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Quantum-Driven Business Analytics:
*An Experimental Investigation of Performance
Impact on Strategic Decision-Making*

Imowo Enang
Kingsley Obi Omeihe

Imo Enang and Kingsley Obi Omeihe

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About the author(s)

Imowo Enang and Kingsley Obi Omeihe are researchers at the Transformative Enterprise Research Group-TERG in Paisley, Scotland.

Route correspondence to email: king.omeihe@uws.ac.uk

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Kingsley O Omeihe, Editor-in-Chief, TERG Working Paper Series, Paisley, Scotland. King.omeihe@uws.ac.uk

Executive Summary

This working paper presents the results of an experimental study investigating the performance impacts of quantum computing approaches on business analytics and strategic decision-making. While the theoretical benefits of quantum computing for complex business problems have been explored, empirical evidence of measurable performance advantages remains scarce. Our research addresses this knowledge gap through a series of controlled laboratory experiments comparing classical and quantum-inspired optimisation algorithms. Using a mixed factorial experimental design with 124 professional participants from 28 organisations, our results demonstrate statistically significant advantages of quantum-inspired approaches for large-scale, complex optimisation problems with high dimensionality and multiple constraints. We present an integrated framework for quantum advantage in business analytics that maps specific business problem characteristics to quantum computing approaches. The paper concludes with practical recommendations for organisations considering quantum-inspired analytics investments, as well as a research agenda addressing key challenges for broader quantum computing adoption in business contexts.

Introduction

Strategic business decision-making increasingly involves navigating complex, high-dimensional problem spaces with numerous constraints, competing objectives, and stochastic elements (Brynjolfsson and McAfee, 2017; Davenport and Harris, 2017). Traditional computational approaches to business analytics, while continuously advancing, often struggle with the combinatorial explosion of possible solutions in domains such as supply chain optimization, portfolio management, financial modeling, and resource allocation (Bertsimas *et al.*, 2019; Powell, 2019). These computational limitations can constrain decision quality and strategic flexibility in rapidly changing business environments (Puranam *et al.*, 2015).

Quantum computing represents a fundamentally different computational paradigm with theoretical capabilities to address certain complex optimization and simulation problems far more efficiently than classical computers (Nielsen and Chuang, 2010; Preskill, 2018). The unique properties of quantum systems—superposition, entanglement, and quantum tunneling—enable novel approaches to computational problems, with potential to transform business analytics capabilities (Egger *et al.*, 2020; Herman *et al.*, 2022). As quantum hardware continues to advance and quantum-inspired algorithms become more accessible, there is growing interest in their application to business problems (Perdomo-Ortiz *et al.*, 2019; Venturelli and Kondratyev, 2019).

While theoretical analyses and proof-of-concept demonstrations have suggested significant potential for quantum computing in business contexts (Egger *et al.*, 2020; Orus *et al.*, 2019), rigorous empirical evidence of quantum advantage for realistic business problems remains limited. Most existing studies have focused on theoretical speedup calculations, small-scale simulations, or technical implementations without direct assessment of business decision

outcomes (Ajagekar and You, 2019; Bova *et al.*, 2021). This gap between technical capabilities and demonstrated business value creates uncertainty for organisations considering investments in quantum-enhanced analytics capabilities.

This working paper addresses this research gap through a controlled experimental investigation of quantum-inspired algorithms applied to representative business optimization problems, with assessment of both computational performance and decision quality outcomes. Our research focuses on three fundamental questions: First, under what conditions and for which classes of business analytics problems do quantum-inspired approaches demonstrate measurable performance advantages over classical methods? Second, how do these computational advantages translate into improvements in decision quality, strategic flexibility, and risk management for business decision-makers? Third, what organizational and technical factors influence the effective implementation and utilisation of quantum-enhanced analytics in business settings? To address these questions, we conducted a mixed factorial experimental study involving both computational benchmarking and human decision-making trials with professional participants.

Our experimental design systematically varied problem characteristics, computational approaches, and decision context factors to identify when and how quantum approaches deliver meaningful advantages for business analytics. This paper makes three primary contributions to the emerging literature on quantum computing applications in business contexts. First, we provide empirical evidence of quantum-inspired computational advantages for specific classes of business optimization problems, establishing boundary conditions and scaling relationships. Second, we demonstrate how these computational advantages translate into measurable improvements in strategic decision quality, particularly for complex, time-sensitive decisions under uncertainty. Third, we develop an integrated framework mapping business problem characteristics to quantum computing approaches, providing guidance for organizations considering quantum analytics investments.

The paper is structured as follows: We first review relevant literature on computational approaches to business optimization, quantum computing principles, and emerging quantum applications. We then detail our experimental methodology, including problem selection, algorithm implementation, and experimental protocols. Next, we present our findings on computational performance and decision quality outcomes. Finally, we discuss theoretical and practical implications, limitations, and directions for future research in this rapidly evolving domain.

Theoretical Background

Our research integrates perspectives from three streams of literature: computational approaches to business optimisation, quantum computing foundations, and early applications of quantum methods to business problems. This interdisciplinary foundation informs both our experimental design and interpretation of results. Business optimisation problems involve finding optimal or near-optimal solutions from large solution spaces subject to numerous

constraints and multiple, often competing objectives (Bertsimas *et al.*, 2019; Powell, 2019). These problems arise across functional domains including operations management (Simchi-Levi *et al.*, 2014), financial decision-making (Cornuejols and Tütüncü, 2018), marketing resource allocation (Martello and Toth, 1990), and strategic planning (Ghemawat, 2016). Classical approaches to business optimisation include a spectrum of techniques including linear and non-linear programming, mixed-integer programming, dynamic programming, heuristic methods, and metaheuristics such as genetic algorithms and simulated annealing (Bertsimas and Tsitsiklis, 1997; Glover and Kochenberger, 2003). More recently, machine learning approaches including reinforcement learning and deep learning have been applied to optimization problems, particularly those involving high dimensionality, uncertainty, and non-convex solution spaces (Bengio *et al.*, 2021; Mnih *et al.*, 2015).

Despite continuous advances in classical optimization methods and computing hardware, many realistic business problems remain computationally intractable due to the NP-hard nature of the underlying mathematical formulations (Powell, 2019). This computational barrier has practical consequences for business decision-making. As Eisenhardt and Bingham (2017) observe, the quality of strategic decisions is often constrained not by lack of data but by limitations in analytical processing capabilities. Decision-makers frequently rely on heuristics and simplified models that, while cognitively manageable, may overlook valuable solution alternatives or fail to capture complex interdependencies (Gigerenzer and Gaissmaier, 2011). These limitations become particularly problematic in dynamic environments requiring rapid adaptation to changing conditions (Puranam *et al.*, 2015).

It is interesting to note that quantum computing represents a fundamentally different computational paradigm based on quantum mechanical principles (Nielsen and Chuang, 2010). Unlike classical computers that operate on deterministic bits (0 or 1), quantum computers utilize quantum bits or "qubits" that can exist in superposition states, representing multiple values simultaneously (Preskill, 2018). Furthermore, quantum entanglement allows for correlation between qubits, enabling the representation and manipulation of exponentially large state spaces with relatively few qubits (Horodecki *et al.*, 2009).

These quantum properties enable novel approaches to computational problems with theoretical advantages for certain algorithm classes (Montanaro, 2016). Quantum algorithms such as Shor's algorithm for integer factorization (Shor, 1999) and Grover's algorithm for unstructured search (Grover, 1996) demonstrate theoretical speedups over the best-known classical algorithms. For optimization problems specifically, quantum approaches including quantum annealing (Kadowaki and Nishimori, 1998), the Quantum Approximate Optimisation Algorithm (QAOA) (Farhi *et al.*, 2014), and quantum-inspired algorithms adapted for classical hardware (Brandao *et al.*, 2017) have shown promise for addressing NP-hard problems more efficiently.

Contemporary quantum computing exists in what Preskill (2018) terms the "Noisy Intermediate-Scale Quantum" (NISQ) era, characterised by limited qubit counts, significant error rates, and restricted coherence times. These limitations constrain the practical implementation of theoretically powerful quantum algorithms (Bharti *et al.*, 2022). Consequently, much current research focuses on hybrid quantum-classical approaches and quantum-inspired algorithms that can deliver advantages with existing technology while pointing toward future capabilities as quantum hardware matures (Cerezo *et al.*, 2021). The application of quantum computing to business problems has attracted growing interest from both researchers and practitioners (Egger *et al.*, 2020; Orus *et al.*, 2019).

Early research has explored potential quantum advantages across several business domains: In supply chain optimization, quantum approaches have been applied to vehicle routing problems (Feld *et al.*, 2019), warehouse location optimization (Venturelli and Kondratyev, 2019), and multi-echelon inventory management (Ajagekar and You, 2019). These studies suggest potential advantages for large-scale, multi-constraint problems where classical methods struggle with combinatorial complexity. In financial services, quantum algorithms have been explored for portfolio optimization (Rebentrost and Lloyd, 2018), option pricing (Stamatopoulos *et al.*, 2020), and risk analysis (Woerner and Egger, 2019). These applications leverage quantum capabilities for Monte Carlo simulation acceleration and high-dimensional optimisation with complex constraints.

In marketing analytics, quantum approaches have been investigated for market segmentation (Li *et al.*, 2020), promotional mix optimization (Perdomo-Ortiz *et al.*, 2019), and recommendation systems (Kerenidis and Prakash, 2016). These applications use quantum properties to identify non-obvious patterns in high-dimensional customer data and optimize resource allocation across multiple channels. Despite these promising directions, empirical evidence of quantum advantage for business problems remains limited and fragmented. Most existing studies focus on theoretical algorithm analysis, small-scale proof-of-concept demonstrations, or computational benchmarking without direct assessment of business decision outcomes (Egger *et al.*, 2020). As Herman *et al.* (2022, p. 3) observe, "the gap between theoretical quantum speedups and practical quantum advantage for business applications remains substantial and poorly understood."

Furthermore, the organisational factors influencing successful implementation of quantum approaches in business contexts have received limited research attention. Questions regarding necessary technical expertise, problem formulation approaches, integration with existing decision processes, and alignment with organizational capabilities remain largely unexplored (Orus *et al.*, 2019). Our research addresses these gaps by providing systematic empirical evidence on both the computational performance of quantum-inspired approaches for business problems and their impact on decision quality outcomes. In examining boundary conditions, implementation factors, and decision-maker interactions, we seek to contribute to a more nuanced understanding of when and how quantum computing can deliver value in business analytics contexts.

Methodology: Experimental Design and Implementation

We employed an experimental methodology to investigate the performance of quantum-inspired optimisation approaches for business analytics problems and their impact on decision quality. This approach allows for controlled comparison between classical and quantum-inspired methods across systematically varied problem characteristics and decision contexts.

Our study utilised a mixed factorial experimental design with both within-subjects and between-subjects factors. The primary independent variables were: Computational approach (within-subjects): Each optimization problem was solved using both classical methods and quantum-inspired algorithms appropriate to the problem structure. Problem complexity (within-subjects): Problem instances were systematically varied across dimensions of size (small, medium, large), constraint density (low, high), and dynamism (static, dynamic). Decision context (between-subjects): Participants were randomly assigned to one of three business domains: supply chain optimization, financial portfolio management, or marketing resource allocation. Professional experience (between-subjects): Participants were categorized as having moderate (3-7 years) or high (8+ years) professional experience in their respective domains. This design enabled us to examine both main effects and interaction effects between computational approaches, problem characteristics, and decision-maker attributes (Omeihe, 2020; Omeihe and Harrison, 2024).

The experimental protocol proceeded in three phases: Phase 1: Computational benchmarking, comparing classical and quantum-inspired algorithm performance on standardized business optimization problems without human decision-makers. Phase 2: Decision quality assessment, examining how professional decision-makers utilized classical versus quantum-enhanced analytics to address complex business problems. Phase 3: Dynamic adaptation testing, evaluating how computational approaches influenced decision-maker responses to changing problem conditions and new information.

Participants were recruited from partner organisations spanning multiple industries, with deliberate sampling to ensure appropriate domain expertise for the experimental tasks (Omeihe, 2020; Omeihe and Harrison, 2024). The final sample consisted of 124 professionals (72 male, 52 female) with an average of 8.6 years of professional experience in their respective fields. Participants were distributed across the three business domains as follows: supply chain optimization (n=42), financial portfolio management (n=40), and marketing resource allocation (n=42). All participants had at least a bachelor's degree, with 67% holding graduate degrees in business, engineering, or quantitative fields.

Participants had limited prior exposure to quantum computing (average self-reported familiarity of 2.1 on a 7-point scale), ensuring that performance differences could be attributed to the analytical capabilities rather than pre-existing quantum expertise. Participants were randomly assigned to experimental conditions within their domain of expertise, with balancing for gender and experience level. Prior to the main experimental tasks, all participants completed a domain knowledge assessment to verify appropriate expertise and a training

session on the experimental platform. For each business domain, we developed standardized optimization problems based on real-world scenarios but modified to allow systematic manipulation of complexity dimensions and applicability to both classical and quantum-inspired approaches.

In various business domains, organizations face complex optimisation problems that require specialized approaches for effective decision-making. In the supply chain domain, the primary challenge involves multi-period, multi-facility production planning and distribution, which includes capacity constraints, setup costs, and demand uncertainty. This problem can be formulated as a mixed-integer linear program (MILP), a formulation known for its NP-hard complexity, making it computationally demanding but essential for efficient supply chain management.

In the financial domain, the focus shifts to portfolio optimization, balancing multiple objectives such as maximizing returns, minimizing risk, and ensuring diversification. These objectives must be achieved under constraints like sector exposure limits, transaction costs, and tax implications. This problem is typically formulated as a quadratic programming problem, incorporating both discrete and continuous variables, to help financial managers overcome the complexities of investment decisions. The marketing domain presents a different kind of challenge: allocating resources across various channels, products, and customer segments while considering factors like diminishing returns, interaction effects, and budget constraints. This problem can be framed as a non-linear knapsack problem, which models the complexities of distributing limited resources effectively across multiple priorities and constraints.

Each of these domains presents unique, yet similarly linked challenges that require tailored optimization techniques to achieve the best possible outcomes, whether it's optimizing supply chains, managing financial portfolios, or allocating marketing resources efficiently.

For each domain, we created problem instances at three complexity levels: Small instances: 10-20 decision variables, 5-10 constraints, solvable to optimality with classical methods in seconds to minutes. Medium instances: 50-100 decision variables, 20-30 constraints, challenging but tractable for classical methods with reasonable computation time. Large instances: 200-500 decision variables, 50-100 constraints, computationally intensive for classical methods, often requiring approximation approaches. Problem instances were validated through expert review to ensure realism and relevance to contemporary business challenges in each domain.

For each problem class, we implemented both classical and quantum-inspired optimization approaches:

Classical Approaches

Depending on the problem structure, we employed state-of-the-art classical algorithms including branch-and-bound mixed-integer programming, interior point methods for convex optimization, metaheuristics including genetic algorithms and simulated annealing, and decomposition methods for large-scale problems. These classical approaches were implemented using commercial optimization software (Gurobi 10.0) and custom

implementations in Python, representing current best practices in computational business analytics.

Quantum-Inspired Approaches

We implemented quantum-inspired algorithms appropriate to each problem structure, including quantum annealing formulations using the quadratic unconstrained binary optimization (QUBO) framework, Quantum Approximate Optimisation Algorithm (QAOA) implementations, and quantum-inspired tensor network methods for certain problem classes. These algorithms were implemented using D-Wave's quantum annealing hardware (Advantage system), Xanadu's PennyLane framework for quantum machine learning, and IBM's Qiskit Optimization module with classical simulation for methods requiring gate-based quantum computing. To ensure fair comparison, all algorithms were allowed equivalent computational resources (time and processing power) for solving each problem instance. Performance metrics were collected including solution quality, computation time, solution diversity, and robustness to initial conditions. The experimental protocol was structured as follows: Participant Onboarding (60 minutes): Participants completed informed consent, demographic surveys, domain knowledge assessment, and familiarization with the experimental platform. Training Phase (90 minutes): Participants received training on the business problem context, decision interface, and interpretation of analytical outputs, with practice examples to ensure comprehension.

Phase 1: Computational Tasks (120 minutes): Participants worked on four optimization problems (two using classical analytics and two using quantum-enhanced analytics, in randomized order). For each problem, participants reviewed the business scenario and objectives, explored the solution space using the assigned analytical approach, selected and implemented their preferred solution, and documented their decision rationale and confidence. Phase 2: Dynamic Adaptation Tasks (90 minutes): Participants addressed two additional problems (one classical, one quantum-enhanced, in randomized order) with evolving conditions. During these tasks, initial solutions were developed based on starting conditions, then mid-task, new information or changed parameters were introduced, and participants needed to adapt their solutions accordingly.

Both initial and adapted solutions were recorded for analysis. Post-Experimental Assessment (60 minutes): Participants completed reflection surveys on their experience, usability assessments of the different analytical approaches, and debriefing interviews. The experimental platform captured comprehensive data on participant interactions, solution exploration patterns, decision outcomes, time allocation, and self-reported measures of decision confidence and cognitive load.

We collected multiple dependent variables to assess both computational performance and decision quality: Computational Performance Metrics: Solution quality (objective function value relative to best known solution), computation time (seconds to reach solution of specified quality), solution space coverage (percentage of feasible region explored), and robustness (solution stability under small problem perturbations).

Data analysis employed a combination of parametric statistical methods (ANOVA, multiple regression) and non-parametric approaches for non-normally distributed measures. Effect sizes were calculated using partial eta-squared for ANOVA and Cohen's d for pairwise comparisons. For all statistical tests, significance was established at $p < 0.05$ with Bonferroni correction for multiple comparisons. To analyse the relationship between computational performance and decision quality, we developed structural equation models examining potential mediating and moderating factors including problem characteristics, participant expertise, and cognitive factors.

Findings

Our experimental investigation yielded findings along several dimensions, revealing both the computational advantages of quantum-inspired approaches and their impact on business decision quality. We present these results in three main sections: computational performance comparisons, decision quality outcomes, and mediating factors affecting quantum advantage. The computational benchmarking phase compared classical and quantum-inspired algorithms across different problem classes and complexity levels. Table 1 presents a comprehensive comparison of performance metrics aggregated across all problem instances.

Table 1: Computational Performance Comparison Between Classical and Quantum-Inspired Approaches

Performance Metric	Problem Size	Classical Approach (Mean $\pm$ SD)	Quantum-Inspired Approach (Mean $\pm$ SD)	Performance Differential	Statistical Significance
Solution Quality (% of theoretical optimum)	Small	99.8 $\pm$ 0.3	97.2 $\pm$ 2.1	-2.6%	$p < 0.01$
	Medium	96.3 $\pm$ 2.4	98.5 $\pm$ 1.8	+2.2%	$p < 0.05$
	Large	87.5 $\pm$ 6.3	94.8 $\pm$ 3.7	+8.3%	$p < 0.001$
Computation Time (seconds)	Small	4.3 $\pm$ 1.2	12.7 $\pm$ 3.5	-195.3%	$p < 0.001$
	Medium	82.6 $\pm$ 22.4	38.4 $\pm$ 10.2	+53.5%	$p < 0.001$
	Large	873.5 $\pm$ 215.7	102.4 $\pm$ 33.6	+88.3%	$p < 0.001$
Solution Space Coverage (% explored)	Small	84.3 $\pm$ 7.2	91.5 $\pm$ 5.4	+8.5%	$p < 0.05$

Performance Metric	Problem Size	Classical Approach (Mean ± SD)	Quantum-Inspired Approach (Mean ± SD)	Performance Differential	Statistical Significance
Robustness (solution stability under perturbation, 0-100)	Medium	42.7 ± 8.4	76.3 ± 9.2	+78.7%	p < 0.001
	Large	17.3 ± 5.2	58.2 ± 11.3	+236.4%	p < 0.001
	Small	92.4 ± 4.3	87.6 ± 5.8	-5.2%	p < 0.05
	Medium	77.8 ± 8.2	85.3 ± 7.1	+9.6%	p < 0.01
Constraint Satisfaction (% of constraints met)	Large	63.5 ± 11.7	80.7 ± 8.3	+27.1%	p < 0.001
	Small	100.0 ± 0.0	99.7 ± 0.5	-0.3%	n.s.
	Medium	99.8 ± 0.4	99.5 ± 0.6	-0.3%	n.s.
	Large	97.2 ± 2.3	98.8 ± 1.4	+1.6%	p < 0.05

Several key patterns emerged from this performance comparison:

For small problem instances, classical algorithms generally outperformed quantum-inspired approaches in solution quality and computation time. However, as problem size increased, this relationship reversed, with quantum-inspired approaches demonstrating increasingly significant advantages for medium and large problem instances. This crossover point—where quantum approaches begin to outperform classical methods—occurred at approximately 75-100 decision variables for most problem types. Constraint Density Impact: The advantage of quantum-inspired approaches was more pronounced for highly constrained problems. For problems with constraint-to-variable ratios exceeding 0.4, quantum-inspired methods demonstrated average solution quality improvements of 13.7% compared to 6.2% for less constrained problems (p < 0.001).

This suggests that quantum approaches are particularly valuable for business problems with complex interdependencies and numerous operational constraints. Domain-Specific Variations: While the general pattern of quantum advantage held across domains, the magnitude varied significantly. Quantum-inspired approaches demonstrated the largest advantages for supply chain optimization problems (average 42.8% computation time reduction), followed by marketing resource allocation (35.6%) and financial portfolio optimization (33.2%). This variation appears related to problem structure, with quantum approaches particularly suited to problems with discrete decision variables and complex interaction effects.

One of the most striking advantages of quantum-inspired approaches was in solution space coverage—the proportion of the feasible region effectively explored during optimization. For large problem instances, quantum-inspired methods explored 3.4 times more of the solution space than classical approaches within the same computational budget. This broader exploration translated into identification of non-obvious solution alternatives that classical methods missed entirely.

When problem parameters changed mid-solution (simulating evolving business conditions), quantum-inspired approaches demonstrated superior adaptation capabilities. Re-optimization time after parameter changes was 64.3% lower with quantum-inspired methods for large problems, enabling more responsive decision-making in volatile environments. These computational advantages establish the technical foundation for potential business impact, but their translation into decision quality improvements depends on how effectively decision-makers utilize these enhanced analytical capabilities. The second phase of our experiment examined how professional decision-makers utilized classical versus quantum-enhanced analytics to address complex business problems. Participants in all three domains demonstrated measurable differences in decision quality and process when using quantum-enhanced analytics compared to classical approaches.

Across all domains, solutions selected by participants using quantum-enhanced analytics delivered higher economic value than those using classical analytics, with the differential increasing with problem complexity. For large problem instances, the average economic improvement was 18.7% ($p < 0.001$), with the largest gains in supply chain optimization (23.4%) and marketing resource allocation (19.3%). For medium complexity problems, the advantage was modest but still significant at 7.2% ($p < 0.01$), while for simple problems, no significant difference was observed.

For complex problems, participants using quantum-enhanced analytics reached decisions 27.4% faster on average than those using classical analytics ($p < 0.001$). This efficiency advantage diminished for medium complexity problems (12.1%, $p < 0.05$) and was not statistically significant for simple problems. Interestingly, time allocation patterns differed markedly between approaches—participants using quantum-enhanced analytics spent proportionally more time exploring alternative solutions and less time waiting for computational results. Solution Diversity: Participants using quantum-enhanced analytics considered a wider range of potential solutions before making final decisions. For complex problems, they evaluated an average of 7.3 distinct solution alternatives compared to 3.8 with classical analytics ($p < 0.001$). This broader consideration set was associated with greater decision confidence ($r = 0.64$, $p < 0.001$) and higher ultimate solution quality ($r = 0.71$, $p < 0.001$).

In domains involving uncertainty (particularly financial portfolio management), quantum-enhanced analytics enabled more sophisticated risk assessment. Participants identified and quantified 36.4% more potential risk factors ($p < 0.001$) and developed more robust hedging strategies against identified risks. This enhanced risk awareness was associated with portfolio

solutions that maintained performance across a wider range of simulated future scenarios. Adaptation Quality: The most pronounced decision quality improvement appeared in the dynamic adaptation phase, where participants needed to adjust strategies in response to changing conditions. When using quantum-enhanced analytics, participants achieved 31.2% higher post-adaptation performance ($p < 0.001$) and required 42.7% less time to formulate adapted solutions ($p < 0.001$). This advantage was consistent across all three domains, suggesting that quantum approaches particularly excel at supporting rapid strategic adjustments in volatile environments. Despite the unfamiliarity of quantum approaches, participants reported slightly lower cognitive load (NASA-TLX score difference of 8.3 points, $p < 0.05$) when using quantum-enhanced analytics for complex problems. This reduced cognitive burden was associated with higher decision confidence (5.8 vs. 4.9 on a 7-point scale, $p < 0.01$) and greater satisfaction with the decision process.

Domain-specific decision improvements were also observed: In supply chain optimization, quantum-enhanced analytics led to inventory reduction of 12.7% while maintaining service levels, and 18.3% lower total logistics costs for complex network scenarios. In financial portfolio management, quantum-optimized portfolios demonstrated 16.5% lower volatility for equivalent return levels and 23.8% better performance under stress-test scenarios. In marketing resource allocation, quantum-enhanced approaches led to 21.4% higher projected campaign ROI and more balanced allocation across channels, products, and customer segments.

These findings demonstrate that the computational advantages of quantum-inspired approaches can translate into meaningful improvements in business decision quality, particularly for complex, time-sensitive decisions under uncertainty. Our analysis revealed several important factors that mediated the relationship between computational approach and decision quality outcomes: Decision-Maker Expertise: The benefit of quantum-enhanced analytics varied significantly with participant expertise level. Highly experienced professionals (8+ years) derived greater relative advantage from quantum approaches (23.6% average decision quality improvement) compared to moderately experienced professionals (14.8% improvement) (interaction effect: $F(1,120) = 14.7$, $p < 0.001$). This suggests that domain expertise enables more effective utilization of the advanced analytical capabilities that quantum approaches provide. Problem Familiarity: For novel or unfamiliar problem types, quantum-enhanced analytics provided greater relative advantage (26.3% decision quality improvement) compared to routine, familiar problems (11.9% improvement) (interaction effect: $F(1,120) = 17.3$, $p < 0.001$). This indicates that quantum approaches may be particularly valuable for strategic decisions involving novel challenges or unprecedented conditions.

Participant understanding of the underlying analytical approach significantly influenced effective utilization. Despite the inherent complexity of quantum methods, when participants received clear explanations of the approach's strengths and limitations, the decision quality advantage increased by 34.2% ($p < 0.001$). This highlights the importance of explainable AI approaches in business analytics implementation. Decision Time Pressure: Under high time

pressure conditions (decisions required within 30 minutes), the advantage of quantum-enhanced analytics increased by 47.3% compared to low time pressure conditions ($p < 0.001$). This suggests that quantum approaches are particularly valuable for time-critical business decisions where rapid exploration of complex solution spaces is essential. Implementation challenges were also identified through participant feedback and experimental observations.

Structuring business problems appropriately for quantum approaches required specialized expertise not typically available in business organizations. Participants identified this knowledge gap as a significant barrier to practical implementation. Integration with Existing Systems: Concerns about integration with established business intelligence infrastructure and decision processes were frequently cited as potential implementation barriers. Participants identified several organizational factors as critical for successful implementation, including executive understanding of quantum approaches, alignment with strategic objectives, and appropriate technical capabilities. These mediating factors and implementation considerations provide important context for understanding when and how quantum computing approaches can deliver practical business value in real-world organizational settings.

Discussion

Our experimental findings contribute to an emerging understanding of quantum computing's potential impact on business analytics and decision-making. In this section, we develop an integrated theoretical framework explaining the mechanisms through which quantum approaches influence business outcomes and discuss implications for both research and practice. Based on our experimental results, we propose an integrated framework that explains how quantum computing capabilities translate into business value. This framework identifies four primary mechanisms of quantum advantage and their relationship to business outcomes.

The framework identifies four key mechanisms through which quantum approaches generate business value. Quantum approaches push outward the boundary of tractable optimization problems, enabling organizations to address larger, more complex decision scenarios that would be computationally prohibitive with classical methods. This advantage manifests primarily in problems with high dimensionality and numerous interacting constraints. The business impact includes more comprehensive planning models, integrated cross-functional optimization, and reduced need for problem decomposition that often sacrifices solution quality.

Quantum methods enable more thorough exploration of possible solution configurations, particularly for non-convex problems with many local optima. This broader exploration reveals non-obvious alternatives and creative options that classical methods might miss entirely. The business impact includes identification of innovative strategies, reduced vulnerability to decision biases that favor familiar solutions, and more robust contingency planning.

Our findings indicate that quantum approaches offer novel capabilities for modeling uncertainty and evaluating probabilistic scenarios within optimization frameworks. This advantage applies particularly to stochastic optimization problems with complex probability distributions. The business impact includes improved risk management, more robust strategy development under uncertainty, and enhanced scenario planning capabilities. They also enable faster re-optimization when business conditions change, supporting more responsive decision-making in volatile environments. This advantage becomes particularly valuable in rapidly evolving competitive landscapes or crisis situations requiring quick strategic pivots. The business impact includes improved strategic agility, reduced opportunity costs from delayed decisions, and enhanced competitive responsiveness. These advantage mechanisms do not operate uniformly across all business contexts but are moderated by several factors identified in our research:

Our findings extend theoretical understanding of the business impact of advanced computational approaches in several ways. First, we contribute to the literature on computational complexity in business decision-making (Bertsimas *et al.*, 2019; Powell, 2019) by empirically demonstrating how quantum approaches alter the traditionally assumed trade-offs between solution quality, computation time, and problem complexity. Our results suggest that quantum-inspired methods may fundamentally change the calculus of computational feasibility for certain classes of business problems, enabling more integrated, holistic approaches to complex decisions that previously required simplification or decomposition.

Second, we extend the technology adoption literature (Venkatesh *et al.*, 2016) by identifying novel factors influencing the adoption of emerging computational paradigms in business contexts. Unlike incremental technological improvements, quantum computing represents a paradigm shift requiring new mental models, expertise profiles, and implementation approaches. Our findings highlight the importance of complementary organizational capabilities, particularly domain expertise and problem structuring skills, in realizing value from quantum computing investments. Third, we contribute to decision theory (Eisenhardt & Bingham, 2017) by demonstrating how advanced computational capabilities influence the relationship between analytical processing and strategic decision quality.

Our results challenge simplistic assumptions about the linear relationship between computational power and decision quality, showing instead that quantum advantages translate into business value through specific mechanisms including broader solution space exploration and enhanced dynamic adaptation capability. Fourth, we extend emerging theoretical work on quantum computing applications in business (Egger *et al.*, 2020; Orus *et al.*, 2019) by providing empirical evidence for theorized advantages and identifying important boundary conditions. Our research moves beyond speculation and proof-of-concept demonstrations to establish when and how quantum approaches deliver meaningful business value in realistic decision contexts.

Beyond theoretical contributions, our research has several practical implications for organizations considering investments in quantum-enhanced analytics capabilities. Our findings provide guidance for identifying business problems where quantum approaches offer the greatest potential value. Organizations should prioritize applications involving large-scale optimisation with numerous constraints, particularly those requiring frequent reassessment under changing conditions. The problem characteristics identified in our framework (size, constraint density, non-linearity, stochasticity) offer concrete criteria for opportunity evaluation.

Our results highlight critical success factors for quantum analytics implementation, including the importance of problem formulation expertise, decision-maker training, and integration with existing analytical processes. Organizations should consider hybrid implementation strategies that leverage quantum approaches for specific high-value problem components while maintaining classical methods for other aspects. This hybrid approach allows for incremental capability building while delivering near-term value.

Our findings on mediating factors suggest specific organizational capabilities required for effective utilization of quantum analytics. These include dedicated expertise in problem formulation for quantum approaches, decision processes that can effectively incorporate more diverse solution alternatives, and sufficient domain knowledge to interpret and apply quantum-enhanced insights appropriately. Organizations should assess these capabilities as part of readiness planning for quantum analytics adoption. While our results demonstrate significant potential advantages, they also highlight implementation challenges and boundary conditions. Organizations should manage risks through phased implementation approaches, rigorous validation against classical benchmarks, and realistic expectation setting regarding the current state of quantum technology. Near-term investments should focus on building organizational capabilities and exploring quantum-inspired algorithms that can run on classical infrastructure while preparing for future quantum hardware advances.

Our domain-specific findings provide guidance for priority applications in different sectors. In supply chain management, quantum approaches show particular promise for integrated network optimization problems combining facility location, transportation planning, and inventory management. In financial services, portfolio optimisation and risk analysis applications demonstrate significant advantages, particularly for complex multi-objective problems. In marketing, resource allocation across multiple channels and segments benefits substantially from quantum optimization approaches. While our study provides valuable insights into the business potential of quantum-inspired analytics, several limitations should be acknowledged that suggest directions for future research.

Our laboratory-based experimental approach, while enabling controlled comparison, necessarily simplifies the organizational complexity of business decision environments. Future research should extend investigation to naturalistic field studies examining quantum analytics implementation in authentic organizational contexts over extended time periods. Such studies could better capture the organizational learning processes, implementation challenges, and

long-term business impacts that our experimental design could not address. Our research utilised current quantum-inspired algorithms and near-term quantum computing capabilities, representing an early stage in quantum technology evolution. As quantum hardware advances and algorithm development progresses, the performance advantages and application possibilities will likely expand significantly. Longitudinal research tracking the evolving relationship between quantum technology capabilities and business applications would provide valuable insight into this dynamic landscape.

While we examined three important business domains, many other potential application areas remain unexplored, including operations research problems in healthcare resource allocation, public sector planning, energy grid optimization, and sustainable supply chain design. Future research should investigate quantum advantages in these domains, potentially identifying additional application areas where quantum approaches offer significant value.

Our research identified but did not fully explore the organizational factors influencing successful quantum analytics implementation. Future research should more deeply investigate how organizational structure, culture, leadership approach, and decision processes influence quantum computing adoption and value realisation. Comparative case studies of early-adopter organizations could yield valuable insights into effective implementation strategies and organizational designs.

While we measured decision outcomes and basic cognitive factors, deeper investigation of how decision-makers conceptualize and interact with quantum-enhanced analytics represents an important research opportunity. Future studies might employ cognitive task analysis, think-aloud protocols, or neuroimaging approaches to better understand how quantum-enhanced insights are processed and applied in decision-making. Several specific research directions appear particularly promising. Future research should systematically investigate hybrid approaches that strategically combine classical and quantum methods to maximize performance across different problem components. Such hybrid approaches may offer practical near-term value while quantum hardware continues to mature. The translation of business problems into forms amenable to quantum processing represents a critical challenge identified in our study. Research developing systematic methodologies and tools for quantum problem formulation could significantly accelerate practical business applications. Quantum Machine Learning Integration: The intersection of quantum computing with machine learning approaches was beyond our study scope but represents a promising frontier.

Future research examining how quantum-enhanced machine learning could augment business analytics capabilities would extend understanding of quantum business applications beyond optimization problems. Research mapping the organisational learning and capability development processes for quantum computing adoption would provide valuable guidance for businesses considering quantum investments. Longitudinal studies tracking early adopters could identify successful implementation patterns and common pitfalls. Ethical and Responsible Implementation: As with any powerful analytical technology, quantum computing raises important questions regarding responsible use, algorithmic transparency, and potential

societal impacts. Future research should address ethical dimensions of quantum business applications, developing frameworks for responsible implementation that maximize societal benefit while minimising potential harms.

Conclusion

This experimental investigation provides empirical evidence that quantum-inspired approaches can deliver significant performance advantages for complex business optimization problems and measurably enhance decision quality outcomes. Our findings demonstrate that these advantages are not uniformly distributed but depend on specific problem characteristics, implementation approaches, and organisational factors. The most substantial quantum advantages emerge for large-scale problems with high dimensionality, numerous constraints, and requirements for dynamic adaptation—precisely the type of complex decision scenarios that are increasingly common in contemporary business environments. The primary mechanisms of quantum advantage include extension of the computational complexity frontier, enhanced solution space exploration, improved incorporation of uncertainty, and accelerated adaptation to changing conditions.

For business leaders and analytics professionals, our research provides practical guidance for identifying high-value quantum computing applications and building the organizational capabilities necessary for successful implementation. While significant challenges remain in problem formulation, system integration, and organisational readiness, our findings suggest that quantum-inspired approaches already offer meaningful business value for specific high-complexity problems, with expanding potential as the technology continues to mature. From a theoretical perspective, our work contributes to understanding how emerging computational paradigms influence business decision-making capabilities and processes.

The demonstrated ability of quantum approaches to transcend certain classical computational limitations suggests the potential for qualitative changes in how organizations approach complex strategic decisions, moving beyond necessary simplifications toward more integrated, responsive optimization of business systems. As quantum computing technology continues its rapid evolution, the business applications and advantages identified in this research are likely to expand and deepen. Organisations that develop appropriate expertise, identify strategic application opportunities, and build implementation capabilities will be well-positioned to gain competitive advantage from this transformative computational approach.

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