct safety consequences in construction, commissioning, and operations environments. And it dissipates according to a half-life decay pattern — the analogy developed in Section 3.6 — that enables predictive modeling rather than requiring reactive response.

QPM's internalities framework (Prieto 2026) treats fatigue not as a binary condition (fatigued or not fatigued) but as a continuous state variable with the following formal characteristics:

- **Inputs:** Cumulative work hours, shift length and sequencing, circadian disruption (night work, time zone changes), sleep opportunity windows, physical and cognitive demand intensity, environmental stressors (heat, noise, altitude).
- **Trajectory:** Fatigue accumulates in a pattern that is approximately linear under constant input and dissipates exponentially during recovery — the half-life character that connects to QPM's decay analogy.
- **Threshold effects:** Fatigue does not degrade performance linearly. Below certain thresholds, performance degradation is modest and recoverable. Above critical thresholds, performance degradation is steep, error rates increase nonlinearly, and safety risk escalates rapidly. These threshold transitions resemble the decoherence transitions discussed in Section 3.3.
- **Propagation dynamics:** Fatigue does not remain contained within the individual or work package in which it originates. When a work package reaches a fatigue peak, its downstream interfaces are affected: handoffs become less complete, communications become less precise, and the receiving work package inherits degraded information quality. This propagation follows a quadratic contagion pattern — the fatigue impact on a work package at distance d from the origin scales approximately with d^2, creating a steepening slope of impact across the project network.

© 2026 Robert Prieto

The Fatigue Risk Index (FRI) — a composite score integrating exposure hours, circadian disruption, sleep-opportunity proxies, behavioral signals, and task/environment multipliers — operationalizes fatigue as a QPM state variable. The FRI provides a continuous, real-time representation of a work package's or crew's fatigue state, enabling threshold-aware intervention before safety and performance consequences materialize.

5.2 Internalities and Decoherence

The connection between project internalities and QPM's decoherence analogy is not merely conceptual; it is structural. Fatigue is not only a safety and productivity concern at the level of individual workers or crews. As the FRI rises across a project organization, the system-level consequences extend to the project's coherence state. Supervisory cognition degrades under fatigue load: supervisors make less precise coordination decisions, communicate with less clarity, and become less effective at the alignment-maintenance activities that sustain project coherence. Communication quality across interfaces deteriorates. The shared interpretive framework that constitutes project coherence — the shared understanding of priorities, methods, and progress — begins to dissolve as the cognitive and communicative substrate that maintains it becomes impaired.

This is the link between the internalities framework and the Quantum Fragility Index (QFI): project internalities generate the micro-perturbations — at the level of individual and crew performance — that drive the QFI toward fragility at the system level. The FRI is, in this sense, a micro-level leading indicator for the macro-level coherence degradation that the QFI tracks. A governance system that monitors the QFI without monitoring the internalities that drive it is measuring the symptom without the causes. QPM governance must integrate both levels of analysis.

5.3 Beyond Fatigue: A Taxonomy of Project Internalities

5.3.1 The Taxonomy and Its Measurement Obligation

Fatigue is the canonical project internality because it is the most tractable: it has measurable physical inputs, a well-characterized physiological mechanism, and established research bases in both occupational health and cognitive science. But QPM's internalities framework recognizes a broader taxonomy of intrinsic human-performance conditions that qualify as state variables in the project system. These are not peripheral human factors; they are properties of the system that determine its coherence, its cascade susceptibility, and its governance responsiveness. A taxonomy of state variables that cannot be measured is not a governance instrument — it is a narrative. The revision of this section in response to peer review therefore adds, for each internality in the taxonomy, the specific measurement instruments through which it can be operationalized in a live project governance system.

The five internalities beyond fatigue that QPM's framework identifies are: trust degradation, psychological safety, decision fatigue in project leadership, motivational decay, and cognitive

© 2026 Robert Prieto

load. Each is treated below with its definitional characterization, its mechanism of influence on project system behavior, and its measurement instrument suite.

5.3.2 Trust Degradation

Definitional characterization. Trust degradation is an organizational coherence internality that accumulates when commitments are not kept, information is withheld, or accountability is avoided. Trust is not a soft organizational metric; it is a state variable with direct consequences for interface efficiency, information sharing, and the willingness of project participants to absorb and manage risk on behalf of the collective system. As Prieto (2022) established in the context of large complex projects, trust is foundational to project success precisely because LCPs depend on the voluntary cooperation of multiple organizations across contractual interfaces whose terms cannot anticipate every condition that execution will generate. When trust degrades, participants retreat to contractual minimums, information sharing contracts, early warning signals are withheld, and the interface roughness that QPM's IRC metric captures escalates — not because the technical conditions have changed, but because the human conditions governing information flow across the interface have. Prieto (2025b) extends this foundation by establishing that leadership integrity is the primary determinant of trust formation and degradation in project organizations: integrity failures — commitments not kept, accountability avoided, information selectively shared — are not merely ethical lapses but system-level events that alter the project's coherence properties in measurable and consequential ways.

Mechanism of influence. Trust degradation operates through three distinct pathways in the project system. First, information contraction: as trust degrades, participants share less information voluntarily, increasing T_3 (Time-to-Truth) and widening the gap between field conditions and governance knowledge. Second, interface stiffening: the willingness to absorb minor interface frictions informally — to give the benefit of the doubt at organizational boundaries — decreases, converting manageable informal issues into formal disputes that consume governance bandwidth and extend DL. Third, risk redistribution: in low-trust environments, participants actively shed risk rather than managing it, creating risk accumulation points at interface boundaries that produce the cascade conditions QPM's QFI-S instrument is designed to detect. Each of these pathways has a direct mapping to a QPM metric: T_3 for information contraction; IRC for interface stiffening; and QFI-S C_3 (Entanglement Density) for cascade-susceptible risk concentration.

Measurement instruments. Four instruments are available, forming a complementary suite that measures trust at different scales and through different lenses:

Instrument 1 *— Mayer-Davis-Schoorman Multi-Dimensional Trust Scale.* (Mayer, Davis and Schoorman 1995) provide the foundational multi-dimensional trust model, decomposing trust into three independently measurable components: **ability** (the trustee's competence in the relevant domain), **benevolence** (the trustee's positive orientation toward the trustor's interests), and **integrity** (the trustee's adherence to an acceptable set of principles). The model has been adapted and validated across multiple organizational contexts, including construction and engineering

© 2026 Robert Prieto

project environments. Each component is measured through validated Likert-format items administered to project participants. The three-component structure is directly relevant to QPM governance because each component degrades through a different mechanism and requires a different intervention: ability-based trust failures call for competence development or role reassignment; benevolence-based trust failures call for interest realignment; integrity-based trust failures call for leadership action at the level of the individual or organization whose integrity is in question.

Instrument 2 *— Project Trust Scale (Pinto, Slevin and English, 2009).* Pinto, Slevin and English developed a validated instrument specifically calibrated for the owner-contractor trust relationship that is the defining inter-organizational interface in large complex projects. The instrument measures trust across five dimensions relevant to project execution: competence, integrity, openness, benevolence, and overall satisfaction with the relationship. Its project-specific calibration makes it more immediately deployable in a live project governance context than the more general Mayer-Davis-Schoorman instrument, and its five-dimension structure provides greater diagnostic specificity for identifying which dimension of the owner-contractor relationship is degrading and why.

Instrument 3 *— QPM Trust-NPS (adapted from Prieto, 2025a).* Prieto (2025a) establishes the Net Promoter Score (NPS) methodology as a deployable instrument for measuring stakeholder trust and loyalty in engineering and construction organizations and their projects. NPS is based on a single question administered to project participants and stakeholders — typically of the form "How likely are you to recommend working with [this project team / organization / partner] to a colleague?" — rated on a 0–10 scale. Respondents are classified as Promoters (9–10), Passives (7–8), or Detractors (0–6), and the Trust-NPS score is computed as the percentage of Promoters minus the percentage of Detractors, yielding a score from −100 to +100. Prieto (2025a) demonstrates that positive NPS scores correlate with better performance outcomes and that NPS can be extended from external customer measurement to internal project organization assessment — measuring the trust and confidence that project participants, subcontractors, and support organizations have in the project's leadership, decision-making processes, and delivery capability. The QPM Trust-NPS adapts this methodology for internality governance as follows:

QPM Trust-NPS Question (inter-organizational): *"How likely are you to proactively share a developing problem with [the project leadership team / the other party at this interface] before it becomes a formal issue? (0 = not at all likely; 10 = extremely likely)"*

This formulation targets the specific trust behavior that matters most to QPM's cascade prevention mission — the voluntary early sharing of information across organizational boundaries that compresses T_3 and prevents cascade propagation — rather than the generic loyalty measurement that standard NPS assesses. A declining QPM Trust-NPS score on this question is a leading indicator of T_3 extension and IRC elevation before either metric has moved perceptibly in the formal governance data. Prieto (2025a) establishes that NPS provides identification of at-risk relationships for timely intervention and allows closing the loop with dissatisfied participants to

© 2026 Robert Prieto

improve experiences — a governance function directly aligned with QPM's threshold-triggered intervention protocols.

The QPM Trust-NPS is a proposed adaptation of NPS and should be considered exploratory pending independent validation.

Instrument 4 *— Integrity Behavioral Indicators.*. Prieto (2025b) identifies the specific leadership behaviors that constitute integrity in project organizations and that can be observed and scored through structured 360-degree assessment: commitment follow-through rates, information disclosure completeness, accountability acceptance frequency, and consistency between stated and revealed priorities. These indicators are measurable through structured supervisor and peer assessment instruments and provide a behavioral complement to the attitudinal measures of Instruments 1–3.

QPM governance integration. The four instruments above are administered at different frequencies consistent with their measurement characteristics: the Mayer-Davis-Schoorman and Pinto-Slevin-English scales at project phase boundaries (typically three to four times over a project's life); the QPM Trust-NPS monthly at each major interface; and the Prieto integrity behavioral indicators quarterly for key leadership roles. Declining scores on any instrument at any interface trigger an escalation to the TFRB for interface-specific assessment. A combined score below a pre-defined threshold - calibrated during project setup against the specific inter-organizational relationships present - constitutes a Trust Degradation Alert that appears on the TFHP dashboard as a C_3 (Entanglement Density) elevation signal, reflecting the direct pathway from trust degradation to increased cascade susceptibility documented above.

5.3.3 Psychological Safety

Definitional characterization. Psychological safety is the team-level condition in which members feel safe to speak up, raise concerns, and report problems without fear of punishment or humiliation. It is a dynamic team-level internality with measurable antecedents — leadership behavior, prior incident responses, organizational climate — and measurable consequences for error detection, early warning generation, and adaptive response.

Mechanism of influence. Psychological safety operates primarily through its effect on information flow within the project team: teams with low psychological safety systematically suppress early warning signals, converting manageable developing conditions into governance crises by the time they become visible. This is the team-level analog of trust degradation's inter-organizational information contraction pathway — both reduce the voluntary sharing of problem-relevant information, both extend T_3, and both increase the gap between field conditions and governance knowledge.

Measurement instrument. Edmondson (1999) developed and validated the seven-item Team Psychological Safety Scale, which has been applied in construction project environments in

© 2026 Robert Prieto

multiple peer-reviewed studies. The seven items probe the team's perceived safety to take interpersonal risks — to ask for help, to admit errors, to raise concerns — and are scored on a Likert scale to produce a team-level psychological safety score. Low scores are a leading indicator of information suppression and should be treated in QPM governance as a T_3 risk flag requiring leadership intervention before they manifest in formal schedule or cost data. The instrument is administered at team level — meaning scores are computed as team averages, not individual assessments — and is appropriate for administration at monthly or phase-boundary intervals.

5.3.4 Decision Fatigue in Project Leadership

Definitional characterization. Decision fatigue is the cognitive depletion that accumulates in project leadership teams managing high-volume, high-stakes decision environments. Decision fatigue degrades decision quality in characteristic ways: increased risk aversion, preference for the status quo, reduced willingness to engage with complex or ambiguous information, and a tendency toward decision avoidance that in a project governance context manifests as DL extension — issues that require decisions being held open longer than they should because the decision-maker's cognitive resources are insufficient to engage with them at the quality the decision requires.

Mechanism of influence. Decision fatigue operates directly on DL: a leadership team experiencing decision fatigue will process fewer decisions per governance session, will tend toward the less cognitively demanding choice when options are presented, and will defer decisions that appear complex even when early intervention would prevent cascade propagation. This is not a character failure; it is a documented neurological consequence of sustained high-frequency decision-making (Baumeister 1998) that project governance systems must design around rather than assume away.

Measurement and governance response. Decision fatigue is most practically monitored through proxy indicators observable in governance system outputs rather than through direct psychological assessment: the proportion of decisions deferred from one forum to the next; the frequency of "no decision" outcomes at forums with adequate information for decision; and the distribution of decision times over the course of governance sessions (decision fatigue typically increases with session length and meeting sequence position). QPM governance design should structure the most consequential decisions at the beginning of governance sessions, should limit governance session length to intervals consistent with sustained cognitive performance, and should monitor the DL distribution for the systematic drift toward the end of sessions that signals a decision fatigue effect.

5.3.5 Motivational Decay

Definitional characterization. Motivational decay is the gradual dissipation of intrinsic motivation over the course of a long and demanding project, analogous in its trajectory to the exponential decay that QPM's half-life analogy (Section 3.6) describes for schedule coherence and assumption validity. It is particularly significant in large complex projects whose delivery timelines span years or decades, during which the team experiences multiple cycles of challenge,

© 2026 Robert Prieto

setback, and partial recovery — each cycle leaving a residue of reduced intrinsic motivation that compounds over time.

Mechanism of influence. Motivational decay operates through its effect on discretionary effort — the voluntary contribution of effort beyond the contractual minimum that is responsible for a disproportionate share of project performance in complex, ambiguous, and demanding environments. As intrinsic motivation decays, discretionary effort declines; participants shift from identifying and resolving problems proactively toward managing their contractual obligations. This shift is not captured in any classical project metric — a workforce operating at 80% of its prior discretionary effort level shows no variance in schedule or cost reports until the cumulative effect of reduced proactive problem-solving manifests as a cascade event.

Measurement and governance response. Motivational state is monitored through brief validated pulse surveys adapted from the Work Engagement Scale (Schaufeli, Bakker and Salanova 2006), administered monthly at workfront level with three-item versions appropriate for operational project environments. Declining engagement scores at key workfronts are treated as a leading indicator of discretionary effort erosion and are escalated to the TFRB for workfront-specific intervention assessment.

5.3.6 Cognitive Load and Attention Bottlenecks

Definitional characterization. Cognitive load is the dynamic allocation of scarce cognitive processing capacity across competing demands in the project system. In large complex projects, cognitive load on key decision-makers and interface managers routinely exceeds sustainable levels, creating attention bottlenecks that distort information processing, delay critical decisions, and reduce the quality of the decisions that are made.

Mechanism of influence. Cognitive overload in key roles creates a specific governance failure mode: the decision-maker becomes the bottleneck rather than the decision. Issues queue waiting for cognitive bandwidth that is already fully committed, extending DL not because the governance forum cadence is insufficient but because the individual at the center of the decision network cannot process information at the rate it arrives. This is the human-performance analog of the queue buildup that QPM's QBM (Queue Buildup Metric) measures in the work execution system — and it has the same consequence: accumulating backlogs, increasing cascade risk, and ultimately threshold breach.

Measurement and governance response. Cognitive load is monitored through structured role-load assessments — inventories of the number of concurrent open decisions, interface issues, and escalations assigned to key decision-makers — and through observation of information processing indicators: response time to governance queries; proportion of issues receiving substantive versus procedural responses; and frequency of information requests being delegated rather than resolved. QPM governance responds to cognitive overload signals by restructuring decision authority — pre-authorizing decisions within defined parameters that currently require senior sign-off,

© 2026 Robert Prieto

reallocating interface management responsibilities, and adjusting the governance session structure to reduce the concurrent decision load on any single decision-maker.

Prieto (2026e) maps these internality conditions onto eight observable signal categories available in operational project reporting systems.

5.3.7 The Internalities Composite: Integration with QFI-S

The five internalities described in Sections 5.3.2 through 5.3.6, together with fatigue as the canonical internality of Section 5.2, constitute QPM's complete internalities state vector for a live project. Each internality is monitored through the instruments described above and contributes to the project's overall governance fragility through its specific pathway — information contraction, decision-lag extension, discretionary effort erosion, or decision bottleneck creation.

In the QFI-S composite, internality states are incorporated as modifiers to the **C_4 (Time-to-Truth)** and **C_5 (Assumption Diffusion Rate)** components. The routing reflects the causal mechanism of each internality class:

Trust degradation and psychological safety deterioration below threshold **elevate C_4 (Time-to-Truth)**. Degraded trust contracts the voluntary flow of information within and across organizational boundaries. When individuals withhold field-level intelligence — concerns, anomalies, early indicators of assumption failure — the lag between the emergence of field reality and its formal recognition at the governance level increases directly. C_4 captures this information-lag mechanism; trust degradation and psychological safety deterioration are therefore its primary internality drivers.

Motivational decay and decision fatigue scores below threshold **elevate C_5 (Assumption Diffusion Rate).** These conditions erode the proactive assumption-monitoring behaviors that prevent unchecked diffusion: individuals cease actively tracking critical assumption status, exception conditions are underreported, and assumption invalidation propagates without intervention. C_5 captures the rate at which assumption degradation spreads through the project system; motivational decay and fatigue-related internalities are therefore its primary drivers at this component.

C_3 (Entanglement Density) is a structural property of the project's architecture — reflecting the number and strength of interdependencies among work packages, organizations, and governance structures — and is not primarily driven by internality conditions. While severely degraded internality states may indirectly increase the effective cascade susceptibility of an entangled system, C_3 does not serve as a direct pathway for internality modifiers within the QFI-S governance architecture.

The combined effect of multiple internalities simultaneously in degraded state is multiplicative rather than additive — consistent with the QPM framework's general treatment of entangled

© 2026 Robert Prieto

system properties — and a project in which three or more internality scores are simultaneously below threshold should be treated as operating in the Moderately Fragile band irrespective of its structural QFI-S inputs. This constitutes a governance floor override independent of the calculated base QFI-S value.

A second governance floor override rule applies to project manager transition history. Each PM transition constitutes a compound decoherence event: tacit knowledge accumulated by the departing manager is lost, stakeholder relationships must be re-established from a lower trust baseline, and the assumption inventory undergoes effective discontinuity as the incoming manager's interpretive frame diverges from that of the project's earlier governance epochs. These three effects are simultaneous and mutually reinforcing rather than sequential, producing an aggregate internality perturbation whose governance impact exceeds what any single internality instrument is calibrated to detect. The SPM portfolio evidence (Prieto 2026e) establishes that projects recording a third PM transition exhibit qualitatively distinct deterioration trajectories — extended execution duration, accelerated assumption diffusion, and elevated T_3 lag as incoming leadership reconstructs information channels from a reduced baseline — regardless of whether individual internality monitoring instruments register below threshold at the transition moment. Accordingly, a project recording a third PM transition should be treated as operating in the Moderately Fragile band irrespective of its structural QFI-S inputs and irrespective of whether the simultaneous-internality threshold of three or more degraded internality scores has been reached. This PM-transition governance floor is independent of the calculated base QFI-S value. The two floor override rules defined in this section — the simultaneous-internality floor and the PM-transition floor — operate as parallel governance triggers: either condition alone is sufficient to impose the Moderately Fragile governance floor, and neither requires confirmation by the other.

5.4 Governance of Internalities: Passive Monitoring, Trend Detection, and Tiered Response

5.4.1 The Monitoring Paradox and Its Resolution

Governance of project internalities requires fundamentally different instruments than governance of structural project factors. Structural factors — scope, schedule, cost — can be monitored through periodic reporting against established baselines. Internalities are dynamic state variables that change continuously, often rapidly, and with nonlinear threshold effects that make periodic monitoring inadequate. By the time a traditional periodic report captures a fatigue or trust degradation signal, the threshold may already have been crossed.

The response to this inadequacy might appear straightforward: monitor internalities in real time. But this apparent solution introduces a second problem that the framework must explicitly resolve. Section 3.5 of this paper identifies the observer effect as a mapped QPM analogy: the act of observing a quantum system disturbs it, and the act of intensively monitoring a human project system disturbs it in an analogous way. A program of continuous intensive assessment — frequent surveys, structured interviews, supervisor evaluations, and self-report instruments administered at high frequency — does not merely measure fatigue, trust degradation, and cognitive load. It

© 2026 Robert Prieto

contributes to them. The administrative burden of intensive internality surveillance adds cognitive load to already-loaded participants, the perception of constant assessment reduces psychological safety, and the time consumed by monitoring instruments reduces the operational time available for the productive work whose quality the monitoring is designed to protect. This is not a peripheral concern; it is a governance design constraint of the first order.

The resolution to this paradox lies in the distinction between **passive monitoring** and **active surveillance**. These are not points on a continuum of monitoring intensity; they are categorically different approaches to the governance of internality state variables, with different data sources, different administrative burdens, and different observer-effect profiles.

5.4.2 Passive Monitoring: Integration of Existing Data Streams

Passive internality monitoring draws exclusively on signals already generated by the project's normal operational, health and safety, and administrative management systems. No new data collection burden is imposed on project participants. The monitoring system integrates, scores, and presents signals that the project generates in the ordinary course of its execution, capturing their internality-relevant content without requiring any participant action beyond what normal project operations already demand.

The primary passive data streams from which the Fatigue Risk Index (FRI) and the broader internality state vector are computed are:

Operational and scheduling data. Shift patterns and shift lengths drawn from the project's workforce scheduling system; overtime hours by role category and workfront from the payroll and time-recording system; consecutive days worked without rest from the access control and site attendance system; and day-of-week and time-of-day distribution of governance decisions from the project's decision register. These data characterize fatigue exposure and decision fatigue risk without requiring any participant to report their own state.

Health, safety, and incident data. Near-miss incident rates by workfront, shift, and week-of-project from the project's safety management system; medical referral rates for fatigue-related conditions from the occupational health system; and first-aid attendance frequency from the site medical records. These are established leading safety indicators that also serve as lagging internality signals — elevated near-miss rates are a documented consequence of fatigue and cognitive load before they manifest in productivity or quality metrics.

Communication and response pattern data. Email and document management system metadata — specifically, response latency to governance queries by role; frequency of decision deferrals from one governance session to the next from the decision register; and proportion of issues receiving substantive versus procedural responses in governance forum minutes. These patterns are computable from systems already in use without accessing message content, preserving privacy

© 2026 Robert Prieto

while capturing the decision fatigue and cognitive load signals embedded in observable response behavior.

Interface and document management data. Document review cycle times from the project's document management system; interface notification response times from the interface register; and the frequency of informal versus formal issue resolution from the correspondence log. These capture trust degradation signals at inter-organizational interfaces - stiffening of informal resolution and extension of formal cycle times are leading indicators of trust degradation before the trust state has been directly assessed.

Supervisor brief-assessment inputs. The one active element in the passive monitoring regime - brief daily supervisor assessments of two to three minutes per shift, integrated into the existing pre-shift briefing and post-shift debrief that safety-compliant project sites conduct as a matter of operational standard. These are not psychological assessment instruments; they are structured observational checklists covering observable indicators: apparent fatigue indicators, engagement level, responsiveness to pre-shift briefing content, and any reported concerns. Their brevity and integration into existing operational routines means they add negligible administrative burden while providing a direct human observation signal that purely data-driven passive monitoring cannot replicate.

5.4.3 Active Surveillance: Scheduled, Targeted, and Bounded

Active surveillance - the administration of the validated psychometric instruments described in Section 5.3 (the Mayer-Davis-Schoorman trust scale, the Pinto-Slevin-English Project Trust Scale, the Edmondson psychological safety scale, and the Schaufeli Work Engagement Scale) — is not a continuous real-time monitoring activity. It is a scheduled, targeted, and bounded complement to the passive monitoring regime, administered at defined intervals and triggered by passive monitoring signals that indicate a more detailed assessment is warranted.

In the baseline QPM internality governance regime, active surveillance instruments are administered at four defined points in the project lifecycle: project mobilization (establishing baseline internality state vectors for all major interfaces and workfronts); project midpoint (the primary scheduled assessment, providing the data for the prospective validation program described in Section 9.1); at each major phase transition; and on intervention trigger (when passive monitoring signals breach a defined threshold, active assessment is triggered at the affected workfront or interface to establish the clinical picture before the intervention is designed). Between these scheduled administrations, active surveillance is silent — no instruments are in the field, no assessments are occurring, and no observer-effect disturbance is operating. This bounded active surveillance regime produces the rich diagnostic data of validated psychometric instruments while constraining the observer-effect disturbance they generate to four defined windows in the project's life.

© 2026 Robert Prieto

5.4.4 Three-Point Trend Detection and the Minimum Reporting Cadence

A single internality monitoring reading — whether from passive data integration or active instrument administration - cannot distinguish a genuine state change from measurement noise. A downward deviation in the QPM Trust-NPS at a single reporting period may reflect a genuine trust degradation event, a transient response to an operational setback that will self-correct, or random measurement variation. Governing on single-period readings produces alert fatigue - an excess of false-positive triggers that desensitizes the governance team to the signals that genuinely require action.

QPM's internality governance framework adopts a minimum of **three consecutive deteriorating readings** on any passive monitoring indicator as the threshold for escalation from passive monitoring to active surveillance, and three consecutive deteriorating active surveillance readings as the threshold for formal intervention. This three-point trend criterion is not an arbitrary convention; it reflects the minimum number of observations required to distinguish a trend from noise in a time series with the signal-to-noise ratio characteristic of organizational behavioral data, without requiring the extended observation periods that higher-confidence statistical trend detection would impose. Three points define a direction. One or two points define a question.

The practical implication for reporting cadence is as follows. Passive monitoring data streams are integrated and scored continuously - the FRI and the broader internality composite are recomputed with each new data input, which in a fully instrumented project environment occurs multiple times per day for operational data streams and daily for safety and communication data streams. This continuous computation produces the underlying signal. But the governance reporting of that signal - the presentation of internality state to the forums responsible for acting on it - occurs at the cadence appropriate to each forum tier, not at the cadence of the underlying computation.

5.4.5 Tiered Governance Integration: Cadence, Resolution, and Authority

The QPM internality monitoring and reporting regime is explicitly aligned to the three-tier governance architecture that structures the framework's operational governance system:

Daily operational forum (Tier 1 — Field Coordination Protocol, FCP). The FCP receives a daily internality summary covering fatigue indicators at each active workfront, drawn exclusively from passive data streams updated since the previous FCP. The daily internality summary is a single-page dashboard presenting FRI score by workfront (Green/Amber/Red); near-miss frequency trend (3-day rolling); and any supervisor brief-assessment flags from the preceding 24 hours. The FCP's authority with respect to internality signals is operational: shift pattern adjustment, workfront rotation, mandatory rest enforcement, and escalation to Tier 2 if any indicator has produced a second consecutive deteriorating reading.

Twice-weekly governance forum (Tier 2 — Temporal Fragility Review Board, TFRB). The TFRB receives a twice-weekly internality trend report covering the three-point trend status of all

© 2026 Robert Prieto

passive monitoring indicators across all workfronts and all major inter-organizational interfaces. The twice-weekly cadence provides the minimum observation frequency for three-point trend detection within a two-week window — the governance response timescale within which developing internality conditions must be identified to prevent cascade propagation. The TFRB's authority with respect to internality signals extends to triggering active surveillance assessments at workfronts or interfaces where passive monitoring trends have reached the three-consecutive-deterioration threshold, and to commissioning interface-specific trust interventions within its pre-authorized scope.

Monthly executive governance session (Tier 3 — Executive Governance Session, EGS). The EGS receives a monthly internality governance report presenting the internality state vector across all project dimensions — workfronts, interfaces, and leadership team — integrating both passive monitoring trend data and the results of any active surveillance assessments completed in the preceding month. The EGS's authority with respect to internality signals extends to the full range of governance interventions, including leadership reassignment, contract relationship restructuring, and major workforce management changes that Tier 1 and Tier 2 do not have the authority to execute. The monthly EGS also reviews the aggregate internality state vector for its implications for the QFI-S composite, updating the C_4 and C_5 modifiers and governance floor conditions described in Section 5.3.7.

5.4.6 Intervention Trigger Protocols and Effectiveness Assessment

QPM governance must institutionalize internality monitoring as a first-class project control instrument, not an adjunct to the core management system. The governance logic that the FRI model establishes — monitor continuously, score dynamically, trigger interventions at defined thresholds, assess intervention effectiveness, recalibrate — is applicable to the full taxonomy of project internalities and is implemented through the tiered forum structure described above.

Intervention trigger protocols are pre-defined at project mobilization for each internality category, specifying the passive monitoring threshold that triggers active surveillance, the active surveillance threshold that triggers formal intervention, and the intervention menu available to each forum tier. Intervention effectiveness is assessed through the passive monitoring trend: a successful intervention produces a measurable reversal in the passive monitoring indicators within a defined window — typically two weeks for fatigue interventions, four weeks for trust and psychological safety interventions, and six to eight weeks for motivational decay interventions, reflecting the different recovery timescales of each internality category. Interventions that do not produce measurable passive monitoring improvement within the assessment window are escalated to the next forum tier for review and augmentation.

This complete governance cycle — passive monitoring, trend detection, active surveillance trigger, formal intervention, effectiveness assessment, recalibration — is the operational expression of QPM's commitment to governing the human dimensions of large complex projects with the same

© 2026 Robert Prieto

rigor, specificity, and evidence-based discipline that the framework applies to their structural, technical, and temporal dimensions.

6. The Quantum Fragility Index as a Boundary Instrument

The Quantum Fragility Index (QFI) represents QPM's most operationally significant contribution to date: a formal instrument for measuring a project system's proximity to the boundaries that separate coherent execution from instability, cascade propagation, and systemic failure. Traditional project metrics measure variance around expected performance. QFI measures something fundamentally different: the sensitivity of the project system to perturbation. It therefore functions not primarily as a risk metric, but as a boundary-detection instrument that makes QPM's theoretical constructs observable in practice.

Classical project controls answer the question: *How far are we from plan?*

QFI answers a deeper question:

How close is the project system to a state transition?

This distinction is critical. A project may exhibit minimal schedule or cost variance while operating dangerously close to a coherence boundary. Equally, a project may display substantial variability yet remain structurally robust. The former condition is often invisible to traditional metrics and is precisely the condition QFI was created to detect. The theoretical foundations of the metric are developed in the Quantum Fragility Index framework, where fragility is formally defined as the curvature of the expected-value function under increasing perturbation dispersion.

6.1 Formal Definition of QFI

6.1.1 Fragility as Curvature

At its most fundamental level, fragility is a property of curvature.

Following the QFI framework, the Quantum Fragility Index is defined as:

$$QFI(S) = -\frac{\partial^2 E[V(S;x)]}{\partial \sigma^2}$$

where:

- $V(S;x)$represents project value under perturbation x,
- Srepresents the project state vector,
- $E[V]$is expected project value, and

© 2026 Robert Prieto

- $\sigma$is the dispersion of environmental perturbations.

6.1.2 From Theoretical QFI to Operational QFI-S

The preceding expression defines fragility in its theoretical form as a property of the project's value-function curvature under increasing environmental dispersion. While conceptually rigorous, direct estimation of this curvature is rarely practical in live project environments where the underlying value function cannot be observed with sufficient precision. QPM therefore employs an operational implementation, designated QFI-S, that estimates fragility through observable project-system characteristics. QFI-S is intended as a governance proxy for the theoretical QFI construct rather than a direct numerical computation of it. The relationship between the two is analogous to that between a physical quantity and the instrument used to estimate it: the theoretical formulation provides the underlying definition, while the operational measure provides the practical means of observation and governance application.

The translation from theoretical to operational also requires the corresponding translation of component concepts into measurable project-system variables. The most significant of these translations concerns **Structural Curvature**, the first QFI-S dimension (C_1). Structural Curvature, as defined theoretically in Section 6.3, describes the degree to which a project's architecture amplifies disturbances — the curvature of the system's response surface. In the operational QFI-S implementation, this theoretical property is measured through **Schedule Coherence**: the degree to which the project's schedule structure accurately reflects actual work sequencing, constraint relationships, and critical-path dependencies at each reporting period. Schedule Coherence is the operational measure of Structural Curvature within QFI-S; the two terms refer to the same underlying fragility dimension at different levels of abstraction. The QFI-S component C_1 is designated **Schedule Coherence** in all operational governance contexts, while Structural Curvature remains the theoretical construct it operationalizes.

6.1.3 QFI Interpretation

The interpretation is direct:

- **QFI < 0:** the project is antifragile; volatility improves expected outcomes.
- **QFI = 0:** the project is robust; volatility has no systematic effect.
- **QFI > 0:** the project is fragile; increasing volatility disproportionately degrades value.

In theoretical terms, QFI measures the concavity or convexity of the project's value function. In governance terms, it measures how easily a project can be pushed across a meaningful operational boundary.

Because direct computation of the second derivative is rarely possible in live project environments, QPM employs an operational implementation of this theoretical construct.

© 2026 Robert Prieto

6.2 QFI-S: The Operational Governance Instrument

QFI-S is the governance-scale implementation of QFI.

Where QFI expresses fragility in its theoretical form, QFI-S translates fragility into a measurable project-management instrument using observable indicators derived from project execution, stakeholder interaction, information quality, and governance performance.

QFI-S therefore serves as the project's primary boundary-monitoring instrument.

Its role is analogous to a flight instrument in aviation. Pilots do not directly observe aerodynamic equations while flying; they observe instrument readings derived from those equations. In the same way, governance teams observe QFI-S as the operational representation of the theoretical QFI construct.

The purpose of QFI-S is not to replace the theoretical formulation but to make it actionable.

6.3 The Five-Dimensional Structure of QFI-S

QFI-S evaluates project fragility across five dimensions that collectively capture the principal mechanisms through which large complex projects lose coherence.

These dimensions are designated C_1 through C_5.

C_1 — Schedule Coherence *(operational measure of Structural Curvature)*

Schedule Coherence measures the degree to which the project's schedule structure accurately reflects actual work sequencing, constraint relationships, and critical-path dependencies at each reporting period. It is the operational expression of the theoretical property of Structural Curvature: the degree to which the project's architecture amplifies disturbances. Highly coupled systems with dense interface dependencies exhibit lower Schedule Coherence and greater curvature than modular systems with clear boundaries, such that small disturbances generate disproportionately large consequences.

Schedule Coherence represents the structural dimension of fragility in QFI-S.

C_2 — Assumption Validity

Assumption Validity measures the degree to which the foundational assumptions underpinning the project's cost, schedule, scope, and technical approach remain consistent with evolving execution reality. This dimension operationalizes the quantum uncertainty analogy: just as a quantum system's state cannot be precisely known prior to measurement, a project's assumption base

© 2026 Robert Prieto

degrades progressively as execution reveals divergence from the conditions that obtained at project sanction. Sources of assumption validity loss include:

- forecast instability,
- estimate divergence,
- market volatility,
- regulatory uncertainty,
- technological novelty.

This dimension corresponds most closely with the Uncertainty Principle analogy developed in Section 3.4.

C_3 — Entanglement Density

Entanglement Density measures the degree of coupling among project elements. It reflects the number and strength of interdependencies between:

- work packages,
- organizations,
- stakeholder groups,
- governance structures,
- critical assumptions.

High values of C_3 indicate increased cascade susceptibility because disturbances propagate rapidly across interconnected systems.

C_4 — Time-to-Truth (T_3)

Time-to-Truth measures the information lag between the emergence of a significant project condition in the field and its formal recognition at the governance level. It captures the mechanism through which decoherence propagates at the governance level: when decisions are made on the basis of information that is delayed, filtered, or attenuated relative to current field reality, the project system loses the alignment between intended and actual behavior that coherent execution requires. Decoherence — the divergence between intended and actual project behavior — is best understood as the collective outcome that QFI-S is designed to measure; C_4 identifies the information-lag pathway through which that coherence loss originates and through which governance can detect it earliest.

Sources of elevated T_3 include:

- communication degradation,

© 2026 Robert Prieto

- trust contraction and voluntary information withholding,
- reporting-cycle constraints,
- leadership misalignment,
- organizational filtering of adverse signals,
- priority inconsistency.

C_4 is therefore the operational expression of the information-lag mechanism described in Section 3.3, and its measurement provides the primary leading-indicator pathway through which governance can detect decoherence before it manifests in classical cost and schedule variances.

C_5 — Assumption Diffusion Rate

Assumption Diffusion Rate measures the rate at which critical assumptions become invalidated, forgotten, inconsistently interpreted, or unevenly distributed throughout the project system.

Because assumptions are the hidden substrate upon which large complex projects operate, increasing diffusion often precedes visible deterioration in cost or schedule performance.

C_5 therefore functions as a leading indicator of future fragility.

6.4 Mathematical Relationship Between QFI and QFI-S

Theoretical QFI and operational QFI-S describe the same underlying phenomenon at different levels of abstraction.

QFI expresses fragility through the curvature of the value function.

QFI-S expresses fragility through measurable project-system state variables.

Accordingly:

$$QFI\text{-}S = f(C_1, C_2, C_3, C_4, C_5)$$

where:

- C_1= Schedule Coherence (Structural Curvature),
- C_2= Assumption Validity,
- C_3= Entanglement Density,
- C_4= Time-to-Truth (T_3),
- C_5= Assumption Diffusion Rate.

© 2026 Robert Prieto

In practical implementation, these components are normalized and combined into a composite fragility score ranging from Robust to Critically Fragile states. The exact weighting and calibration of individual dimensions remains provisional and subject to empirical refinement through the validation program described in Section 9.1. The current calibration baseline applies equal weighting to all five components (QFI-S = mean of C_1 through C_5), subject to refinement as the empirical validation program generates component-level performance data.

QFI-S measures operational fragility, while antifragility remains a property of the theoretical QFI construct. QFI-S should therefore be understood as the governance proxy through which the theoretical QFI formulation becomes observable and actionable within a live project environment.

6.5 QFI-S Classification Bands

QFI-S classifies operational fragility across four governance bands ranging from Robust to Critically Fragile. Antifragility remains a property of the theoretical QFI construct rather than operational QFI-S.

This spectrum is adopted here without modification and serves as the operational basis for governance escalation.

State	QFI-S Range	Governance Interpretation
Robust	$0.00 \leq$ QFI-S < 0.30	Stable operating region
Moderately Fragile	$0.30 \leq$ QFI-S < 0.60	Enhanced monitoring required
Highly Fragile	$0.60 \leq$ QFI-S < 0.85	Executive intervention warranted
Critically Fragile	QFI-S ≥ 0.85	Immediate stabilization action required

These thresholds should be regarded as provisional calibration parameters rather than immutable constants. Their predictive validity forms one of the central objectives of the validation pathway developed in Section 9.1.

6.6 Internalities and the QFI-S State Vector

QPM's internalities framework expands the QFI-S state vector beyond purely structural project variables.

Fatigue, trust degradation, psychological safety, motivational decay, decision fatigue, and cognitive load do not constitute independent fragility dimensions. Rather, they act as modifiers that influence the behavior of the five-dimensional fragility structure.

Most directly:

© 2026 Robert Prieto

- trust degradation and psychological-safety deterioration elevate C_4 (Time-to-Truth), extending the information lag between field reality and governance recognition;
- decision fatigue and motivational decay elevate C_5 (Assumption Diffusion Rate),
- workforce fatigue further elevates C_4 (Time-to-Truth) through degradation in communication quality, coordination effectiveness, and execution consistency.

The internalities framework therefore provides the human-performance mechanism through which micro-level conditions influence macro-level fragility.

6.7 QFI-S as an Ontological Boundary Instrument

The significance of QFI-S extends beyond governance.

QFI-S operationalizes the central claim of this paper: that QPM possesses identifiable ontological boundaries.

A project operating in the Robust region remains largely within the explanatory reach of classical project management. As QFI-S rises into the Moderately Fragile and Highly Fragile bands, the quantum-inspired phenomena described throughout this paper become increasingly prominent: uncertainty, entanglement, decoherence, observer effects, and cascade propagation emerge as dominant explanatory mechanisms.

The QFI-S therefore functions as a boundary detector between competing explanatory regimes.

It identifies when the project has entered the domain for which QPM was developed.

In this sense, QFI-S is not merely a governance metric. It is an ontological instrument: a practical mechanism through which the theoretical boundaries of Quantum Project Management become visible, measurable, and actionable in live project systems.

7. Theoretical Limits of QPM

Every mature theoretical framework must specify not only its domain of applicability but its conditions of breakdown — the circumstances under which its explanatory architecture becomes unreliable. Specifying these limits is not a concession to critics; it is the intellectual work that distinguishes a serious theoretical framework from an ideological position that cannot be falsified. This section addresses QPM's theoretical limits directly and without deflection.

7.1 The Scale Boundary: Minimum Complexity Threshold

QPM is not a universal replacement for classical project management. Its theoretical architecture - quantum-inspired state variables, entanglement mapping, decoherence monitoring, QFI-based

© 2026 Robert Prieto

governance — is specifically designed for large complex projects where classical project management breaks down systematically. Below a complexity threshold characterized by high decomposability, bounded scope, limited stakeholder entanglement, and near-deterministic delivery paths, classical project management remains theoretically and practically superior.

A routine building renovation, a well-scoped systems upgrade, a product development cycle with established technology and known market requirements - these projects are well-served by classical WBS-based scheduling, earned value management, and structured risk registers. QPM's added analytical overhead is not justified, and its quantum-inspired framework introduces conceptual complexity without analytical benefit. The ontological boundary between QPM's domain and classical PM's domain is a complexity threshold, not an absolute claim about the superiority of quantum-inspired frameworks in all contexts. QPM governance must include a principled framework for determining when the complexity threshold has been crossed and QPM's framework becomes necessary.

7.2 The Measurement Limit: Observational Coarseness

Quantum phenomena operate at the level of individual particles described by precise mathematical wave functions with exact quantum numbers. Project phenomena operate at the level of organizations, contracts, human beings, and social systems - described by approximations, proxies, and statistical summaries. QPM's analogies are structural, not numerical: no project state can be described with the mathematical precision of a quantum wave function, and no project uncertainty can be computed from first principles in the way that quantum uncertainty is grounded in Planck's constant.

QPM's measurement instruments - QFI, FRI, and related state variable metrics — are necessarily coarser than their physical analogs. They integrate multiple input streams through frameworks that involve professional judgment in their calibration and threshold-setting. This coarseness is a feature of the project environment, not a deficiency in QPM's theoretical design. The instruments must be calibrated to the precision the project system can support — which is substantially less than the precision of quantum mechanical measurement but substantially more than the precision of classical project management's baseline variance metrics. QPM governance must acknowledge this measurement coarseness explicitly and design its instruments, accordingly, avoiding false precision while maximizing the information value of available signals.

7.3 The Consciousness Problem: Agency Without Classical Analog

The quantum-physical world has no agency. Particles do not make decisions. They do not strategize, deceive, improvise heroically, or change their minds based on a conversation they had yesterday. Projects are executed by human beings with consciousness, volition, motivation, cultural embedding, and judgment - and by organizations of human beings with collective identities, political dynamics, leadership cultures, and institutional memories. This introduces a class of project behaviors that have no quantum analog and cannot be modeled within QPM's analogical framework without fundamental distortion.

© 2026 Robert Prieto

Strategic deception by a contractor seeking to protect its financial position, heroic improvisation by an engineering team confronting an unexpected technical failure, a chief executive's visionary decision to restructure the project delivery strategy at a critical juncture, an organizational culture change that transforms a project team's collective performance — these are phenomena that belong to a different ontological category. They involve conscious agency operating within the QPM framework but not reducible to it. QPM must acknowledge that human agency is a sui generis category — a category unto itself — that operates within the project system QPM describes but is not itself a quantum phenomenon and is not fully captured by quantum analogies.

This acknowledgment does not weaken QPM; it places it correctly. QPM provides the framework within which human agency operates — the coherence basin, the entanglement landscape, the decoherence trajectory — but it does not predict or determine the specific exercise of agency within that framework. That is appropriately the domain of leadership theory, organizational behavior, and decision science.

7.4 The Analogical Overreach Risk

The most significant theoretical risk facing QPM as a developing framework is analogical overreach: the temptation to map every observed project behavior onto a quantum phenomenon, regardless of whether the structural correspondence is present. This risk is not hypothetical. The history of science contains numerous examples of frameworks that began with genuine analogical insight and degenerated into unfalsifiable metaphor as the original analogies were stretched beyond their structural basis to accommodate every new phenomenon the framework encountered.

QPM must maintain the discipline of structural correspondence as its criterion for analogical inclusion. The mapped analogies in Section 3 meet this criterion. The frontier phenomena in Section 4 do not yet meet it. As QPM's corpus grows and new phenomena are proposed for analogical inclusion, each must be subjected to the same structural correspondence test: Is there a formal or behavioral logic shared between the quantum phenomenon and the project behavior, or is the resemblance primarily linguistic and superficial? The rigor of this test is QPM's primary protection against analogical overreach.

7.5 The Falsifiability Frontier

For QPM to mature from a theoretical framework to an empirical science, its core claims must be falsifiable — there must be specified evidence that would, if observed, require revision or rejection of the framework's central propositions. This paper proposes several falsifiability tests as a contribution to QPM's scientific development:

- If QFI-based governance interventions, applied at Moderately Fragile, Highly Fragile, and Critically Fragile threshold triggers, do not produce statistically better outcomes than classical risk-based interventions in a sufficiently large and controlled sample of large complex projects, the QFI's theoretical basis requires substantive revision.

© 2026 Robert Prieto

- If fatigue propagation does not exhibit quadratic contagion dynamics when measured in controlled field studies across project interfaces - if it follows linear or random propagation instead - the half-life and decay analogies as applied to fatigue require revision.
- If project outcome distributions in LCPs do not exhibit the fat-tailed character predicted by QPM's uncertainty analogy - if they are better described by normal distributions - the irreducible uncertainty claim requires modification.
- If entanglement mapping does not produce more accurate predictions of cascade risk than classical risk register approaches when applied to a common project dataset, the entanglement analogy's practical value requires reassessment.

Specifying these falsifiability tests is not a display of weakness. It is an invitation to the project management research community to engage with QPM's claims empirically — to bring the full apparatus of rigorous quantitative and qualitative research to bear on the framework's propositions. QPM's theoretical development requires this engagement.

8. Governance Implications: Designing for Boundary Conditions

The preceding sections have developed governance implications within each analytical domain. This section synthesizes those implications into an integrated QPM governance framework — a set of organizing principles for project governance that reflects QPM's theoretical architecture and its ontological boundary conditions.

Principle 1: Coherence preservation as primary governance objective. QPM governance is fundamentally organized around the preservation of project coherence — the shared interpretive alignment across teams, leadership, and stakeholders that enables the project system to maintain quantum-characteristic (integrated, adaptive, globally optimizing) behavior. Variance minimization — the organizing objective of classical project management governance — is a secondary instrument in service of coherence preservation, not the primary objective. A project can minimize cost variance while experiencing catastrophic coherence loss. QPM governance must not mistake the former for evidence of the latter.

Principle 2: State variable monitoring as a first-class governance function. QPM governance integrates internality monitoring (FRI and related instruments) with structural QFI monitoring in a unified state-variable framework. The state vector S that drives QFI computation includes both structural and internality-based inputs. Governance reporting must surface state variable dynamics at appropriate frequencies - continuously for internalities with rapid change rates, periodically for structural variables with slower trajectories.

Principle 3: Governance designed for irreducible uncertainty. No contractual structure, planning methodology, or risk management process eliminates the fundamental uncertainty of large complex projects. Governance designed on the premise that uncertainty can be eliminated —

© 2026 Robert Prieto

through sufficiently detailed planning, fixed-price contracts, or intensive surveillance — will systematically fail by creating false certainty that masks the actual uncertainty distribution until it reasserts itself in execution. QPM governance designs for irreducible uncertainty through probabilistic contingency frameworks, risk-sharing contract structures, and decision architectures that treat early estimates as distributions rather than commitments.

Principle 4: Entanglement management as continuous alignment activity. The stakeholder and institutional entanglements that constitute the project's actual wave function - $\Psi_{LCP\ Actual}$ - require continuous, not episodic, alignment management. QPM governance includes structured entanglement scanning (systematic identification of new and evolving stakeholder entanglements), regular alignment assessment against the project's strategic business outcomes, and proactive engagement protocols for entanglements approaching misalignment thresholds.

Principle 5: Observer-effect-aware measurement design. QPM governance recognizes that monitoring systems disturb the systems they monitor and designs accordingly. Surveillance-heavy monitoring generates metric gaming, concealment behavior, and organizational optimization toward reported metrics rather than underlying performance. QPM governance substitutes leading indicators for lagging metrics where possible, uses internality-based state variables that are less susceptible to gaming than structural metrics, and limits the density of external monitoring to the minimum required for coherence assurance rather than the maximum supportable by contractual obligation.

Principle 6: Boundary-crossing protocols calibrated to QFI thresholds. QPM governance specifies the governance actions that trigger at each QFI threshold — Robust, Moderately Fragile, Highly Fragile, Critically Fragile — as defined in Section 6[3]. These protocols are not improvised responses to emerging problems; they are pre-specified governance algorithms that activate when threshold conditions are met. The pre-specification of boundary-crossing protocols is essential to QPM governance effectiveness: in the high-stress environments surrounding coherence-boundary approaches, governance quality degrades precisely when it is most needed. Pre-specified protocols maintain governance quality under stress.

Principle 7: Antifragility design as a strategic governance objective. Where the project system's characteristics permit, QPM governance pursues antifragility - design choices that move the QFI toward negative values, creating a payoff function that is convex in environmental dispersion. Antifragility cannot always be achieved - some project systems are inherently fragile due to their technical characteristics, contractual structures, or stakeholder landscapes - but where it is achievable, it represents the highest expression of QPM's governance aspirations. An antifragile large complex project does not merely survive environmental volatility; it systematically converts volatility into improved outcomes through the architecture of its adaptive response systems.

[3] Antifragility remains a strategic design objective rather than an operational QFI-S classification.

© 2026 Robert Prieto

9. Conclusion: The Value of Bounded Theory

9.1 Validation Pathway: Retrospective and Prospective Testing Program

The four validation tests described below evaluate the predictive validity of the QFI-S construct introduced in Section 6, including its five-dimensional architecture (C_1-C_5), its threshold classifications, and its governance implications.

9.1.1 The Validation Obligation

A theoretical framework proposing new instruments for governing large complex projects must demonstrate empirical adequacy, not only conceptual coherence. QPM's mapped analogies, boundary conditions, and theoretical limits establish internal consistency — the necessary condition. The sufficient condition is empirical validation: evidence that QPM's instruments classify project states correctly, detect developing fragility ahead of classical schedule metrics, and support governance responses whose effectiveness can be independently assessed.

This section describes a four-test validation program to validate the QPM analogy and QFI-S operational instrument, sequenced to maximize use of publicly available retrospective data before requiring new primary data collection. Retrospective tests provide the evidential foundation that justifies investment in a more expansive testing program that this paper seeks to encourage. The section concludes with a suggested validation sequence to ensure that QPM's quantitative specifications remain empirically accountable.

9.1.2 Existing Empirical Foundation

The QPM Empirical Data Corpus (Prieto, 2026e) provides the immediate foundation for the retrospective tests, referencing initial databases for consideration in the testing program. Three components of the corpus directly support the validation commitments:

- **Reference Class Outcome Distributions (DB-1).** Flyvbjerg and Gardner's (2023) dataset of more than 16,000 projects provides fat-tail frequency and magnitude distributions — the classification criterion required for retrospective QFI threshold validation.
- **Cascade and Amplification Case Data (DB-3 and DB-4).** Eden, Williams, Ackermann and Howick (2000) and Lyneis, Cooper and Els (2001) document cascade propagation dynamics, amplification ratios, and information-lag structures. These cases contain sufficient narrative and temporal detail to support retrospective reconstruction of QFI-S component values.
- **Internality and Fatigue Empirics (DB-5 and DB-6).** Thomas and Horman (2006) and Cooper (1994) provide long-run field observations of workforce degradation,

© 2026 Robert Prieto

quality-fraction decay, and the 90% syndrome — empirical signatures of fatigue and internality variables required for retrospective FRI assessment.

These corpus elements provide an initial basis for partial retrospective execution of Tests 1 and 2, subject to data sufficiency and completion of the scoring protocol. Test 3 requires new primary data collection. Test 4 includes a retrospective proxy-based phase using existing World Bank and related datasets and may be extended through prospective comparative studies.

9.1.3 Test 1 — QFI Reference Class Validation

Research question: Does the QFI-S operational instrument produce higher readings in the months preceding documented cascade events than during stable execution?

Design: Retrospective QFI reconstruction can be performed using documented cases from Lyneis-Cooper-Els (2001), Eden-Williams-Ackermann-Howick (2000), World Bank Project Performance Assessment Reports, and other available data for projects above USD $500 million.

Procedure: QFI-S component values (C_1–C_5) would be reconstructed from narrative and tabular project-state descriptions at each reporting period. Composite-S QFI scores are computed and classified into pre-cascade, stable-execution, and recovery periods. Score distributions are compared using non-parametric tests appropriate to available sample sizes.

Validation criterion: Pre-cascade periods should exhibit statistically significantly higher QFI scores than stable-execution periods ($p < 0.10$). Threshold bands should classify pre-cascade periods as Moderately Fragile or above in a majority of cases.

Limitation: Retrospective scoring requires interpretive judgment. To mitigate bias, scoring rubrics must be pre-registered before case coding.

9.1.4 Test 2 — Fat-Tail Distribution Test

Research question: Do project types with higher fat-tail frequency generate systematically higher QFI readings when assessed at comparable phases?

Design: Flyvbjerg and Gardner's (2023) fat-tail ranking — Olympic Games, nuclear, airports, buildings, rail, tunnels, roads — provides the structural fragility spectrum against which QFI readings can be compared.

Procedure: Using publicly available cases from the World Bank PPAR database, the UK National Audit Office, the GAO's Major Defense Acquisition Program assessments, and other comparable data sets, QFI-S component values are reconstructed at project midpoint. Mean QFI-S scores are compared across project types. Rank correlation is assessed using Spearman's ρ.

© 2026 Robert Prieto

Validation criterion: A positive rank correlation ($\rho > 0.60$, $p < 0.10$) between fat-tail frequency and mean QFI-S score supports QPM's claim that QFI measures structural fragility rather than generic complexity.

9.1.5 Test 3 — Internality Instrument Validation

Research question: Do trust and psychological safety measurements at project midpoint predict outcome quality at completion?

Design: Prospective data collection from active Large Complex Projects applies two validated instruments: – Mayer-Davis-Schoorman (1995) trust model (project-adapted), – Edmondson (1999) psychological safety scale.

Procedure: A minimum sample of twenty LCPs above USD $500 million is required. Instruments are administered at project midpoint. Outcome quality is assessed at completion using schedule, cost, and production performance. Correlations between midpoint internality scores and outcome quality are computed using Pearson's r and point-biserial correlation.

Validation criterion: Statistically significant positive correlations ($r > 0.35$, $p < 0.05$) support QPM's internality framework. Lower effect sizes indicate the need for calibration or further theoretical refinement.

9.1.6 Test 4 — Observer Effect Validation (Two-Stage)

Research question: Does monitoring density exhibit a curvilinear relationship with reporting accuracy, consistent with QPM's observer-effect claim?

Design: Variation in monitoring intensity across World Bank infrastructure projects (STEP database, 2013–2022) provides the required proxy measures. Other available databases should also be evaluated.

Procedure: Monitoring density is proxied by supervision-mission frequency. Reporting accuracy is proxied by the magnitude of revision between final implementation status reports and independent completion evaluations. Quadratic regression tests for the predicted inverted-U relationship.

Validation criterion: A statistically significant curvilinear relationship ($R^2 > 0.15$, $p < 0.05$) supports the observer-effect claim. A monotonic relationship would require revision of QPM's governance implications. Because monitoring density and reporting accuracy are represented through proxy variables, this test should be interpreted as evidence consistent with, rather than definitive proof of, the observer-effect mechanism.

© 2026 Robert Prieto

9.1.7 Program Timeline and Threshold Commitment

These corpus elements provide an initial basis for partial retrospective execution of Tests 1 and 2, subject to data sufficiency and completion of the scoring protocol. Test 3 requires new primary data collection. Test 4 begins with a retrospective proxy-based analysis using existing datasets and may subsequently be extended through prospective comparative testing. The author has intended this paper to encourage valuable new data collection. Explicitly, **the paper's contribution is theoretical framework delineation, and that this four-test validation program represents the essential next stage of QPM's development as an empirical science.**

The prospective internality validation program (Test 3) requires collaboration with project owner organizations willing to permit instrument administration and outcome data sharing under anonymization protocols.

QPM's current quantitative thresholds — the QFI band boundaries, the FE band values, the ADI-S impact coefficients, and the WDEC accumulation rates — were calibrated through AI analysis of the publicly available empirical corpus and must be considered theoretically derived rather than empirically anchored pending the completion of Tests 1 and 2.

Specifically, the validation program should test and refine the currently adopted QFI fragility bands:

- Antifragile: QFI < 0
- Robust: 0.00-0.30
- Moderately Fragile: 0.30-0.60
- Highly Fragile: 0.60-0.85
- Critically Fragile: ≥ 0.85

These values are treated as provisional calibration parameters pending empirical validation.

The validation program should test and refine the currently adopted theoretical and operational fragility classifications. Theoretical QFI classifications include Antifragile (QFI < 0). Operational QFI-S classifications include Robust, Moderately Fragile, Highly Fragile, and Critically Fragile.

Upon completion of Test 1 and Test 2, thresholds that are refuted by the validation evidence would be revised. Upon completion of Test 3 and Test 4, the internality framework's causal claims and observer effect governance implications should be assessed against the prospective evidence and revised as the evidence requires. The QPM framework is committed to empirical accountability, and that commitment begins with this explicit statement of the conditions under which its current specifications will be treated as provisional and subject to revision.

© 2026 Robert Prieto

Section 9.2 Conclusions

This paper has undertaken the systematic mapping of QPM's ontological terrain — charting what the framework can explain with structural rigor (mapped analogies), what remains intellectually provocative but structurally ungrounded (unmapped frontier), what is genuinely outside QPM's explanatory domain (theoretical limits), and how these boundaries translate into governance design principles. The synthesis undertaken in this paper was assisted by artificial intelligence, employed not to generate conclusions but to ensure the comprehensive, consistent, and systematic treatment that QPM's own insistence on rigor demands. The exercise has been, by design, intellectually rigorous and explicitly self-limiting — and the use of AI in its construction reflects that same discipline: a tool chosen to extend the reach of analysis without relaxing its standards.

The central argument of the paper is that QPM's ontological boundaries are not weaknesses to be concealed or minimized; they are structural features that define the framework's proper domain, distinguish it from metaphor, and point toward the next generation of theoretical development in large-scale project science. A framework that acknowledges its limits is more trustworthy than one that claims universal applicability. A theory that specifies its falsifiability conditions is more scientifically serious than one that cannot be tested. QPM's ontological map, by specifying both what the framework claims and what it does not claim, makes QPM safer to use, easier to extend, and more credible to the project management field.

The key contributions of this paper are fourfold. First, it establishes the criterion of structural correspondence as the disciplinary boundary between QPM's mapped analogies and its unmapped frontier — a criterion that protects against analogical overreach as the corpus continues to develop. Second, it formally integrates project internalities — with fatigue as the canonical example — into QPM's ontological architecture as boundary-marking state variables that inhabit the intersection of quantum-inspired theory and human-organizational reality. Third, it positions the Quantum Fragility Index as not merely a risk metric but a theoretical instrument that makes QPM's boundary conditions observable in real project systems, operationalizing the framework's deepest insights about coherence, decoherence, and state transitions. Fourth, it proposes explicit falsifiability tests that invite empirical engagement with QPM's core propositions — the engagement that will be required for QPM to mature from a theoretical framework to an empirical project science.

As the foundational monograph observed, QPM is "a framework to see more, know more, and importantly, do better" (Prieto, 2025). The ontological map presented in this paper is the next step in that journey. It does not close the framework; it opens it — with greater precision, greater intellectual honesty, and greater confidence in what the framework can deliver. The project management field's most consequential challenge — the persistent failure of large complex projects despite decades of methodology development — demands nothing less than this level of theoretical rigor. QPM's ontological map is offered in that spirit.

© 2026 Robert Prieto

Supplementary Notes

Note 1. The wave function notation Ψ (Psi) as used throughout this paper follows the convention established in Prieto (2024) for QPM applications. It is used as a formal structural analog and does not imply that Schrödinger's equation is applied numerically to project systems.

Note 2. The QFI formula as presented follows the mathematical convention of Prieto (2025/2026). The second derivative of the expected value function with respect to dispersion is evaluated at the current operating dispersion σ_0. In practice, this second derivative is estimated numerically from the project's value distribution under varying dispersion assumptions.

Note 3. The Fatigue Risk Index (FRI) referenced throughout this paper as a 0–100 composite score is formalized in Prieto (2026), "Governing Project Internalities." The composite integrates exposure hours, circadian disruption, sleep-opportunity proxies, behavioral signals, and task/environment multipliers with empirically calibrated weighting factors.

Note 4. The Hyperion analogy (Saturn's moon) referenced in Section 3.2 draws on Prieto (2024), "Quantum Project Management, Large Complex Projects, and Entanglement." Hyperion's chaotic rotation was confirmed observationally and has been the subject of theoretical study by Wisdom, Peale, and Mignard. The application to project systems is QPM's original contribution.

Note 5. The antifragility concept in Section 8 (Principle 7) draws on Taleb (2012) for the formal definition of antifragility as a convex payoff function in environmental volatility. QPM's application of this concept to project systems, through the QFI's negative-value regime, is an original extension developed in Prieto (2025).

Keywords: *Quantum Project Management, ontological boundaries, quantum analogies, large complex projects, internalities, Quantum Fragility Index, decoherence, entanglement, superposition, project governance, theoretical limits, fatigue risk, systems thinking, structural correspondence, fat-tailed outcomes, abductive reasoning*

References

Aspect, A., Dalibard, J. & Roger, G. (1982). *Experimental Test of Bell's Inequalities Using Time-Varying Analyzers*. Physical Review Letters, 49(25), 1804–1807.

Baumeister, R.F., Bratslavsky, E., Muraven, M. & Tice, D.M. (1998) 'Ego Depletion: Is the Self a Limited Resource?', *Journal of Personality and Social Psychology*, 74(5), pp. 1252–1265.

Beer, S. (1985) *Diagnosing the System for Organizations*. Chichester: Wiley.

Bell, J.S. (1964) 'On the Einstein Podolsky Rosen paradox', *Physics*, 1(3), pp. 195–200.

© 2026 Robert Prieto

Bourne, L. (2011) *Advising Upwards: A Framework for Understanding and Engaging Senior Management Stakeholders*. Farnham: Gower.

Checkland, P. (1981) *Systems Thinking, Systems Practice*. Chichester: Wiley.

Checkland, P. & Scholes, J. (1990) *Soft Systems Methodology in Action*. Chichester: Wiley.

Cooper, G. (1994) 'The 90% Syndrome', *Project Management Journal*, 25(1), pp. 17–21.

Eden, C., Williams, T., Ackermann, F. & Howick, S. (2000) 'The Role of Feedback Dynamics in Disruption and Delay on Major Projects', *Journal of the Operational Research Society*, 51(3), pp. 291–300.

Edmondson, A.C. (1999) 'Psychological Safety and Learning Behavior in Work Teams', *Administrative Science Quarterly*, 44(2), pp. 350–383.

Einstein, A. (1915) 'Die Feldgleichungen der Gravitation', *Sitzungsberichte der Preussischen Akademie der Wissenschaften*.

Einstein, A. and Born, M., (1971) *The Born-Einstein letters: correspondence between Albert Einstein and Max and Hedwig Born 1916-1955*. Translated by I. Born. London: Macmillan.

Everett, H. (1957) '"Relative State" Formulation of Quantum Mechanics', *Reviews of Modern Physics*, 29(3), pp. 454–462.

Fayol, H. (1916). *Administration Industrielle et Générale*. Paris: Dunod.

Flyvbjerg, B. & Gardner, D. (2023) *How Big Things Get Done*. London: Penguin Press.

GAO (U.S. Government Accountability Office) (annual) *Major Defense Acquisition Programs: Assessments and Performance Reports*. Washington, DC: GAO.

Heisenberg, W. (1927) 'Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik', *Zeitschrift für Physik*, 43, pp. 172–198.

Holland, J.H. (1995) *Hidden Order: How Adaptation Builds Complexity*. Reading, MA: Addison-Wesley.

Kahneman, D. (2011) *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux.

Lyneis, J.M., Cooper, G. & Els, S. (2001) 'Strategic Management of Complex Projects: A Case Study Using System Dynamics', *System Dynamics Review*, 17(3), pp. 237–260.

© 2026 Robert Prieto

McCabe, T.J. (1976) 'A Complexity Measure', *IEEE Transactions on Software Engineering*, 2(4), pp. 308–320.

McKinsey Global Institute (2013) *Infrastructure Productivity: How to Save $1 Trillion a Year*. McKinsey & Company.

Mayer, R.C., Davis, J.H. & Schoorman, F.D. (1995) 'An Integrative Model of Organizational Trust', *Academy of Management Review*, 20(3), pp. 709–734.

Merrow, E.W. (2011) *Industrial Megaprojects: Concepts, Strategies, and Practices for Success*. Hoboken, NJ: Wiley.

Misra, B. & Sudarshan, E.C.G. (1977). *The Zeno's Paradox in Quantum Theory*. Journal of Mathematical Physics, 18(4), 756–763.

Peirce, C.S. (1903) *Pragmatism and Pragmaticism*. Cambridge, MA: Harvard University Press.

Pinto, J.K., Slevin, D.P. & English, B. (2009) 'Trust in Projects: An Empirical Assessment of Owner/Contractor Relationships', *International Journal of Project Management*, 27(6), pp. 638–648.

Prieto, R. (2021) 'Large Complex Project Success: Have We Institutionalized the Wrong Lessons?', *PM World Journal*. https://pmworldlibrary.net/wp-content/uploads/2021/01/pmwj101-Jan2021-Prieto-Large-Complex-Project-Success.pdf

Prieto, R. (2022) 'The Role of Trust in Projects', *PM World Journal*, Vol. XI, Issue I. https://pmworldlibrary.net/wp-content/uploads/2022/01/pmwj113-Jan2022-Prieto-Role-of-trust-in-projects.pdf

Prieto, R. (2024a) 'Quantum Project Management', *PM World Journal*, Vol. XII, Issue I. https://pmworldlibrary.net/wp-content/uploads/2024/01/pmwj137-Jan2024-Prieto-Quantum-Project-Management-.pdf

Prieto, R. (2024b) 'Quantum Project Management, Large Complex Projects, and Entanglement', *PM World Journal*, Vol. XII, Issue VII. https://pmworldlibrary.net/wp-content/uploads/2024/06/pmwj143-Jul2024-Prieto-Quantum-Project-Management-Large-Complex-Projects-and-Entanglement.pdf

Prieto, R. (2025) *Quantum Project Management: A Monograph on a New Theory for Management of Large Complex Projects*. Lulu Press.

Prieto, R. (2025a) 'Net Promoter Score — Measure Customer Loyalty and Satisfaction', *NAC Executive Insights*. National Academy of Construction.

© 2026 Robert Prieto

Prieto, R. (2025b) *Transformative Leadership: Leading with Integrity*. Lulu Press.

Prieto, R. (2026a) 'Quantum Fragility Index (QFI)', *PM World Journal*, Vol. XIV, Issue VII. https://pmworldlibrary.net/wp-content/uploads/2026/07/pmwj166-Jul2026-Prieto-Quantum-Fragility-Index.pdf

Prieto, R. (2026b) 'Governing Project Internalities', *PM World Journal*, Vol. XIV, Issue IX. https://pmworldlibrary.net/wp-content/uploads/2026/09/pmwj168-Sep2026-Prieto-Governing-Project-Internalities.pdf

Prieto, R. (2026c) *Ontological Boundaries of Quantum Project Management: Mapped and Unmapped Analogies, Theoretical Limits, and Governance Implications*. Submitted to *PM World Journal*, August 2026.

Prieto, R. (2026d) 'Rethinking How We Deliver the World's Largest Projects', *PM World Library*. https://pmworldlibrary.net/wp-content/uploads/2026/09/pmwj168-Sep2026-Prieto-Governing-Project-Internalities.pdf

Prieto, R. (2026e). *QPM Empirical Data Foundation: A Structured Corpus of Publicly Available Evidence for Quantum Project Management Framework Calibration*. Research dataset[4]. https://www.researchgate.net/publication/415165148_QPM_EMPIRICAL_DATA_FOUNDATION_latestdocx

Schaufeli, W.B., Bakker, A.B. & Salanova, M. (2006) 'The Measurement of Work Engagement with a Short Questionnaire', *Educational and Psychological Measurement*, 66(4), pp. 701–716.

Schrödinger, E. (1935) 'Die gegenwärtige Situation in der Quantenmechanik', *Naturwissenschaften*, 23, pp. 807–812.

Senge, P.M. (1990) *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday.

STEP (World Bank) (various years) *Systematic Tracking of Exchanges in Procurement (STEP) Database*. Washington, DC: World Bank.

Taleb, N.N. (2012) *Antifragile: Things That Gain from Disorder*. New York: Random House.

Taylor, F.W. (1911) *The Principles of Scientific Management*. New York: Harper & Brothers.

[4] Includes extensive insights from an assembled proprietary database.

© 2026 Robert Prieto

Thomas, H.R. & Horman, M.J. (2006) 'Fundamental Principles of Workforce Management', *Journal of Construction Engineering and Management*, 132(1), pp. 97–104.

Weick, K.E. (1989) 'Theory Construction as Disciplined Imagination', *Academy of Management Review*, 14(4), pp. 516–531.

Wisdom, J., Peale, S.J. & Mignard, F. (1984) 'The Chaotic Rotation of Hyperion', *Icarus*, 58(2), pp. 137–152.

World Bank (2013–2022) *STEP database,* The Independent Evaluation Group (IEG). Washington, DC: World Bank.

World Bank (various years) *Project Performance Assessment Reports (PPAR)*. Washington, DC: World Bank.

About the Author



Bob Prieto

Chairman & CEO
Strategic Program Management LLC
Jupiter, Florida, USA

Bob Prieto is Chairman & CEO of Strategic Program Management LLC focused on strengthening engineering and construction organizations and improving capital efficiency in large capital construction programs. Previously, Bob was a senior vice president of Fluor, focused on the development, delivery, and turnaround of large, complex projects worldwide across all of the firm's business lines; and Chairman of Parsons Brinckerhoff, where he led growth initiatives throughout his career with the firm.

Bob's board level experience includes Parsons Brinckerhoff (Chairman); Cardno (ASX listed; non-executive director); Mott MacDonald (Independent Member of the Shareholders Committee); and Dar al Riyadh Group (current)

Bob consults with owners of large, complex capital asset programs in the development of programmatic delivery strategies encompassing planning, engineering, procurement, construction, financing, and enterprise asset management. He has assisted engineering and

© 2026 Robert Prieto

construction organizations to improve their strategy and execution and has served as an executive coach to a new CEO. He is author of eleven books, over 1000 papers and National Academy of Construction Executive Insights, and an inventor on 4 issued patents.

Bob's industry involvement includes the National Academy of Construction and Fellow of the Construction Management Association of America (CMAA). He serves on the New York University Tandon School of Engineering Department of Civil and Urban Engineering Advisory Board and New York University Abu Dhabi Engineering Academic Advisory Council and previously served as a trustee of Polytechnic University. He has served on the Millennium Challenge Corporation Advisory Board and ASCE Industry Leaders Council. He received the ASCE Outstanding Projects and Leaders (OPAL) award in Management (2024). He was appointed as an honorary global advisor for the PM World Journal and Library.

Bob served until 2006 as one of three U.S. presidential appointees to the Asia Pacific Economic Cooperation (APEC) Business Advisory Council (ABAC). He chaired the World Economic Forum's Engineering & Construction Governors and co-chaired the infrastructure task force in New York after 9/11. He can be contacted at rpstrategic@comcast.net.

© 2026 Robert Prieto