Journal of Decision Science and Optimization
Vol. 1 (2025), No. 1, pp. 35-54
DOI: https://doi.org/10.55578/jdso.2506.002

ARTICLE

The Quantum Dynamics of Cost Accounting: Investigating WIP via the Time-Independent Schrödinger Equation

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Received: 21 March 2025, Accepted: 26 May 2025, Published: 13 June 2025

Abstract

The intersection of quantum theory and accounting presents an alternative way of understanding financial valuation and accounting practices. This paper applies quantum theory to cost accounting's work-in-progress (WIP). WIP is conceptualized as in multiple states simultaneously, which provides probability amplitudes for different WIP values, and models interdependencies between various aspects of WIP. The study demonstrates how quantum concepts such as entanglement, superposition, measurement, teleportation , entropy , and tunnelling can be adapted to represent the dynamic nature of WIP. The primary contribution of this work is a more nuanced understanding of the uncertainties involved, which emerges by applying quantum phenomena to model the complexities and uncertainties inherent in managerial accounting. In contrast, previous works focus more on financial accounting or general accountancy.

Keywords: Managerial Accounting; Work in Progress; Quantum Information Theory; Accounting Information Systems; Continuous Audit

1. INTRODUCTION

The traditional accounting treatment of Work in Progress (WIP) involves estimating the value of partially completed goods, which poses inherent challenges due to the production processes' uncertain and dynamic nature [1]. By drawing parallels with quantum superposition, where particles exist in multiple states until measured [2], we can propose a novel perspective on accounting for WIP. This quantum-inspired approach addresses the intrinsic uncertainties in valuing WIP and aligns with the evolving landscape of accounting standards that increasingly recognize the complexity of modern business operations.

To effectively study the application of quantum theory to managerial accounting, we integrate principles from quantum mechanics, such as superposition and entanglement, with accounting theories related to asset valuation and measurement, both of which rely on estimates. This work mainly focuses on the classical percentage of completion method and the completed contract method of accounting for WIP. This interdisciplinary approach combines theoretical exploration with conceptual analysis and illustrative examples from quantum physics and accounting. Examining the parallels between quantum phenomena and WIP valuation challenges establishes a robust framework that offers fresh insights into accounting methodologies.

This endeavour aims to examine conventional accounting methodologies concerning WIP and elucidate the intricacies inherent in the valuation processes associated with such practices. The literature review will expound upon the traditional accounting paradigms employed in WIP valuation, expatiating on the challenges that pervade these established frameworks. Subsequently, the paper will pivot to an unconventional perspective by introducing key tenets from quantum theory, specifically exploring the quantum phenomena of superposition and entanglement. This section aims to elucidate the nuanced connections between quantum concepts and their potential applicability to accounting. Following this quantum theory exposition, the research will articulate a conceptual framework synthesizing quantum principles with accounting practices. It will focus on their integration to mitigate

https://doi.org/10.55578/jdso.2506.002

valuation uncertainties inherent in WIP accounting. This conceptual development will address the perennial challenges of traditional accounting methodologies. The subsequent segment will scrutinize the implications of adopting this quantum-inspired accounting model for WIP on established accounting standards, practices, and the overarching financial reporting landscape. This exploration will navigate the potential transformative effects on accounting, considering the theoretical underpinnings and practical consequences of embracing quantum principles. Ultimately, the paper aspires to contribute to the ongoing discourse surrounding accounting innovation by integrating quantum theory into the valuation framework of Work-in-Progress, fostering a deeper understanding of the intricate dynamics at play within contemporary reporting practices.

Quantum computing maturing as a technology means accountants should keep up with the times. As production processes become more intricate and interconnected [3], traditional accounting methods struggle to accurately capture WIP valuation's dynamic and uncertain nature [4]. There are existent challenges in WIP measurement, such as optimal cost allocation, revenue recognition, and unforeseen delays or changes that may impact the process. Accounting professionals leveraging quantum-inspired methodologies can build upon established advances in quantum information science to enhance valuation models and risk assessments [5]. This paper aims to demonstrate that quantum theory offers valuable insights and tools to enrich accounting practices, making a compelling case for accountants to explore and embrace this innovative perspective.

2. LITERATURE REVIEW

The following literature review summarizes key findings from several seminal works in quantum accounting. It discusses the current gap in accounting literature regarding the application of quantum theory to WIP accounting. In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[1]., the literature review section is systematically structured to include the selection criteria, search strategy, data collection and analysis, and study quality and risk of bias. The following rephrased paragraphs are presented to fit within this structured approach:

2.1. Selection Criteria

The inclusion criteria for this review were studies that examined integrating quantum theory with accounting practices. Specifically, the review focused on seminal works that explored the conceptual applications of quantum information to accounting information systems, the valuation of WIP, and the implications of quantum features such as entanglement and superposition in accounting. Key words were accounting, WIP, and quantum.

2.2. Search Strategy

The search strategy involved identifying key studies that have contributed to the field of quantum accounting. The search included works by [6-11]. These studies are selected for their exploration of the intersection between quantum financial information theory found in previous works for over half a century and accounting principles. They represent a comprehensive list focusing on the intersection of quantum and accounting.

2.3. Study Quality & Risk of Bias

The quality of the included studies was assessed based on their conceptual rigor and the novelty of the approaches proposed. The risk of bias is considered low, as the studies were primarily theoretical explorations of quantum theory's application to accounting.

2.4. Synthesis of Results

- Demski et al. [5] proposed that quantum theory could provide a novel perspective on the fundamental laws of accounting, potentially enriching the approach to accounting information with a different way of looking at things [5].

[1] http://www.prisma-statement.org/

- Fellingham and Schroeder [5] discuss the use of quantum probabilities in a two-agent control setting, deriving the logical consequences of quantum probabilities if they occur [11].
- Demski et al. [12] investigated the conceptual applications of topology within quantum information and accounting in the context of internal controls mandated by the Sarbanes-Oxley Act of 2002. They also contrasted financial statements' monetary amounts with internal controls' error frequencies [12].
- In a subsequent study, Demski et al. [12] explored the role of topological quantum computation in addressing issues of decoherence and imprecision in quantum computation, proposing the use of exotic topological states for global information storage and manipulation [12].
- Fellingham, Lin, and Schroeder [10] examined quantum entropy and its potential applications in accounting, suggesting parallels between the uncertainty in quantum systems and financial information [10].
- Fellingham, Lin, and Schroeder [9] discussed the interrelation between entropy, double-entry accounting, and quantum entanglement, providing insights into the potential integration of these concepts within accounting frameworks. For example, equality between accounting numbers, firm rate of return, and the amount of information available to the firm, using Shannon's entropy as the information metric [9].
- De Oliveira and Lustosa [7] applied quantum physics concepts to the economic nature of goodwill. They brought up Valuation challenges and reporting considerations and implied that current methods of goodwill impairment testing might be inadequate due to the entangled and non-local nature of goodwill [7].
- Kahyaoglu [6] examines how traditional accounting and auditing practices, built on classical computing and periodic reporting structures, are becoming obsolete in an increasingly complex business environment characterized by VUCA (volatility, uncertainty, complexity, and ambiguity). Additionally, the editorial note introduces the concept of "quantum corporate governance principles" from an accounting perspective and argues for new business culture and professional rules that can accommodate the instantaneous, complex data processing requirements of modern organizations, particularly in risk management and fraud detection [6].
- Lazirko [13] compared quantum standards between the European Union and the US while exploring their implications on AIS. It was found that the two's history and culture impacted the development of quantum standards [13].

Despite the contributions provided by the aforementioned works, there remains a significant gap in the literature regarding applying quantum theory to accounting. Applying quantum information theory to inventory management during production is a novel approach that has yet to be extensively explored. Hence, there is uncertainty regarding buyers/usage, which can be captured by existing uncertainty models and valuating the appearance in several states.

The current literature primarily focuses on the conceptual overlap between quantum theory and accounting principles, emphasizing the potential for quantum theory to provide a new lens through which to view accounting challenges. Applying quantum theory to managerial accounting would necessitate a more detailed exploration of how quantum measurement, uncertainty, and the dynamics of superposition could be analogously applied to the valuation of materials and goods that are in the production process but still need to be completed, which may not always be deterministic dependant on certain risks. This represents an opportunity for this research to bridge the gap by developing a quantum accounting information systems framework.

3. THEORETICAL FRAMEWORK

3.1. Introduction to Quantum Concepts Relevant to Accounting

Integrating quantum concepts into accounting practices offers a perspective on addressing the complexities and uncertainties inherent in financial information systems [11]. This section introduces several quantum concepts that are particularly relevant to developing a quantum accounting model for WIP. Table 1 summarizes the following sub-sections.

Table 1. Quantum Accounting Concepts

Concept	Description	Implications in Accounting
Entanglement	Interdependence of accounting entities and transactions; changes in one affect another.	Highlights the need to consider interconnections in financial reporting.
Superposition	Allows a system to occupy multiple states and collapse when an event justifies it, related to WIP uncertainty.	Shows the uncertainty in project states and the impact of decision-making.
Measurement	Current stage of WIP progress is measured when new information impacts its state.	Emphasizes the importance of accurate measurement upon receiving new information.
Teleportation	Metaphor for instantaneous transfer of value/information across parts of an organization.	Suggests a streamlined approach to information transfer in financial processes.
Entropy	Represents complexity and uncertainty in financial information, affecting measurement accuracy.	Points to the challenges of managing complexity and uncertainty in financial states.
Quantum Tunneling	Describes arbitrage opportunities as barriers that investors can tunnel through for profit.	Illustrates market dynamics and decision-making based on price discrepancy

Entanglement

Quantum entanglement describes a phenomenon where the state of one particle cannot be described independently of the state of another, regardless of the distance separating them. In accounting, this concept can be applied to understand the interdependence of various accounting entities and transactions, where the change in one can instantaneously affect the state of another [14].

Superposition

Superposition refers to quantum systems' ability to exist simultaneously until measured in multiple states [15]. Rather than make an assumption about a system and collapse the unobserved[2] to a single point, we can allow it to occupy multiple states instead. Moreover, accounting systems collapse as a wave function when something happens to justify the collapse. In managerial accounting, superposition can be used to model the uncertain state of Work-In-Progress (WIP), which depends on potential buyers or users. Unlike a quantum observation, which captures a current state, these values are not determined by a present observation. Instead, if the available alternatives and decision field are known, an observation isn't necessary to define the decision value. For example, if an offer is to arrive at this moment, it prompts an evaluation of the WIP's current stage.

Measurement

Quantum measurement is the process by which the state of a quantum system becomes known, collapsing superposition into one of the possible states [16]. In accounting, the current stage of the WIP's progress would be measured when new information arrives that directly impacts the current stage of the WIP at that moment.

[2] Exogenous variables as a comprehensive measure are inherently ubovservable because we can not capture all of them.

Teleportation

Quantum teleportation involves the transfer of quantum states from one location to another without the physical movement of the particles [17]. While more abstract in its application to accounting, teleportation could metaphorically represent the transfer of value or information across different parts of an organization instantaneously, without the traditional transfer of documentation or entries [18].

Entropy

Entropy measures the uncertainty or disorder within a quantum system in quantum mechanics. Applied to accounting, entropy can represent the complexity and uncertainty in financial information, highlighting the challenges in achieving accurate and precise measurements of financial states [10], such as the valuation of WIP.

Quantum Tunneling

Quantum tunneling, a fundamental concept in quantum mechanics, explains that a particle can tunnel through an energy barrier that it would not be able to surmount classically, a phenomenon that is not directly observable but can be inferred from the presence of the particle on the other side of the barrier [19]. Similarly, arbitrage opportunities can be considered "energy barriers" that can be "tunneled" through by investors seeking to profit from price differences in different markets. This analogy implies that quantum tunneling might serve as a model for arbitrage behaviour, indicating that there is a barrier between markets that typically cannot be surmounted. In accounting research, we historically utilize Bayesian theory for inference problems [20].

3.2. Overview of WIP in Accounting & Its Challenges

Work in Progress (WIP) refers to the goods in production that are not yet completed. Accounting for WIP involves estimating the value of these goods, which can be challenging due to the dynamic nature of production processes and the uncertainty regarding the outcome and costs. Absorption costing is one of the most widely used methodologies for accounting Work-in-Progress (WIP). While absorption costing offers a comprehensive approach to capturing all manufacturing costs, it presents challenges in accurately allocating overhead to partially completed units [21]. This difficulty arises due to the inherent complexity in assigning overhead, particularly for units in different stages of completion.

Activity-Based Costing (ABC) provides a more detailed approach to overhead allocation by linking costs directly to activities that drive them. For WIP accounting, ABC enables a more granular and precise cost breakdown, which can result in more accurate valuations. However, the complexity of this method, especially for smaller businesses, poses challenges in terms of implementation and operational feasibility. ABC is often more resource-intensive, requiring significant data collection and analysis to track activity-based cost drivers accurately.

Standard costing, an alternative approach, involves using predetermined estimates for material, labor, and overhead costs per unit of production. In the case of WIP, this approach calculates value based on the percentage of completion and multiplies it by these standard costs. Although this method simplifies the WIP calculation process, it may introduce inaccuracies if significant deviations from the standard costs occur during production.

The valuation of Work-in-Progress (WIP) is inherently subject to a range of uncertainties that can compromise its accuracy. One significant factor is the estimation of the completion stage, where determining the exact percentage of completion for partially finished units can be subjective, especially in the case of complex products or multi-stage production processes. Additionally, fluctuations in raw material prices, labor rates, and overhead costs during production further complicate the accurate assessment of WIP. Quality issues also play a critical role, as unanticipated defects may necessitate rework, thereby diminishing the value of WIP. Moreover, changes in specifications, such as customer requests or design modifications made mid-production, can substantially alter WIP's cost structure and valuation. Variations in efficiency, influenced by factors such as equipment downtime or differences in worker skill levels, impact the actual costs incurred. Another challenge lies in allocating fixed overhead costs to WIP, as establishing a direct relationship between these costs and individual production units is often tricky. Lastly, market conditions, particularly shifts in demand for custom or specialized products during the production process, can affect the realizable value of WIP, further complicating its valuation.

These uncertainties can introduce potential inaccuracies with significant implications for financial reporting, pricing strategies, and broader business decisions. Consequently, firms must balance the need for precision in their WIP accounting with the practicalities of available measurement methods. Thus, traditional accounting methods often struggle to capture real-time fluctuations and inherent uncertainties in value, leading to potential inaccuracies in decision-making [22].

4. METHODOLOGY

This section outlines the methodology for integrating quantum theory with WIP accounting, focusing on applying quantum entanglement, superposition, and measurement theory to model the complexities and uncertainties inherent in WIP valuation. Drawing parallels between the abovementioned quantum concepts and the challenges in accounting for WIP, we can propose a quantum accounting model for WIP that leverages the principles of superposition, entanglement, measurement, teleportation, and entropy. This model conceptualizes WIP as existing in a superposition, embodying multiple states. The value of WIP is entangled with other financial entities and transactions, reflecting the interconnected nature of business operations.

The model suggests that the value of WIP can exist in multiple potential states (superposition) during WIP until an event (e.g., completion of production, sale) leads to the measurement and recognition of a specific value. This approach acknowledges the uncertainty in WIP valuation. By recognizing the entangled nature of financial transactions and the instantaneous impact of certain events on financial states, the model can account for the complex interactions within an organization's financial system. The metaphorical use of teleportation emphasizes the need for accounting systems that can rapidly and accurately reflect changes in financial information across different parts of the organization. The model acknowledges the role of entropy in increasing the uncertainty and complexity of accounting for WIP. By applying quantum concepts, the model aims to provide a more nuanced understanding of the uncertainties involved and suggests strategies for managing and reducing entropy in financial information systems[3].

Applying the Time-Independent Schrödinger Equation (TISE)

The Time-Independent Schrödinger Equation (TISE) is a fundamental concept in quantum mechanics [23] that we can use to explain Quantum WIP; it describes the time evolution of a quantum system. It is given by the equation:

$$\hat{H}\psi = E\psi$$

- $\hat{H}$ represents the Hamiltonian operator of the system
- ψ is the system's wave function
- E is the eigenvalue of the system's total energy

The solution to this equation provides information about the behavior of quantum systems. In Work in Progress (WIP) accounting, applying the TISE would involve treating the accounting system as a quantum mechanical system. This would require the identification of the Hamiltonian operator $\hat{H}$ that describes the accounting system and its interactions with the environment. The Hamiltonian operator would include terms representing the energy associated with the accounting system's state, such as the energy associated with the accounting entries and their relationships.

Applying the TISE to WIP accounting would allow for calculating the “energy levels” of the accounting system, which could be interpreted as the various states of the accounting system. These energy levels could represent different stages of the accounting process. This quantum accounting

[3] AIS keeps systems from decoherence, but with the gradual culling of labor, we can predict a potential collapse due to entropy - unless there is accountancy to ensure systems stay coherent.

model for WIP offers a theoretical framework that captures WIP valuation's dynamic and uncertain nature, providing a foundation for developing more accurate and responsive accounting practices.

The measurement process would involve periodic assessments of WIP, considering the progress of production, cost changes, and other relevant factors that could affect its valuation. This could be facilitated by adopting a probabilistic approach to accounting, where the value of WIP is expressed as a range of possible values with associated probabilities rather than a single deterministic figure. The probabilistic values can be updated to reflect new information, ultimately leading to a more precise valuation of WIP. This methodology, inspired by quantum measurement theory, offers a novel way to address the challenges of WIP accounting, providing a framework better aligned with modern production processes' complexities and uncertainties. The wave function solutions to the TISE provide probability amplitudes, which can be interpreted as the likelihood of different WIP values. Because the TISE naturally leads to discrete energy levels, which can be analogous to discrete value levels in WIP accounting, potentially simplifying the valuation process, the Heisenberg uncertainty principle, derived from the TISE, can be used to model the trade-off between precision in cost estimation and timing of measurement in WIP accounting.

5. CASE STUDY

This case study demonstrates how quantum principles can enhance traditional accounting frameworks within manufacturing contexts characterized by high variability and uncertain outcomes. The manufacturing environment exhibits varying cost structures that are contingent upon final product specifications, creating inherent valuation challenges for traditional accounting systems. Furthermore, the presence of uncertain customer requirements that frequently change during production introduces additional complexity that conventional deterministic accounting struggles to capture accurately. The implementation of multiple valuation points throughout the production process becomes necessary to adequately reflect the evolving nature of the product's economic value, establishing a foundation for applying quantum principles to accounting measurement challenges.

Consider a partially completed customizable product that could be finished according to several different customer specifications- each completion pathway carries distinct cost implications and profit potential. Traditional accountants would typically assign a single expected value or use the lower of cost and net realizable value, potentially misrepresenting the economic reality. In contrast, a quantum-inspired model maintains a probability distribution of possible values, weighted by likelihood of occurrence, providing a more nuanced representation of materiality under uncertainty due to the principle of superposition. This approach more accurately reflects the contingent nature of value in dynamic manufacturing environments where completion pathways remain undetermined until later production stages.

Entanglement manifests when changes in one aspect of production instantaneously affect other accounting entities due to underlying relationships and dependencies. For example, a sudden change in customer specifications for one production batch will immediately alter the valuation profiles of seemingly separate WIP inventories that share production resources, raw materials, or technological dependencies. Unlike traditional accounting systems that might recognize these effects only during periodic reconciliation, a non-linear approach explicitly acknowledges and models these interdependencies, allowing for real-time valuation adjustments across the production ecosystem. This network perspective of value creation better captures the complex reality of modern manufacturing environments where distinct accounting entities exhibit significant correlation in their valuation dynamics.

A critical element in quantum-inspired accounting is the identification and treatment of measurement events—specific points where new information causes the superposition of possible WIP values to collapse into more definitive valuations. These measurement events might include confirmed customer orders, quality assessments, regulatory approvals, or significant market changes that clarify the completion pathway of WIP inventory. For instance, when a customer finalizes specifications for a customizable product, the various potential states of that product's valuation collapse into a more defined range of values. The quantum-inspired framework formalizes these measurement events within the accounting system, establishing specific protocols for when and how valuations transition from probability distributions to more concrete figures. This approach maintains the integrity of traditional accounting measurement principles while enhancing them with a more sophisticated treatment of uncertainty resolution, providing stakeholders with more transparent insights into how value crystallizes throughout the production process.

Overall, traditional WIP accounting methods, such as job costing and process costing, rely on deterministic models [24] that may not fully capture the complexities and uncertainties of modern business operations. These methods often assume linear progress and clear-cut distinctions between different stages of production, which may not always be the case. In contrast, by incorporating principles like superposition and entanglement, quantum accounting approaches offer a more nuanced and dynamic framework that can adapt to the probabilistic nature of business activities [25].

Simulating H

Following the aforementioned environment, the TISE formulation $\hat{H}\psi = E\psi$ translates to accounting contexts through these component definitions:

Operator:

$$H = -\frac{\hbar^2}{2m}\nabla^2 + V(x) \rightarrow \ H_{acc} \ = \alpha\frac{\partial^2}{\partial v^2} + \beta\mathcal{F}(C, L, M, D)$$

Where:

α = Information diffusion coefficient (measures market uncertainty propagation)

v = Valuation basis (equivalent to spatial coordinate in quantum systems)

β = Cost structure scaling factor

$\mathcal{F}$ = Operator combining production costs (C), labor inputs (L), material flows (M), and demand factors (D)

The structure follows the classical quantum Hamiltonian form, which combines kinetic and potential energy terms to determine a quantum system's total energy [26]. In this accounting adaptation, where an accounting hamiltonian is postulated, the first term ($\alpha \ \partial^2/\partial v^2$) functions analogously to the kinetic energy operator in quantum mechanics, while the second term $\beta\mathcal{F}(C, L, M, D)$ parallels the potential energy operator. The valuation basis variable v serves as the spatial coordinate equivalent, creating a mathematical space where accounting information can propagate and transform. This approach aligns with Hamiltonian theory, where complex systems can be represented using operators that maintain the essential properties of the original system, and several established quantum finance approaches validate this adaptation strategy. For instance, nonlinear Schrödinger equations have been successfully applied to option pricing models, serving as alternatives to the Black-Scholes model [27].

In quantum mechanics, potential energy terms typically include scaling factors that determine the strength of the potential relative to the kinetic term. Similarly, β determines how strongly cost structure factors influence the overall accounting system compared to information diffusion processes [28]. The martingale condition (i.e., the risk-neutral measure) corresponds to the ground state of the system; spontaneous symmetry breaking induced by market perturbations such as volatility shocks or demand fluctuations then destabilizes this vacuum, generating a family of degenerate martingale (excited) states [29]. The operator $\mathcal{F}$ introduces analogous symmetry-breaking effects. For instance, rising labor costs (L) or material shortages (M) would elevate $\mathcal{F}$, thereby reducing the net present value of a WIP asset unless offset by demand growth (D) [30]. Thus, in this accounting adaptation, increased costs create financial "barriers" that reduce asset valuation probabilities [31].

This operator departs from quantum mechanics by replacing wave-like oscillations with a hybrid model of stochastic diffusion and deterministic cost-demand interactions. The α-driven term governs the probabilistic dispersion of valuations under uncertainty, while the $\beta\mathcal{F}$-term anchors valuations to tangible operational realities. Together, they describe how WIP assets evolve dynamically: market noise (α) introduces valuation volatility, while operational efficiency ($\beta\mathcal{F}$) imposes structure, akin to a Langevin equation in stochastic processes [32].

Empirically, H_{acc} enables us to simulate valuation trajectories under scenarios such as tariff uncertainty (α↑), supply chain disruptions (M↓), labor strikes (L↑), or demand shocks (D↓). Through solving the associated accounting Schrödinger equation, practitioners can forecast probabilistic valuation distributions, moving beyond static discounted cash flow models. For example, a manufacturing firm might use H_{acc} to project the distribution of a partially completed factory's value, incorporating both labor cost variances ($\beta\mathcal{F}$) and the unpredictability of tariff announcements (α).

Wave Function:

$$\psi(v,\tau) = \sum_n c_n \phi_n(v) e^{-iE_n\tau/\hbar} \rightarrow \psi_{acc}(v,\tau) = \sum_k w_k \chi_k(v) e^{-\gamma_k \tau}$$

Where:
w_k = Probability amplitude for valuation state
$\chi_k(v)$ = Valuation eigenstates
γ_k = Entropic decay rates
τ = Operational time parameter

Consider that the valuation wave function encodes how each discrete valuation scenario (the "eigenstates") χ_k contributes to the overall WIP value over operational time τ, with weights w_k reflecting their likelihood and decays γ_k capturing risk-driven value erosion.

Parameter k serves as an indexing mechanism for distinct valuation states, similar to how quantum mechanics uses indices to represent different energy eigenstates [33]. Central to this model is the concept of probability amplitudes (denoted w_k), which quantify the relative likelihood of distinct valuation scenarios [34]. These amplitudes are not probabilities themselves but encode the weighting of each scenario, with the squared magnitude $|w_k|^2$ yielding the classical probability of observing a specific valuation state. This formalism allows accountants to represent overlapping or competing valuation outcomes simultaneously, which is fundamentally a different approach from deterministic single-value bookkeeping. The valuation eigenstates $\chi_k(v)$ define discrete, mutually exclusive valuation scenarios for an asset, such as market value, depreciated value, or salvage value. A material's grade, for example, might occupy eigenstates like $100k (new), $60k (used), or $20k (scrap), each representing a potential financial outcome. These eigenstates form the basis of the valuation spectrum, analogous to discrete financial scenarios in traditional accounting, but with the added flexibility of superposition.

Critical to the model's temporal dynamics are the entropic decay rates γ_k, which embed risk factors or depreciation mechanisms that erode value over time (τ). These rates capture both systematic risks (e.g., physical wear at $\gamma_1 = 10\%$ annually) and unsystematic risks (e.g., market obsolescence at $\gamma_2 = 15\%$ annually). The exponential decay term $e^{-\gamma_k \tau}$ modulates each valuation eigenstate's contribution over time, reflecting how specific risks diminish value. For example, a $100k "new" eigenstate with $\gamma_2 = 13.86\%$ annually decays to $50k after five years, akin to a straight-line halving process.

This substitution transforms the system from one governed by phase rotations to one dominated by monotonic value dissipation, aligning with the irreversible nature of financial decay (e.g., depreciation, obsolescence). As seen in Figure 1, the result is a superposition of decaying valuation paths, weighted by their probabilities, offering a dynamic and probabilistic alternative to static book values. This framework provides a rigorous method to quantify uncertainty and temporal value erosion in WIP accounting, advancing traditional practices toward a more nuanced representation of financial reality by unifying scenario-based forecasting, risk-adjusted depreciation, and probabilistic weighting.

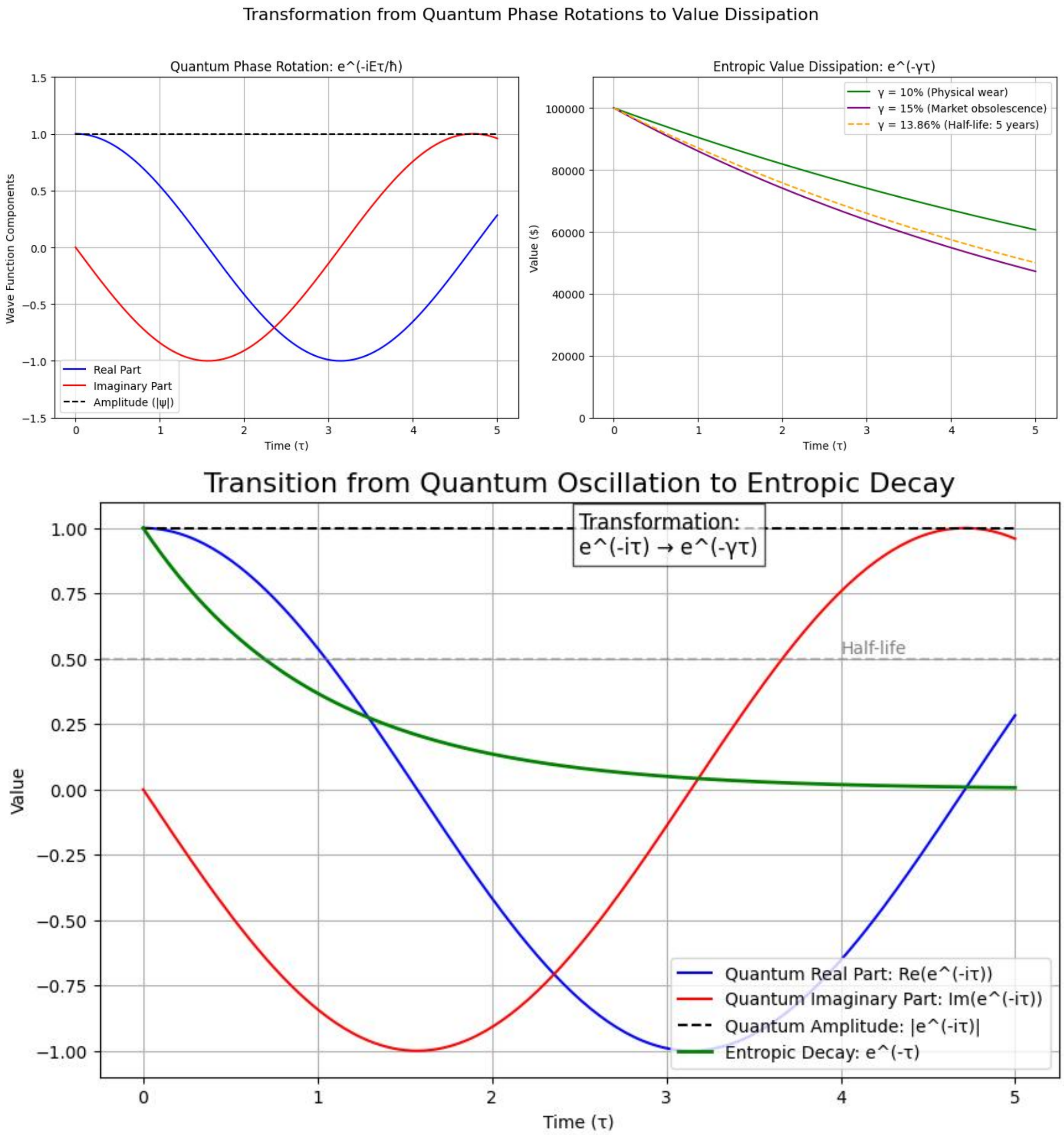


Figure 1. Visualization of the Entropic Decay Transformation

This example depicts the replacement of the imaginary unit (i) with real decay rates (γ_k), which transforms the system from being governed by phase rotations to one dominated by monotonic value dissipation, aligning with the irreversible nature of financial decay processes such as depreciation and obsolescence.

The structure of quantum state decoherence models, where τ parameterizes the system's internal dynamical evolution rather than external chronological time aligns with WIP accounting requirements, where operational timelines (production cycles, inventory turnover) often decouple from calendar time (35). The operational time τ should relate to chronological time t through:

$$\tau = \int_0^t \quad f(C.L, M, D)dt'$$

Where $f(C, L, M, D)$ represents a production rate function incorporating:
C= Cost structure variables
L= Labor productivity metrics

M= Material flow rates
D= Demand factors

This is inspired by the Tau theory's approach to timing of movements, but for financial position [36]. The transformation from standard quantum time evolution to financial decay dynamics aligns with established quantum mathematics, where "the dual Hopf algebraic structures of observables and states [37]. may be utilised to create efficient models for pricing". Thus, valuation of a construction project, for instance, can be modeled probabilistically to reflect both operational uncertainties and temporal decay. Consider a partially completed building with three discrete valuation eigenstates: $10 million (on-time completion), $7 million (delayed completion), and $4 million (project cancellation). These states are weighted by probability amplitudes w_1=0.6, w_2=0.3 , and w_3=0.1 , corresponding to classical probabilities of 36%, 9%, and 1%, respectively, derived from the squared magnitudes $|w_k|^2$. Each state is further modulated by entropic decay rates (γ) that quantify time-dependent value erosion: the on-time completion scenario decays at 5% annually (γ_1=0.05), reflecting gradual risks such as minor cost overruns, while delayed or canceled states decay rapidly at 20% annually (γ_2=0.2), capturing severe risks like contractual penalties or stranded costs. Figure 2 depicts such states.

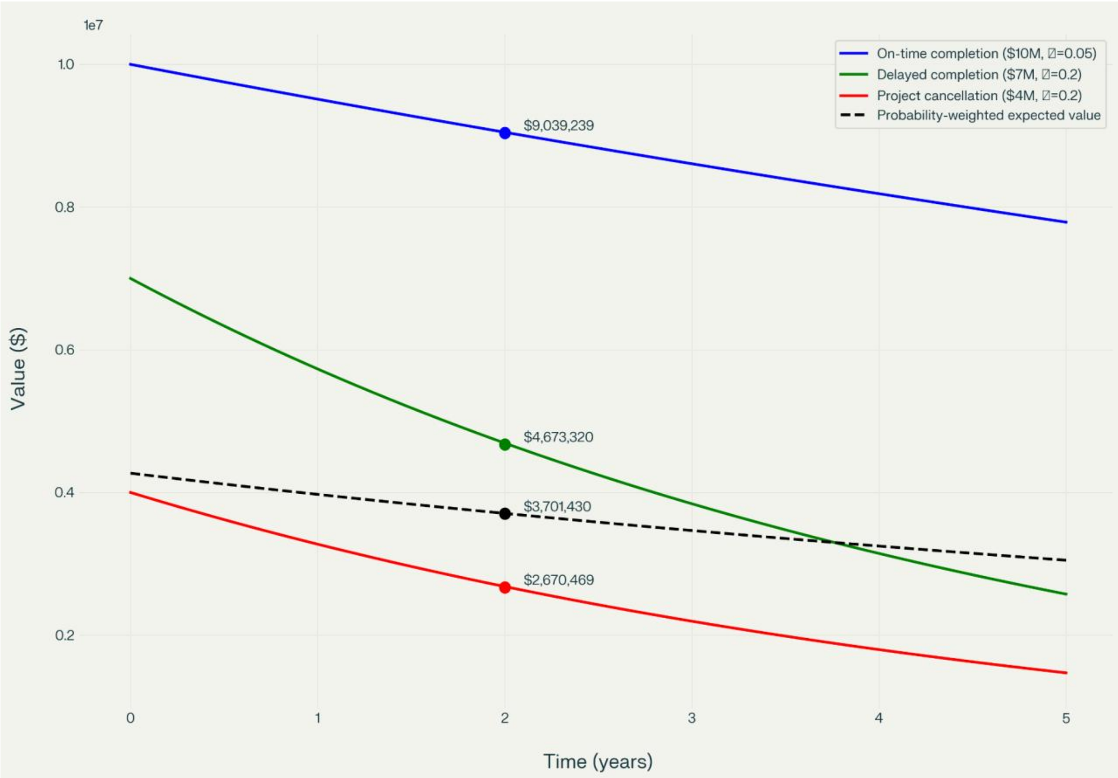


Figure 2. Quantum Accounting project forecast example

Over a two-year horizon, the accounting wave function ψ_{acc} synthesizes these components into a blended valuation:

$$\psi_{acc} = 0.6 \cdot (\$10M) \cdot e^{-0.1} + 0.3 \cdot (\$7M) \cdot e^{-0.4} + 0.1 \cdot (\$4M)e^{-0.4}$$

Where the exponential terms $e^{-\gamma_k \tau}$ attenuate each state's contribution. The resulting value integrates probabilistic outcomes with time-driven decay, yielding a risk-adjusted present valuation that diverges from static GAAP-compliant book values. For instance, the $10M on-time scenario decays to $9.05M after two years, while the $7M delayed scenario drops to $4.70M, and the $4M cancellation scenario falls to $2.68M. The superposition of these decayed values, weighted by their probabilities, produces a dynamic, forward-looking estimate that quantifies uncertainty in both outcome likelihood and temporal value erosion. This approach advances traditional WIP accounting by embedding scenario analysis and risk-adjusted depreciation into a unified framework, enabling stakeholders to assess projects through a lens of probabilistic financial realism [38].

Limitations

Quantum Accounting faces significant implementation barriers that constrain its practical adoption across manufacturing sectors. A primary limitation stems from the computational complexity inherent in the proposed entropy modeling framework, which requires solving partial differential equations with $O(n^3)$ time complexity for n valuation parameters. This computational demand creates prohibitive infrastructure costs for small-to-medium enterprises lacking access to cloud-based high-performance computing resources, effectively excluding a substantial segment of the manufacturing sector from adopting the methodology [39]. Quantum-enhanced implementations could reduce this to polynomial or quasi-linear complexity through Hamiltonian simulation, Quantum amplitude estimation, or Variational quantum algorithms [40,41].

Data acquisition and quality requirements present another critical challenge, as the model's accuracy depends on continuous real-time monitoring systems that exceed the capabilities of most production environments. Tracking value correlations across multiple production stages necessitates more independent data channels, while maintaining superposition states demands sensor networks capturing production variables with high accuracy at short intervals—a standard that may not be realistically met by some operations [42]. This creates a paradoxical implementation barrier where organizations most needing advanced WIP valuation tools often lack the necessary data infrastructure, forcing them to choose between suboptimal traditional methods or costly system upgrades.

Regulatory and standardization gaps further complicate adoption, as existing accounting frameworks lack provisions for quantum-inspired valuation techniques. Materiality thresholds for probabilistic valuations and audit procedures for superposition states remain undefined, while disclosure requirements for entangled production variables require fundamentally new reporting paradigms. The Financial Accounting Standards Board may take years for standards development, creating adoption limbo for early implementers who must navigate uncharted compliance territory.

Finally, the model creates unprecedented human capital challenges by requiring accounting professionals to master both traditional Accounting Principles and quantum mechanical concepts. This dual expertise requirement exceeds the current competency framework for certified public accountants (Quantum Accounting is not yet part of the CMA exam), necessitating extensive retraining programs or specialized hiring practices that many organizations cannot readily implement, nor would it always be practical/possible to monitor every aspect of WIP. Together, these limitations reveal fundamental tensions between the model's theoretical sophistication and practical implementation feasibility across diverse manufacturing ecosystems.

Implementation

To test the potential of practical implementation, a Monte Carlo simulation was carried out [40]. This simulation adheres to the formalism discussed supra. The simulation should sample from eigenstates and apply the decay factor to model time-independent WIP valuation. The simulation's code (appendix) adapts Monte Carlo sampling techniques as seen in quantum finance to model superpositioned WIP states [43,44]. Using numerical eigenvalue solvers, the code computes scalar eigenstates and corresponding decay rates γ_k. Note that the code assumes that the provided eigenstates and decay rates are already accurate; in practice, residual norms $|H_{acc}\ \chi_k\ - \gamma_k|$ need to be verified, thereby ensuring precision in mapping theoretical operators to computational objects.

The initialization phase incorporates domain-specific knowledge through probability amplitudes w_k; the experimental code performs normalization in the probabilities() function regardless of whether the input amplitudes are already normalized. In practice, data must undergo strict normalization to satisfy $\sum_k |w_k|^2=1$ - a critical requirement for maintaining probabilistic consistency. The sampling mechanism employs a Born-rule[4] implementation where each trial probabilistically selects eigenstate k according to $P(k) = |w_k|^2$, simulating quantum measurement collapse within classical computation.

[4] the modulus of the amplitude is squared to get the classical probability.

Subsequent time evolution applies state-specific decay factors $e^{-\gamma_k\tau}$, with the operational time parameter τ aggregating production variables. This dual-stage process - probabilistic selection followed by exponential decay - generates valuation distributions whose first moment corresponds to the theoretical expectation $\sum_k |w_k|^2 e^{-\gamma_k\tau}$. Table 2 depicts the differences in the information available between the quantum and traditional approaches, as evident in existing quantum accounting literature [9].

Table 2. Interpreting Classical Accounting vs. Quantum Accounting

Parameter	Traditional Model	Quantum Model
Valuation Basis	Fixed \$10M (GAAP book)	Superposition: \$10M (60%), \$7M (30%), \$4M (10%)
Risk Adjustment	10% flat discount rate	Entropic decay rates: γ_1=5%, γ_2=20%, γ_3=20%
Time Horizon	2 calendar years	τ=2 (operational years)

The simulation quantifies information entropy of the valuation distribution, providing a more nuanced measure of uncertainty than classical variance [45]. This is particularly valuable for industries with high production variability or custom manufacturing, where traditional methods may understate risk. The quantum model's lower mean valuation and the presence of entropy suggest it may account for uncertainties that the traditional model does not consider, adhering to the principles of conservatism in GAAP. This could be valuable for decision-making, as it provides a sense of the risk associated with the valuation [46]. The traditional model, with its higher mean valuation and no mentioned entropy, appears to be more deterministic, potentially overlooking uncertainties.

Interactive visualizations (e.g., histograms, scenario trees) can show how the distribution of WIP value shifts as you adjust decay rates, scenario probabilities, or operational time. Figure 3 takes the output of the simulation and visualizes it.

Figure 3. Quantum Accounting Dashboard

The simulation can also illustrate quantum financial tunneling, for example, modeling how WIP value can "leap" between states (e.g., from delayed to on-time completion) when certain operational barriers (high $\beta\mathcal{F}$) are overcome. This captures financial arbitrage opportunities in complex supply chains, where non-linear effects and resource reallocations can have outsized impacts on valuation.

6. DISCUSSION

Although "Hamiltonian" is physics jargon, here it represents the combination of variance (diffusion) and cost constraints on WIP. Additionally, while a quantum probabilistic approach to accounting can be adopted without the TISE, the equation provides a framework for modelling the quantum-like behaviour of WIP valuation. Work-in-process (WIP) inventory, Finished Goods, and Raw Materials are interconnected in the manufacturing process and, therefore, could be considered quantum-interdependent. This interdependence arises from the fact that WIP inventory is not a single, well-defined state but rather a superposition of multiple possible states, each representing a different stage of the production process. The states of raw materials, WIP, and finished goods inventory accounts can affect each other.

The Time-Dependent Schrödinger Equation (TDSE) accounts for how the wavefunction changes with time. It involves both spatial and temporal derivatives of the wavefunction [47]. On the other hand, the TISE focuses solely on the spatial behavior of the wavefunction. It does not consider time explicitly. Applying this concept to WIP inventory, the "time independence" aspect can be interpreted as focusing on the valuation and state of WIP at a specific point in time without directly accounting for how these values may change over time. In quantum mechanics, the TISE helps identify stable states of a system that are not explicitly time-dependent. In practical terms, the TISE helps us find the allowed energy levels (quantized energies) and corresponding wavefunctions for a given potential energy landscape.

Understanding the quantized energies and wavefunctions that the Schrödinger Equation provides could benefit accounting, potentially reshaping accounting standards and practices by adopting quantum theory. Beyond the managerial scope of this work, current standards, primarily based on classical accounting principles, may need to be revised to accommodate the probabilistic and interconnected nature of quantum accounting. This could involve the development of new frameworks that allow for the representation of data in multiple states and the recognition of the entangled relationships between different financial entities, which would foster the development of accounting applications utilizing quantum computing. Additionally, implementing quantum accounting could necessitate changes in auditing practices, with auditors requiring new tools and methodologies to assess the accuracy of quantum-based financial statements.

A thorough event study would provide quantifiable metrics demonstrating the advantages of quantum-inspired accounting over traditional methods, key metrics to aim for would be:

- Improved accuracy in predicting final production costs
- Better representation of uncertainty in financial reporting
- Enhanced decision-making capability for resource allocation
- More robust handling of complex, interdependent production systems

The practical applications of quantum WIP accounting may benefit from including a phased implementation strategy:

1. Initial assessment of organizational accounting needs
2. Identification of WIP processes with high uncertainty
3. Parallel implementation of traditional and quantum-inspired methods
4. Comparative evaluation of results
5. Full integration into accounting information systems

7. CONCLUSION

This work finds that a probabilistic approach to WIP accounting expresses the value of WIP as a range of possible values with associated probabilities rather than a single deterministic figure. This method reflects the uncertainties inherent in WIP valuation, such as variability in completion stages, fluctuations in material and labor costs, potential quality issues, and changes in project specifications.

This analysis underscores the value of quantum theory in enriching accounting practices. Employing this approach allows for developing a more sophisticated framework that reflects the intricacies of contemporary business realities. Understanding the quantum perspectives of accounting will allow for more efficient quantum circuits and smoother implementation of quantum technology. Future research should focus on bridging the gap in understanding the application of quantum theory to accounting, including developing more comprehensive accounting information systems frameworks.

Integrating quantum theory into managerial accounting, particularly in cost accounting, is essential to adapt to the complexities of modern business. Traditional methods are inadequate for accurately capturing the dynamic nature of WIP valuation. Adopting quantum principles offers new insights and tools to enhance accounting practices. This work lays the groundwork for the emerging field of quantum accounting, challenging traditional paradigms and suggesting new directions for research and practice. By embracing quantum principles, accountants can unlock new insights and tools to improve the accuracy and responsiveness of accounting practices. This work aims to lay the foundations for the emerging field of quantum accounting, challenging traditional accounting paradigms and suggesting new avenues for research and practice.

Funding Statement: The author received no financial support for the research, authorship, and/or publication of this article.

Acknowledgment:This work gratefully acknowledges Professor Neepa Maitra for her generous provision of background materials and insightful discussions.

Contribution: Conceptualization, Writing - original draft, Formal analysis, Writing - review & editing, Methodology, Resources, Investigation, Validation, Software, Visualization, Software, Formal analysis review and editing: Maksym Lazirko. The author has read and agreed to the published version of the manuscript.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflict of Interest Statement: The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

1. Budd, C. S. (2010). Traditional measures in finance and accounting, problems, literature review, and TOC measures. *Theory of Constraints Handbook*, 335–372.
2. Frino, R. A. (2015). Quantum Superposition, Parallel Universes and Time Travel. *viXra*. https://consensus.app/papers/quantum-superposition-parallel-universes-time-travel-frino/ed44c9f2285955fdb31b8a4f108d200c/
3. Kovács, G. (2016). LOGISTICS AND PRODUCTION PROCESSES TODAY AND TOMORROW. *Acta Logistica*, *3*(4), 1–5. https://doi.org/10.22306/al.v3i4.71
4. Myrelid, A., & Olhager, J. (2015). Applying modern accounting techniques in complex manufacturing. *Industrial Management & Data Systems*, *115*(3), 402–418. https://doi.org/10.1108/IMDS-09-2014-0250
5. Demski, J. S., FitzGerald, S. A., Ijiri, Y., Ijiri, Y., & Lin, H. (2006). Quantum information and accounting information: Their salient features and conceptual applications. *Journal of Accounting and Public Policy*, *25*(4), 435–464. https://doi.org/10.1016/j.jaccpubpol.2006.05.004
6. Kahyao, ğlu S. B. (2023). An evaluation of accounting and auditing framework within the quantum perspective. *Southern African Journal of Accountability and Auditing Research*, *25*(1), 1–5. https://doi.org/10.10520/ejc-sajaar_v25_n1_a1
7. De Oliveira, K. V., & Lustosa, P. R. B. (2022). The entanglement of accounting goodwill: Einstein's "spooky action at a distance." *Accounting Forum*, 1–22. https://doi.org/10.1080/01559982.2022.2089319
8. Demski, J. S., FitzGerald, S. A., Ijiri, Y., Ijiri, Y., & Lin, H. (2006). Quantum information and accounting information: Their salient features and conceptual applications. *Journal of Accounting and Public Policy*, *25*(4), 435-464.
9. Fellingham, J., Lin, H., & Schroeder, D. (2022). Entropy, Double Entry Accounting and Quantum Entanglement. *Foundations and Trends® in Accounting*, *16*(4), 308–396. https://doi.org/10.1561/1400000069
10. Fellingham, J. C., Lin, H., & Schroeder, D. (2018). Quantum Entropy and Accounting. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3220892
11. Fellingham, J., & Schroeder, D. (2006). Quantum information and accounting. *Journal of*

Engineering and Technology Management, *23*(1–2), 33–53. https://doi.org/10.1016/j.jengtecman.2006.02.004
12. Demski, J. S., FitzGerald, S. A., Ijiri, Y., Ijiri, Y., & Lin, H. (2009). Quantum information and accounting information: Exploring conceptual applications of topology. *Journal of Accounting and Public Policy*, *28*(2), 133–147. https://doi.org/10.151016/j.jaccpubpol.2009.01.002
13. Lazirko, M. (2023). *Quantum Computing Standards & Accounting Information Systems* (arXiv:2311.11925). arXiv. http://arxiv.org/abs/2311.11925.
14. Orrell, D. (2019). Quantum Financial Entanglement: The Case of Strategic Default. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3394550
15. Lee, R. S. (2021). Quantum finance forecast system with qu15antum anharmonic oscillator model for quantum price level modeling. *International Advance Journal of Engineering Research*, *4*(02), 01–21.
16. Peres, A. (2000). Classical interventions in quantum systems. I. The measuring process. *Physical Review A*, *61*(2), 022116. https://doi.org/10.1103/PhysRevA.61.022116
17. Wang, X.-L., Cai, X.-D., Su, Z.-E., Chen, M.-C., Wu, D., Li, L., Liu, N.-L., Lu, C.-Y., & Pan, J.-W. (2015). Quantum teleportation of multiple degrees of freedom of a single photon. *Nature*, *518*(7540), 516–519. https://doi.org/10.1038/nature14246
18. Lee, S. M., Lee, S.-W., Jeong, H., & Park, H. S. (2020). Quantum Teleportation of Shared Quantum Secret. *Physical Review Letters*, *124*(6), 060501. https://doi.org/10.1103/PhysRevLett.124.060501
19. Davis, M. J., & Heller, E. J. (1981). Quantum dynamical tunneling in bound states. *The Journal of Chemical Physics*, *75*(1), 246–254. https://doi.org/10.1063/1.441832
20. Swieringa, R., Gibbins, M., Larsson, L., & Sweeney, J. L. (1976). Experiments in the Heuristics of Human Information Processing. *Journal of Accounting Research*, *14*, 159. https://doi.org/10.2307/2490450
21. Meade, D. J., Kumar, S., & Kensinger, K. R. (2008). Investigating impact of the order activity costing method on product cost calculations. *Journal of Manufacturing Systems*, *27*(4), 176–189. https://doi.org/10.1016/j.jmsy.2009.02.003
22. Almeida, R., Abrantes, R., Romão, M., & Proença, I. (2020). *The Impact of Uncertainty in the Measurement of Progress in Earned Value Analysis*. 457–467. https://doi.org/10.1016/J.PROCS.2021.01.191
23. Specogna, R., & Trevisan, F. (2011). A discrete geometric approach to solving time independent Schrödinger equation. *Journal of Computational Physics*, *230*(4), 1370–1381. https://doi.org/10.1016/j.jcp.2010.11.007
24. CHENG, T. C. E. (1991). An Economic Order Quantity Model with Demand-Dependent Unit Production Cost and Imperfect Production Processes. *IIE TRANSACTIONS*. https://doi.org/10.1080/07408179108963838
25. Hussain, O., Dillon, T., Hussain, F. K., & Chang, E. (2011). Probabilistic assessment of financial risk in e-business associations. *Simulation Modelling Practice and Theory*, *19*(2), 704–717. https://doi.org/10.1016/j.simpat.2010.10.007
26. Wróblewski, M. (2017). Nonlinear Schrödinger approach to European option pricing. *Open Physics*, *15*(1), 280–291. https://doi.org/10.1515/phys-2017-0031
27. Ivancevic, V. G. (2010). Adaptive-Wave Alternative for the Black-Scholes Option Pricing Model. *Cognitive Computation*, *2*(1), 17–30. https://doi.org/10.1007/s12559-009-9031-x
28. Chen, J. M. (2017). Econophysical Models of Finance: Baryonic Beta Dynamics and Beyond. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3059436
29. Arraut, I., Au, A., & Ching-biu Tse, A. (2020). Spontaneous symmetry breaking in quantum finance. *Europhysics Letters*, *131*(6), 68003. https://doi.org/10.1209/0295-5075/131/68003
30. Arraut, I., Lobo Marques, J. A., & Gomes, S. (2021). The Probability Flow in the Stock Market and Spontaneous Symmetry Breaking in Quantum Finance. *Mathematics*, *9*(21), Article 21. https://doi.org/10.3390/math9212777
31. Zheng, H., & Bai, J. (2024). Quantum Leap: A Price Leap Mechanism in Financial Markets. *Mathematics*, *12*(2), Article 2. https://doi.org/10.3390/math12020315

32. Srokowski, T. (2001). Stochastic processes with finite correlation time: Modeling and application to the generalized Langevin equation. *Physical Review E*, *64*(3), 031102. https://doi.org/10.1103/PhysRevE.64.031102
33. Korzh. R, & P.в, K. (2024). Quantum economics: Key features and postulates. *Economy and Entrepreneurship*, *52,* 17-26.https://doi.org/10.33111/EE.2024.52.
34. Ledinauskas, E., & Anisimovas, E. (2023). Scalable Imaginary Time Evolution with Neural Network Quantum States. *SciPost Physics*, *15*(6), 229. https://doi.org/10.21468/SciPostPhys.15.6.229
35. Demeter, K., & Matyusz, Z. (2011). The impact of lean practices on inventory turnover. *International Journal of Production Economics*, *133*(1), 154–163. https://doi.org/10.1016/j.ijpe.2009.10.031
36. Holster, A. (2021). *Explaining Relativity: Summary of TAU - A Unified Theory*. https://mail.vixra.org/abs/2108.0039
37. Majid, S. (1994). The quantum double as quantum mechanics. *Journal of Geometry and Physics*, *13*(2), 169–202. https://doi.org/10.1016/0393-0440(94)90026-4
38. Li, L. (2025). Quantum Probability Theoretic Asset Return Modeling: A Novel Schrödinger-Like Trading Equation and Multimodal Distribution. *Quantum Economics and Finance*, 29767032251331075. https://doi.org/10.1177/29767032251331075
39. Osypanka, P., & Nawrocki, P. (2022). Resource Usage Cost Optimization in Cloud Computing Using Machine Learning. *IEEE Transactions on Cloud Computing*, *10*, 2079–2089. https://doi.org/10.1109/TCC.2020.3015769
40. Zhao, T., Sun, C., Cohen, A., Stokes, J., & Veerapaneni, S. K. (2022). Quantum-inspired variational algorithms for partial differential equations: Application to financial derivative pricing. *CoRR*. https://openreview.net/forum?id=pxtos0Okgm&referrer=%5Bthe%20profile%20of%20Tianchen%20Zhao%5D(%2Fprofile%3Fid%3D~Tianchen_Zhao1)
41. Sato, Y., Kondo, R., Hamamura, I., Onodera, T., & Yamamoto, N. (2024). Hamiltonian simulation for hyperbolic partial differential equations by scalable quantum circuits. *Physical Review Research*, *6*(3), 033246. https://doi.org/10.1103/PhysRevResearch.6.033246
42. Olajiga, O. K., Ani, E. C., Olu-lawal, K. A., Montero, D. J. P., & Adeleke, A. K. (2024). INTELLIGENT MONITORING SYSTEMS IN MANUFACTURING: CURRENT STATE AND FUTURE PERSPECTIVES. *Engineering Science & Technology Journal*. https://doi.org/10.51594/estj.v5i3.870
43. Cui, J., Brouwer, P. J. S. de, Herbert, S., Intallura, P., Kargi, C., Korpas, G., Krajenbrink, A., Shoosmith, W., Williams, I., & Zheng, B. (2024). *Quantum Monte Carlo Integration for Simulation-Based Optimisation* (arXiv:2410.03926). arXiv. https://doi.org/10.48550/arXiv.2410.03926
44. Wolf, M.-O., Ewen, T., & Turkalj, I. (2023). Quantum Architecture Search for Quantum Monte Carlo Integration via Conditional Parameterized Circuits with Application to Finance. *2023 IEEE International Conference on Quantum Computing and Engineering (QCE)*, 560–570. https://doi.org/10.1109/QCE57702.2023.00070
45. Christmann, J. (2025). From quantum-enhanced to quantum-inspired Monte Carlo. *Physical Review A*, *111*(4). https://doi.org/10.1103/PhysRevA.111.042615
46. Buonaiuto, G., Gargiulo, F., De Pietro, G., Esposito, M., & Pota, M. (2023). Best practices for portfolio optimization by quantum computing, experimented on real quantum devices. *Scientific Reports*, *13*(1), 19434. https://doi.org/10.1038/s41598-023-45392-w
47. Schneider, B. I., & Collins, L. A. (2005). The discrete variable method for the solution of the time-dependent Schrödinger equation. *Journal of Non-Crystalline Solids*, *351*(18), 1551–1558. https://doi.org/10.1016/j.jnoncrysol.2005.03.028

APPENDIX

Appendix A. Monte Carlo Simulation Code & Output

Python

```
import numpy as np

class QuantumWIP:
    def __init__(self, amplitudes, eigenstates, decay_rates, tau):
        """
        Initialize a QuantumWIP object.

        Parameters
        ----------
        amplitudes : list of float
            Probability amplitudes (w_k) for each eigenstate.
        eigenstates : list of float
            Valuation eigenstates (chi_k) corresponding to each amplitude.
        decay_rates : list of float
            Entropic decay rates (gamma_k) for each eigenstate.
        tau : float
            Operational time parameter in years; must be positive.

        Raises
        ------
        ValueError
            If the lengths of amplitudes, eigenstates, and decay_rates do not match.
            If tau is not a positive number.
        """
        if not (isinstance(amplitudes, (list, np.ndarray)) and
                isinstance(eigenstates, (list, np.ndarray)) and
                isinstance(decay_rates, (list, np.ndarray))):
            raise TypeError("amplitudes, eigenstates, and decay_rates must be lists or numpy arrays.")

        if len(amplitudes) != len(eigenstates) or len(amplitudes) != len(decay_rates):
            raise ValueError("amplitudes, eigenstates, and decay_rates must have the same length.")

        if tau <= 0:
            raise ValueError("tau must be a positive number.")

        self.w = np.array(amplitudes, dtype=np.complex128)
        self.chi = np.array(eigenstates, dtype=np.float64)
        self.gamma = np.array(decay_rates, dtype=np.float64)
        self.tau = tau

    def probabilities(self):
        """
        Compute the classical probabilities from the squared amplitudes.
```

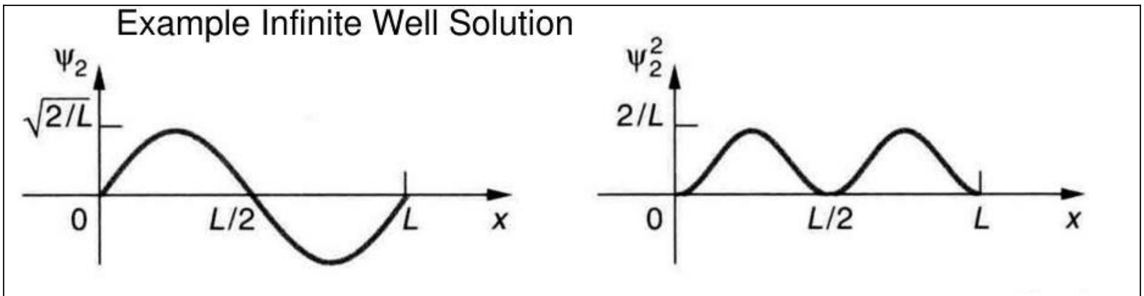
```
        Returns
        -------
        probs : numpy.ndarray
            Array of probabilities corresponding to each eigenstate.
        """
        probs = np.abs(self.w) ** 2
        probs = probs / np.sum(probs)
        if np.sum(probs) == 0:
            raise ValueError("Sum of probabilities is zero.")
        return probs

def quantum_monte_carlo(psi_acc, scenarios=100000):
    """
    Perform a quantum-inspired Monte Carlo simulation.

    Parameters
    ----------
    psi_acc : QuantumWIP
        Instance of QuantumWIP containing the model parameters.
    scenarios : int, optional
        Number of Monte Carlo scenarios to simulate. Default is 100000.

    Returns
    -------
    valuations : numpy.ndarray
        Array of simulated valuations.

    Raises
    ------
    TypeError
        If scenarios is not an integer.
    """
    if not isinstance(scenarios, int):
        raise TypeError("scenarios must be an integer.")
    if scenarios <= 0:
        raise ValueError("scenarios must be a positive integer.")

    valuations = []
    probs = psi_acc.probabilities()
    for _ in range(scenarios):
        k = np.random.choice(len(psi_acc.w), p=probs)
        decayed_value = psi_acc.chi[k] * np.exp(-psi_acc.gamma[k] * psi_acc.tau)
        valuations.append(decayed_value)
    return np.array(valuations)

# Example parameters
amplitudes = [np.sqrt(0.6), np.sqrt(0.3), np.sqrt(0.1)]
eigenstates = [10_000_000, 7_000_000, 4_000_000]
decay_rates = [0.05, 0.20, 0.20]
tau = 2

# Create QuantumWIP object and run simulation
```

```
psi_acc = QuantumWIP(amplitudes, eigenstates, decay_rates, tau)
quantum_vals = quantum_monte_carlo(psi_acc)

# Traditional model for comparison
traditional_value = 10_000_000 * np.exp(-0.10 * tau)
traditional_vals = np.full(quantum_vals.shape, traditional_value)

# Compute entropy
counts, bins = np.histogram(quantum_vals, bins=10)
probs = counts / len(quantum_vals)
entropy = -np.sum(probs * np.log2(probs + 1e-10))
# 1e-10 prevents log(0)

# Output summary statistics
print(f"Quantum-inspired mean valuation: ${quantum_vals.mean():,.2f}")
print(f"Traditional mean valuation:      ${traditional_vals.mean():,.2f}")
print(f"Quantum-inspired valuation entropy: {entropy:.3f} bits")
```

```
Quantum-inspired mean valuation: $7,104,238.61
Traditional mean valuation:      $8,187,307.53
Quantum-inspired valuation entropy: 1.295 bits
```

In the context of quantum WIP accounting, the particle-in-a-box model illustrates a scenario where a quantum system, representing WIP, is confined within a limited space delineated by impenetrable barriers. These barriers can represent the constraints and boundaries of the WIP account, including project timelines, resource availability, and regulatory requirements.

Appendix B. Wave Equation for Value vs. Schrödinger equation for WIP[5]



- A solution to Schrödinger equation gives wave function Ψ
- Ψ^2 gives us a probability of finding the eigenvalue in a certain region

Much like the particle in a box model in quantum mechanics, where the behavior of the particle is influenced by the size and shape of the confinement, the dynamics of WIP within the accounting system are shaped by various internal and external factors.

[5] IMAGE ADAPTED FROM https://www.slideserve.com/hayfa-david/topic-5-schr-dinger-equation