Research article

Smart Pre-Decision Accounting: A Digital-Twin-Driven Framework for National Project Trade-Offs – Global Evidence

Amin El Sayed Ahmed Lotfy*

Ex-President of Beni Suef University, Professor of Accounting and Auditing Faculty of Commerce, Egypt

***Corresponding Author**
Amin El Sayed Ahmed Lotfy, Ex-President of Beni Suef University, Professor of Accounting and Auditing Faculty of Commerce, Egypt.

Abstract

Purpose
This study aims to design a Smart Pre-Decision Accounting Framework that employs digital twin simulation and real-options analysis to evaluate national project trade-offs before implementation. The framework provides policymakers with scientifically modeled scenarios for governance, privatization, or partnership alternatives to optimize national value creation and resource efficiency.

Design/Methodology/Approach
The study integrates counterfactual simulation, reference-class forecasting, and real-options valuation within a digital twin environment. It applies a comparative mixed method approach, combining econometric forecasting for Egypt's national projects with benchmark data from advanced and emerging economies to test predictive validity and scenario adaptability.

Findings
Results demonstrate that using digital-twin-driven accounting enables governments to visualize multidimensional trade-offs (financial, social, and strategic) before committing resources. The framework reduces policy uncertainty, enhances governance quality, and supports data-driven decision-making for public investment portfolios.

Theoretical, Practical, Economic, and Social Implications
Theoretically, the study extends decision-usefulness theory to pre-decision contexts. Practicality establishes a structured accounting model for evaluating national project alternatives. Economically, it improves capital allocation efficiency and mitigates costly misallocations. Socially, it strengthens transparency and intergenerational equity in national asset management.

Originality and Value
This is the first accounting-based model combining digital twin simulation and real-options thinking to support pre-decision evaluation of national investments, offering a novel mechanism for sustainable public wealth management.

Keywords: Smart Accounting, Digital Twin, Pre-Decision Framework, National Projects, Real Options, Counterfactual Simulation, Governance, Public Wealth, Emerging Economies, Global Benchmarks

1. Introduction

1.1 Background and Context

Public investment decisions increasingly define the trajectory of national economic resilience, especially in emerging economies where state-led projects dominate the fiscal landscape. Over the last decade, many governments-Egypt included-have expanded large-scale infrastructure and development projects as instruments of growth, employment, and modernization. However, evidence from the, World Bank, and OECD indicates that the success of such projects often depends less on their financial scope and more on the quality of ex-ante decision processes that precede resource commitment. Traditional accounting and budgeting systems, which emphasize post-implementation reporting, provide limited insight for strategic evaluation before funds are allocated [1,2]. In the evolving global landscape, Digital Twin technology-the creation of virtual replicas of physical or policy systems-has emerged as a powerful analytic tool for simulation, forecasting, and adaptive governance [3,4]. Parallel advances in real-options theory and counterfactual analytics enable decision-makers to model multiple "what-if" pathways and quantify the trade-offs among governance, privatization, or public-private partnership (PPP) scenarios. Yet, most public-sector accounting frameworks remain descriptive rather than predictive, limiting their usefulness in guiding national investment choices under uncertainty [5,6].

1.2 Motivation and Problem Orientation

In emerging economies, governments frequently face competing pressures: fiscal constraints, social expectations, and the pursuit of economic sustainability. When evaluation mechanisms are static or politically biased, project approval tends to rely on optimism rather than analytical validation. Egypt's current development agenda toward Vision 2030 exemplifies this dilemma-rapid implementation has sometimes outpaced systematic pre-decision analysis [7,8]. International experience suggests that the absence of integrated, simulation based accounting tools contributes to budget overruns, time delays, and under-performance [1,2].

Consequently, there is a critical need for an accounting-driven decision system that functions before commitment-one capable of quantifying the trade-offs among alternative policy options and visualizing their economic and social consequences. The emerging integration of digital-twin environments with real-options and counterfactual simulation offers a unique opportunity to redesign how accounting information supports strategic choices [9,10]. By shifting from retrospective reporting to anticipatory modeling, accounting can evolve from a record keeping function into a decision-optimization platform for public wealth management.

1.3 Aim and Research Objective

This study introduces a Smart Pre-Decision Accounting Framework that leverages digital-twin simulation to evaluate national project trade-offs before resource allocation. The model integrates multidimensional performance indicators-financial, governance, and societal-into a unified decision dashboard. It aims to provide evidence-based guidance for policymakers in Egypt and benchmark economies on how different strategic choices affect national value creation, fiscal sustainability, and inter-generational equity.

1.4 Research Approach and Methodological Orientation

To operationalize this objective, the study adopts a comparative mixed-method design that merges quantitative modeling with qualitative benchmarking. The empirical component integrates econometric forecasting and counterfactual simulation across selected national projects in Egypt, benchmarked against cases from advanced economies such as Singapore, Sweden, and the United Kingdom, and from emerging peers like Indonesia and Brazil. This multi-tiered comparison ensures that the framework reflects both local institutional realities and global efficiency standards [7,11].

The digital twin architecture developed in this study functions as a dynamic simulation platform, continuously fed by accounting, financial, and socio-economic indicators. Through real-options valuation, alternative policy pathways are quantified in probabilistic terms-illustrating how different governance or privatization choices affect fiscal sustainability, debt ratios, and public value outcomes. The resulting model generates a "decision dashboard" that visualizes trade-offs among financial, social, and environmental variables before final approval [3,4].

1.5 Expected Contributions

Theoretically, the research extends the decision-usefulness paradigm in accounting by shifting its focus from ex-post reporting to ex-ante simulation. It integrates elements of real options theory and systems thinking into the accounting discipline, establishing a new lens-Smart Pre-Decision Accounting (SPDA)-for analyzing national investment behavior. Practically, the study proposes a replicable analytical tool that can be institutionalized within nation-al audit offices, ministries of finance, and public investment authorities. The framework enables evidence-based prioritization, enhancing transparency, accountability, and strategic foresight in government spending.

Economically, SPDA contributes to improved capital allocation and reduces the macro-fiscal risks associated with politically driven project selection. By simulating multi-year outcomes, it helps prevent cost overruns and underperforming assets-issues frequently documented in emerging economies [6,12].

Socially, the model reinforces the principle of intergenerational equity, ensuring that today's investments do not compromise future fiscal space or societal welfare. It offers a pathway toward sustainable development that balances economic growth with social value and environmental stewardship [8,13].

1.6 Structure of the Paper

- The remainder of this paper is structured as follows.
- reviews the literature on national project evaluation, digital-twin applications, and real-options theory, leading to the development of research hypotheses.
- presents the theoretical foundation and the proposed Smart

Pre-Decision Accounting Frame work.
- details the research methodology, data sources, and comparative benchmarks.
- reports and discusses empirical findings.
- elaborates on theoretical, practical, economic, and social implications, concluding with policy recommendations.
- closes with conclusions and future research directions.

2. Literature Review and Hypothesis Development

2.1 Conceptual Foundations: From Ex-Post Reporting to Smart Pre-Decision Accounting

Traditional public-sector accounting has long emphasized ex-post financial reporting, focusing on compliance, stewardship, and fiscal accountability [5]. While this paradigm provides transparency after project completion, it offers limited guidance before funds are committed. According to Flyvbjerg and Bester, nearly 80% of large public projects globally experience overruns or performance shortfalls because governments lack predictive accounting tools that assess alternative scenarios ex ante [2]. This gap has driven the recent evolution of decision-oriented accounting frameworks that embed forecasting, simulation, and behavioral modeling into financial analysis [9,14-19].

The decision-usefulness theory, a cornerstone of modern accounting research, posits that accounting information must assist users in making rational economic decisions [20]. However, in the context of national projects, usefulness depends not on retrospective accuracy but on predictive relevance how well accounting data anticipate future outcomes. Studies by IMF and World Bank emphasize that shifting accounting's role from record keeping to decision optimization is vital for fiscal resilience and sustainable investment [7,12,21-27].

Emerging research extends this paradigm through Smart Accounting Systems, integrating AI-driven analytics, real-time data streams, and simulation technologies [6,4]. Yet, even within this modernization wave, most frameworks remain reactive-reporting deviations rather than simulating trade-offs. The concept of Smart Pre-Decision Accounting (SPDA) introduced in this study builds on these advancements by positioning accounting as a predictive mechanism for evaluating strategic alternatives among governance, privatization, or partnership paths prior to implementation [10,25-45].

2.2 The Evolution of Digital Twin Simulation in Accounting and Public Decision-Making

The term Digital Twin originated in engineering and manufacturing to describe a virtual replica of a physical system that continuously mirrors real-world performance [3]. Recent advances have extended this logic to policy modeling and public finance [46,47]. By creating dynamic data environments, digital twins enable policymakers to simulate policy interventions and observe outcomes across financial, social, and environmental dimensions [13].

In accounting, the digital twin paradigm represents a profound methodological shift-from static re-ports to living models that learn and adapt [4]. Through data integration, scenario simulation, and counterfactual testing, digital twins support continuous assurance and pre-implementation risk evaluation [10]. Research by Tao et al. demonstrates that digital twin systems reduce forecasting errors and improve resource allocation in public infrastructure programs [3]. Similarly, studies in Computers in Industry and Journal of Emerging Technologies in Accounting show that combining digital twins with real options valuation enhances decision quality under uncertainty [9,48-53].

However, literature addressing digital twins within accounting research remains fragmented. Most existing applications are technical-focused on data architecture rather than decision relevance. Recent reviews by the OECD (2023) and UNDP note that while several countries (e.g., Singapore, Finland, and the UAE) have developed national digital twin platforms, few integrate these systems with accounting or performance measurement. This underlines the novelty of connecting digital twin simulation directly to pre-decision accounting in the public sector an innovation central to this study [8,54-57].

2.3 Real-Options Theory and Decision Flexibility in National Investments

The real-options approach provides a powerful conceptual lens for understanding flexibility in investment decision-making [58]. Unlike static net present value (NPV) models, real-options analysis values the right but not the obligation to expand, delay, or abandon a project as new information emerges. In public finance, this logic translates into designing policies that can adapt to shifting economic or political conditions without irreversible commitments [5,12].

Recent accounting studies highlight the potential of integrating real-options reasoning into performance management systems [9,14]. For instance, the Harvard Business Review identifies "option-based decision windows" as a critical factor for successful megaproject governance [1]. When embedded within a digital twin environment, real-options valuation allows governments to model multiple "policy pathways," quantify downside risks, and identify the optimal point of resource commitment [3,4].

The integration of real-options logic with digital-twin simulation is especially relevant for countries like Egypt, where policy choices often involve trade-offs between rapid implementation and fiscal prudence. Through this combined approach, accounting information becomes dynamic, enabling policymakers to visualize not only expected outcomes but also the distribution of possible futures-transforming accounting into a true decision laboratory.

Table 1 – Presents Key Conceptual Pillars of Smart Pre-Decision Accounting

Conceptual Dimension	Core Idea	Key References (2020–2025)
Decision-Usefulness	Accounting should guide ex-ante decision-making, not just report ex-post results	Kothari et al. (2022); IMF (2023); World Bank (2024)
Digital Twin Simulation	Virtual replication of real systems for scenario modeling	Tao et al. (2023); Deloitte (2024); EY (2022)
Real-Options Theory	Valuing flexibility and strategic timing in investment decisions	D'Amato & Esposito (2021); Grant & Collis (2021)
Counterfactual Analytics	Testing "what-if" policy scenarios and causal pathways	Chen & Hu (2023); Li & Qi (2023)
Smart Accounting Integration	Combining data analytics, simulation, and governance indicators	PwC (2023); OECD (2023); UNDP (2023)

Table 1: Key Conceptual Pillars of Smart Pre-Decision Accounting

2.4 Comparative Evidence from Emerging and Advanced Economies

A growing body of international literature has explored how public-sector decision frameworks differ between emerging and advanced economies, particularly in terms of accounting maturity, digital transformation, and governance integration. In advanced economies such as the United Kingdom, Sweden, and Singapore, public accounting has evolved toward integrated pre-decision analytics, where digital-twin environments and performance dashboards are embedded into the investment appraisal cycle [11,59]. The U.K. Green Book model combines financial, social, and environmental criteria under a standardized cost benefit analysis that incorporates probabilistic simulation an early institutionalized version of digital-twin thinking [60-70].

In contrast, emerging economies often rely on static cost–benefit frame works, where ex-post reporting dominates policy evaluation [12]. Egypt, Indonesia, and Brazil exhibit a similar pat-tern: despite substantial public investment portfolios, decision-making tends to be reactive, and scenario-based evaluation tools remain underdeveloped [7,8]. Empirical assessments by Flyvbjerg and Bester reveal that the average cost overrun in mega projects across emerging economies exceeds 30%, compared with less than 10% in advanced economies [2]. This discrepancy is attributed not only to governance weaknesses but also to the absence of digital decision infrastructures that integrate accounting, risk, and performance data [6, 4,71-75].

Singapore and Finland provide exemplary cases of how digital-twin-driven evaluation systems transform national project governance. In Singapore's Smart Nation initiative, real-time data from construction and infrastructure projects feed into a centralized analytics platform that simulates pol-icy trade-offs before parliamentary approval [13]. Similarly, Sweden's Digital Infrastructure Agency employs digital-twin models linked with public-sector accounting databases to project alternative fiscal outcomes [5]. These experiences highlight how the digital twin functions not only as a technical innovation but also as a decision accountability instrument-one that embeds pre-decision analytics into fiscal governance [76,77].

In Egypt and comparable emerging markets, reforms have increasingly recognized this need. The Egypt Vision 2030 framework and Public Investment Management Assessment (PIMA) mission have both emphasized the necessity of decision analytics preceding project selection [12]. However, institutional practices remain anchored in manual feasibility studies and traditional financial ratios. Hence, there exists a strong argument for localizing the digital-twin and real-options concepts within a Smart Pre-Decision Accounting (SPDA) model specifically adapted to the Egyptian and emerging context.

2.5 Integrating Real-Options and Digital-Twin Perspectives: Toward a Unified Decision Model

Bringing together the literatures on real-options analysis and digital-twin simulation establishes a conceptual bridge between financial flexibility and informational intelligence. Real-options theory addresses when to act, whereas digital-twin simulation explains how alternative actions might per-form [9,3]. When merged within an accounting framework, the two approaches yield a predictive model that not only estimates future outcomes but quantifies the value of decision timing.

In advanced economies, such integration has already shown tangible outcomes. Research by the World Bank and IMF demonstrates that combining simulation-based analytics with option valuation significantly enhances the return-on-investment (ROI) of public capital expenditure by reducing sunk costs and improving prioritization [7]. For example, the U.K. Infrastructure and Projects Authority (IPA) apply a decision gate system-akin to real-options reasoning-within digital dashboards that update project valuations in real time [11].

By contrast, emerging economies face systemic challenges such as fragmented data systems, inconsistent disclosure standards, and limited analytical capacity [8]. These constraints underscore the need for accounting frameworks that are not merely descriptive but prescriptive and adaptive, enabling decision-makers to experiment virtually before acting physically. Smart Pre-Decision Accounting (SPDA) thus serves as a mechanism for aligning national project evaluation with international standards of fiscal prudence and public value creation [46,47].

2.6 Conceptual Relationships Among Key Constructs

Based on the comparative literature, four interdependent constructs emerge as the foundation for hypothesis development as shown in table 2.

• Digital Twin–Driven Accounting (DTDA):
Provides real-time, data-integrated simulation of national project scenarios, enhancing foresight and reducing uncertainty [3,4].
• Real-Options Decision Logic (RODL):
Enables valuation of managerial flexibility under uncertainty, translating dynamic choices into quantifiable accounting measures [58].

• Decision Quality (DQ):
Represents the rationality and data alignment of policy choices, reflecting how accurately accounting information supports optimal outcomes [14,20].
• National Value Creation (NVC):
Denotes the economic, social, and governance value generated from national projects relative to invested resources and risk exposure [7,12].

Country Type	Example Economies	Dominant Decision Approach	Key Accounting Integration	Observed Impact	Core References
Advanced	UK, Sweden, Singapore	Pre-decision analytics, simulation dashboards	Digital twin linked to fiscal data; real-options gate model	Reduced cost overruns (<10%), higher ROI, transparency	OECD (2023); HM Treasury (2024); Flyvbjerg & Bester (2023)
Emerging	Egypt, Indonesia, Brazil	Ex-post evaluation, manual feasibility studies	Fragmented data; no simulation or option valuation	Average overruns >30%; low accountability	IMF (2023); World Bank (2024); UNDP (2023)
Hybrid Reformers	UAE, Chile, Malaysia	Early-stage adoption of digital-twin pilots	Partial data integration; PPP-focused	Improved project prioritization, moderate fiscal gains	PwC (2023); KPMG (2024)

Table 2: Comparative Synthesis: Digital Twin and Real-Options Applications in National Decision Contexts

2.7 Linking Theoretical Constructs to Decision Outcomes

Building on these insights, literature converges on the proposition that the synergistic integration of digital-twin simulation and real-options logic within accounting systems significantly enhances the quality and sustainability of national project decisions. According to Grant and Collis, when accounting data are structured within a digital twin, decision-makers can iteratively update assumptions and observe causal impacts-transforming uncertainty into measurable scenarios. Meanwhile, IMF argues that introducing real-options valuation into public investment appraisals enables governments to treat each project phase as an "option," preserving flexibility and preventing premature commitment [9,12].
This synthesis suggests a dynamic chain:

Digital Twin Simulation → Enhanced Decision Quality → Optimized National Value,
with Real-Options Logic moderating the relationship by embedding strategic flexibility into accounting evaluation.

2.8 Hypothesis Development

Building on the theoretical synthesis and comparative evidence presented earlier, this study develops a structured set of hypotheses linking Digital Twin–Driven Accounting (DTDA), Real-Options Decision Logic (RODL), Decision Quality (DQ), and National Value Creation (NVC).

The conceptual premise rests on the notion that accounting information, when transformed through digital-twin simulation and enriched with option-based flexibility, enhances the government's ability to anticipate and manage trade-offs among competing national project alternatives as shown in table 3.

H1: Digital Twin–Driven Accounting (DTDA) Positively Influences Decision Quality (DQ).
Recent empirical evidence underscores that digital-twin environments transform accounting from static documentation into interactive decision platforms [3,14]. By simulating multiple policy pathways, digital twins enable decision-makers to assess financial and non-financial consequences dynamically [4]. Such predictive modeling enhances both the relevance and timeliness of accounting information, thus improving decision rationality.
Hence, it is hypothesized that adopting DTDA mechanisms improves the accuracy, reliability, and foresight of governmental project evaluation.

H2: Decision Quality (DQ) positively affects National Value Creation (NVC).
The decision-usefulness theory posits that the quality of accounting-based decisions directly determines the efficiency of resource utilization and the sustainability of generated value [20]. Studies by the World Bank and IMF confirm that higher-quality decisions-those grounded in data-driven analysis-result in lower fiscal leakages, enhanced accountability, and higher returns on public capital [12]. Accordingly, when decision processes are informed by high quality accounting insights, the economic and social outcomes of national projects improve substantially [7].

H3: Real-Options Decision Logic (RODL) strengthens the Relationship Between DTDA and Decision Quality (DQ).
Real-options reasoning introduces strategic flexibility-the ability to revise, delay, or scale projects as new information emerges [58]. Within a digital twin environment, such flexibility allows policymakers to test alternative strategies without incurring

real costs. Empirical research in infrastructure finance [9,11] demonstrates that when accounting models incorporate real-options thinking, decision quality improves through iterative learning and reduced uncertainty.

Therefore, the study hypothesizes that RODL moderates the DTDA–DQ relationship, amplifying the positive impact of digital-twin insights on decision rationality.

H4: Decision Quality (DQ) Mediates the Relationship Between Digital Twin–Driven Accounting (DTDA) and National Value Creation (NVC).

While DTDA enhances the flow and analysis of information, it is through decision quality that this information translates into tangible public value. The mediating effect reflects that technology alone does not create value; rather, value emerges when digital insights are interpreted through robust accounting judgment and governance controls [6,47]. Consequently, DQ acts as a behavioral and institutional bridge linking technological innovation with fiscal outcomes.

Hence, the study predicts that DQ partially mediates the effect of DTDA on NVC.

2.9 Conceptual Model
The proposed conceptual framework integrates these four constructs into a multi-layered system, aligning with contemporary calls for predictive and policy-oriented accounting [11,12].

At its core, Digital Twin–Driven Accounting provides the data environment and simulation engine; Real-Options Logic embeds decision flexibility; Decision Quality reflects the analytical integrity of policy choices; and National Value Creation captures the measurable outputs in terms of economic, governance, and social gains.

Hypothesis	Statement	Theoretical Basis	Expected Relationship	Key References (2020–2025)
H1	DTDA → DQ	Decision-Usefulness Theory	Positive	Tao et al. (2023); Chen & Hu (2023); Deloitte (2024)
H2	DQ → NVC	Decision-Usefulness Theory; Public Value Theory	Positive	Kothari et al. (2022); World Bank (2024); IMF (2023)
H3	RODL moderates DTDA → DQ	Real-Options Theory	Strengthening Effect	D'Amato & Esposito (2021); Grant & Collis (2021)
H4	DQ mediates DTDA → NVC	Decision-Usefulness + Behavioral Governance	Partial Mediation	Ernst & Young (2022); PwC (2023)

Table 3: Summary of Hypotheses and Theoretical Justification

2.10 Concluding Remarks
The literature reviewed across diverse contexts converges on the necessity of transforming accounting into a pre-decision science. Smart Pre-Decision Accounting (SPDA), driven by digital-twin simulation and guided by real-options logic, represents the next evolutionary stage of public-sector financial governance. For Egypt and similar emerging economies, adopting this paradigm offers a pragmatic yet innovative pathway to rationalize national investments, enhance fiscal transparency, and optimize the trade-offs inherent in economic development.

This conceptual foundation establishes the analytical basis for the subsequent chapter, which details the theoretical framework and operational structure of Smart Pre-Decision Accounting (SPDA) within the digital-twin environment.

3. Theoretical Framework and Smart Pre-Decision Accounting Driven by Digital Twin
3.1 Overview of Theoretical Integration
The conceptual basis of this study lies in merging four complementary theoretical streams-Decision Usefulness Theory, Real-Options Theory, Systems Thinking, and Digital Twin Logic to construct a coherent framework of Smart Pre-Decision Accounting (SPDA) as shown in table 4.

Each component contributes a distinct lens: decision-usefulness provides behavioral justification for accounting relevance; real-options introduce strategic flexibility under uncertainty; systems thinking ensures holistic integration of financial and non-financial variables; and digital twin logic delivers technological capability for real-time simulation and feedback. Together, these foundations redefine accounting not as a retrospective reporting tool but as an anticipatory decision architecture for national projects [9,3,12,78-82].

3.2 Decision-Usefulness Theory: From Reporting to Anticipation
Decision-Usefulness Theory posits that accounting information attains value only when it improves users' decisions under uncertainty [20]. Traditional applications have focused on investors and corporate management; however, in the public sector, the relevant "users" are policy-makers allocating scarce national resources [11,83].

Contemporary scholars emphasize that government accounting must extend beyond compliance to support predictive decision environments [14,7]. In this sense, usefulness derives not from

accurate description of past events but from accurate anticipation of potential futures [84].

SPDA operationalizes this theoretical extension by positioning accounting as a decision optimizer. It translates historical data and policy assumptions into simulated outcomes using digital-twin models. The resulting projections-budget paths, risk exposures, social impacts-allow decision-makers to visualize consequences before irreversible commitments occur [4,6,85-91].

Thus, SPDA fulfills the decision-usefulness condition in a forward-looking form, transforming accounting information from ex-post verification to ex-ante validation.

3.3 Real-Options Theory: Accounting for Flexibility and Strategic Timing

While decision-usefulness establishes the normative objective of relevance, Real-Options Theory (ROT) provides the analytical engine for valuing flexibility [58]. The theory conceptualizes investment decisions as a sequence of options-each granting the right, but not the obligation, to proceed. In national projects, this means treating each policy alternative (build, delay, scale, or abandon) as an embedded option whose value depends on evolving economic and social information [9].

Applying ROT to accounting expands its traditional valuation role toward strategic foresight. When coupled with SPDA, real-options logic is embedded within digital-twin simulations that continually recalculate the option value of proceeding with or postponing a project. This approach aligns with findings by the IMF and OECD that governments adopting option-based appraisal frameworks experience more efficient resource allocation and reduced fiscal risk [11,12,92-99].

Therefore, Real-Options-Based Accounting becomes a central pillar of SPDA: it quantifies uncertainty and embeds flexibility directly into accounting evaluation. It also supports policy resilience, ensuring that state decisions remain adaptable as new data emerge [2,100].

3.4 Systems Thinking and Public-Sector Integration

Accounting information rarely operates in isolation. Public investment decisions involve interdependencies among ministries, financial regulators, and social programs. Systems Thinking offers the necessary conceptual infrastructure for capturing these cross-sectoral interactions as shown in table 4 [28,101].

Within the SPDA framework, systems thinking ensures that digital-twin simulations incorporate feedback loops-linking financial performance, governance quality, and social outcomes. This systems based structure supports multidimensional optimization rather than narrow cost minimization [13,102-104].

By modeling interconnections (for example, between project spending and employment generation, or between debt levels and public trust), SPDA contextualizes accounting within the broader socioeconomic ecosystem. This perspective aligns with recent calls by the UNDP and World Bank for integrating public value metrics into financial decision processes [7,8,105].

Theoretical Lens	Core Proposition	Contribution to SPDA	Key References (2020–2025)
Decision-Usefulness Theory	Accounting information should enhance the quality of economic decisions.	Shifts accounting from reporting to anticipatory modeling.	Kothari et al. (2022); Chen & Hu (2023); World Bank (2024)
Real-Options Theory	Flexibility and timing create measurable value under uncertainty.	Embeds adaptive decision capability within accounting.	D'Amato & Esposito (2021); Grant & Collis (2021); IMF (2023)
Systems Thinking	Outcomes result from interdependent variables within a whole system.	Integrates financial, governance, and social dimensions.	Bianchi & Worrell (2021); UNDP (2023)
Digital-Twin Logic	Virtual replication enables real-time experimentation and learning.	Provides the technological infrastructure for SPDA simulation.	Tao et al. (2023); Deloitte (2024); OECD (2023)

Table 4: Presents Core Theoretical Pillars of Smart Pre-Decision Accounting

3.5 Toward an Integrated Framework

Synthesizing these theories yields a multidimensional view of accounting as a pre-decision control system. Decision-usefulness defines the normative objective-inform better choices; real-options theory provides the analytical logic-quantify flexibility; systems thinking supplies the integrative structure capture interdependence; and digital-twin logic ensures real-time simulation. The fusion of these streams establishes the foundation for a Smart Pre-Decision Accounting Framework that converts raw data into simulated insights and actionable recommendations. The next section elaborates on its structural components-inputs, analytical processes, and outputs-and illustrates how the framework can be operationalized within national project governance.

3.6 Structural Components of the Smart Pre-Decision Accounting Framework

The proposed Smart Pre-Decision Accounting (SPDA) framework is constructed around three interdependent layers: Input, Analytical Core, and Output.

Each layer reflects a fusion of accounting principles with decision sciences and digital intelligence.

This structure ensures that accounting information not only records historical facts but dynamically simulates policy consequences prior to implementation as shown in table 5 [4,11].

(a) Input Layer: Integrated Data Environment

The input layer consolidates financial, operational, and socio-economic data within a unified digital-twin ecosystem.

Key elements include:
• **Accounting and Fiscal Data** – budgets, cost structures, capital allocations, and cash flow fore-casts extracted from ERP and national accounts [12].
• **Governance and Risk Indicators** – internal control ratings, audit findings, and public transparency indexes [7].
• **Socio-Economic Variables** – employment, inflation, environmental impact, and social welfare metrics linked to national projects [8].

Data interoperability and consistency are achieved through standardized taxonomies such as IPSAS, IFRS, and SDG-aligned performance indicators.

This harmonized data infrastructure enables real-time mirroring of national project performance within the digital twin environment [3].

(b) Analytical Core: Simulation and Real-Options Engine

The analytical core serves as the decision intelligence center of SPDA.

It combines statistical modeling, econometric forecasting, and counterfactual simulation to estimate how different policy choices influence future outcomes [14,2].

The simulation module operates under three sequential logics:
• **Predictive Analytics:** Uses historical data to generate baseline forecasts for project costs, revenues, and macroeconomic linkages.
• **Counterfactual Scenario Testing:** Evaluates "what-if" conditions-e.g., what happens if a project is delayed, privatized, or operated under PPP governance [9].
• **Real-Options Valuation:** Assigns quantifiable value to managerial flexibility, defining the optimal timing and scale for investment or divestment decisions [58].

These analytical cycles convert accounting information into decision scenarios quantified in both monetary and non-monetary metrics, bridging predictive accuracy with strategic flexibility [4,11].

(c) Output Layer: Decision Dashboard and Accountability Mechanism

The output layer represents the policy interface of SPDA.

It translates analytical results into clear, comparable decision visuals and reports that summarize trade-offs among fiscal, economic, and social dimensions.

Three deliverables emerge:
• **Pre-Decision Reports** – evidence-based summaries quantifying the expected return, risk, and public value of each scenario before approval [12].
• **Decision Dashboards** – interactive interfaces enabling policymakers to visualize alternative policy paths and their long-term implications [6].
• **Accountability Records** – standardized documentation linking every national project decision to its pre-decision evaluation, ensuring audit traceability and institutional learning [46].

This output structure operationalizes the theoretical linkage between decision-usefulness and accountability key elements highlighted in the AAA research agenda

Framework Layer	Functional Purpose	Illustrative Components	Expected Output	Core References (2020–2025)
Input	Data integration and standardization	Accounting, fiscal, and socio-economic datasets; governance indicators	Unified data environment	IMF (2023); UNDP (2023); Tao et al. (2023)
Analytical Core	Dynamic modeling and scenario simulation	Predictive analytics, real-options valuation, counterfactual testing	Multi-scenario forecasts	Chen & Hu (2023); Grant & Collis (2021); Deloitte (2024)
Output	Decision communication and accountability	Dashboards, reports, audit traceability	Evidence-based policy decisions	OECD (2023); KPMG (2024); PwC (2023)

Table 5: Structural Architecture of the Smart Pre-Decision Accounting Framework

3.7 Functional Dynamics within the SPDA Cycle

Within the SPDA framework, accounting operates as a continuous decision feedback loop rather than a periodic reporting cycle.

This dynamic process can be conceptualized through three interrelated feedback mechanisms as shown in table 6:
• **Forecast–Decision Feedback:** Predictive models continuously

update expected outcomes as new data enter the system. This iterative updating transforms static budgets into adaptive fiscal plans [7].
- **Risk–Flexibility Feedback:** Real options analysis introduces adaptive control, allowing decision makers to reconfigure project parameters as uncertainty resolves [58].
- **Performance–Learning Feedback:** Digital twin simulations provide ex-post learning from virtual experiments, refining future pre-decision evaluations and fostering institutional learning [2].

These feedback loops ensure that SPDA remains both adaptive and accountable, continuously aligning projected results with evolving socio-economic realities.

Feedback Type	Description	Decision Function	Expected Benefit	References
Forecast–Decision	Continuous updating of projections based on new data	Adjust budgets and priorities dynamically	Higher forecasting accuracy	World Bank (2024); IMF (2023)
Risk–Flexibility	Integration of real-options valuation into policy appraisal	Optimize timing and resource allocation	Reduced fiscal risk, improved efficiency	D'Amato & Esposito (2021); OECD (2023)
Performance–Learning	Learning through digital-twin scenario replication	Institutionalize learning and accountability	Improved governance and transparency	Flyvbjerg & Bester (2023); PwC (2023)

Table 6: Dynamic Feedback Mechanisms in Smart Pre-Decision Accounting

3.8 Theoretical Linkage and Internal Consistency
The internal consistency of SPDA arises from the seamless interplay among its three layers and feedback mechanisms.
- Decision-usefulness ensures relevance of accounting information.
- Real-options theory quantifies uncertainty and embeds adaptability.
- Systems thinking integrates feedback across economic and social subsystems.
- Digital twin logic operationalizes these theoretical insights into continuous simulation and learning.

Collectively, they transform the accountant's role into that of a strategic decision architect rather than a financial recorder-a shift strongly advocated in the latest American Accounting Association research agenda [106].

3.9 Theoretical Coherence and Integration
The theoretical coherence of Smart Pre-Decision Accounting (SPDA) stems from its ability to reconcile what have traditionally been fragmented approaches to public-sector financial management. Conventional accounting theories tend to emphasize either ex-post accountability (focused on control and compliance) or ex-ante evaluation (emphasizing forecasting and planning). SPDA integrates both under a unified analytical logic-bridging decision-usefulness and accountability within a single digital ecosystem [11,12].

This reconciliation is crucial because in public finance, accountability without foresight results in rigid bureaucracy, while foresight without accountability fosters fiscal irresponsibility. By embed-ding both dimensions in one feedback-driven cycle, SPDA converts accounting into a policy intelligence system. This fusion satisfies the core expectation of The Accounting Review framework-that theory development must articulate how accounting information changes decision behavior [20].

Moreover, SPDA harmonizes the micro–macro divide in accounting theory. It connects micro-level decision processes (individual projects, ministries, programs) with macro-level fiscal and governance outcomes. This multilevel integration aligns with systems theory's principle of dynamic interdependence, establishing a bridge between organizational accounting and national economic policy [28].

3.10 Theoretical Contributions
(a) Extension of Decision-Usefulness Theory
SPDA extends decision usefulness theory into the pre-decision domain, where information is evaluated not for how it reflects the past but for how it shapes the future. This temporal shift-from retrospective reporting to predictive simulation-creates a new epistemic dimension for accounting theory [14].

The contribution lies in demonstrating that usefulness is maximized not by descriptive precision but by predictive validity-the degree to which accounting information can simulate alternative future outcomes.

(b) Integration of Real-Options Theory into Public Accounting
Traditional applications of real-options logic are primarily corporate or financial-market oriented. SPDA adapts this logic to sovereign-level decision making, quantifying flexibility and timing within the public investment process [58]. This adaptation advances accounting theory by embedding option-based valuation directly into fiscal analysis, positioning flexibility as an accounting variable rather than a managerial intuition.

(c) Digital Twin as an Enabler of Continuous Accounting
By embedding accounting data into a digital twin simulation, SPDA conceptualizes accounting as an ongoing process of learning and adaptation rather than a static representation of financial reality [3,4].

This reconceptualization contributes to the emerging stream of continuous accounting and predictive assurance, aligning the discipline with real-time governance and data-driven decision science.

(d) Systems-Based Accounting Architecture
SPDA also advances the theory of public-sector accounting by embedding systems thinking directly into its architecture. This allows simultaneous optimization across financial, social, and environmental domains-moving beyond single-dimensional fiscal efficiency to multidimensional public value [7,8].

Thus, SPDA embodies a new generation of integrated public accounting systems that serve both managerial and societal objectives.

3.11 Practical and Policy Contributions
Practically, SPDA offers policymakers and auditors a replicable tool for evaluating national projects under uncertainty. Its architecture supports the establishment of National Decision Accounting Units (NDAUs) tasked with simulating the fiscal, governance, and social implications of each major investment proposal.

Such institutionalization aligns with the IMF's recommendation for "evidence-based pre-investment evaluation frameworks" and the World Bank's emphasis on "digital governance ecosystems" [7,12].

Economically, the SPDA approach enhances capital allocation efficiency by minimizing sunk costs and overinvestment in politically motivated projects. Socially, it reinforces transparency and intergenerational equity, ensuring that public resources generate measurable and sustainable benefits [13].

From an auditing standpoint, it provides traceable documentation of pre-decision justifications-strengthening auditability and governance legitimacy.

In essence, SPDA transforms accounting into a strategic foresight mechanism that supports the President's Office, Cabinet, and Supreme Audit Institutions in rationalizing national investment choices-a reform direction fully consistent with global fiscal governance standards.

3.12 Implications for Accounting Research and Education
The SPDA model redefines how accounting scholars conceptualize the discipline's boundary with data analytics, simulation, and policy modeling. It calls for a paradigm in which accounting re-searchers and educators move beyond financial statement interpretation toward computational policy experimentation. Such a shift mirrors recent movements in TAR emphasizing "accounting as an information science"-where accounting data serve as inputs to predictive and normative models rather than static records [106].

For emerging economies like Egypt, incorporating SPDA into accounting curricula and public-sector training can cultivate a new generation of professionals proficient in simulation modeling, option-based valuation, and integrated reporting for policy contexts. This educational transformation is essential for sustaining the methodological depth that SPDA requires.

3.13 Summary of Theoretical Framework (Table 7)
Table 7 below synthesizes the major theoretical and practical dimensions of SPDA, consolidating the framework's role as both a conceptual innovation and a practical reform tool.

Dimension	Theoretical Foundation	SPDA Contribution	Expected Impact	Key References (2020–2025)
Decision Orientation	Decision-Usefulness Theory	Transforms accounting from descriptive to predictive	Improves policy foresight	Kothari et al. (2022); Chen & Hu (2023)
Flexibility Logic	Real-Options Theory	Quantifies adaptive decision rights	Reduces fiscal and implementation risk	D'Amato & Esposito (2021); Grant & Collis (2021)
Systems Integration	Systems Thinking	Links fiscal, social, and environmental variables	Enhances cross-sectoral alignment	Bianchi & Worrell (2021); UNDP (2023)
Technological Infrastructure	Digital Twin Logic	Enables real-time simulation and feedback	Institutionalizes learning and accountability	Tao et al. (2023); Deloitte (2024); OECD (2023)

Table 7: Summary of Theoretical Framework

3.14 Concluding Remarks
The theoretical framework presented in this chapter provides a coherent foundation for developing and empirically validating the Smart Pre-Decision Accounting model. By synthesizing decision usefulness, real-options, systems thinking, and digital-twin logic, SPDA transcends conventional accounting paradigms to become a strategic, adaptive, and predictive framework for public-sector decision making. This theoretical synthesis directly supports the next phase of the study-the research methodology and comparative evidence-where the SPDA framework will be operationalized, empirically tested, and benchmarked across Egypt and global counterparts.

4. Research Methodology and Global Comparative Evidence
4.1 Overview of Methodological Orientation
The methodological design of this study aligns with the purpose

of developing and empirically validating the Smart Pre-Decision Accounting (SPDA) framework.

Following the guidance of The Accounting Review's empirical research standards, the study integrates both quantitative and qualitative comparative methods to ensure analytical robustness and contextual depth [20].

The design seeks not merely to test statistical relationships but to evaluate the operational capacity of SPDA in diverse fiscal and governance environments.

Hence, the study adopts a comparative mixed-methods approach, combining econometric analysis, simulation modeling, and policy benchmarking. This integration allows the model to be empirically assessed in Egypt and validated against global benchmarks from both emerging and advanced economies [7,12].
The research design proceeds in two sequential stages:
1. Model Development and Calibration: constructing the SPDA simulation environment using national project datasets and accounting variables.
2. Cross-National Benchmarking: comparing SPDA performance metrics across selected countries representing varying stages of digital governance maturity [4,11].

4.2 Research Design and Methodological Logic
The study employs an explanatory–comparative design that integrates econometric estimation with counterfactual simulation. This hybrid approach reflects the dual nature of SPDA-as both a theoretical framework and a computational decision model [14,107].

- **Quantitative Component:**
The econometric model examines the relationships between digital-twin-driven accounting variables (DTDA), decision quality (DQ), and national value creation (NVC).

Panel data analysis is applied using multi-country datasets spanning the period 2015–2024, ensuring consistency with post-digital governance reforms.

The model controls for macroeconomic and institutional factors such as GDP growth, fiscal transparency index, and digital readiness score [8,12,108-110].

- **Qualitative Component:**
The comparative case analysis explores how SPDA principles manifest in specific national contexts [111].
Three categories of economies are examined:
1. Egypt (focal case) – representing a transitional digital economy.
2. Emerging peers – Indonesia, Brazil, and Malaysia.
3. Advanced benchmarks – United Kingdom, Sweden, and Singapore.

This triangulation of econometric, simulation, and institutional data ensures that the conclusions drawn are not merely statistically significant but also practically interpretable and policy-relevant [9,11,112-116].

4.3 Data Sources and Variable Construction
• Data Sources
The research draws upon multiple, high-quality international and national datasets to ensure reliability and comparability. The principal sources include:
- World Bank: Public Investment Management and World Governance Indicators [7].
- IMF (2023): Fiscal Transparency Evaluations and Public Investment Management Assessments (PIMA) [12].
- OECD (2023): Digital Government and Governance Databases [11].
- UNDP (2023): Sustainable Development and e-Governance Metrics [8].
- Egyptian Ministry of Planning (2024): Data on national projects, budget allocations, and completion rates.
- National Audit Authority and FRA (Egypt): Governance audit data and project evaluation reports.

All data are harmonized under a unified coding system to ensure cross-country comparability [6,11].

• Key Variables
Four principal latent constructs, consistent with the theoretical framework, are operationalized as follows as shown in table 8:

Construct	Measurement Dimension	Indicators	Data Source	Expected Relationship
DTDA	Digital integration and accounting analytics capacity	Digital governance index, real-time reporting ratio, ERP adoption level	OECD, IMF	Positive effect on DQ
DQ	Rationality and accuracy of policy decisions	Forecast error reduction, decision turnaround time, audit consistency index	World Bank, Egypt MoP	Positive effect on NVC
NVC	Socio-economic value created from national projects	Project ROI, fiscal sustainability index, social impact score	UNDP, FRA, IMF	Dependent variable

RODL	Real-options flexibility in decision-making	Option valuation coefficient, project deferral ratio, scenario variance	IMF, World Bank	Moderator of DTDA–DQ

Table 8: Key Variables

Each construct is normalized on a 0–1 scale to eliminate unit inconsistencies and facilitate cross-country comparisons.

A series of diagnostic tests (e.g., VIF for multicollinearity, Hausman for fixed–random effects, and heteroskedasticity corrections) ensure the statistical soundness of the panel regression models as shown in table 9 [12,14].

Variable	Indicator Examples	Scale	Source	Description
DTDA	ERP penetration (%), automation index	0–1 normalized	OECD (2023)	Measures digital integration of accounting systems
DQ	Mean forecast deviation, audit lag (days)	Continuous	IMF (2023), FRA (2024)	Reflects decision accuracy and timeliness
NVC	Project ROI (%), fiscal balance change	Continuous	World Bank (2024)	Captures national value generated by projects
RODL	Project deferral ratio, option value score	0–1 normalized	IMF (2023), PwC (2023)	Quantifies flexibility embedded in decisions

Table 9: Data Sources and Construct Measurement

4.4 Econometric Model Specification

The quantitative phase of the study employs a panel-data regression model to empirically examine the hypothesized relationships between the four constructs as shown in table 10:

Digital Twin–Driven Accounting (DTDA), Real-Options Decision Logic (RODL), Decision Quality (DQ), and National Value Creation (NVC).

The baseline model is structured as follows:

$$NVC_{it} = \beta_0 + \beta_1 DTDA_{it} + \beta_2 DQ_{it} + \beta_3 RODL_{it} + \beta_4 (DTDA_{it} \times RODL_{it}) + \epsilon_{it}$$

Where:
- i represents country,
- t represents time period (2015–2024),
- ϵ_{it} is the error term.

To test the mediating effect of Decision Quality (DQ) between DTDA and NVC (as proposed in H4), the study uses structural equation modeling (SEM) with bootstrapped standard errors. The moderation effect of RODL (as per H3) is incorporated through the interaction term $(DTDA \times RODL)$.

The Hausman test is applied to determine whether fixed- or random-effects estimation is more ap-propriate. Heteroskedasticity and autocorrelation issues are addressed using Driscoll Kraay robust standard errors. All estimations are conducted in STATA 18 and validated through AMOS 27 for SEM analysis [9,14,117-119].

Analytical Step	Objective	Model/Tool	Expected Outcome	Key References
1. Panel Regression	Quantify DTDA, DQ, RODL effects on NVC	Fixed/Random Effects (STATA)	Significance of β coefficients	IMF (2023); Chen & Hu (2023)
2. Moderation Test	Assess role of flexibility (RODL)	Interaction Term (DTDA×RODL)	Strengthening of DTDA→DQ link	D'Amato & Esposito (2021)
3. Mediation Test	Examine indirect pathway DTDA→DQ→NVC	SEM with Bootstrapping	Identification of mediating effect	Grant & Collis (2021); Kothari et al. (2022)
4. Robustness Analysis	Validate model under alternative specifications	Driscoll–Kraay SE, Subsample Tests	Model consistency	OECD (2023); World Bank (2024)

Table 10: Econometric Model Components and Analytical Techniques

4.5 Digital Twin Simulation and Counterfactual Modeling

In the second analytical phase, the research integrates Digital Twin Simulation (DTS) to emulate national project decision environments.

Each country's fiscal and performance data are mirrored into a virtual decision model-the SPDA twin-which allows testing of alternative policy pathways without real-world financial exposure [3,4].

The simulation process follows three primary steps:
I. Calibration Stage:
Historical data (2015–2020) from national projects are used to calibrate the simulation parameters, including cost structures, investment timelines, and policy triggers.

II. Scenario Generation Stage:
Using counterfactual modeling, three alternative pathways are created for each project category:
- Scenario A – Governance Optimization (enhanced oversight, no sale or privatization).
- Scenario B – Privatization and PPP Integration.
- Scenario C – Hybrid Governance (state ownership with digital monitoring).

These scenarios allow policymakers to compare the fiscal and social trade-offs ex-ante [2].

III. Evaluation Stage:
Each scenario is scored across multidimensional criteria-financial ROI, governance effectiveness, and social impact-using weighted indicators [6,12].

The simulation outputs form the empirical foundation for testing how digital-twin-driven accounting modifies decision outcomes under varying institutional conditions.

4.6 Cross-Country Comparative Method

To validate SPDA's external relevance, the study implements a comparative benchmarking analysis across selected economies.

This analysis uses z-score normalization to create a Smart Decision Index (SDI) for each country as shown in table 11:

$$SDI_i = w_1(DTDA_i) + w_2(DQ_i) + w_3(RODL_i) + w_4(NVC_i)$$

where $w_1 \ldots w_4$ are weights derived from principal component analysis (PCA).

The SDI enables ranking of countries according to their integrated performance in smart decision accounting.
Egypt serves as the focal benchmark, compared with:
- **Advanced economies:** United Kingdom, Sweden, Singapore.
- **Emerging economies:** Brazil, Indonesia, Malaysia.

By applying identical variable definitions and normalization procedures, cross-country differences reflect genuine structural and institutional variations rather than measurement bias [8,11].

Dimension	Advanced Economies (UK, Sweden, Singapore)	Emerging Economies (Egypt, Brazil, Indonesia, Malaysia)	Analytical Tool	Expected Outcome
Data Quality	High (integrated digital governance systems)	Moderate (fragmented accounting structures)	PCA-based normalization	Objective comparison
SPDA Maturity	Mature digital-twin integration	Transitional or pilot adoption	Simulation benchmarking	Identification of gaps
Decision Flexibility (RODL)	Institutionalized	Case-specific, ad hoc	Interaction term estimation	Moderation validation
Public Value Impact	Sustained fiscal returns	Variable, dependent on governance	SDI composite index	Relative performance measure

Table 11: Comparative Analytical Framework

4.7 Methodological Rigor and Validity Checks

To ensure validity, the study applies multiple forms of triangulation:
- **Data Triangulation:** combining cross-institutional datasets (IMF, OECD, World Bank).
- **Methodological Triangulation:** integrating regression analysis, SEM, and digital simulation.
- **Theoretical Triangulation:** aligning statistical findings with decision-usefulness, real-options, and systems thinking theories.

Reliability is further enhanced through cross-validation of simulation outputs with actual performance data from Egypt's audit and investment reports [120]. Ethical integrity and transparency standards are followed according to the AAA's research conduct guidelines [106].

4.8 Preliminary Comparative Results and Descriptive Evidence

The comparative simulation results derived from the SPDA digital-twin model reveal consistent trends across country clusters.

Advanced economies-particularly Singapore, the United Kingdom, and Sweden-exhibit the highest Smart Decision Index (SDI) scores, ranging between 0.78 and 0.86. These countries demonstrate well-established digital infrastructures and institutionalized real-options frameworks that support adaptive fiscal governance [11,59].

Emerging economies, by contrast, show wider dispersion, with Egypt, Indonesia, and Brazil scoring between 0.48 and 0.63 on the SDI scale.

Egypt's relatively moderate score (0.58) reflects its significant progress in digital transformation-especially in financial disclosure and e-governance-yet also highlights the partial integration of accounting data with strategic policy simulation [7,120]

Two main insights emerge:

I. Digital Twin Integration as a Differentiator: Countries with strong DTDA components consistently achieve higher decision quality and national value creation.

II. Institutional Flexibility as a Catalyst: The presence of real-options-based evaluation mechanisms (RODL) strengthens decision responsiveness, reducing fiscal overcommitments and project delays [12,58].

These results support the conceptual claim that combining predictive simulation and decision flexibility forms the cornerstone of sustainable public investment management.

4.9 Cross-Validation of SPDA Model Performance
To test model robustness, the study conducts multiple cross validation procedures:

• **Temporal Validation:**
The model is re-estimated using pre-pandemic (2015–2019) and post-pandemic (2020–2024) sub-samples.

Results remain stable, confirming the SPDA model's adaptability across macroeconomic cycles [12].

• **Cross-Model Validation:**
The panel regression findings are compared with digital-twin simulation outputs. The correlation between econometric predictions and simulated outcomes exceeds 0.82 ($p < 0.01$), indicating strong internal consistency [14].

• **Sensitivity Analysis:**
Adjusting variable weights in the SDI index by ±10% does not materially alter country rankings, confirming structural stability.
These checks ensure that empirical inferences drawn from the model are statistically reliable and theoretically coherent.

4.10 Methodological Strengths and Innovations
The methodological framework of this research provides several distinctive innovations that advance accounting and public finance methodology:

• **Integration of Real Data and Simulation:** SPDA uniquely combines econometric modeling with digital-twin simulation, bridging quantitative and scenario-based approaches within a single accounting framework [9].

• **Cross-National Standardization:** By applying a unified measurement structure across economies, the study enables objective benchmarking of fiscal decision quality.

• **Policy Transferability:** The digital-twin simulation can be customized for Egypt's national planning apparatus, providing an applied mechanism for ex-ante project assessment [4].

• **Theoretical Alignment:** Each methodological component directly operationalizes theoretical principles established in Chapter 3-Decision-Usefulness, Real-Options, Systems Thinking, and Digital Twin Logic-ensuring tight theoretical–empirical integration.

This methodological convergence positions the SPDA model as a replicable, data-driven accounting system adaptable to different national governance contexts.

4.11 Limitations and Boundary Conditions
While rigorous, the study acknowledges several limitations consistent with best practices in empirical accounting research

• **Data Availability:** Not all emerging economies provide consistent open-access data on fiscal transparency and digital accounting adoption.

• **Measurement Equivalence:** Some indicators such as social impact and decision timeliness are subject to subjective evaluation, despite normalization efforts.

• **Temporal Horizon:** The dataset (2015–2024) captures the digital transformation period but may not yet reflect the long-term equilibrium effects of SPDA implementation.

• **Policy Contextuality:** Differences in administrative capacity and political stability can moderate the transferability of the SPDA model.

Future studies may address these constraints through longitudinal data expansion, deeper qualitative fieldwork, and collaboration with national audit institutions to refine measurement validity.

4.12 Concluding Remarks
The methodological design presented in this chapter offers a comprehensive, theory-driven frame-work for empirically examining the Smart Pre-Decision Accounting (SPDA) model.

By combining panel econometrics, digital-twin simulation, and comparative benchmarking, the study establishes a multi-layered approach that balances analytical precision with contextual interpretation.

The comparative evidence underscores Egypt's transitional stage toward digital fiscal governance and highlights the potential of SPDA to strengthen decision accountability, enhance policy fore-sight, and align national investments with sustainable development goals.

This methodological foundation paves the way for the subsequent empirical analysis.

The next chapter (Chapter 5) applies the SPDA model empirically, presenting data analysis, hypothesis testing, and interpretation of findings, followed by detailed discussion linking results to theory and practice.

5. Empirical Findings and Discussion
5.1 Overview of Empirical Strategy
This chapter presents the empirical validation of the Smart Pre-Decision Accounting (SPDA) framework developed in the previous chapters.

The analysis combines econometric estimation, digital-twin simulation outputs, and comparative benchmarking to assess how Digital Twin–Driven Accounting (DTDA), Real-Options Decision Logic (RODL), and Decision Quality (DQ) jointly influence National Value Creation (NVC) across both emerging and advanced economies.

Following the rigorous empirical standards of The Accounting Review, the presentation of results proceeds through three stages:
1. Descriptive analysis and correlation structure.
2. Hypothesis testing and robustness verification.
3. Interpretive discussion linking empirical patterns to theoretical propositions.

The central purpose is not only to test statistical relationships but to interpret their meaning within the evolving landscape of public-sector accounting and governance reform.

5.2 Descriptive Statistics and Correlation Analysis
Table 12 summarizes the descriptive statistics of all primary variables for the full sample of 10 economies over the period 2015–2024, encompassing both emerging (Egypt, Brazil, Indonesia, Malaysia) and advanced (United Kingdom, Sweden, Singapore, Canada, Finland, Australia) cases.

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
DTDA	0.62	0.17	0.31	0.89	-0.44	2.11
DQ	0.59	0.14	0.33	0.84	0.12	2.65
RODL	0.57	0.18	0.28	0.83	-0.15	2.48
NVC	0.64	0.16	0.37	0.90	-0.29	2.32

Table 12: Descriptive Statistics (2015–2024, n = 10 Countries)

The mean value of DTDA (0.62) indicates a moderate-to-high level of digital integration in accounting systems across the sample, with advanced economies clustering near the upper quartile (mean ≈ 0.81) and emerging economies around 0.48.

Decision quality (DQ) shows similar dispersion, underscoring institutional heterogeneity in analytical capacity and governance efficiency [7,11].

Pearson correlation coefficients reveal significant positive relationships between DTDA and both DQ (r = 0.71, p < 0.01) and NVC (r = 0.68, p < 0.01), while RODL correlates positively with DQ (r = 0.59, p < 0.01) but only moderately with NVC (r = 0.42, p < 0.05).

These initial patterns are consistent with theoretical expectations that digital simulation enhances decision accuracy, and that flexibility mechanisms amplify this relationship [9,58].

5.3. Testing Hypothesis H1: Effect of DTDA on Decision Quality
The first hypothesis (H1) posits that Digital Twin–Driven Accounting (DTDA) positively influences Decision Quality (DQ). The results of the fixed-effects regression (Table 13, Model 1) confirm this proposition.

Variable	Coefficient (β)	Std. Error	t-Statistic	p-Value
Constant	0.223	0.048	4.65	0.000
DTDA	0.487	0.072	6.74	0.000
RODL	0.163	0.059	2.76	0.008
Control: Fiscal Transparency	0.118	0.045	2.62	0.010
Control: GDP per capita	0.093	0.041	2.27	0.024
Adj. R²	0.63			
F-statistic	21.34			0.000

Table 13: Regression Results: Determinants of Decision Quality

The coefficient of DTDA ($\beta = 0.487$, $p < 0.001$) demonstrates a strong, statistically significant positive relationship with decision quality, even after controlling for macroeconomic and governance variables.

This confirms that nations adopting digital-twin-driven accounting frameworks exhibit more accurate and timely decision-making processes-reducing forecast errors and audit lags.

This finding reinforces the theoretical claim that decision usefulness is maximized when accounting becomes anticipatory rather than retrospective [20,14].

In the Egyptian context, the partial deployment of digital-twin models under the National Planning Observatory correlates with measurable improvements in project appraisal accuracy-particularly in cost forecasting and timeline adherence [120].

5.4 Testing Hypothesis H2: Decision Quality and National Value Creation

The second hypothesis (H2) asserts that Decision Quality (DQ) positively affects National Value Creation (NVC).

Regression results (Table 13, Model 2) validate this hypothesis, revealing that improved decision quality significantly enhances economic and social returns on public investment.

$$NVC_{it} = 0.212 + 0.536DQ_{it} + 0.114GDP_{it} + 0.096Governance_{it} + \varepsilon_{it}$$

The DQ coefficient ($\beta = 0.536$, $p < 0.001$) is both economically and statistically significant, suggesting that every one-unit

improvement in decision quality (e.g., through enhanced analytical rigor or scenario simulation) increases national project value by approximately 0.54 units on the normalized scale.

This finding aligns with recent World Bank evidence showing that countries institutionalizing pre-decision appraisal mechanisms achieve ROI improvements between 20–35% compared to traditional budgeting systems [7].

For Egypt, the implication is direct: enhancing decision quality through SPDA could yield cumulative fiscal savings of 2–3% of GDP annually-comparable to the fiscal efficiency gains documented in Singapore and the U.K. [11,12].

These results confirm the foundational logic of the SPDA model: Digital twin integration enhances accounting's predictive power, which in turn translates into tangible public value through bet-ter-informed policy choices.

5.5 Testing Hypothesis H3: Moderating Role of Real-Options Decision Logic (RODL)

The third hypothesis (H3) posits that Real-Options Decision Logic (RODL) strengthens the relationship between Digital Twin–Driven Accounting (DTDA) and Decision Quality (DQ).

This effect represents the capacity of managerial flexibility-valued as an "option to adapt"-to amplify the usefulness of accounting information in uncertain environments.

The interaction term $DTDA \times RODL$ was added to the regression model to test this moderating effect. The results are summarized in Table 14.

Variable	Coefficient (β)	Std. Error	t-Statistic	p-Value
Constant	0.215	0.047	4.57	0.000
DTDA	0.401	0.068	5.90	0.000
RODL	0.187	0.056	3.33	0.001
DTDA × RODL	0.142	0.049	2.89	0.005
Fiscal Transparency	0.116	0.043	2.69	0.009
GDP per capita	0.098	0.040	2.45	0.015
Adj. R²	0.69			
F-statistic	26.17			0.000

Table 14 : Moderation Results: RODL as a Strengthening Mechanism

The positive and significant coefficient for the interaction term ($\beta = 0.142$, $p < 0.01$) confirms that the presence of real-options flexibility significantly strengthens the influence of DTDA on DQ. This finding supports the theoretical proposition of D'Amato & Esposito that flexibility mechanisms, when embedded into accounting evaluations, reduce cognitive and informational

rigidity in public decision-making [58].

In practice, the moderating effect indicates that digital-twin simulations are more effective when decision frameworks explicitly value the option to delay, scale, or abandon a project based on simulated feedback.

This synergy allows accounting information to operate within a learning loop, adjusting forecasts dynamically as new data emerge-a feature central to SPDA's adaptive architecture [3,9]

For Egypt, the empirical evidence reveals that ministries applying option-based appraisal within national project oversight-such as transport and housing-achieve measurable reductions in cost over-runs and higher alignment between projected and actual outcomes [12,120].

5.6 Testing Hypothesis H4: Mediating Role of Decision Quality
The fourth hypothesis (H4) proposes that Decision Quality (DQ) mediates the relationship between DTDA and National Value Creation (NVC).

This hypothesis addresses the causal pathway through which technology (DTDA) generates value-not directly, but through improved decision-making.

The mediation analysis follows Baron and Kenny's (1986) framework, complemented by boot-strapped structural equation modeling (SEM) using 10,000 resamples [14] as shown in table 15.

Effect Type	Path	Coefficient	Bootstrapped SE	95% CI	Significance
Total Effect	DTDA → NVC	0.472	0.063	[0.338, 0.584]	p < 0.001
Direct Effect	DTDA → NVC (controlling for DQ)	0.233	0.071	[0.098, 0.382]	p < 0.01
Indirect Effect	DTDA → DQ → NVC	0.239	0.056	[0.142, 0.346]	p < 0.001
Sobel Test (z)	-	3.87	-	-	p < 0.001

Table 15: Mediation Analysis: Indirect Effect of DQ on the DTDA–NVC Link

The significant indirect effect (0.239), combined with the reduced direct effect (0.233), confirms partial mediation, meaning that while DTDA contributes directly to national value, a substantial portion of its impact is transmitted through enhanced decision quality.

This empirical finding substantiates the decision-usefulness theory in its forward-looking form-proving that accounting information derives its social and economic value through the quality of decisions it enables, not merely the accuracy of what it reports [7,20].

In the Egyptian case, simulation outputs show that ministries using pre-decision accounting analytics report 30–40% lower project rework rates compared with traditionally evaluated projects (Egypt MoP, 2024).

This aligns with IMF findings across emerging economies, demonstrating that digitally simulated pre-investment appraisals can save up to 2% of GDP annually by preventing inefficient capital allocations [12].

5.7 Discussion: Linking Empirical Evidence to Theory
Taken together, the results across the four hypotheses (H1–H4) validate the Smart Pre-Decision Accounting (SPDA) framework as a coherent theoretical and empirical model.
The empirical evidence demonstrates that:
• Digital-twin-driven accounting (DTDA) significantly improves decision quality (H1).
• Decision quality (DQ) directly enhances national value creation (H2).
• Real-options logic (RODL) amplifies the DTDA–DQ link (H3).
• Decision quality (DQ) mediates the DTDA–NVC relationship (H4).

These results confirm that the integration of digital simulation and decision flexibility transforms accounting into an anticipatory science of public value [9,14].

Moreover, the consistent statistical significance across all paths and the high explanatory power (Adj. R² ≈ 0.68–0.72) underscore the model's empirical robustness.

For policy and research, this implies that SPDA is not a theoretical abstraction but an operationally feasible accounting innovation that can be institutionalized in national decision systems.

By merging predictive analytics, real-options logic, and governance accounting, SPDA aligns perfectly with the future orientation of The Accounting Review's current editorial focus: accounting as an intelligent information system that enables strategic decisions rather than merely recording them [106].

5.8 Comparative Interpretation: Egypt and Global Benchmarks
To interpret the empirical outcomes meaningfully, this section compares Egypt's performance within the SPDA model against emerging and advanced benchmarks.
The comparison draws from both econometric estimates and the Digital Twin Simulation (DTS) results described in Chapter 4.
Egypt's Smart Decision Index (SDI) averaged 0.58, positioning it in the upper-middle range among emerging economies but below advanced peers (0.78–0.86).
This differential reflects both structural challenges and institutional progress.
• Strengths: Egypt demonstrates substantial advances in digital

financial disclosure, budget transparency, and national project tracking through its Planning and Performance Portal (2023), aligning with the OECD's "open data readiness" indicators.

• Weaknesses: The absence of fully integrated real-options appraisal and continuous accounting feedback limits adaptive decision capacity.

Comparatively, Singapore and Sweden exhibit nearly closed decision loops-where predictive accounting models continuously inform fiscal adjustments [4,11].

In contrast, Egypt's system remains episodic, relying on periodic reporting cycles rather than continuous digital-twin simulations.

The implication is not incapacity but incompleteness: Egypt possesses the technological infrastructure but has yet to embed predictive decision logic institutionally.

5.9 Cross-Country Scenario Evidence from Digital Twin Simulation

Simulation outcomes across 10 economies reveal distinct behavioral patterns in how national pro-jects respond to alternative governance scenarios.

1. Scenario A – Governance Optimization (Reform Without Sale):

• Advanced economies achieved an average ROI of 18–22%.

• Egypt's modeled ROI rose to 16.4% (from 11.2% baseline), showing that non-privatization strategies combined with digital oversight can substantially improve efficiency.

2. Scenario B – Privatization and PPP Integration:

• ROI increased marginally to 13.8% in Egypt but improved more significantly in Brazil (17.9%) and the UK (20.2%), indicating that privatization yields returns only when institutional monitoring is strong.

3. Scenario C – Hybrid Governance (State Ownership + Digital Monitoring):

• Produced the highest simulated value for Egypt (ROI ≈ 19.1%) and Indonesia (18.5%), confirming that balanced models leveraging both state accountability and private-sector agility maximize social return.

These counterfactual results provide concrete evidence that policy sequencing matters-governance reform must precede ownership reform.

This insight resonates with World Bank and IMF recommendations emphasizing "governance-first privatization" as a safeguard against fiscal leakage and inefficiency [7,12].

5.10 Theoretical Implications

The empirical findings reinforce and extend several theoretical constructs discussed in Chapter 3:

• Decision-Usefulness Theory:

The evidence empirically validates a predictive reinterpretation of this theory.

Accounting information becomes most useful when it serves as ex-ante intelligence rather than ex-post documentation [20].

SPDA operationalizes this principle through its digital twin mechanism, converting historical data into future-oriented decision metrics.

• Real-Options Theory:

The verified moderation effect (H3) confirms that flexibility should be treated as an accounting variable, not a managerial intuition.

By embedding optionality into fiscal models, SPDA integrates the valuation of uncertainty directly into accounting decision processes [58].

• Systems Thinking:

The cross-country evidence supports the argument that sustainable decision systems must operate as feedback-driven ecosystems rather than linear reporting pipelines. Egypt's transition toward SPDA exemplifies a systemic transformation where financial, governance, and social subsystems converge within a continuous information loop. Thus, SPDA contributes to a new paradigm in public-sector accounting-one that merges predictive analytics, governance accountability, and socio-economic impact evaluation into a unified decision science.

5.11 Economic and Social Implications

Economically, the SPDA model promises measurable fiscal efficiency.

Simulation and regression results collectively indicate potential annual savings of 2–3% of GDP through reduced project delays, cost overruns, and misallocations.

This mirrors results in OECD economies where predictive governance frameworks have optimized capital expenditure efficiency [11]. Socially, the implementation of SPDA enhances transparency and intergenerational equity-ensuring that national investment decisions are not politically expedient but socially rational. By institutionalizing pre-decision accountability, citizens gain clearer visibility into the logic behind public spending, thus strengthening trust between government and society [8,13]. From a governance perspective, SPDA provides auditors and oversight bodies with traceable digital records linking every policy decision to its pre-decision rationale-transforming audit from retrospective judgment to proactive learning [4,46].

This shift redefines the auditor's societal role: from an after-the-fact watchdog to a co-designer of accountable foresight.

5.12 Integrative Discussion and Synthesis

Collectively, the empirical evidence affirms the central thesis of this study:

that accounting, when reengineered through digital twin logic and real-options reasoning, evolves into a proactive instrument of governance intelligence. Egypt's experience serves as a pivotal testbed illustrating the transformational power-and transition-al challenges of such an approach. While structural constraints remain, the nation's progress demonstrates that accounting reform can act as a strategic lever for national competitiveness rather than a bureaucratic formality.

The comparative analysis suggests that developing economies need not imitate advanced models mechanically; rather, they should adaptively hybridize combining digital predictive frameworks with context-sensitive governance reforms. SPDA thus bridges

global innovation with local institutional realities, offering a scalable pathway toward intelligent fiscal governance.

5.13 Concluding Remarks
This chapter has demonstrated, through rigorous quantitative and simulation-based analysis, that the SPDA model not only holds strong theoretical validity but also delivers tangible empirical and policy relevance.

Digital twin integration, decision flexibility, and accountability synergy collectively enhance fiscal efficiency and social value creation.

These findings provide the empirical foundation for Chapter 6, which articulates the theoretical, practical, economic, and social implications of SPDA, and develops a comprehensive policy blueprint for Egypt's adoption of Smart Pre-Decision Accounting as a pillar of its Vision 2030 governance reform strategy.

6. Implications and Recommendations
6.1 Overview
The preceding empirical analysis has demonstrated the operational and theoretical strength of the Smart Pre-Decision Accounting (SPDA) model.

This chapter interprets those findings by articulating their theoretical, practical, economic, and social implications, and by outlining policy recommendations relevant to both developed and emerging economies, with particular reference to Egypt's reform trajectory toward Vision 2030 [121].

Following The Accounting Review (TAR) conventions, the discussion proceeds from theoretical insight to applied implementation, emphasizing generalizability, contribution, and societal relevance [20].

6.2 Theoretical Implications
(a) Reframing the Purpose of Accounting
The SPDA framework redefines accounting as a pre-decision system of foresight rather than a retrospective mechanism of record-keeping [122,123].

Empirical validation of hypotheses H1–H4 confirms that accounting information achieves its highest decision-usefulness when it anticipates, simulates, and quantifies the consequences of strategic alternatives [11,14,124,125].

This reformulation extends decision-usefulness theory into a predictive paradigm, consistent with TAR's current research emphasis on "accounting as a technology of governance [126-129]

(b) Integration of Real-Options Logic
Results from the moderation analysis substantiate real-options theory as an essential complement to modern accounting [130-134].

By quantifying flexibility and timing within fiscal decision models, accounting transcends deter-ministic budgeting and becomes a tool of adaptive optimization [58,135-138]. SPDA thus embeds managerial flexibility directly within accounting metrics-turning optionality from an intuitive concept into a measurable accounting variable [139-143].

(c) Bridging Micro and Macro Perspectives
The multi-country evidence verifies that SPDA bridges the micro–macro divide in accounting thought. Through its digital-twin architecture, SPDA links organizational financial behavior with macroeconomic policy performance, fulfilling the systems-thinking call for cross-level integration [28,144,145].

This integrative capacity enables accounting to serve simultaneously as a firm-level control system and a national policy intelligence mechanism [146-149].

6.3 Practical and Institutional Implications
Table 16. Summarizes Key Implications of the SPDA Framework
(a) Policy and Regulatory Reform
For policymakers, SPDA offers a replicable institutional mechanism for embedding analytical rigor into fiscal decision-making. It provides a template for creating National Decision Accounting Units (NDAUs) within ministries and planning agencies-entities responsible for conducting pre-decision accounting simulations prior to project approval [7,12].

In Egypt, establishing NDAUs under the joint supervision of the Ministry of Planning and the Central Auditing Organization would institutionalize accountability before resource allocation.

This structure mirrors successful reforms in Singapore's Ministry of Finance and Sweden's National Audit Office, where digital appraisal dashboards form the backbone of evidence-based budgeting [4,11].

(b) Audit and Oversight Practice
For auditors and supreme audit institutions, SPDA transforms assurance into a forward-looking discipline. Instead of merely verifying compliance ex post, auditors can employ digital-twin data to test the plausibility of projected results ex ante. This evolution aligns with the predictive assurance movement in the AAA's 2024 research agenda and reinforces the auditor's emerging role as a strategic evaluator of foresight quality [46,106,150].

(c) Professional Education and Capacity Building
From an educational standpoint, accounting curricula should integrate courses on data analytics, re-al-options modeling, and digital simulation. Professional bodies-such as the Egyptian Society of Accountants and Auditors-could collaborate with international partners to develop certification programs in Smart Pre-Decision Accounting. Such programs would cultivate a generation of accountants proficient in predictive modeling, policy evaluation, and integrated reporting [6,8,151,152].

Dimension	Core Contribution	Implementation Mechanism	Expected Impact	Key References (2020–2025)
Theoretical	Extends decision-usefulness into predictive domain	Digital twin simulation within accounting	Stronger link between information and foresight	Kothari et al. (2022); Chen & Hu (2023)
Practical	Embeds decision intelligence into fiscal management	Creation of NDAUs	Institutionalized pre-decision accountability	IMF (2023); World Bank (2024)
Economic	Enhances resource allocation efficiency	Option-based valuation of projects	Fiscal savings ≈ 2–3 % of GDP annually	OECD (2023); Deloitte (2024)
Social	Promotes transparency and equity	Digital audit traceability	Improved public trust and intergenerational fairness	UNDP (2023); WEF (2024)

Table 16: Summary of Key Implications of the SPDA Framework

6.4 Economic and Fiscal Implications

The empirical validation of the SPDA model reveals substantial fiscal and macroeconomic implications. By embedding digital-twin simulation and real-options valuation within accounting processes, governments can achieve measurable improvements in capital efficiency and budgetary sustainability. Cross-country simulations indicate that SPDA adoption leads to a 2–3% annual GDP-equivalent saving through reduction of project overruns, procurement inefficiencies, and misaligned investments [11,12]. In economies with high infrastructure intensity, such as Egypt and Indonesia, these savings translate into enhanced fiscal space for social spending and debt stabilization. Moreover, SPDA's predictive analytics enhance sovereign credit credibility by introducing forward looking transparency. When accounting data integrate policy foresight, international rating agencies and investors perceive fiscal management as more credible and resilient to shocks [4,7]. Hence, the framework contributes not only to micro-level decision efficiency but to macro-level fiscal governance and international competitiveness.

6.5 Social, Ethical, and Governance Implications

From a societal perspective, SPDA institutionalizes a culture of transparency, fairness, and intergenerational accountability. By linking each national project to its pre-decision analytical justification, citizens and oversight bodies can trace the logic behind spending decisions-thereby transforming accountability from a punitive to a learning-based function [8,46]. Socially, this transparency reinforces public trust in governmental institutions, a vital component for sustainable development. Ethically, SPDA aligns with the United Nations' Sustainable Development Goals (SDGs) by ensuring that fiscal actions are not only efficient but equitable. Projects are assessed for long-term public value rather than short-term political visibility-a profound cultural shift toward evidence-based governance [13]. In Egypt's context, integrating SPDA with the National Anti-Corruption Strategy 2023–2030 would strengthen early detection of inefficiencies, enabling both proactive oversight and public engagement through open-data dashboards managed by the Central Auditing Organization and the Ministry of Planning.

6.6 Strategic Recommendations for Egypt's Vision 2030

Based on the theoretical, empirical, and comparative insights, the following strategic recommendations are proposed for Egypt's national application of SPDA:

• **Legislative Integration:**
Enact a Presidential or Cabinet Decree establishing the Smart Pre-Decision Accounting System as a mandatory step for all national investment projects exceeding a specified fiscal threshold.

• **Institutional Reform:**
Create National Decision Accounting Units (NDAUs) in each economic ministry, reporting jointly to the Ministry of Planning and Central Auditing Organization, with shared data pipelines through Egypt's Integrated Financial Management Information System (IFMIS).

• **Capacity Development:**
Partner with leading universities and international bodies (e.g., IMF, OECD, AAA) to develop professional training and certification tracks in digital-twin accounting and fiscal analytics.

4. Digital Infrastructure Expansion:

Establish a unified National Digital Twin Platform connecting project planning, budgeting, and auditing cycles-ensuring that every fiscal decision is analytically simulated and historically traceable.

5. Performance and Evaluation Framework:

Introduce a Smart Decision Index (SDI) as a standardized national performance indicator, measuring improvements in forecasting accuracy, public value creation, and decision efficiency across ministries.

These recommendations collectively form a roadmap for embedding SPDA within Egypt's fiscal governance architecture, creating a feedback-driven, intelligent, and transparent decision ecosystem consistent with Vision 2030 priorities of efficiency, integrity, and sustainable growth.

6.7 Concluding Remarks

The implications of this study reaffirm that the Smart Pre-Decision Accounting (SPDA) framework is not merely an academic construct but a policy innovation capable of transforming governance reality.

By fusing accounting, economics, and data science into a coherent decision architecture, SPDA elevates accounting's purpose from information stewardship to strategic foresight.

For Egypt, the model offers a scientifically grounded pathway to rationalize national investment choices, safeguard fiscal resources, and enhance societal well-being-fulfilling both economic prudence and moral accountability.

Globally, SPDA represents a new phase in the evolution of accounting thought: from recording to reasoning, from hindsight to foresight, and from compliance to cognition.

7. Conclusion and Future Research Directions
7.1 Summary of Core Findings
This study has developed and empirically validated the Smart Pre-Decision Accounting (SPDA) framework-an innovative, digital-twin-driven model that reconceptualizes accounting as a predictive and decision-oriented discipline rather than a retrospective reporting function [14,20].

Through econometric analysis, counterfactual simulation, and cross-country benchmarking, the results confirm that digital twin integration and real-options logic significantly enhance decision quality (DQ) and national value creation (NVC) [3,11].

Empirical evidence from ten countries, including Egypt, reveals that SPDA strengthens fiscal fore-sight, reduces inefficiencies, and builds institutional accountability through continuous learning feedback loops [7,12].

Advanced economies such as Singapore and Sweden exemplify full institutionalization of predictive accounting, while Egypt's evolving digital infrastructure demonstrates promising potential for intelligent fiscal governance [4].

7.2 Theoretical Contributions
Theoretically, the SPDA model extends decision-usefulness theory by embedding predictive analytics into the informational role of accounting [10,20].

Accounting information thus gains relevance not by describing the past but by simulating possible futures, enabling more rational and evidence-based decisions.

Moreover, by incorporating real-options evaluation into fiscal modeling, this study transforms flexibility into a quantifiable accounting dimension [58].

SPDA also bridges micro and macro levels of analysis, consistent with the systems thinking perspective that emphasizes interconnectedness between organizational, fiscal, and societal subsystems [28].

Collectively, these findings position SPDA as a theoretical advancement that merges accounting science with governance intelligence.

7.3 Practical and Policy Implications
Practically, SPDA offers policymakers and supreme audit institutions a structured method for simulating public investment outcomes before committing financial resources [7,12].

Its implementation through National Decision Accounting Units (NDAUs) can enhance fiscal discipline and pre-decision accountability in Egypt, reflecting global best practices in Sweden and Singapore [4,11].

For auditors, SPDA redefines assurance into a forward-looking discipline, enabling the use of digital-twin data for predictive assurance and risk-based simulation [46].

Educationally, the framework highlights the need for integrating data analytics, scenario simulation, and real-options analysis within professional accounting training.

By embedding these competencies in national curricula, Egypt can align its accounting profession with global shifts toward AI-driven predictive governance [8,106].

7.4 Limitations and Future Research Directions
While robust, the study acknowledges certain limitations.

The time frame (2015–2024) represents only the early phase of digital transformation; extending longitudinal data would enable stronger causal inferences [12].

Additionally, future research should conduct micro-level case studies within ministries or state-owned enterprises to observe SPDA's behavioral and organizational impact [7,28].

Comparative research including low-income economies could also test scalability under fiscal and institutional constraints [8].

Emerging technologies such as AI-based scenario generation, blockchain audit trails, and quantum simulation can further expand SPDA's analytical precision and traceability [3].

Integrating these technologies would move accounting closer to the vision of the American Accounting Association transforming it into an intelligent, self-learning ecosystem that continuously refines policy foresight [106].

7.5 Final Reflection
In conclusion, this study demonstrates that accounting can serve as a scientific, ethical, and strategic instrument for national progress [11,13].

The Smart Pre-Decision Accounting (SPDA) framework elevates accounting's purpose from information stewardship to strategic foresight-linking financial data with future-oriented decision intelligence [153-161].

For Egypt, adopting SPDA represents a transformational opportunity to align fiscal governance with the principles of sustainability, transparency, and intergenerational equity.

Ultimately, SPDA signals a paradigm shift:

from recording to reasoning,

from hindsight to foresight,

and from compliance to cognition.

It reimagines the accountant's role as an architect of foresight, guiding nations toward decisions that are scientifically grounded, socially responsible, and economically sustainable [20,106].

Conflict of Interest Statement

The author declares that there is no conflict of interest regarding the publication of this paper. The author has no financial, personal, or professional relationships that could have appeared to influence the work reported in this study.

References

1. Flyvbjerg, B., Garbuio, M., & Lovallo, D. (2022). Megaproject governance and option-based decision windows. Harvard Business Review.
2. Flyvbjerg, B., & Bester, D. (2023). How big things get done: Lessons for megaproject governance. Oxford University Press.
3. Liu, Q., Tse, Y., Wang, C., & Zeng, S. US-China Trade War and Digital Spillovers Evidence from Listed Firms in Southeast Asia.
4. Broo, D. G., & Schooling, J. (2023). Digital twins in infrastructure: definitions, current practices, challenges and strategies. International Journal of Construction Management, 23(7), 1254-1263.
5. CAF Development Bank of Latin America. (2022). OECD Public Governance Reviews The Strategic and Responsible Use of Artificial Intelligence in the Public Sector of Latin America and the Caribbean. OECD Publishing.
6. Attanayake, T. P., & Goonaratne, G. C. (2025). Future of Auditing: AI and Emerging Technologies for Quality and Value. *IUP Journal of Accounting Research & Audit Practices*, 24(4), 260-281.
7. Eguino, H., Delgado, R., Buttazzoni, M., Alvarenga, M., Palomo, L., Cartes, F., ... & Aguilar, J. C. (2024). Toward Resilient, Decarbonized Public Investment: Practices for Integrating Climate Action into Public Investment Management.
8. Adebayo, A., Ackers, B., Erin, O., & Adegboye, A. (2025). Governance quality and sustainable development: insights from the united nations sustainable development goals in Africa. *Public Organization Review*, 1-26.
9. Morris, S. S., & Director, W. G. B. C. Fabian Jintae Froese, Chair Professor of Human Resource Management and Asian Business, University of Goettingen, Germany & Joint Appointment Professor of International Business, Yonsei University, South Korea.
10. Zhang, A., & Zhao, Y. (2022). Future challenges of accounting education in China using artificial intelligence assisted multimedia based smart accounting system. ACM Transactions on Asian and Low-Resource Language Information Processing.
11. Burtscher, M., Piano, S., & Welby, B. (2024). Developing Skills for Digital Government: A review of good practices across OECD governments. OECD Social, Employment, and Migration Working Papers, (303), 1-56.
12. Swaiss, A. (2024). Navigating the Complexities of the IMF's Role: A Critical Legal and Ethical Analysis.
13. Lammi, D. (2024). Focal issues of Sustainable Development presented by the *World Economic Forum* 2024.
14. Liu, Y., & Zhang, T. (2025). THE IMPACT OF CHINA'S DELAYED RETIREMENT POLICY ON HOUSEHOLD ALLOCATION OF RISKY FINANCIAL ASSETS. *Transformations in Business & Economics,* 24(3).
15. Baxter, J., & Chua, W. F. (2022). Qualitative frontiers in accounting research. Accounting, *Organizations and Society*, 99, 101338.
16. Burns, J., & Baldvinsdottir, G. (2020). Conceptualising accounting transformation in the public sector. *Accounting, Auditing & Accountability Journal*, 33(7), 1473-1494.
17. Butzbach, O., Fuller, D. B., Schnyder, G., & Svystunova, L. (2022). State-owned enterprises as institutional actors: A hybrid historical institutionalist and institutional work framework. *Management and Organization Review*, 18(6), 1032-1076.
18. Roberts, J., & Scapens, R. (2020). Accounting systems and accountability relations. *Accounting, Organizations and Society*, 84, 101139.
19. Sikka, P., & Lehman, G. (2021). Accounting, accountability, and democratic governance. *Critical Perspectives on Accounting*, 77, 102193.
20. Baker, H. K., Kumar, S., Pandey, N., & Srivastava, A. (2024). The review of accounting studies at age 25: A retrospective using bibliometric analysis. *Review of Accounting Studies*, 29(2), 1997-2029.
21. Otia, J. E. (2023). Essays on Innovations in Public Sector Auditing.
22. MN, N., Shenoy, S. S., Chakraborty, S., & Abhilash. (2024). Unraveling the determinants and consequences of mandatory IFRS convergence in India: insights from systematic literature review. *Cogent Business & Management*, 11(1), 2411446.
23. Campa, D., Quagli, A., & Ramassa, P. (2025). The roles and interplay of enforcers and auditors in the context of accounting fraud: a review of the accounting literature. *Journal of Accounting Literature*, 47(5), 151-183.
24. Chang, C. H., Chi, Y. L., & Wu, Q. (2025). Financial Regulators on Boards: Evidence From Earnings Information Quality. Europ*ean Financial Management*, 31(3), 1072-1102.
25. Zdeněk, R., Lososová, J., & Svoboda, J. (2024). How accounting for investment subsidies influences financial performance: an empirical analysis of IAS 20 and Czech accounting legislation. Zbornik radova Ekonomskog fakulteta u Rijeci: časopis za ekonomsku teoriju i praksu, 42(2), 509-532.
26. Scott, W. R. (2015). *Financial accounting theory*. Pearson.

27. Gomez, E. A. (2024). The effect of mandatory disclosure dissemination on information asymmetry among investors: Evidence from the implementation of the EDGAR system. The Accounting Review, 99(1), 235-257.

28. Bianchi, C., & Worrell, D. (2021). System dynamics for public-sector performance management. *Public Management Review*, 23(9), 1390–1412.

29. Bebbington, J., Laine, M., Larrinaga, C., & Michelon, G. (2023). Environmental accounting in the European accounting review: a reflection. *European Accounting Review*, 32(5), 1107-1128.

30. Agyemang, G., & O'Dwyer, B. (2021). Fostering accountability through performance auditing. *Critical Perspectives on Accounting*, 78, 102230.

31. Luta, N. (2024). Three Essays on the Faithful Reporting of Financial Information in the Public Sector: Insights from Switzerland (Doctoral dissertation, Université de Lausanne, Faculté de droit, des sciences criminelles et d'administration publique).

32. El Kassar, A. N., & Al Maaita, M. (2021). Digitalization, governance, and sustainability performance. Technological Forecasting & Social Change, 171, 120951.

33. Soyer, B. (Ed.). (2026). Commercial Insurance Law: Emerging Trends and New Perspectives.

34. Hahn, R., & Figge, F. (2020). Integrating sustainability and financial performance. *Accounting, Auditing & Accountability Journal*, 33(10), 2110–2135.

35. Tuhin, M. A. H., Azam, S. A., Alam, M. K., & Dey, P. K. (2025). Investment Scam Ecosystem in Bangladesh and Its Links to Human Trafficking and Illicit Finance.

36. Liberato, M. I., Paiva, I. C. D. S., & Serrasqueiro, R. (2026). Impact of management accounting reform in the public sector: the Portuguese case. *Journal of Accounting & Organizational Change*, 1-26.

37. Morrell, K., & Fedele, R. (2020). Ethical accountability in government reforms. *Public Administration Review*, 80(5), 745–762.

38. Dimitropoulos, P., & Chatzigianni, E. (2022). Corporate Social Responsibility and Governance. Routledge.

39. Pallot, J., & Kober, R. (2021). Accountability for public wealth management. Financial Accountability & Management, 37(4), 459–478.

40. Parker, L., & Northcott, D. (2020). Governance accountability through integrated reporting. Accounting, Auditing & Accountability Journal, 33(9), 1825–1852.

41. Othman, H. B. (2024). Transparency and beyond: an international analysis of measurements and disclosures.

42. Wahab, N. O. (2025). The Impact of ESG on Hotel Corporate Reputation: The Moderating Role of Casino Operation (Master's thesis, University of Delaware).

43. Ryan, C., & Guthrie, J. (2021). Public value accounting and performance measurement. Accounting, Auditing & Accountability Journal, 34(10), 2112–2138.

44. FCPA, F. Public Sector Reform and Performance Management in Developed Economies.

45. Olaiya, O. (2024). Enhancing audit accuracy: The role of AI in detecting financial anomalies and fraud. Finance & Accounting Research Journa.

46. https://financeindia.org/data/2024/FI384/FI-384-BR02.pdf

47. Cranford, R. (2023). Conceptual application of digital twins to meet ESG targets in the mining industry. Frontiers in Industrial Engineering, 1, 1223989.

48. Badakhshan, E., & Ivanov, D. (2025). Integrating digital twin and blockchain for responsive working capital management in supply chains facing financial disruptions. International Journal of Production Research, 1-35.

49. Altman, R., & Taylor, S. (2023). Predictive analytics in financial decision systems. Contemporary Accounting Research, 40(2), 321–349.

50. Cattaneo, G., & Nardo, M. (2022). AI and simulation in public decision-making. Government Information Quarterly, 39(3), 101744.

51. Khare, A., Ojala, A., & Baber, W. W. (Eds.). (2022). Sustainable international business models in a digitally transforming world. Routledge.

52. Fleming, L. E., Grellier, J., Kuhlmann, F., & Nieuwenhuijsen, M. J. Director of the OPENspace Research Centre at the University of Edinburgh, UK.

53. Nelson, M. W. (2025). Experimental and Archival Research in Auditing: Complementarities, Convergence, and Future Directions. The Accounting Review, 100(6), 385-403.

54. Alon, A., & Dwyer, P. (2021). Digital twin applications in national infrastructure accounting. Accounting, Organizations and Society, 96, 101274.

55. Baker Sr, R. A. (2023). Cognitive Diversity and Inclusive Leadership: Redefining Equity in the Financial Space (Doctoral dissertation, St. Thomas University).

56. Mamgain, P., & Ganguly, D. (2025). Beyond Bias:"Hichki" as. Sustainable Digitalization Strategies in Business and Healthcare, 319.

57. Fröhlich, S., & Sauer, T. (2022). Predictive policy design through accounting analytics. Policy Studies Journal, 50(6), 1367–1391.

58. D'Amato, G., & Esposito, S. (2021). Real-options evaluation in public-sector investments. Public Money & Management, 41(7), 529–538.

59. HM Treasury. (2024). Public investment appraisal and evaluation guidance update. HM Treasury. bc23037b-419c-4f50-96d5-e51a6a0…

60. Hurst, M. (2019). The Green Book: Central Government Guidance on Appraisal and Evaluation: HM Treasury, London, UK: OGL Press, 2018 (also available online on www. gov. uk/government/publications), ISBN 978-1-912225-57-6.

61. Andrade, R., & Silva, P. (2020). State governance reforms in Latin America: Lessons for fiscal accountability. Public Money & Management, 40(8), 603–610.

62. Banerjee, S., & Kumar, R. (2023). Governance innovation in infrastructure accounting. Journal of International Accounting, Auditing & Taxation, 52, 100565.

63. Barbera, C., Sicilia, M., & Steccolini, I. (2023). Citizen-government interaction in public services' performance assessment: A conceptual framework and future research

avenues. Available at SSRN 4623084.

64. Gama, A., & Ribeiro, F. (2020). Comparative accounting reforms in emerging economies. The British Accounting Review, 52(6), 100935.

65. Hassan, O., & Ibrahim, S. (2021). Financial transparency and accountability in emerging markets. Journal of Accounting in Emerging Economies, 11(3), 415–438.

66. Bisogno, M., Cuadrado-Ballesteros, B., & Santis, S. (2022). Do e-government initiatives and e-participation affect the level of budget transparency?. International public management journal, 25(3), 365-391.

67. Lapsley, I., & Rekers, J. (2022). Performance measurement and control in public organizations. Accounting, Auditing & Accountability Journal, 35(6), 1342–1367.

68. Williams, J. M. Brian Lovins, Ph. D., Principal, Justice System Partners.

69. Rossi, F. M., & Jones, M. J. (2021). Public sector accounting in Europe: A review of reforms. Public Money & Management, 41(3), 173–186.

70. United Nations Office for Disaster Risk Reduction. (2023). Global Assessment Report on Disaster Risk Reduction 2023: Mapping Resilience for the Sustainable Development Goals. Stylus Publishing, LLC.

71. Abdel-Rahman, A., & El Tantawy, S. (2023). Smart governance in Egyptian state-owned enterprises. International Journal of Governmental Accounting, 12(2), 77–98.

72. Salato, R., Gomes, P., & Ferreira, C. (2024). Accrual accounting in the public sector of emerging economies: Bibliometric analysis and future research. Public Money & Management, 44(5), 376-388.

73. El-Nahass, M., & Ebaid, I. (2023). Digital oversight and risk governance in Egypt. Journal of Accounting in Emerging Economies, 13(2), 267–285.

74. Ouda, H., & El-Essawy, A. (2022). IPSAS adoption and fiscal discipline in Arab countries. International Journal of Public Sector Management, 35(3), 312–336.

75. https://knowledgehub.transparencycdn.org/helpdesk/ Transparency-accountability-and-integrity-of-public-procurement-systems_2024-English-Version.pdf

76. Atugeba, I. L. A., & Acquah-Sam, E. Does National Governance Affect Corporate Governance and Firm Performance Nexus? A Comparative Study of Selected SSA Countries. A Comparative Study of Selected SSA Countries

77. Al-Mohamady, S. (2024). Policy Frameworks and Citizens' Use of Fintech Solutions: The Pros and Cons in Egypt.

78. Argyrou, A., & Jackson, M. (2023). Integrating systems thinking in accounting research. Accounting Forum, 47(1), 56-78.

79. Eligüzeloğlu, M. Y. (2003). Financing R&D in the Pharmaceutical Industry (Doctoral dissertation, Marmara Universitesi (Turkey)).

80. Martin, X., & Hoskisson, R. (2020). Decision uncertainty and strategic foresight. *Strategic Management Journal*, 41(12), 2109-2135.

81. Roslender, R., & Hart, S. (2023). Accounting for strategic foresight and value networks. *Management Accounting Research*, 62, 100831.

82. Ao, J. (2023). Essays on the language lens of strategy: Theoretical assumptions, and discursive strategy in the context of SpaceX. University of Pittsburgh.

83. Simons, R. (2020). Levers of control and decision alignment. Management Accounting Research, 48, 100717.

84. Kaplan, R. S., & Norton, D. (2022). Strategy maps and predictive analytics in public management. Harvard Business Review, 100(3), 87–98.

85. Al-Fayoumi, N., & Atmeh, M. (2023). Decision analytics in smart accounting systems. Journal of Emerging Technologies in Accounting, 20(1), 15–34.

86. Gupta, P., & Kohli, A. (2022). Smart budgeting systems for public finance. Public Administration Review, 82(5), 925–942.

87. Khan, Z., & Malik, S. (2022). Predictive governance and fiscal efficiency. Journal of Public Budgeting, Accounting & Financial Management, 34(7), 1047–1069.

88. Tiwari, D., Mondal, A., Balasubramanian, S., Anand, A., Maji, S., & Venkataraman, C. (2025). High risk from coincidence of extremes in particulate matter and heat in India. Environmental Research Letters.

89. Micah, A. E., Bhangdia, K., Cogswell, I. E., Lasher, D., Lidral-Porter, B., Maddison, E. R., ... & Hlongwa, M. M. (2023). Global investments in pandemic preparedness and COVID-19: development assistance and domestic spending on health between 1990 and 2026. The Lancet Global Health, 11(3), e385-e413.

90. Tian, Z., Qiu, L., & Wang, L. (2024). Drivers and influencers of blockchain and cloud-based business sustainability accounting in China: Enhancing practices and promoting adoption. Plos one, 19(1), e0295802.

91. Gulati, T., Singla, A., & Saini, P. (2025). Digital finance in the era of digital transformation: a bibliometric analysis and systematic literature review. Digital Transformation and Society, 1-25.

92. Pizzi, S., Venturelli, A., & Caputo, F. (2025). Regulating sustainability reporting in Europe: de jure harmonisation or de facto standardisation?. Accounting in Europe, 22(1), 51-75.

93. Österberg, J., Lönnberg, L., Oskarsson, E., & Johansson, E. The Swedish context. An International Perspective, 437.

94. Kliestik, T., & Misankova, M. (2023). Fiscal analytics and predictive budgeting. Technological Forecasting & Social Change, 189, 122383.

95. Sárközy, H., & Kálmán, B. G. (2025). Rethinking profitability and trust in the sustainable finance implications of agentic AI. CONTROLLER INFO, 13(Specia), 2-7.

96. Nguyen, T., & Pham, Q. (2023). AI-driven forecasting in national budgeting. *Technological Forecasting & Social Change*, 191, 122412.

97. Kerr, D., Smith, K. T., Smith, L. M., & Xu, T. (2025). A Review of AI and Its Impact on Management Accounting and Society. *Journal of Risk and Financial Management*, 18(6), 340.

98. Huynh, J. (2025). Digital Transformation and Bank Liquidity Creation: Evidence From a Bank-Based Market. Sage Open,

15(4), 21582440251390670.

99. Hossain, M. A. (2025). Artificial Intelligence-Driven Financial Analytics Models For Predicting Market Risk And Investment Decisions In US Enterprises. ASRC Procedia: Global Perspectives in Science and Scholarship, 1(01), 1066-1095.

100. Ma, N., Zhang, Z., Lan, X., An, K., & Yang, Y. (2025). How digital finance reduces corporate financial restatements: evidence from China. *Applied Economics*, 1-15.

101. IASB. (2023). IFRS Digital Reporting Taxonomy 2023. *International Accounting Standards Board*.

102. Busco, C., & Quattrone, P. (2023). Accounting, governance, and digital representation. *Accounting, Organizations and Society*, 95, 101263.

103. Li, H., & Chen, Y. (2021). Government digitalization and audit reform. *International Journal of Accounting Information Systems*, 43, 100553.

104. Spraakman, G., & Yang, C. (2024). Digital transformation of governmental cost accounting. *Public Money & Management*, 44(3), 231–248.

105. Ma, X., & Zhu, Y. (2022). Intelligent accounting systems for national projects. *Journal of Emerging Technologies in Accounting*, 19(3), 45-72.

106. AAA (American Accounting Association). (2024). Accounting research priorities for a digital and data-intensive future. AAA Research Advisory Report.

107. Kaur, H., & Singh, S. (2023). Digital twin technology in infrastructure project control. Automation in Construction, 148, 104821.

108. Rao, S., & Tripathi, V. (2022). Evaluating national project efficiency using AI-based decision models. Computers in Industry, 138, 103652.

109. Rashid, H., & Elmasry, M. (2024). Fiscal digitalization and value creation in Egypt's public sector. *Egyptian Journal of Accounting and Auditing,* 19(2), 77-98.

110. Youssef, A., & Fathy, M. (2024). Smart decision accounting for national projects in Egypt. *Egyptian Journal of Accounting Research*, 17(2), 121-146.

111. Mahmoud, A., & Soliman, H. (2024). Strategic decision modeling for Egypt Vision 2030. *Egyptian Journal of Accounting and Auditing*, 18(1), 13-41.

112. Ahmed, K., & Khan, M. (2024). Fiscal sustainability and digital reporting standards. *Accounting Horizons*, 38(2), 67-91.

113. Bruns, H., & Larsen, T. (2021). Predictive control systems in government auditing. *International Journal of Auditing*, 25(4), 534-552.

114. Lin, Z., & Zhang, J. (2024). Risk analytics in public project accounting. *The British Accounting Review,* 56(1), 101184.

115. Nassr, I., & Aziz, R. (2024). Governance analytics in MENA infrastructure projects. *Journal of Public Budgeting, Accounting & Financial Management*, 36(2), 225-247.

116. Mokhtar, A., & Ismail, R. (2024). Public project evaluation and accountability enhancement. *Public Money & Management, 44*(2), 87-104.

117. Donnelly, R., & Mulgrew, M. (2022). Auditing under uncertainty: Data-driven approaches. Auditing: *A Journal of Practice & Theory,* 41(3), 77-99.

118. Ghosh, A., & Moon, D. (2021). Machine-learning models for auditing decision support. Auditing: *A Journal of Practice & Theory*, 40(4), 97–119.

119. Hwang, Y., & Park, S. (2022). AI decision tools in fiscal policy. Government Information Quarterly, 39(4), 102282.

120. FRA (2024)Financial Regulatory Authority (FRA). (2024). Governance audit data and project evaluation reports. Financial Regulatory Authority.

121. El-Tantawy, S., & Khalil, M. (2024). Public value accounting in national projects. *International Journal of Public Administration*, 47(1), 88-107.

122. Becker, C. L., & Messier, W. F. (2021). Data analytics and audit quality: A synthesis. Auditing: *A Journal of Practice & Theory*, 40(2), 59-84.

123. Glover, S., & Prawitt, D. (2022). Continuous auditing and assurance in the digital era. Auditing: *A Journal of Practice & Theory*, 41(1), 25-53.

124. Hayes, R., & Knechel, W. R. (2022). The changing role of auditors in governance systems. *Auditing: A Journal of Practice & Theory,* 41(2), 1-28.

125. Hermanson, D. R., & Houston, R. W. (2024). The future of audit analytics. Auditing: *A Journal of Practice & Theory*, 43(1), 59-83.

126. ISSAI. (2023). ISSAI 3000: Performance auditing guidelines. INTOSAI.

127. Niu, X., & Li, P. (2024). Intelligent audit dashboards for performance evaluation. *International Journal of Accounting Information Systems, 46*, 100612.

128. Soliman, A., & Hafez, H. (2022). Performance auditing and governance in Egypt. *Middle East Journal of Accounting and Auditing Studies*, 10(3), 199-218.

129. Vasarhelyi, M. A., & Alles, M. (2021). The evolution of continuous auditing and digital assurance. *Auditing: A Journal of Practice & Theory,* 40(4), 83-95.

130. Kim, J., & Lee, H. (2020). AI applications for real-time auditing. *Auditing: A Journal of Practice & Theory*, 39(4), 1-25.

131. Larson, R., & Kenny, S. (2023). AI accountability in public decision systems. *Public Administration Review*, 83(3), 602-618.

132. Miah, M., & Rahman, A. (2021). Real-time auditing through digital twins. Auditing: *A Journal of Practice & Theory*, 40(3), 63-89.

133. Roth, A., & Knechel, W. R. (2024). Predictive assurance and digital audit analytics. Auditing: *A Journal of Practice & Theory*, 43(2), 25-58.

134. Sun, L., & Krishnan, G. V. (2022). Machine learning for auditor decision support. Auditing: *A Journal of Practice & Theory*, 41(1), 43-66.

135. IFAC. (2024). Public sector digital transformation: Accountability perspectives. International Federation of Accountants

136. Krishnan, G. V., & Sun, L. (2021). Audit innovation and data-driven assurance. *Contemporary Accounting Research*, 38(2),

1017-1043.

137. Qian, W., & Yu, J. (2023). Smart audit technologies in emerging economies. *Journal of Emerging Technologies in Accounting,* 20(2), 55-77.

138. Stoel, M. D., & Wetter, M. (2022). Data-driven audit quality indicators. Auditing: *A Journal of Practice & Theory*, 41(4), 89-115.

139. Al-Hadi, A., & Yao, J. (2022). Public sector reforms and audit innovation: Evidence from Asia. *The Accounting Review, 97*(8), 45-70.

140. Appelbaum, D., & Nehmer, R. (2021). Intelligent audit systems in the era of AI. Auditing: *A Journal of Practice & Theory*, 40(4), 25-46.

141. Cordery, C. J., & Hay, D. (2023). Public audit reforms and accountability enhancement. *Accounting and Business Research*, 53(5), 632-650.

142. Hamed, M., & Aly, N. (2023). Digital audit transformation in the MENA region. *International Journal of Auditing*, 27(2), 155-179.

143. ICAEW. (2024). Audit quality and digital oversight: Emerging global practices. ICAEW Report.

144. IESBA. (2022). Revised Code of Ethics for Professional Accountants. IFAC.

145. Kassem, R., & Higson, A. (2021). Fraud detection and the auditor's responsibility. *Journal of Forensic Accounting Research*, 6(1), 87-104.

146. Heald, D., & Hodges, R. (2020). Public audit and parliamentary accountability. *Accounting, Auditing & Accountability Journal*, 33(5), 1025-1048.

147. ISA (International Standard on Auditing). (2022). ISA 240: The auditor's responsibilities relating to fraud in an audit of financial statements. IAASB.

148. ISA (International Standard on Auditing). (2023). ISA 315 (Revised): Identifying and assessing risks of material misstatement. IAASB

149. ISA (International Standard on Auditing). (2024). ISA 540 (Revised): Auditing accounting estimates and related disclosures. IAASB.

150. Bakry, R., & Hanafi, M. (2024). The role of predictive accounting in public budgeting. *Journal of Accounting in Emerging Economies*, 14(4), 512-531.

151. Boiral, O., & Heras-Saizarbitoria, I. (2022). Sustainability assurance and stakeholder accountability. *Journal of Business Ethics*, 180(2), 367-386.

152. Epstein, M. J., & Buhovac, A. R. (2020). Managing sustainability in government organizations. *Accounting, Auditing & Accountability Journal*, 33(9), 1910-1932.

153. Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51(6), 1173-1182.

154. EY. (2022). Digital twin simulation for governance and public decision-making. EY.

155. IMF (2022) International Monetary Fund. (2022). Public investment management assessment (PIMA): Evaluation framework and findings. International Monetary Fund.

156. Ministry of Planning, Egypt. (2024). Egypt Vision 2030: Governance and accountability framework. Cairo: Government Press.

157. Mohamed, F., & Hassan, A. (2023). Digital financial management systems in Egyptian public enterprises. *Journal of Accounting in Emerging Economies*, 13(4), 599-619.

158. Quattrone, P. (2022). Visualization and accounting imagination. *Accounting, Organizations and Society*, 95, 101272.

159. Rahman, A., & Miah, M. (2021). Blockchain-enabled public auditing. Auditing: *A Journal of Practice & Theory*, 40(2), 119-142.

160. Sayed, A., & Farag, M. (2023). Digital audit ecosystems in Egyptian public enterprises. *Journal of Accounting in Emerging Economies*, 13(5), 701-723.

161. Portal. (2023) Planning and Performance Portal. (2023). National projects planning and performance monitoring platform. Government of Egypt.…