A Conceptual Model for Enhancing Internal Audit Quality through Technology-Enabled Risk Assessment Frameworks

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Abstract- ***Internal audit functions face increasing pressure to enhance audit quality, ensure independence, identify emerging risks, and provide value-adding assurance within complex organizational environments. Traditional audit approaches are largely manual, compliance-oriented, and transaction-focused have struggled to respond adequately to growing operational complexity, digital transformation, and risk volatility. Prior to 2018, scholars and practitioners recognized that the integration of technology-enabled risk assessment mechanisms could significantly strengthen internal audit quality by improving risk identification, enhancing analytical depth, supporting continuous monitoring, and enabling data-driven audit planning. However, the literature remained fragmented across internal auditing, risk management, information systems, and technology adoption studies. This paper synthesizes pre-2018 scholarship to propose a conceptual model that aligns internal audit quality determinants with technology-enabled risk assessment processes. The model identifies how governance structures, information quality, analytical tools, audit methodologies, and organizational capabilities interact to produce higher-quality audit outcomes. By grounding the model in established theory and regulatory principles, the paper contributes to the advancement of audit quality research and provides guidance for developing technology-supported internal audit environments.***

Keywords: Internal audit quality; Risk assessment; Technology-enabled auditing; Governance; Data analytics; Assurance frameworks.

I. INTRODUCTION

Internal auditing serves as a core mechanism of organizational assurance, governance oversight, and risk management [1], [2]. Within both public and private sectors, internal auditors are entrusted with evaluating internal controls, reviewing risk management processes, ensuring regulatory compliance, and providing independent insights into operational effectiveness [3], [4]. As organizations confront increasingly complex and dynamic environments, the expectations placed on internal audit functions have expanded significantly [5], [6]. Stakeholders require audits to be not only compliant with standards but also risk-focused, forward-looking, and value-adding. Consequently, internal audit quality has become a central topic in governance research, and questions about how auditors can enhance quality amid organizational complexity have become more urgent [7], [8].

Traditionally, internal audit functions relied on manual, cyclical, and backward-looking methodologies where auditors selected samples, reviewed documents, conducted fieldwork, and prepared reports based on historical data [9], [10]. These approaches, although foundational, face structural limitations in risk environments shaped by technological change, globalization, cyber threats, regulatory evolution, and operational interdependencies [11], [12]. Manual sampling may fail to capture anomalies in large datasets, retrospective analysis may overlook emerging risks, and paper-based processes may be slow to detect issues in real time [13], [14], [15]. These limitations create risk blind spots and constrain internal audit's ability to deliver high-quality assurance across governance, processes, and controls [16], [17].

As early as the 2000s, scholars and professional bodies such as the Institute of Internal Auditors (IIA) began to emphasize the importance of risk-based internal auditing (RBIA) to align audit activities with organizational risk profiles [18], [19]. RBIA represented a shift from cyclical audit planning to dynamic, risk-informed selection of audit engagements. While this shift advanced the relevance and strategic contribution of internal auditing, its effectiveness remained dependent on the quality of underlying risk assessment processes [20], [21]. If risk assessments were inaccurate, incomplete, or poorly integrated, audit planning would reflect these flaws. Furthermore, RBIA frameworks prior to 2018 were often constrained by data limitations, manual processes, and fragmented information systems that limited insight into operational risks [22], [23], [24].

Parallel to developments in RBIA, information systems research highlighted the increasing potential for technology to enhance organizational risk assessment [25], [26]. Tools such as automated analytics, continuous auditing systems, computer-assisted audit techniques (CAATs), and dashboard reporting were available well before 2018, yet adoption across internal audit functions remained uneven due to technological, organizational, and behavioral barriers [27]. Many organizations, particularly those with traditional governance models, lacked the infrastructure or capability to harness the potential of technology-enabled audit tools [28]. As a result, internal audit quality varied widely across contexts, and the full benefits of technology-enabled risk assessment remained unrealized [29].

By 2018, it had become evident that technology could significantly strengthen risk assessment accuracy, improve audit planning, support real-time monitoring, enhance data quality, and enable more strategic assurance engagements. However, integrating technology into risk assessment requires more than acquiring software tools. It requires conceptual clarity about how technological capabilities align with internal audit roles, risk assessment processes, and governance structures. It also requires understanding how auditors can use technology to interpret complex data, identify patterns, challenge management assumptions, and provide deeper analytical insights. The absence of such a conceptual model has contributed to inconsistencies in implementation and a lack of theoretical grounding for the integration of technology into audit functions.

Furthermore, internal audit quality itself is multidimensional, encompassing attributes such as auditor competence, independence, objectivity, methodological rigour, stakeholder communication, and adherence to standards [30], [31]. Technology influences many of these dimensions, but the nature and mechanisms of this influence are not always well understood. Enhanced risk assessment may strengthen audit planning and workpaper quality, but auditor judgement and ethical standards still determine how technology outputs are interpreted. Similarly, automated tools may increase audit coverage, but without skilled auditors, the risk of misinterpretation remains. These complexities underscore the need for a conceptual model that clarifies the relationship between technology-enabled risk assessment and internal audit quality.

In addition, regulatory and governance expectations prior to 2018 increasingly demanded more robust risk assessment and technology adoption within audit functions. Regulatory guidance, such as that from the Public Company Accounting Oversight Board (PCAOB), emphasized the importance of using technology to assess fraud risk, evaluate internal controls, and support substantive testing [32], [33]. Similarly, corporate governance frameworks such as COSO's Internal Control–Integrated Framework highlighted the importance of information quality, monitoring processes, and control automation as enablers of reliable assurance [34]. These frameworks provided foundational principles but did not explicitly integrate technology-enabled risk assessment into internal audit quality models.

Against this background, the need for a conceptual model that integrates technology-enabled risk assessment with internal audit quality determinants became increasingly apparent. Such a model must synthesize insights from internal audit theory, risk management, information systems research, organizational governance, and behavioral auditing studies. It must identify how technology interacts with risk assessment processes, how risk assessment influences audit quality, and how governance

conditions shape these relationships [35]. It must also clarify how organizational characteristics such as culture, structure, resource allocation, data availability, and technological maturity mediate or enhance the impact of technology-enabled risk assessment [36].

The significance of developing such a model extends beyond theoretical contribution. In practice, internal auditors face real challenges in identifying risks that emerge from digital transactions, automated processes, network interconnections, cyber incidents, and data flows. Technology-enabled risk assessment provides tools for addressing these challenges but only if embedded within a structured and well-designed audit environment. Organizations increasingly require internal audit functions that can interpret vast datasets, identify systemic risks, monitor continuous processes, and provide assurance over technology-dependent controls. Without conceptual clarity, internal auditors may underutilize technological tools or misalign technology with audit objectives, thereby failing to realize the full potential of digital transformation in risk assessment.

Moreover, internal audit quality has implications for organizational governance beyond the audit function [37], [38]. High-quality internal audits enhance oversight, support risk governance, improve control effectiveness, and contribute to organizational resilience [39]. Conversely, deficiencies in audit quality can lead to control failures, fraud, operational breakdowns, and reputational damage. By linking technology-enabled risk assessment to audit quality, the conceptual model proposed in this paper contributes to broader governance and organizational performance outcomes [40]. It helps clarify how internal audit can evolve from a reactive, compliance-driven function into a proactive, analytically capable, and strategically aligned governance actor [41].

Therefore, the objective of this paper is to propose a conceptual model that enhances internal audit quality through technology-enabled risk assessment processes, grounded entirely in pre-2018 scholarship. The model identifies the components, relationships, and mechanisms through which technology influences risk assessment and, in turn, how risk assessment shapes audit quality. It integrates insights from internal auditing, risk management, information systems, data analytics, and organizational governance to offer a coherent theoretical foundation for research and practice. By doing so, the paper contributes to addressing existing gaps in literature and provides guidance for internal audit functions seeking to strengthen their impact through technology-supported methodologies.

The rest of the paper is structured as follows. Section 2 presents a detailed literature review covering internal audit quality determinants, risk assessment principles, technology adoption in auditing, and governance factors that influence audit processes. Section 3 proposes a conceptual model linking technology-enabled risk assessment with audit quality. Section 4 discusses the implications for practice and research. Section 5 concludes by highlighting key contributions and potential areas for future empirical investigation.

II. LITERATURE REVIEW

2.1 Internal Audit Quality: Definitions, Determinants, and Conceptual Evolution

Internal audit quality has received considerable scholarly attention, particularly as organizations increasingly rely on internal auditors to support governance, risk management, and control processes [25], [42]. Prior to 2018, internal audit quality was widely conceptualized as the degree to which internal audit activities meet stakeholder expectations, adhere to professional standards, and provide reliable, insightful, and value-adding assurance [1]. Several determinants of audit quality emerge from the literature, including auditor competence, independence and objectivity, methodological rigor, organizational support, communication quality, and adherence to professional norms [43].

Audit competence is one of the most frequently cited determinants. Competence encompasses technical knowledge, analytical skills, industry expertise, and familiarity with internal control frameworks. Competent auditors are better able to identify risk, interpret evidence, evaluate controls, and exercise professional judgement. Independence and objectivity are equally important. Without independence from management influence, internal auditors may fail to challenge existing assumptions or reveal unfavorable

findings. The organizational placement of the internal audit function, reporting lines to the audit committee, and the absence of operational responsibilities support independence.

Methodological rigor, including the use of systematic audit procedures, risk-based planning, evidence gathering, and structured documentation, also enhances audit quality. Rigorous audit processes ensure consistency, transparency, and defensibility of audit findings. Organizational support, including adequate resourcing, training opportunities, access to information, and executive commitment to governance, further contributes to audit quality by enabling auditors to carry out their duties effectively. Communication quality, both during and after audit engagements, ensures that findings are clearly articulated, recommendations are actionable, and stakeholders understand the implications of audit results.

Finally, adherence to professional auditing standards, such as those issued by the Institute of Internal Auditors, provides a foundation for consistent and reliable audit performance. These standards emphasize ethics, quality assurance, risk-based planning, engagement management, evidence sufficiency, and reporting clarity [44], [45], [46]. Before 2018, the literature consistently highlighted the interplay among these determinants as central to understanding variations in internal audit quality across organizations [47], [48].

2.2 Risk Assessment as a Foundation for Internal Audit Quality

Risk assessment has long been recognized as a cornerstone of internal auditing [49], [50]. Modern internal audit practice relies on risk-based methodologies in which audit planning, resource allocation, and engagement scope are determined by an understanding of organizational risks [51], [52]. Early research identified that internal audit functions that fail to incorporate risk assessment into their work often produce audits that are misaligned with organizational priorities, insufficiently comprehensive, or overly focused on low-risk areas [53].

Risk assessment involves identifying risks, evaluating their likelihood and impact, understanding their causes, and determining the controls that mitigate them. Prior to 2018, scholars emphasized that risk assessment underpins key audit processes including audit planning, engagement design, evidence collection, and reporting [54], [55]. Strong risk assessment enables auditors to priorities areas of significant exposure, focus resources on material risks, and provide assurance that is directly relevant to organizational objectives.

However, traditional risk assessment approaches often relied on subjective judgement, interviews, checklists, and historical analysis. These techniques, although valuable, were limited in their ability to detect emerging risks, assess complex interdependencies, and analyze large datasets. As organizational processes became increasingly digital, networked, and data-intensive, the limitations of manual risk assessment became more apparent. Scholars argued that improved risk assessment processes could substantially enhance audit quality by enabling auditors to identify anomalies, strengthen analytical insight, reduce information asymmetry, and support strategic decision making [56], [57].

2.3 Technology-Enabled Risk Assessment Tools Prior to 2018

Before 2018, internal audit functions had begun incorporating a range of technology-enabled tools that supported risk assessment, although adoption varied significantly across sectors and organizations. These tools included computer-assisted audit techniques (CAATs), continuous auditing systems, data analytics platforms, enterprise resource planning (ERP) audit modules, and automated exception reporting tools [58], [59]. CAATs enabled auditors to analyses large datasets beyond the scope of manual sampling. Data analytics tools allowed auditors to identify trends, detect anomalies, and test full populations rather than samples. Continuous auditing systems supported ongoing monitoring of key controls by analyzing data in real time, thereby reducing the lag between risk occurrence and detection.

Other technologies, such as dashboard reporting and business intelligence tools, enhanced internal auditors' ability to visualize risk indicators, track key

performance metrics, and evaluate complex relationships among control processes. In addition, risk management information systems (RMIS) provided integrated platforms where risk registers, mitigation plans, and control assessments could be consolidated and analyzed [60], [61].

Despite these advancements, the literature noted several barriers to technology adoption, including insufficient auditor skills, resource constraints, incompatible legacy systems, lack of organizational support, and concerns about data reliability. These factors contributed to inconsistent implementation of technology-enabled risk assessment practices across internal audit functions. Scholars argued that technology must be embedded within broader audit methodologies and supported by strong governance structures to realize its full impact on audit quality.

2.4 Linking Technology-Enabled Risk Assessment to Audit Quality

Several theoretical and empirical studies prior to 2018 began to link technology use with improvements in audit quality. Technology-enabled risk assessment enhances audit planning by providing more accurate and timely risk information [62]. Auditors who use data-driven risk assessment tools are better equipped to select high-risk audit areas, design targeted audit procedures, and allocate resources efficiently. Enhanced risk assessment also supports deeper analytical procedures, enabling auditors to test large data populations, identify unusual patterns, and detect potential fraud indicators [63].

Furthermore, technology enables continuous risk monitoring, which helps auditors identify issues earlier, support real-time decision making, and reduce audit delays [64], [65]. This strengthens audit quality by improving the timeliness of audit findings and enabling more proactive governance responses. Technology also improves the documentation and transparency of audit work, supporting quality assurance and supervisory review. Additionally, the use of integrated information systems enhances communication between auditors and stakeholders by providing interactive dashboards, clear visualizations, and up-to-date risk information.

However, the literature also emphasized that technology does not automatically improve audit quality. The effectiveness of technology-enabled risk assessment depends on auditor competence, organizational support, governance oversight, and the quality of underlying data. Poor data quality, weak control over information systems, or inadequate auditor training can reduce the benefits of technology and potentially introduce new risks. Therefore, a conceptual model linking technology-enabled risk assessment with audit quality must consider both technological and organizational determinants.

2.5 Organizational Governance and Its Influence on Technology-Enabled Audit Processes

Governance structures play a crucial role in shaping internal audit performance and technology adoption. Strong audit committees, clear reporting lines, and independent internal audit functions create conditions for auditors to use technology effectively and challenge management assumptions. Prior to 2018, research indicated that audit committee expertise, independence, and engagement were positively associated with audit quality, particularly when audit committees encouraged risk-based methodologies, continuous monitoring, and data-driven decision making [66], [67].

Organizational culture, resources, and leadership commitment further influence the success of technology-enabled risk assessment. Support from senior management ensures adequate investment in audit technology, training opportunities for audit staff, and integration of data sources into audit platforms. Conversely, resistance to digital transformation or lack of governance oversight may lead to underutilization of available tools, thereby weakening the potential benefits for audit quality.

The literature also highlighted the importance of internal control environments and information system governance for successful technology adoption. Weak control environments, fragmented information systems, or inconsistent data governance can undermine automated risk assessment processes and limit their reliability. Thus, understanding the organizational context is essential when examining how technology-enabled risk assessment influences internal audit quality.

III. CONCEPTUAL MODEL FOR ENHANCING INTERNAL AUDIT QUALITY THROUGH TECHNOLOGY-ENABLED RISK ASSESSMENT FRAMEWORKS

3.1 Introduction to the Conceptual Model

The purpose of this conceptual model is to provide a coherent theoretical structure that explains how technology-enabled risk assessment can enhance internal audit quality within contemporary governance environments, while remaining grounded in pre-2018 scholarship. The model integrates insights from internal auditing, risk management, information systems research, behavioral governance, and organizational theory. It proposes that internal audit quality is the result of an interaction between three major domains: (1) organizational governance conditions that facilitate the adoption of advanced audit methodologies, (2) technology-enabled risk assessment processes that improve the accuracy, scope, and relevance of audit activities, and (3) internal audit quality determinants that shape the reliability and value of audit outcomes.

The conceptual model assumes that internal audit quality cannot be improved through technological tools alone. Technology functions as a catalyst that strengthens risk assessment, but its impact on audit quality is mediated by organizational culture, auditor competence, information quality, and governance oversight. Technology-enabled risk assessment enhances audit quality by improving risk identification, enabling deeper analytical testing, supporting continuous monitoring, strengthening audit planning, and increasing the transparency of audit evidence. However, these benefits materialize only when supported by appropriate governance structures and aligned with professional audit standards.

The model therefore positions technology-enabled risk assessment as an embedded component of internal audit methodology, rather than as a peripheral support system. It conceptualizes internal audit quality as emerging from the degree to which auditors can integrate technological capabilities into risk-based audit processes while maintaining independence, objectivity, methodological rigor, and ethical commitment.

3.2 Core Construct 1: Organizational Governance Foundations

Organizational governance provides the enabling conditions for high-quality internal auditing. Prior to 2018, research consistently demonstrated that governance structures such as audit committees, internal control frameworks, risk governance policies, and senior management support significantly influenced the effectiveness of internal audit functions [68], [69]. In the context of technology-enabled risk assessment, governance conditions play an even more critical role.

The conceptual model assumes that governance influences internal audit quality through three pathways. First, governance determines the level of independence and authority granted to internal auditors [70], [71]. Independent reporting lines to an engaged audit committee give internal auditors the organizational legitimacy needed to adopt technologically advanced methodologies, challenge management positions, and ensure objective assessment of risks [72]. Second, governance structures shape resource allocation, including funding for audit technology, training in data analytics, and integration of information systems. Without these resources, technology-enabled risk assessment cannot be effectively implemented [73], [74]. Third, governance establishes expectations regarding risk oversight and transparency. Organizations with strong governance cultures encourage continuous risk monitoring, analytical insight, and evidence-based assurance conditions that support the use of automated risk tools.

Thus, governance functions as a foundational domain that shapes the organizational readiness for technology-enabled auditing and provides the conditions under which risk assessment tools can be effectively integrated into audit planning and execution.

3.3 Core Construct 2: Technology-Enabled Risk Assessment Processes

Technology-enabled risk assessment constitutes the central mechanism through which internal audit quality is enhanced in the proposed model. Pre-2018 literature on continuous auditing, CAATs, and data

analytics consistently highlighted the potential of these tools to transform audit practice by enabling auditors to test entire data populations, perform sophisticated analytics, and detect anomalies that traditional sampling-based methods may overlook [75], [76].

Within the conceptual model, technology-enabled risk assessment includes several interrelated components:

Digital Risk Identification: Automated systems help auditors detect patterns, trends, or anomalies in operational, financial, or transactional data. For example, data mining and exception reporting tools can reveal unusual transactions, control deviations, or process bottlenecks that may signal risk. These tools strengthen auditors' ability to identify both known risks and emerging risks that would be difficult to detect manually.

Analytical Risk Evaluation: Technology supports quantitative and qualitative risk analysis through statistical analytics, ratio analysis, predictive models, and trend monitoring. These tools enable deeper understanding of risk magnitude, likelihood, and root causes. Compared to traditional risk assessment approaches, technology-based evaluation offers greater precision and may uncover relationships across datasets that are otherwise invisible.

Continuous Risk Monitoring: Continuous auditing and continuous monitoring systems allow ongoing evaluation of key controls, performance indicators, and risk metrics. This reduces the lag between risk occurrence and detection, enabling internal auditors to provide real-time insights. Prior to 2018, continuous auditing was shown to enhance audit relevance and timeliness, particularly in data-intensive environments [77], [78].

Risk-Based Planning Supported by Technology: With stronger risk identification and evaluation inputs, internal auditors can design audit plans that focus on high-risk areas. Technology also supports dynamic, rather than static, audit planning by updating risk assessments throughout the audit cycle.

Taken together, these elements make risk assessment more systematic, evidence-based, and timely, thereby improving the foundation upon which internal audit quality is built [79], [80].

3.4 Core Construct 3: Internal Audit Quality Determinants

The third domain of the conceptual model concerns the determinants of internal audit quality. Prior studies identified competence, independence, methodological rigor, communication, and adherence to standards as critical attributes of high-quality auditing [81]. Technology does not replace these traditional determinants; rather, it interacts with and strengthens them.

In the model, internal audit quality emerges from enhanced auditor judgement, more rigorous testing methods, improved evidence quality, and better alignment between audit scope and organizational risk [82], [83]. Technology-enabled risk assessment supports these determinants in several ways. Enhanced data analytics improve the sufficiency and appropriateness of audit evidence. Automated insights support but do not substitute professional judgement, meaning auditors must still interpret evidence, evaluate relevance, and reach conclusions grounded in their expertise [84], [85]. Technology also strengthens methodological rigor by enabling full population testing and by documenting audit trails more precisely [86], [87].

Furthermore, by improving communication through dashboards and visual reporting tools, technology supports clearer articulation of audit findings [88], [89]. However, all of these contributions are moderated by the competence and training of auditors. Without adequate analytical skills, internal auditors may misinterpret automated outputs [90], [91]. Thus, internal audit quality is conceptualized not merely as a function of technology, but as the combined effect of technology, auditor capability, and governance support [92], [93].

3.5 Interactions and Pathways in the Conceptual Model

The proposed model emphasizes interactive relationships rather than linear causality. Internal audit quality is influenced by technology-enabled risk assessment, but only under enabling governance

conditions and through the application of competent professional judgement [94], [95]. Governance influences the adoption and integration of technology, while risk assessment processes influence the relevance and depth of audit engagements. Auditor competence moderates the relationship between technology and audit quality, as more skilled auditors are better positioned to derive meaningful insights from complex data [96], [97].

The model also incorporates feedback loops. Improved internal audit quality strengthens organizational governance by enhancing transparency, risk oversight, and control reliability. These strengthened governance conditions further support the adoption of technology-enabled risk tools, creating a cycle of reinforcing improvement [98], [99]. Thus, the conceptual model illustrates a multi-level, dynamic relationship among governance conditions, technological capabilities, risk assessment processes, and audit quality determinants [100], [101].

3.6 Summary of the Conceptual Model

Overall, this conceptual model positions technology-enabled risk assessment as the mechanism that links governance conditions with internal audit quality. Governance structures provide authority, resources, and expectations. Technology provides analytical power, automation, and continuous monitoring capabilities. Auditors provide judgement, ethics, objectivity, and methodological rigor. High-quality internal audit outcomes arise when these elements operate in alignment. The model therefore offers both a theoretical lens for academic research and a practical blueprint for improving audit functions within organizations that aim to strengthen assurance processes through technology-supported, risk-based methodologies.

IV. DISCUSSION

The purpose of this section is to interpret the conceptual model developed in Section 3 and explore its implications for internal audit practice, governance structures, and audit quality. By synthesizing insights from internal auditing, information systems, risk management, and organizational theory, the model provides a coherent framework explaining how technology-enabled risk assessment can shape and strengthen internal audit outcomes. The discussion highlights the significance of the model, contextualizes it within existing challenges faced by internal audit functions, and demonstrates how the proposed relationships advance both the academic understanding and practical execution of internal auditing in technologically evolving environments.

A major contribution of the conceptual model lies in its articulation of how technology-enabled risk assessment shifts the paradigm of internal auditing from a historically reactive, manual, and cyclical process toward one that is increasingly proactive, data-driven, and continuous. Prior to 2018, audit methodologies were often constrained by the limitations of manual sampling, delayed documentation, and insufficient visibility into high-volume or automated organizational processes. These limitations created structural barriers to audit quality, particularly in environments characterized by rapid digitalization, real-time transactions, and data complexity. The model demonstrates that when technology is systematically integrated into risk identification, analytical evaluation, and ongoing monitoring, auditors are better positioned to detect anomalies, anticipate risks, and align audit scope with organizational priorities. This elevation of risk assessment strengthens the foundation upon which internal audit quality rests, reinforcing methodological rigor and improving assurance relevance.

The framework also underscores the critical role of organizational governance in shaping the effectiveness of technology-enabled internal auditing. Governance mechanisms such as audit committee oversight, independent reporting lines, resource allocation, and ethical leadership influence the conditions under which auditors can adopt technological tools and apply them meaningfully. The discussion highlights that technology alone does not improve audit quality; rather, its benefits depend profoundly on governance support. Boards and audit committees that encourage innovation, provide investment for analytical systems, and prioritize risk-based methodologies create an enabling environment in which technology-enabled risk assessment can flourish. Conversely, weak governance structures limit the impact of technological interventions by constraining auditor independence, reducing access to reliable data, or

discouraging analytical experimentation. Thus, the model positions governance not merely as a contextual variable but as a fundamental driver of quality-enhancing audit processes.

Another significant insight emerging from the model is the interplay between technological capability and auditor competence. Prior scholarship has established that auditor experience, professional judgement, and methodological training are central determinants of audit quality. The proposed model extends this line of thinking by illustrating how auditor competence serves as a moderating mechanism that influences the effectiveness of technology-enabled risk assessment. Advanced tools such as continuous monitoring systems, automated analytics, and exception-detection algorithms provide enhanced insights, but interpreting these insights still requires professional judgement, skepticism, and contextual understanding. If auditors lack the skills needed to analyze large datasets, understand system outputs, or question irregularities revealed through analytics, the benefits of technology diminish. The framework therefore identifies a critical requirement for capacity building, analytical training, and development of digital competencies within internal audit teams. This insight has practical implications for audit departments navigating digital transformation, as investments in technology must be complemented by investments in human expertise.

The model also contributes to governance and auditing scholarship by demonstrating that internal audit quality is not a linear outcome but a composite result of multiple interacting domains. Traditional audit quality research often focuses on single determinants such as independence, competence, or compliance with standards. The proposed framework situates these determinants within a broader ecosystem of technology, governance, and organizational processes. By emphasizing the interdependence of these factors, the model aligns with systems-based perspectives of organizational control and highlights the need for integrated audit environments that combine cultural, technological, and procedural elements. This system-oriented interpretation advances theoretical understanding and reflects the complexity of contemporary internal auditing.

Within practical settings, the discussion shows that the model offers a blueprint for institutions seeking to modernize their audit functions. Organizations that implement technology-enabled risk assessment mechanisms often struggle with issues such as fragmented information systems, inconsistent data governance, or insufficient integration between risk management and internal audit. The conceptual model provides guidance on how these challenges can be addressed by clarifying the relationships between governance oversight, technological infrastructure, risk assessment methodologies, and auditor capabilities. It also highlights the importance of information quality, as even the most sophisticated tools cannot compensate for inaccurate, incomplete, or poorly structured data. Furthermore, the model supports the broader adoption of continuous auditing and continuous monitoring, both of which can significantly enhance audit relevance and timeliness when effectively executed.

The framework further offers insights into how internal audit quality contributes to organizational resilience. By strengthening risk identification, improving control oversight, and enabling real-time detection of anomalies, technology-enabled audits contribute to more robust governance outcomes. High-quality internal audit functions provide boards and management with earlier warnings, more accurate analyses, and more credible assurance, ultimately supporting stronger risk governance and organizational learning. This aligns with pre-2018 theoretical perspectives that emphasize the role of internal audit as an essential governance mechanism that adds value beyond compliance. The proposed model reinforces this view by showing how technology-enabled risk assessment enhances internal audit's strategic contribution and positions it as a proactive agent within the organization.

The discussion must also acknowledge limitations inherent in the model. Because technology adoption varies across organizations, the effectiveness of the model depends on contextual factors such as organizational culture, industry characteristics, technological maturity, and regulatory environment. Organizations with outdated systems, hierarchical cultures, or limited investment in governance may experience slower or partial implementation of

technology-enabled risk assessment processes. Moreover, the model is conceptual and therefore requires empirical examination to validate the relationships and pathways proposed. Nevertheless, these limitations do not diminish the explanatory power of the framework; instead, they highlight areas for further research and practical refinement.

Overall, this discussion demonstrates that the conceptual model provides a robust and theoretically grounded mechanism for understanding how internal audit quality can be strengthened through technology-enabled risk assessment frameworks. By linking governance structures, technological capabilities, risk assessment processes, and traditional audit quality determinants, the model advances both academic inquiry and practical application. It responds to key gaps in pre-2018 audit research and offers a coherent lens through which organizations can conceptualize the integration of digital tools into internal audit methodologies. The framework supports the evolution of internal auditing into a more analytical, risk-sensitive, and governance-aligned function, capable of meeting the growing expectations of stakeholders in increasingly complex operational environments.

CONCLUSION

This paper sets out to develop a conceptual model that explains how internal audit quality can be enhanced through technology-enabled risk assessment frameworks, drawing exclusively on theoretical and empirical work published prior to 2018. In doing so, the study responded to the increasing need for internal audit functions to operate effectively within environments shaped by digital transformation, expanding regulatory expectations, and heightened organizational complexity. Although technology had already begun to influence audit processes before 2018, the literature had not fully synthesized how risk assessment tools, governance mechanisms, and audit quality determinants interact as part of a unified system. The conceptual model developed in this paper addresses that gap by providing an integrated theoretical structure that clarifies the pathways through which governance conditions, technological capabilities, and auditor competencies jointly shape internal audit quality outcomes.

The model demonstrates that internal audit quality is not an isolated construct but the cumulative result of interrelated organizational processes. Governance structures form the foundation of audit effectiveness by shaping independence, resource allocation, reporting authority, information access, and organizational expectations regarding risk management. When governance systems emphasize analytical insight, transparency, and risk-based methodologies, internal audit functions are more likely to adopt technology-enabled tools and embed them meaningfully into audit processes. Governance therefore operates as an enabling context that supports the integration of technology-driven approaches to risk assessment.

The second major insight relates to technology-enabled risk assessment itself, which the model conceptualizes as the central mechanism linking governance to audit quality. By enhancing risk identification, enabling deeper analytical testing, supporting continuous monitoring, and improving audit planning, digital tools help bridge the structural limitations of traditional audit methodologies. Prior to 2018, internal audit processes were often constrained by the inability to analyze large datasets, the delays associated with manual document review, and the retrospective nature of cyclical auditing. Technology-enabled risk assessment addresses these constraints by providing real-time insights, improving the accuracy of risk evaluations, and allowing auditors to test entire populations rather than limited samples. This shift from manual to data-driven risk assessment elevates the precision, relevance, and strategic contribution of internal audits.

The model also reinforces the central role of auditor competence in determining how effectively technology supports audit quality. Digital tools cannot replace professional skepticism, ethical judgement, or interpretive capability. Instead, technology improves the abilities of well-trained auditors who can understand analytical outputs, question irregularities, and contextualize findings within organizational realities. Consequently, internal audit quality is strengthened when technology adoption is accompanied by investment in analytical training, skill development, and professional capacity building. The relationship between technology and audit quality

therefore depends not only on tool availability but also on the expertise and judgement applied to those tools.

Another contribution of this conceptual model is its emphasis on dynamic interaction. The model does not present the relationship between technology and audit quality as linear or one-directional. Instead, it recognizes feedback loops where improved audit quality enhances governance credibility, strengthens organizational learning, and reinforces the conditions that support further technological advancement. As internal audit functions become more effective at identifying systemic weaknesses, governance bodies are better informed to allocate resources, refine risk appetite, and encourage more sophisticated audit methodologies. This cyclical interaction contributes to organizational resilience and continuous improvement.

The model has important implications for practice. Internal audit functions seeking to strengthen audit quality must recognize that successful technology adoption requires more than acquiring software. It requires supportive governance, well-structured information systems, data integrity, cross-functional coordination, and a culture that values analytical insight. Organizations must invest not only in audit technology but also in the competencies and governance structures needed to use those technologies effectively. The model can serve as a blueprint for audit leaders and governance committees seeking to modernize their audit functions and align them with the demands of increasingly digital and risk-intensive operational environments.

The conceptual framework also suggests several avenues for future research. Empirical studies are needed to test the relationships proposed in this model across different organizational contexts, industries, and governance environments. Comparative research could explore variations in technology-enabled risk assessment adoption between public and private sectors or between regulated and non-regulated entities. Additional studies could investigate how differences in organizational culture, information system maturity, and risk governance influence the model's applicability. These empirical extensions would help refine the theoretical structure and expand its explanatory power.

In conclusion, this paper contributes to the internal auditing literature by offering a comprehensive conceptual model that integrates governance foundations, technology-enabled risk assessment processes, and internal audit quality determinants. It demonstrates that technology, when supported by effective governance and strong auditor competence, can significantly enhance the quality of internal audit outcomes. By moving beyond fragmented literature and offering a cohesive analytic structure, the model provides scholars and practitioners with a new lens through which to understand and advance internal audit effectiveness in increasingly complex and technologically driven environments.

REFERENCES

[1] G. Sarens, I. De Beelde, and P. Everaert, "Internal audit: A comfort provider to the audit committee," *British Accounting Review*, vol. 41, no. 2, pp. 90–106, Jun. 2009, doi: 10.1016/J.BAR.2009.02.002.

[2] K. A. Endaya and M. M. Hanefah, "Internal auditor characteristics, internal audit effectiveness, and moderating effect of senior management," *Journal of Economic and Administrative Sciences*, vol. 32, no. 2, pp. 160–176, 2016, doi: 10.1108/JEAS-07-2015-0023.

[3] M. J. Nigrini, "Benford's law: Applications for forensic accounting, auditing, and fraud detection," *Benford's Law: Applications for Forensic Accounting, Auditing, and Fraud Detection*, pp. 1–330, Jan. 2012, doi: 10.1002/9781119203094.

[4] G. Sarens and I. De Beelde, "Internal auditors' perception about their role in risk management: A comparison between US and Belgian companies," *Managerial Auditing Journal*, vol. 21, no. 1, pp. 63–80, 2006, doi: 10.1108/02686900610634766.

[5] L. de Zwaan, J. Stewart, and N. Subramaniam, "Internal audit involvement in enterprise risk management," *Managerial Auditing Journal*, vol. 26, no. 7, pp. 586–604, Jul. 2011, doi: 10.1108/02686901111151323.

[6] R. Lenz, G. Sarens, and F. Hoos, "Internal Audit Effectiveness: Multiple Case Study Research Involving Chief Audit Executives and Senior Management," *EDPACS*, vol. 55, no. 1, pp. 1–17, Jan. 2017, doi: 10.1080/07366981.2017.1278980.

[7] J. Goodwin-Stewart and P. Kent, "The use of internal audit by Australian companies," *Managerial Auditing Journal*, vol. 21, no. 1, pp. 81–101, 2006, doi: 10.1108/02686900610634775.

[8] M. K. Power, "Auditing and the production of legitimacy," *Account Organ Soc*, vol. 28, no. 4, pp. 379–94, 2003, doi: 10.1016/s0361-3682(01)00047-2.

[9] J. W. Y Zhang, "Data-driven modeling and scientific computing," *Appl Mech Rev*, vol. 68, no. 5, pp. 050801–051013, 2016.

[10] P. Li *et al.*, "Promoting secondary analysis of electronic medical records in china: Summary of the plagh-mit critical data conference and health datathon," *JMIR Med Inform*, vol. 5, no. 4, Oct. 2017, doi: 10.2196/MEDINFORM.7380.

[11] J. Hemerly, "Public policy considerations for data-driven innovation," *Computer (Long Beach Calif)*, vol. 46, no. 6, pp. 25–31, 2013, doi: 10.1109/MC.2013.186.

[12] S. Fosso Wamba, S. Akter, A. Edwards, G. Chopin, and D. Gnanzou, "How 'big data' can make big impact: Findings from a systematic review and a longitudinal case study," *Int J Prod Econ*, vol. 165, pp. 234–246, Jul. 2015, doi: 10.1016/J.IJPE.2014.12.031.

[13] P. M. Hartmann, M. Zaki, N. Feldmann, and A. Neely, "Capturing value from big data–a taxonomy of data-driven business models used by start-up firms," *International Journal of Operations & Production Management*, vol. 36, no. 10, pp. 1382–1406, 2016, doi: 10.1108/ijopm-02-2014-0098.

[14] M. Bar-Sinai, L. Sweeney, and M. Crosas, "DataTags, Data Handling Policy Spaces and the Tags Language," *Proceedings - 2016 IEEE Symposium on Security and Privacy Workshops, SPW 2016*, pp. 1–8, Aug. 2016, doi: 10.1109/SPW.2016.11.

[15] F. Collins *et al.*, "A database on global health research in Africa," *Lancet Glob Health*, vol. 1, no. 2, pp. e64-5, 2013, doi: 10.1016/s2214-109x(13)70012-3.

[16] M. A. Waller and S. E. Fawcett, "Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management," *Journal of Business Logistics*, vol. 34, no. 2, pp. 77–84, 2013, doi: 10.1111/JBL.12010.

[17] Y. Song, R. Routray, R. Jain, and C. H. Tan, "A data-driven storage recommendation service for multitenant storage management environments," *Proceedings of the 2015 IFIP/IEEE International Symposium on Integrated Network Management, IM 2015*, pp. 1026–1040, Jun. 2015, doi: 10.1109/INM.2015.7140429.

[18] A. Fernández-Laviada, "Internal audit function role in operational risk management," *Journal of Financial Regulation and Compliance*, vol. 15, no. 2, pp. 143–155, 2007, doi: 10.1108/13581980710744039.

[19] J. Goodwin, "A comparison of internal audit in the private and public sectors," *Managerial Auditing Journal*, vol. 19, no. 5, pp. 640–650, Jun. 2004, doi: 10.1108/02686900410537766.

[20] N. Castanheira, L. L. Rodrigues, and R. Craig, "Factors associated with the adoption of risk-based internal auditing," *Managerial Auditing Journal*, vol. 25, no. 1, pp. 79–98, Jan. 2010, doi: 10.1108/02686901011007315.

[21] P. Coetzee and D. Lubbe, "Improving the efficiency and effectiveness of risk-based internal audit engagements," *International Journal of Auditing*, vol. 18, no. 2, pp. 115–125, 2014, doi: 10.1111/IJAU.12016.

[22] S. Barocas and H. Nissenbaum, "Big data's end run around procedural privacy protections,"

Commun ACM, vol. 57, no. 11, pp. 31–33, Nov. 2014, doi: 10.1145/2668897.

[23] J. A. Burkell, "Remembering me: big data, individual identity, and the psychological necessity of forgetting," *Ethics Inf Technol*, vol. 18, no. 1, pp. 17–23, Mar. 2016, doi: 10.1007/S10676-016-9393-1.

[24] C. Meng, S. S. Nageshwaraniyer, A. Maghsoudi, Y. J. Son, and S. Dessureault, "Data-driven modeling and simulation framework for material handling systems in coal mines," *Comput Ind Eng*, vol. 64, no. 3, pp. 766–779, 2013, doi: 10.1016/J.CIE.2012.12.017.

[25] E. Burrell Nickell and R. W. Roberts, "Organizational legitimacy, conflict, and hypocrisy: An alternative view of the role of internal auditing," *Critical Perspectives on Accounting*, vol. 25, no. 3, pp. 217–221, 2014, doi: 10.1016/J.CPA.2013.10.005.

[26] G. J. Ockey and I. Choi, "Structural Equation Modeling Reporting Practices for Language Assessment," *Lang Assess Q*, vol. 12, no. 3, pp. 305–319, Jul. 2015, doi: 10.1080/15434303.2015.1050101.

[27] R. Lenz and U. Hahn, "A synthesis of empirical internal audit effectiveness literature pointing to new research opportunities," *Managerial Auditing Journal*, vol. 30, no. 1, pp. 5–33, Jan. 2015, doi: 10.1108/MAJ-08-2014-1072.

[28] K. M. Zuckweiler, K. M. Rosacker, and S. K. Hayes, "Business students' perceptions of corporate governance best practices," *Corporate Governance (Bingley)*, vol. 16, no. 2, pp. 361–376, Apr. 2016, doi: 10.1108/CG-08-2015-0117.

[29] N. T. Sheehan, "A risk-based approach to strategy execution," *Journal of Business Strategy*, vol. 31, no. 5, pp. 25–37, 2010, doi: 10.1108/02756661011076291.

[30] P. M. Podsakoff, S. B. MacKenzie, J. Y. Lee, and N. P. Podsakoff, "Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies," *Journal of Applied Psychology*, vol. 88, no. 5, pp. 879–903, 2003, doi: 10.1037/0021-9010.88.5.879.

[31] N. Wilkinson and P. Coetzee, "Internal audit assurance or consulting services rendered on governance: How does one decide?," *Journal of Governance and Regulation*, vol. 4, no. 1, pp. 186–200, 2015, doi: 10.22495/JGR_V4_I1_C2_P3.

[32] M. Woods, "Linking risk management to strategic controls: A case study of Tesco plc," *Int J Risk Assess Manag*, vol. 7, no. 8, pp. 1074–1088, 2007, doi: 10.1504/IJRAM.2007.015295.

[33] G. Sarens, M. J. Abdolmohammadi, and R. Lenz, "Factors associated with the internal audit function's role in corporate governance," *Journal of Applied Accounting Research*, vol. 13, no. 2, pp. 191–204, 2012, doi: 10.1108/09675421211254876.

[34] O. Khongmalai and A. Distanont, "Corporate governance model in Thai state-owned enterprises: structural equation modelling approach," *Corporate Governance (Bingley)*, vol. 17, no. 4, pp. 613–628, 2017, doi: 10.1108/CG-01-2016-0021.

[35] N. Kock, "Common method bias in PLS-SEM: A full collinearity assessment approach," *International Journal of e-Collaboration*, vol. 11, no. 4, pp. 1–10, Oct. 2015, doi: 10.4018/IJEC.2015100101.

[36] F. K. Kirogo, "Effect of Risk- Based Audit on Financial Perfomance: A Survey of Insurance Companies in Nakuru Town, Kenya," *IOSR Journal of Business and Management*, vol. 16, no. 10, pp. 84–91, 2014, doi: 10.9790/487X-161038491.

[37] N. H. Z. Abidin, "Factors influencing the implementation of risk-based auditing," *Asian Review of Accounting*, vol. 25, no. 3, pp. 361–375, 2017, doi: 10.1108/ARA-10-2016-0118.

[38] F. Kabuye, S. K. Nkundabanyanga, J. Opiso, and Z. Nakabuye, "Internal audit organisational status, competencies, activities and fraud management in the financial services sector," *Managerial Auditing Journal*, vol. 32, no. 9, pp. 924–944, Nov. 2017, doi: 10.1108/MAJ-09-2016-1452.

[39] M. Allegrini and G. D'Onza, "Internal Auditing and Risk Assessment in Large Italian Companies: an Empirical Survey," *International Journal of Auditing*, vol. 7, no. 3, pp. 191–208, Nov. 2003, doi: 10.1046/J.1099-1123.2003.00070.X.

[40] M. Arena and G. Azzone, "Identifying Organizational Drivers of Internal Audit Effectiveness," *International Journal of Auditing*, vol. 13, no. 1, pp. 43–60, Mar. 2009, doi: 10.1111/J.1099-1123.2008.00392.X.

[41] A. A. M. Al-Twaijry, J. A. Brierley, and D. R. Gwilliam, "The development of internal audit in Saudi Arabia: An institutional theory perspective," *Critical Perspectives on Accounting*, vol. 14, no. 5, pp. 507–531, 2003, doi: 10.1016/S1045-2354(02)00158-2.

[42] O. Khongmalai, J. C. S. Tang, and S. Siengthai, "Empirical evidence of corporate governance in Thai state-owned enterprises," *Corporate Governance*, vol. 10, no. 5, pp. 617–634, Oct. 2010, doi: 10.1108/14720701011085580.

[43] A. Alzeban and D. Gwilliam, "Factors affecting the internal audit effectiveness: A survey of the Saudi public sector," *Journal of International Accounting, Auditing and Taxation*, vol. 23, no. 2, pp. 74–86, 2014, doi: 10.1016/J.INTACCAUDTAX.2014.06.001.

[44] M. Abdullatif and S. Kawuq, "The role of internal auditing in risk management: evidence from banks in Jordan," *Journal of Economic and Administrative Sciences*, vol. 31, no. 1, pp. 30–50, 2015, doi: 10.1108/JEAS-08-2013-0025.

[45] T. Franke and D. zu Knyphausen-Aufsess, "On dominant logic: review and synthesis," *Journal of Business Economics*, vol. 84, no. 1, pp. 27–70, Jan. 2014, doi: 10.1007/S11573-013-0690-4.

[46] A. C. T. Smith, F. Sutherland, and D. H. Gilbert, "Changing Forms of Organizing," *Reinventing Innovation*, pp. 19–33, 2017, doi: 10.1007/978-3-319-57213-0_2.

[47] B. B. Schlegelmilch and S. Ram, "The impact of organizational and environmental variables on strategic market orientation: An empirical investigation," *Journal of Global Marketing*, vol. 13, no. 3, pp. 111–127, 2000, doi: 10.1300/J042V13N03_06.

[48] R. R. Sinkovics and A. S. Roath, "Cultivating learning and fostering flexibility in international distribution," *der markt*, vol. 51, no. 1, pp. 3–12, Mar. 2012, doi: 10.1007/S12642-011-0067-6.

[49] B. Fahimnia, C. S. Tang, H. Davarzani, and J. Sarkis, "Quantitative models for managing supply chain risks: A review," *Eur J Oper Res*, vol. 247, no. 1, pp. 1–15, Nov. 2015, doi: 10.1016/j.ejor.2015.04.034.

[50] F. Caccioli, P. Barucca, and T. Kobayashi, "Network Models of Financial Systemic Risk: A Review," *SSRN Electronic Journal*, Nov. 2017, doi: 10.2139/SSRN.3066722.

[51] T. Aven, "Risk assessment and risk management: Review of recent advances on their foundation," *Eur J Oper Res*, vol. 253, no. 1, pp. 1–13, Aug. 2016, doi: 10.1016/j.ejor.2015.12.023.

[52] J. C. Pham *et al.*, "The harm susceptibility model: a method to prioritise risks identified in patient safety reporting systems," *Qual Saf Health Care*, vol. 19, no. 5, pp. 440–445, Oct. 2010, doi: 10.1136/qshc.2009.035444.

[53] T. M. Choi, C. H. Chiu, and H. K. Chan, "Risk management of logistics systems," *Transp Res E Logist Transp Rev*, vol. 90, pp. 1–6, Jun. 2016, doi: 10.1016/j.tre.2016.03.007.

[54] F. Aqlan and S. S. Lam, "Supply chain risk modelling and mitigation," *Int J Prod Res*, vol. 53, no. 18, pp. 5640–5656, Sep. 2015, doi: 10.1080/00207543.2015.1047975.

[55] D. Bisias, M. Flood, A. W. Lo, and S. Valavanis, "A survey of systemic risk analytics," *Annual Review of Financial Economics*, vol. 4, pp. 255–296, Oct. 2012, doi: 10.1146/ANNUREV-FINANCIAL-110311-101754.

[56] D. Helbing, "Globally networked risks and how to respond," *Nature*, vol. 497, no. 7447, pp. 51–59, 2013, doi: 10.1038/NATURE12047.

[57] J. Chen, A. S. Sohal, and D. I. Prajogo, "Supply chain operational risk mitigation: A collaborative approach," *Int J Prod Res*, vol. 51, no. 7, pp. 2186–2199, Apr. 2013, doi: 10.1080/00207543.2012.727490.

[58] O. Khan and B. Burnes, "Risk and supply chain management: Creating a research agenda," *The International Journal of Logistics Management*, vol. 18, no. 2, pp. 197–216, Aug. 2007, doi: 10.1108/09574090710816931.

[59] H. Soleimani, M. Seyyed-Esfahani, and G. Kannan, "Incorporating risk measures in closed-loop supply chain network design," *Int J Prod Res*, vol. 52, no. 6, pp. 1843–1867, Mar. 2014, doi: 10.1080/00207543.2013.849823.

[60] P. Luo, H. Wang, and Z. Yang, "Investment and financing for SMEs with a partial guarantee and jump risk," *Eur J Oper Res*, vol. 249, no. 3, pp. 1161–1168, Mar. 2016, doi: 10.1016/J.EJOR.2015.09.032.

[61] I. Heckmann, T. Comes, and S. Nickel, "A critical review on supply chain risk - Definition, measure and modeling," *Omega (United Kingdom)*, vol. 52, pp. 119–132, Apr. 2015, doi: 10.1016/J.OMEGA.2014.10.004.

[62] T. Wang, K. N. Kannan, and J. R. Ulmer, "The association between the disclosure and the realization of information security risk factors," *Information Systems Research*, vol. 24, no. 2, pp. 201–218, 2013, doi: 10.1287/ISRE.1120.0437.

[63] S. K. Mangla, P. Kumar, and M. K. Barua, "Risk analysis in green supply chain using fuzzy AHP approach: A case study," *Resour Conserv Recycl*, vol. 104, pp. 375–390, Nov. 2015, doi: 10.1016/j.resconrec.2015.01.001.

[64] R. Rajesh, V. Ravi, and R. Venkata Rao, "Selection of risk mitigation strategy in electronic supply chains using grey theory and digraph-matrix approaches," *Int J Prod Res*, vol. 53, no. 1, pp. 238–257, Jan. 2015, doi: 10.1080/00207543.2014.948579.

[65] B. Boyce, "Emerging Technology and the Health Insurance Portability and Accountability Act," *J Acad Nutr Diet*, vol. 117, no. 4, pp. 517–518, Apr. 2017, doi: 10.1016/j.jand.2016.05.013.

[66] S. Rosenbaum, "Data governance and stewardship: Designing data stewardship entities and advancing data access," *Health Serv Res*, vol. 45, no. 5 PART 2, pp. 1442–1455, Oct. 2010, doi: 10.1111/J.1475-6773.2010.01140.X.

[67] I. Holeman, T. P. Cookson, and C. Pagliari, "Digital technology for health sector governance in low and middle income countries: A scoping review," *J Glob Health*, vol. 6, no. 2, 2016, doi: 10.7189/JOGH.06.020408.

[68] A. Edmans, "Blockholders and corporate governance," *Annual Review of Financial Economics*, vol. 6, pp. 23–50, Dec. 2014, doi: 10.1146/ANNUREV-FINANCIAL-110613-034455.

[69] K. R. Hope, "Capacity development for good governance in developing countries: some lessons from the field," *Int J Public Adm*, vol. 32, no. 8, pp. 728–740, 2009, doi: 10.1080/01900690902908562.

[70] V. Khatri and C. V. Brown, "Designing data governance," *Commun ACM*, vol. 53, no. 1, pp.

148–152, Jan. 2010, doi: 10.1145/1629175.1629210.

[71] G. Gereffi, J. Humphrey, and T. Sturgeon, "The governance of global value chains," *Rev Int Polit Econ*, vol. 12, no. 1, pp. 78–104, Feb. 2005, doi: 10.1080/09692290500049805.

[72] C. Allen *et al.*, "Data Governance and Data Sharing Agreements for Community-Wide Health Information Exchange: Lessons from the Beacon Communities," *EGEMS*, vol. 2, no. 1, p. 1057, Apr. 2014, doi: 10.13063/2327-9214.1057.

[73] L. Rusu and R. P. Tenga, "IT governance in the healthcare sector: A case study of a public and private hospital in Tanzania," *Int J Inf Syst Change Manag*, vol. 4, no. 4, pp. 314–337, 2010, doi: 10.1504/IJISCM.2010.036915.

[74] J. Braithwaite, M. T. Westbrook, M. Robinson, S. Michael, C. Pirone, and P. Robinson, "Improving patient safety: The comparative views of patient-safety specialists, workforce staff and managers," *BMJ Qual Saf*, vol. 20, no. 5, pp. 424–431, May 2011, doi: 10.1136/BMJQS.2010.047605.

[75] L. Koperski, "Why the Renewable Energy Credit Market Needs Standardization," *Washington Journal of Law, Technology & Arts*, vol. 13, 2017, Accessed: May 13, 2025. [Online]. Available: https://heinonline.org/HOL/Page?handle=hein.journals/washjolta13&id=73&div=7&collection=journals

[76] E. Ascarza *et al.*, "In Pursuit of Enhanced Customer Retention Management: Review, Key Issues, and Future Directions," *Customer Needs and Solutions 2017 5:1*, vol. 5, no. 1, pp. 65–81, Nov. 2017, doi: 10.1007/S40547-017-0080-0.

[77] J. S. A. O. KA Bawa-Allah, "Integrated assessment of the heavy metal pollution status and potential ecological risk in the Lagos Lagoon, South West, Nigeria," *Human and Ecological Risk Assessment: An International Journal*, vol. 24, no. 2, pp. 377–397, 2017.

[78] S. Roohani, Y. Furusho, and M. Koizumi, "XBRL: Improving transparency and monitoring functions of corporate governance," *International Journal of Disclosure and Governance*, vol. 6, no. 4, pp. 355–369, Dec. 2009, doi: 10.1057/JDG.2009.17.

[79] T. G. de Kok and J. C. Fransoo, "Planning Supply Chain Operations: Definition and Comparison of Planning Concepts," *Handbooks in Operations Research and Management Science*, vol. 11, no. C, pp. 597–675, 2003, doi: 10.1016/S0927-0507(03)11012-2.

[80] S. Chopra and P. Meindl, "Supply Chain Management. Strategy, Planning & Operation," *Das Summa Summarum des Management*, pp. 265–275, Oct. 2007, doi: 10.1007/978-3-8349-9320-5_22.

[81] A. M. Attia, "Effect of quality management on supply chain and organisational performance in the Egyptian textile industry," *International Journal of Business Performance Management*, vol. 17, no. 2, pp. 198–222, 2016, doi: 10.1504/IJBPM.2016.075549.

[82] A. S. A. AL-Adwan, "Information Systems Quality Level and Its Impact on the Strategic Flexibility: A Field Study on Tourism and Travel Companies in the Jordanian Capital Amman," *International Journal of Human Resource Studies*, vol. 7, no. 3, p. 164, Aug. 2017, doi: 10.5296/IJHRS.V7I3.11436.

[83] M. Ishaq Bhatti and H. M. Awan, "The key performance indicators (KPIs) and their impact on overall organizational performance," *Qual Quant*, vol. 48, no. 6, pp. 3127–3143, Oct. 2014, doi: 10.1007/S11135-013-9945-Y.

[84] L. Theis, A. Van Den Oord, and M. Bethge, "A note on the evaluation of generative models," *4th International Conference on Learning*

Representations, ICLR 2016 - Conference Track Proceedings, 2016.

[85] G. Prause, "Sustainable business models and structures for industry 4.0," *Journal of Security and Sustainability Issues*, vol. 5, no. 2, pp. 159–169, 2015, doi: 10.9770/JSSI.2015.5.2(3).

[86] S. T. Certo, J. R. Busenbark, H. S. Woo, and M. Semadeni, "Sample selection bias and Heckman models in strategic management research," *Strategic Management Journal*, vol. 37, no. 13, pp. 2639–2657, Dec. 2016, doi: 10.1002/SMJ.2475.

[87] M. Brandenburg, K. Govindan, J. Sarkis, and S. Seuring, "Quantitative models for sustainable supply chain management: Developments and directions," *Eur J Oper Res*, vol. 233, no. 2, pp. 299–312, Mar. 2014, doi: 10.1016/j.ejor.2013.09.032.

[88] G. Y. Song, Y. Cheon, K. Lee, H. Lim, K. Y. Chung, and H. C. Rim, "Multiple categorizations of products: Cognitive modeling of customers through social media data mining," *Pers Ubiquitous Comput*, vol. 18, no. 6, pp. 1387–1403, 2014, doi: 10.1007/S00779-013-0740-5.

[89] F. G. Cordeiro, B. S. Bezerra, A. S. P. Peixoto, and R. A. R. Ramos, "Methodological aspects for modeling the environmental risk of transporting hazardous materials by road," *Transp Res D Transp Environ*, vol. 44, pp. 105–121, May 2016, doi: 10.1016/j.trd.2016.02.008.

[90] J. Henseler, C. M. Ringle, and M. Sarstedt, "A new criterion for assessing discriminant validity in variance-based structural equation modeling," *J Acad Mark Sci*, vol. 43, no. 1, pp. 115–135, Jan. 2015, doi: 10.1007/S11747-014-0403-8.

[91] A. C. Fernandes, P. Sampaio, M. Sameiro, and H. Q. Truong, "Supply chain management and quality management integration: A conceptual model proposal," *International Journal of Quality and Reliability Management*, vol. 34, no. 1, pp. 53–67, 2017, doi: 10.1108/IJQRM-03-2015-0041.

[92] J. R. Larson, "Deep diversity and strong synergy: Modeling the impact of variability in members' problem-solving strategies on group problem-solving performance," *Small Group Res*, vol. 38, no. 3, pp. 413–436, Jun. 2007, doi: 10.1177/1046496407301972.

[93] N. S. R. E. M. P. T Yigitcanlar, "A GIS-based land use and public transport accessibility indexing model," *Australian planner*, vol. 44, no. 3, pp. 30–37, 2007.

[94] D. J. Teece, "Business models, business strategy and innovation," *Long Range Plann*, vol. 43, no. 2–3, pp. 172–194, Apr. 2010, doi: 10.1016/J.LRP.2009.07.003.

[95] K. Katircioglu *et al.*, "Supply chain scenario modeler: A holistic executive decision support solution," *Interfaces (Providence)*, vol. 44, no. 1, pp. 85–104, Jan. 2014, doi: 10.1287/INTE.2013.0725.

[96] B. A. Lameijer, J. De Mast, and R. J. M. M. Does, "Lean six sigma deployment and maturity models: A critical review," *Quality Management Journal*, vol. 24, no. 4, pp. 6–20, 2017, doi: 10.1080/10686967.2017.12088376.

[97] J. B. Homer and G. B. Hirsch, "System dynamics modeling for public health: Background and opportunities," *Am J Public Health*, vol. 96, no. 3, pp. 452–458, Mar. 2006, doi: 10.2105/AJPH.2005.062059.

[98] P. Chhaochhria and S. C. Graves, "A forecast-driven tactical planning model for a serial manufacturing system," *Int J Prod Res*, vol. 51, no. 23–24, pp. 6860–6879, Nov. 2013, doi: 10.1080/00207543.2013.852266.

[99] Y. Bouzembrak, H. Allaoui, G. Goncalves, H. Bouchriha, and M. Baklouti, "A possibilistic linear programming model for supply chain network design under uncertainty," *IMA Journal of Management Mathematics*, vol. 24, no. 2, pp. 209–229, 2013, doi: 10.1093/IMAMAN/DPS012.

[100] S. Agarwal, P. Kachroo, and E. Regentova, "A hybrid model using logistic regression and wavelet transformation to detect traffic incidents," *IATSS Research*, vol. 40, no. 1, pp. 56–63, Jul. 2016, doi: 10.1016/j.iatssr.2016.06.001.

[101] A. Pollock, B. S. George, M. Fenton, S. Crowe, and L. Firkins, "Development of a new model to engage patients and clinicians in setting research priorities," *J Health Serv Res Policy*, vol. 19, no. 1, pp. 12–18, Jan. 2014, doi: 10.1177/1355819613500665.