The Impact of Smart Digitalization Technologies on Mitigating Incremental Risks in Sustainable Sourcing Practices

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Abstract

This study explores the intersection between incremental risks introduced by sustainable sourcing practices in procurement and the role of Smart Digitalization Technologies (SDT) in mitigating these risks while enhancing operational efficiency, organizational effectiveness, and resilience. A mixed-methods approach was employed, combining a structured survey of procurement professionals with in-depth interviews with SDT providers. This methodology allowed for both quantitative validation of SDT's perceived effectiveness and qualitative insights into their strategic applications. Findings reveal that while SDT significantly contribute to risk identification and mitigation, particularly through supply chain visibility, automation, and data-driven decision-making, challenges remain. Poor data quality, unrealistic leadership expectations, and ineffective change management limit their full potential. Additionally, SDTs have yet to prove effective in managing crises, particularly unpredictable disruptions. This research highlights SDT as a catalyst for sustainable procurement maturity, reinforcing the relationship between sustainability and operational efficiency. However, successful implementation depends on organizational readiness and strategic alignment. A practical evaluation tool is provided to assess known risks and mitigation mechanisms.

Keywords: Smart Digitalization Technologies, Sustainable Procurement, Risk Mitigation, Supply Chain Resilience, Operational Efficiency, Procurement Risks

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1. Introduction

The increasing global emphasis on sustainability has driven organizations to integrate environmentally and socially responsible practices into their procurement functions. However, the transition toward sustainable sourcing is not without challenges. While sustainability initiatives aim to enhance long-term resilience and compliance with regulatory frameworks, they often introduce incremental risks that can impact procurement efficiency, cost structures, and supplier relationships. This study explores the role of SDT, including artificial intelligence (AI), machine learning (ML), and robotic process automation (RPA), in identifying and mitigating these emerging risks, thereby optimizing operational efficiency and strengthening organizational resilience.

García Rodríguez et al. (2022) define procurement as the function responsible for acquiring goods and services to support an organization's objectives. The Chartered Institute of Procurement and Supply (CIPS, 2020) further delineates procurement as a structured process comprising multiple stages, including requirements definition, supplier evaluation, contract negotiation, and supplier performance monitoring. This process is integral to maintaining supply chain stability and achieving strategic objectives. However, the incorporation of sustainability considerations into procurement decisions significantly alters traditional sourcing dynamics, requiring additional due diligence in supplier selection, adherence to environmental and social governance (ESG) criteria, and lifecycle management of acquired assets.

Sustainable procurement, as conceptualized by Hald et al. (2021) and Seppäläinen (2024), involves embedding sustainability principles into procurement practices to achieve ecological, social, and economic benefits. These principles encompass ethical sourcing, carbon footprint reduction, fair labor practices, and circular economy models. Despite its advantages, sustainable procurement presents new risk dimensions, including increased supplier vetting complexity, supply chain disruptions, and compliance uncertainties (Escobar et al. 2023; Hald et al. 2021). As sustainability goals necessitate a broader set of evaluation criteria beyond cost and quality, procurement teams must develop mechanisms to assess suppliers' sustainability credentials effectively.

Concurrently, the rapid advancement of smart digitalization technologies has disrupted traditional procurement functions, offering new ways to manage these emerging risks. Seppäläinen (2024) highlights the transformative potential of digital tools in enhancing data transparency, predictive analytics, and automated decision-making, facilitating more informed and agile procurement strategies. However, despite the growing body of research on sustainable procurement and digital transformation, the intersection of these domains remains underexplored (Okonta, 2023; Yevu et al., 2021). Addressing this research gap, this study investigates how SDT can mitigate the incremental risks associated with sustainable sourcing while fostering procurement resilience.

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This research aims to answer the following question: How can procurement organizations leverage smart digitalization technologies to identify and mitigate risks introduced by sustainable sourcing practices while optimizing operational efficiency, organizational effectiveness, and resilience?

In response, the study proposes the following hypothesis:

The implementation of SDT in the procurement function positively impacts the management of incremental risks introduced by sustainable sourcing practices, enhancing organizational effectiveness, operational efficiency, and resilience.

To evaluate this hypothesis, the study will analyze key risk categories arising from sustainable procurement adoption and assess the extent to which AI, ML, and RPA contribute to risk mitigation. Furthermore, it will propose a model that procurement leaders can utilize to navigate these challenges effectively.

The term "smart digitalization" encompasses a broad spectrum of digital tools and methodologies aimed at enhancing procurement decision-making and operational efficiencies. Liberale (2023) differentiates between "digitization"—the conversion of analog data into digital formats—and "digitalization," which refers to the integration of digital tools into procurement workflows. Gong & Ribiere (2021) define digitalization as a paradigm shift toward the adoption of digital solutions in procurement operations, enabling enhanced collaboration, automation, and data-driven insights. Hallikas et al. (2021) further elaborate on "digital transformation," emphasizing its role in fundamentally restructuring procurement practices through the integration of AI, automation, and real-time data analytics.

Srai & Lorentz (2019) introduce the concept of "smart digitalization in procurement," defining it as the strategic application of advanced technologies to optimize procurement functions. AI-powered analytics, for instance, can enhance supplier risk assessments by analyzing historical performance data and identifying potential sustainability compliance violations. Similarly, ML algorithms can refine demand forecasting models, reducing procurement uncertainties and minimizing waste. RPA streamlines repetitive procurement tasks, such as purchase order processing and supplier performance tracking, thereby reducing operational bottlenecks and improving process accuracy.

Seppäläinen (2024) asserts that procurement organizations often struggle to manage the hidden risks associated with sustainable sourcing due to the lack of robust risk assessment frameworks. The introduction of new sustainability standards may inadvertently expose organizations to financial, regulatory, and reputational risks, necessitating advanced monitoring mechanisms. In this regard, smart digitalization offers a viable solution by facilitating continuous risk assessment and adaptive mitigation strategies.

By leveraging real-time data analytics, AI-driven supplier scoring models can evaluate sustainability compliance with higher accuracy than traditional methods. Predictive analytics enable procurement teams to anticipate supply chain disruptions linked to sustainability shifts, while blockchain technology enhances traceability and accountability in sustainable sourcing practices (Okot et al., 2023). These capabilities collectively improve procurement resilience, ensuring that sustainability initiatives do not compromise operational stability. The increasing scholarly interest in sustainable procurement underscores the need for integrated frameworks that address both sustainability objectives and risk mitigation strategies (Okonta, 2023); Kabra et al., (2023) and Liberale (2023) emphasize that digital transformation alone does not guarantee sustainability alignment; rather, it requires strategic intent and tailored implementation. While organizations are progressively investing in SDT, many procurement leaders lack the necessary guidance to align digitalization efforts with sustainability goals effectively.

This study contributes to the growing discourse on procurement digitalization by bridging the knowledge gap between sustainable sourcing risks and digital risk management strategies. The findings will provide procurement professionals with a structured approach to leveraging SDT for sustainable procurement, thereby fostering resilience and operational excellence. Furthermore, the proposed framework will serve as a reference for policymakers and industry practitioners seeking to harmonize sustainability mandates with procurement digitalization imperatives.

Figure 1. Conceptual Model: SDT as Enablers of Risk Mitigation in Sustainable Procurement

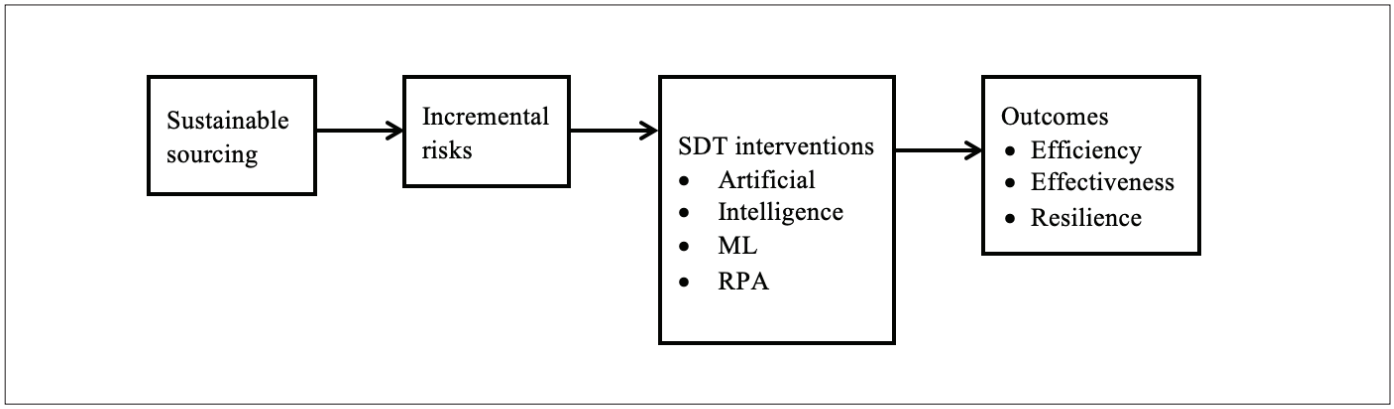


Figure 1 illustrates how SDTs—categorized into AI, Blockchain, and RPA—mitigate incremental risks inherent to sustainable sourcing practices. AI addresses supplier dependency risks by analyzing global supplier databases to identify alternatives, enhancing supply chain diversification. Blockchain reduces compliance risks through immutable tracking of ESG metrics across multi-tier suppliers, ensuring transparency. RPA alleviates logistical risks by automating repetitive tasks like purchase order processing, minimizing human error and delays. Together, these SDTs enable data visibility, predictive analytics, and workflow automation, aligning with the Technology-Organization-Environment (TOE) framework. Here, SDTs function as technological enablers that strengthen organizational capabilities (e.g., risk monitoring) and adapt to environmental pressures (e.g., regulatory demands). This framework bridges the theoretical gap between sustainable procurement risks and SDT-driven solutions, providing a roadmap for subsequent analysis.

2. Theoretical Framework

2.1 Conceptualizing Procurement: Strategic Priorities and Efficiency Considerations

The procurement function operates within two primary dimensions: organizational effectiveness, which assesses the extent to which strategic objectives are achieved (Kakwezi & Nyeko, 2019), and operational efficiency, which evaluates how resources are utilized to meet these objectives (Aulia, 2021). Organizational effectiveness is characterized by alignment with corporate goals, financial performance impact, compliance with quality and timing requirements, and internal customer satisfaction (Kakwezi & Nyeko, 2019). Efficient procurement processes ensure that businesses can respond to market dynamics while maintaining cost control, supplier relationships, and compliance with regulatory requirements.

Recent findings by The Hackett Group (Hillcox & Sawchuk, 2024) identify key strategic priorities for procurement functions, including cost reduction, supply continuity, inflation mitigation, enhanced risk management, digitalization, and the adoption of sustainable sourcing practices. These priorities align with global shifts toward sustainability and digital transformation, emphasizing procurement's role in corporate resilience. Operational efficiency, as outlined by Aulia (2021) and Jama & Mohamud (2024), is measured through cost reduction achievements, on-time and complete deliveries, contract management efficiency, and diversified sourcing channels.

Efficiency in procurement also extends to its ability to integrate technological advancements, automate routine tasks, and leverage data analytics for decision-making. The extent to which firms successfully integrate digital solutions determines their ability to mitigate supply chain disruptions, predict market fluctuations, and ensure supplier compliance with sustainability standards (Liberale, 2023). Thus, procurement efficiency not only affects cost structures but also determines how firms position themselves within increasingly digitalized and sustainable global supply chains.

2.2 Procurement Maturity and the Adoption of Sustainable Sourcing and Digitalization

The evolution of procurement functions is marked by increasing complexity and value contribution (Liinaharja, 2023). Sustainable sourcing practices and smart digitalization technologies are typically implemented at advanced procurement maturity stages, with incremental risks varying based on maturity levels (Seppäläinen, 2024). Organizations with well-established procurement capabilities are better positioned to navigate the complexities of integrating sustainability and digital tools while managing associated risks.

Maturity models, such as the Guth Model (Aulia, 2021) and McKinsey's strategic alignment framework (Drentin et al., 2024), assess procurement development by analyzing structural, managerial, technological, and strategic capabilities. These models serve as roadmaps for organizations aiming to transition from traditional procurement approaches to data-driven, sustainability-oriented systems. Table 1 summarizes procurement maturity stages, ranging from Transactional (basic requisition processing) to Next Generation (leveraging advanced analytics and digitalization).

Table 1. Procurement function Maturity Stages.

Horizons	Horizon 1: Transactional	Horizon 2: Evolved	Horizon 3: Strategic	Horizon 4: Next Generation
Savings Levers	Focus on purchase price ('Purchasing')	Spend consolidation and Total Cost of Ownership	As described in the 'Purchasing Chessboard'	Dynamic cost optimization using advanced analytics
Spend Under Contract	<20% of spend	>50% of spend	>70% of spend	>70% of spend
Tools and Systems	Transaction automation (ERPs) for requisition-to-purchase order processes	Basic procurement tools	Electronic sourcing ('eSourcing'), cost modeling, reverse auctions ('eAuction'), purchasing catalogs	Advanced electronic tools incorporating smart digitalization
Process	Limited supplier analysis; minimal spend consolidation	Supplier consolidation; Category Management	Collaboration with suppliers; data-driven negotiations	Automated compliance and performance management
Capabilities	Non-homogeneous capabilities	Trained category managers	Advanced sourcing capabilities	Talent skilled in using advanced analytical tools
Typical Configuration	'Purchasing' operation	Tactical 'Sourcing'	Category Management and Strategic Sourcing	Procurement as a Strategic Business Advisor

Source: adapted from (Liberale, 2023; Liinaharja, 2023; Hallikas, 2021)

Liinaharja (2023) describes a purchasing operation as one exclusively dedicated to the basic function of processing requisitions and converting them into purchase orders. The introduction of sourcing elements (Horizon 2) implies that, in addition to requisition processing, procurement personnel quote, negotiate, and manage contracts of low to medium value and risk (Aulia, 2021). As it evolves toward a category management state (Horizon 3), the procurement function gains insight into the structure and dynamics of spend, classifies and categorizes it, and develops strategies to leverage economies of scale, increase transparency, and optimize resources allocated to a group of cost types (Milosavljevic et al., 2021; Liinaharja, 2023).

In the Third Horizon (Strategic), tools such as reverse electronic auctions (eAuctions) are employed. eAuctions are auctions conducted on an electronic platform where the buyer sets a maximum acquisition price, and suppliers submit progressively lower sale prices (Li et al., 2020). Another tool used at this maturity stage is electronic purchasing catalogs (eCatalogs) for supplier collaboration. These catalogs help reduce processing times for low-value, low-risk, and repetitive purchase items (a classic example being office supplies) (Al-Kaabi, 2023).

Tools like the Purchasing Chessboard by the consultancy firm A.T. Kearney are particularly useful for advancing within these maturity horizons. This tool provides a wide range of strategies adaptable to market conditions and the buyer's bargaining power (Schuh et al., 2008). At this stage, the introduction of category-based strategies is common. Supplier selection is conducted using structured comparison methods between financial benefits and potential risks, enabling strategic decision-making in the strategic sourcing process (Vladislavovna, 2021).

In this context, smart digitalization enhances the ability to reach Horizon 4 (Next Generation), characterized by using advanced analytics, which enables the procurement function to function as a strategic advisor (Liberale, 2023).

The introduction of sustainable sourcing practices requires the involvement of key functions that are observed at intermediate or advanced maturity stages (Virkkala et al., 2020; Seppäläinen, 2024). According to Mensah & Ameyaw (2021), among these functions, the role of leaders stands out, as they must promote sustainable practices and lead smart digital transformation. Hallikas (2021) highlights that the ability to transform data into actionable insights, supporting decision-making, plays a significant role. This perspective suggests that procurement functions at maturity levels 2, 3, and 4 are better equipped to implement these practices.

This explains why sustainability and smart digitalization topics are rarely observed in the early maturity stages of the procurement function. Functions at advanced stages are characterized by having analytical capabilities that facilitate risk identification and mitigation, strengthening supply chain resilience and sustainability (Escobar et al., 2023). The study draws from the TOE framework, emphasizing how organizational readiness and external pressures condition the successful integration of SDTs. Additionally, the Resource-Based View (RBV) provides the theoretical basis to position digital capabilities as strategic assets that enhance competitive advantage by improving procurement resilience.

Organizations that reach the highest maturity levels leverage procurement as a strategic asset, using predictive analytics to anticipate risks, automate compliance processes, and enhance supplier collaboration. Advanced firms not only mitigate risks but also proactively capitalize on opportunities, such as developing sustainable supplier networks and incorporating circular economy principles into sourcing strategies.

2.3 Sustainable Procurement: Implementation and Risks

The integration of sustainable sourcing practices requires organizational maturity, with advanced procurement functions being more capable of embedding sustainability into decision-making (Mensah & Ameyaw, 2021; Hallikas, 2021). Sustainable procurement entails supplier evaluation beyond cost factors, incorporating environmental and social criteria (Virkkala et al., 2020; Seppäläinen, 2024). Organizations must assess supplier environmental performance, ethical labor practices, carbon footprints, and overall compliance with global sustainability standards such as the UN Sustainable Development Goals (SDGs) and the Science-Based Targets initiative (SBTi).

Firms that lack robust procurement capabilities may struggle with supplier monitoring, increased costs, and compliance burdens. Studies indicate that organizations often face difficulties in verifying supplier claims related to environmental responsibility and ethical labor conditions (Johnson & Brown, 2020). Without adequate digitalization tools, these challenges intensify, leading to reputational risks, supply chain disruptions, and potential legal liabilities.

The transition toward sustainable procurement introduces additional risks alongside inherent procurement challenges. While traditional procurement risks focus on financial, operational, and compliance concerns, sustainability-related sourcing extends the risk landscape. Table 2 categorizes these risks.

According to the reviewed literature, table 3 summarizes the main existing and incremental risks arising from the implementation of sustainable practices in the procurement function.

Table 2. Non-Exhaustive Risk Map

Inherent risks		Incremental Risks from Sustainable Sourcing	
Financial risk: Budget deviations and unforeseen costs due to price fluctuations in materials and services.	Garcia et al., 2022; Almeida & Ramos, 2023;	**Incremental costs:** Increased costs due to certified sustainable suppliers or compliance with environmental standards.	Johnson & Brown, 2020; Hald (2021); Seppäläinen (2024)
Supply risk: Dependence on a single supplier or a limited supplier base.	Bednarski et al., 2023; Gao & Xu (2024); Hillcox & Sawchuk (2024)	**Dependence on single suppliers:** Selecting sustainable suppliers may reduce the diversity of options, increasing dependence on a few suppliers.	Kabra (2023)
Quality risk: Potential failures in delivered products, affecting the expected quality.	Milosavljevic et al. (2021); Kabra et al, (2023); Barimah, 2024	**Sustainable quality risk:** Sustainable products or services may not meet traditional quality or expected functionality standards.	Kabra et al., (2023); Okonta (2023)
Compliance risk: Risk of non-compliance with local and international laws and regulations.	Changalima & Mdee, 2023; Barimah (2024)	**Sustainability compliance risk:** The need to comply with additional sustainability regulations that vary by region, increasing the administrative burden.	Seppäläinen (2024); Sundarasen et al., (2024); Hillcox y Sawchuk (2024)
Reputational risk: Damage to the company's image arising from supplier practices, such as child labor or poor working conditions.	Hald (2021) Barimah (2024)	***Greenwashing* risk:** Negative perception or reputational damage if the implementation of sustainable practices is seen as insufficient or merely superficial.	Seppäläinen (2024); Sundarasen et al., 2024
Logistical risk: Supply chain issues, such as delivery delays or transportation problems.	Aghajanian, 2018; Hillcox & Sawchuk (2024)	**Supply chain complexity:** The integration of sustainable practices may add operational complexity, complicating logistical coordination.	Mensah & Ameyaw (2021); Kabra et al., (2023); EcoVadis (2024)
Data security risk: Loss or theft of confidential supplier and customer information.	Lin et al., (2020) Okot (2025)	**Sustainability data risk:** Lack of accurate or reliable data on suppliers' sustainable performance, which could lead to incorrect decisions.	EcoVadis (2024); Sundarasen et al., (2024)
Supplier performance risk: Suppliers failing to meet standards or delivery timelines.	Hillcox & Sawchuk (2024) Barimah (2024)	**Supplier resistance to sustainable changes:** Suppliers resisting the adoption of sustainable practices, causing conflicts and implementation difficulties.	Hald (2021); Mensah & Ameyaw (2021)
Market stability risk: Market changes affecting the availability and prices of key products.	Gao & Xu (2024); Hillcox & Sawchuk (2024)	**Volatility in the sustainable products market:** Changes in the supply and demand of sustainable materials, which can impact availability and costs.	Hillcox & Sawchuk (2024); United Nations Global Compact (2023).
Corruption	Othman & Zakaria, 2024; García (2022);		

Source: Own elaboration compiling the risks identified by cited authors.

To mitigate these risks, organizations increasingly turn to digital technologies that enhance procurement transparency, automate compliance verification, and provide real-time insights into supplier sustainability metrics. The analysis reveals that specific SDTs have direct causal relationships with various categories of risk. For instance, AI-driven supplier discovery platforms mitigate supply risk and ESG compliance risk by offering real-time supplier performance scoring. Machine learning-based spend analytics reduces financial and sustainability data risks by identifying anomalies and forecasting disruptions. RPA tools address operational complexity and fraud detection through rule-based automation. These mechanisms explain how digitalization not only addresses existing procurement inefficiencies but also actively supports the implementation of sustainable sourcing strategies.

The integration of SDTs enhances procurement efficiency, risk management, and sustainability compliance (Liberale, 2023). SDTs optimize procurement processes through automation, advanced analytics, and decision-making augmentation (EcoVadis, 2024). Predictive analytics, blockchain-based traceability, and AI-driven compliance monitoring enable firms to manage risks proactively rather than reactively. Table 3 outlines key SDTs and their applications.

Table 3. Non-Exhaustive Mapping of SDTs in Procurement

Process	IA, ML or RPA contribution	Examples of solution providers
Supplier onboarding	Through the exploration of global databases, such as import and export records, and web crawlers with enriched metadata, these tools can provide visibility into new suppliers in the market.	*Coupa, GEP, SAP Ariba, Xeeva, Certa*
Category strategy elaboration support	The category strategy is executed as a project. Technological solutions enable task allocation, on-time delivery traceability, and more.	*Cirtuo*
Price comparison	AI enables the analysis of material prices in the market to establish precise and competitive comparisons.	*ScoutBee, Fairmarkit, LevaData, Ivalua, Valdera, Coupa*
Supply planning	ML tools enhance the accuracy of procurement planning through advanced forecasting.	*Keelvar, Suplari*
Spend analysis	Automated spending analysis identifies consumption patterns and optimizes budget allocations.	*Basware, Coupa, Oracle, Suplari*
Supplier discovery	Advanced search and data optimization to find specific suppliers according to defined requirements.	*ScoutBee, Archlet, Tealbook, Valdera, Forestreet, Matchory, SCH*
Should cost / could cost	AI and ML technologies enable tracking the evolution of cost-determining factors for each variable and projecting their future costs when linked to indices that are regularly updated over time.	*GEP, McKinsey, Beroe*
Request for Quotation (RFQ) optimization	AI optimizes requests for quotation by using algorithms that automatically select the best suppliers based on defined criteria.	*Fairmarkit, Archlet, Keelvar, Valdera, Ivalua, Achilles, SCH*
Electronic inverse auctions	AI models facilitate automated auctions to achieve better prices and procurement efficiency.	*SAP Ariba, Oracle, Xeeva, Coupa, Ivalua, SCH*
Negotiations support	AI and ML tools provide recommendations and data analysis to support supplier negotiations.	*Pactum, Coupa, Levadata, Ivalua*
Contract management	RPA automates the creation and monitoring of contracts to ensure compliance with terms and conditions.	*Icertis, Evisort, INHUBBER, SCH*
Purchase order management	RPA systems streamline the issuance and tracking of purchase orders.	*Basware, Oracle, Coupa, SCH*
Catalogs management	Automation enables the maintenance of updated and customized product catalogs for different departments.	*Xeeva, SAP Ariba, Coupa, SCH*
Payments	Automated processes verify invoices and ensure accurate and timely payments.	*Basware, Oracle, Coupa, SCH*
Fraud detection	AI analyzes patterns to identify and prevent fraudulent activities in purchasing transactions.	*ProcessBolt*
Third party risk monitoring	Supply risks, disruptions due to geopolitical issues, bankruptcies of suppliers or their sub-suppliers, news affecting brand reputation, and other factors can be monitored by AI.	*Beroe, McKinsey, EcoVadis, Certa*
Digital assistants / chat bots	Digital assistants support responses to common inquiries and automate low-value activities.	*WeAreBrain, Yaydoo, SCH, Ivalua, Globality*
Automation of non-value-added activities	RPA eliminates repetitive and low-value activities, allowing employees to focus on strategic tasks.	*SCH, Simfoni, Suplari*

Source: Updated and adapted from (Guida et al., 2023; EcoVadis, 2024; Liberale, 2023)

This theoretical framework has been drafted to present different perspectives on the two essential points underpinning this research. The first is the inadvertent introduction of incremental risks during the implementation of sustainable practices in procurement, and the second is the contribution of SDTs to the operational efficiency, organizational effectiveness, and resilience of the function.

The review of the available literature does not address the interconnection of these two areas and suggests the need for further studies. Considering this, this study aims to analyze how SDTs contribute to mitigating incremental risks while optimizing procurement performance and sustainability compliance.

3. Methodology

A rigorous methodological framework is established to empirically validate the research hypothesis. This section outlines the research design, data collection methods, sampling approach, and analytical techniques employed to ensure robustness, coherence, and scientific rigor.

This study adopts a hybrid methodological approach, integrating both secondary and primary research components to achieve a comprehensive understanding of the subject matter:

a) Systematic Literature Review: A structured review of scholarly publications from the past five years will be conducted. The review will focus on (i) inherent risks in procurement, (ii) incremental risks associated with the implementation of sustainable sourcing practices, and (iii) the role of SDTs in risk identification and mitigation. This step ensures the research is grounded in contemporary academic discourse and industry best practices.

b) Mixed-Methods Research Design: The study employs a convergent mixed-methods approach, integrating both quantitative and qualitative data to analyze the interplay between SDT adoption and risk mitigation in sustainable procurement. This approach facilitates a more holistic analysis by incorporating both objective metrics and subjective insights (Creswell & Creswell, 2027).

Primary data will be collected through structured surveys and semi-structured interviews, designed to capture procurement professionals' perceptions, experiences, and insights regarding SDT adoption for risk mitigation. The survey instrument will assess the extent to which AI, ML, and RPA technologies are used in procurement risk management and the awareness levels surrounding these solutions.
To complement the survey data, expert interviews will be conducted with professionals in SDT service provision. These interviews will explore key themes related to adoption barriers, technological capabilities, and strategic decision-making in procurement.

The study focuses on procurement professionals who have been directly involved in implementing sustainable sourcing practices within the last four years. The justification for this criterion is twofold: (i) ensuring firsthand experience with sustainability-driven procurement risks, and (ii) capturing the latest trends in SDT adoption.

According to EcoVadis (2024) and the United Nations Global Compact (2023), approximately 33% of global corporations have integrated sustainability into procurement operations in recent years. Extrapolating from global employment data, this translates to an estimated 14.85 million procurement professionals engaged in sustainable sourcing practices.

A stratified sampling approach will be applied to ensure representation across industries, company sizes, and geographic regions. The sample size is determined using a 95% confidence level and a 5% margin of error:

$$n = \frac{Z^2 pqN}{NE^2 + Z^2 pq}$$

N= 14,850,000 people
p= 0.5
q= 0.5
Z= 1.96
E= 0.05
n= 385

Although the target sample size, based on a 95% confidence level and 5% margin of error, was calculated at 385 procurement professionals, the final valid sample for analysis consisted of 243 respondents. This sample was derived after filtering out individuals with less than two years of experience or no direct involvement in sustainable sourcing implementation. While the total number falls short of the originally calculated figure, the quality and relevance of the responses meet the research's analytical requirements, as many participants hold leadership roles and operate in mature procurement environments.

The survey instrument consisted of four main sections:

- Demographics – capturing experience, role, industry, and geographic location.
- Perceived Risk – a 5-point Likert scale measured perceptions of incremental risks introduced by sustainable sourcing.
- Technology Awareness and Usage – respondents rated awareness and implementation of SDTs across ten procurement phases.
- Impact Evaluation – using a 5-point scale, participants assessed SDT contributions to efficiency, effectiveness, and resilience.

The questionnaire was reviewed by three procurement experts and pilot-tested with 12 professionals to ensure clarity and construct alignment.

Quantitative data will be processed using descriptive and inferential statistical techniques to identify key correlations and patterns. Given the anticipated variability in the dataset, the student's t-test will be employed to assess differences in risk management effectiveness based on SDT usage. The core analytical variables include:

- Independent Variable: SDT adoption in procurement.
- Dependent Variable: Impact on the management of incremental risks arising from sustainable sourcing implementation.

Reliability analysis of the Likert-based constructs yielded Cronbach's alpha values between 0.82 and 0.89, indicating strong internal consistency across all measured variables. Content validity was ensured via expert review during instrument development, and construct validity was supported by the alignment of items with theoretical models such as procurement maturity and SDT integration. Table 4 presents the reliability statistics for each construct.

Table 4. Reliability Statistics for Constructs Used in Survey Instrument

Construct	Number of Items	Example Item	Cronbach's Alpha
Perceived Incremental Risk	5	Sustainable sourcing introduces operational complexities.	0.85
Technology Awareness/Usage	6	We use AI to assess supplier ESG performance.	0.82
Impact on Efficiency	3	SDTs have improved procurement process speed.	0.86
Impact on Effectiveness	4	Digital tools improved sourcing decision quality.	0.89
Contribution to Resilience	3	SDTs enable better response to supply chain disruptions.	0.84

Source, reliability statistics for each construct.

The Student's t-test is chosen due to its robustness in analyzing moderate sample sizes and datasets that may not exhibit perfect normality (Moura et al., 2024).

Interview responses will be transcribed, coded, and thematically analyzed to extract insights into procurement professionals' perceptions of SDT effectiveness. A grounded theory approach (Glaser & Strauss, 2017) will be employed to identify emergent themes regarding technology adoption, risk perceptions, and barriers to implementation. Interview data from 17 SDT provider executives were transcribed and coded using thematic analysis. An inductive coding approach was applied, allowing categories to emerge from the data. Themes were developed around the use of SDTs for ESG risk monitoring, automation challenges, and procurement resilience. Cross-case comparisons were made, and codes were triangulated with the survey findings to validate emerging patterns.

The adoption of a mixed-methods approach is justified by the multifaceted nature of the research question. The integration of quantitative data ensures objective measurement of SDT adoption impacts, while qualitative insights contextualize these findings with subjective perspectives on technological feasibility, organizational readiness, and adoption barriers. This methodological triangulation enhances validity, reduces bias, and ensures a more comprehensive analysis (Yang et al., 2006).

This study acknowledges several limitations. The sample size achieved of 243 respondents, while robust and targeted, does not meet the initial projection. Additionally, self-reported perceptions are subject to bias and may not fully capture system effectiveness. The generalizability of results is also constrained by the concentration of mature procurement functions among respondents. Organizations at earlier maturity stages or in different regional contexts may experience different outcomes when implementing SDTs.

Furthermore, strict ethical considerations will be adhered to, ensuring anonymity, informed consent, and secure data handling. This study's methodological design is expected to provide a robust foundation for understanding how SDTs mitigate incremental risks in sustainable procurement.

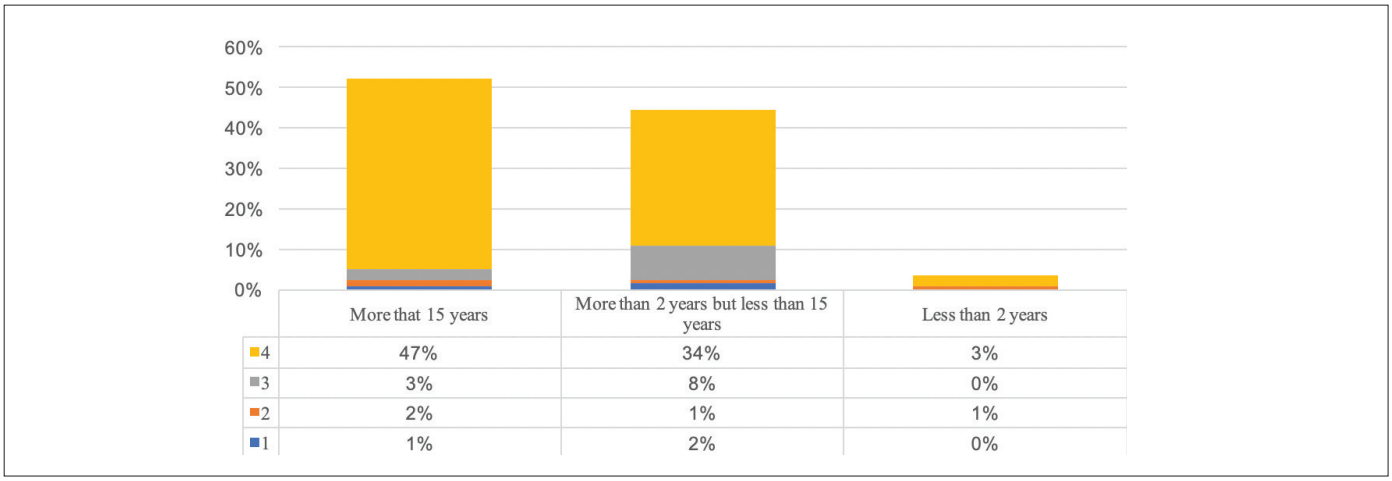
4. Results Analysis

4.1 Professional Background and Industry Representation

The surveyed population comprises procurement professionals with diverse experience levels and industry backgrounds. A total of 58% hold leadership positions, ensuring the study captures perspectives from decision-makers. The most represented industries include Banking and Financial Services (17%), Manufacturing (11%), and Retail (10%), with additional participation from Healthcare, Technology, E-commerce, and Mining.

In terms of experience, 52% of respondents have over 15 years in procurement, while 45% have between 2 and 15 years. Furthermore, 90% have actively participated in sustainable sourcing implementations across various global regions, including North America (23%), Europe (17%), and Central America (13%). The remaining 47% are distributed across Africa, Asia, and Oceania, ensuring a geographically balanced perspective (Figure 2).

Figure 2. Professional Experience and Geographic Representation of Respondents



Source, data tabulation from survey

Impact of Incremental Risks in Sustainable Sourcing Implementation

Among 243 respondents with at least two years of experience in sustainable sourcing, 57% report awareness of projects affected by unforeseen incremental risks (Table 5). These risks often led to project delays or cancellations due to inadequate initial assessments.

Table 5. Awareness of Incremental Risks in Sustainable Sourcing Projects

Hierarchy	Not Aware	Aware
1) Chief Officer	0%	100%
2) Vice-president / Sr Vice-president	0%	100%
3) Director / Sr Director / Managing Director	57%	43%
4) Head of / Manager / Sr Manager / Team Leader	47%	53%
5) Buyer / Sr Buyer / Individual Contributor	6%	57%
Grand Total	**43%**	**57%**

Source, data tabulation from survey.

To address these risks, a structured checklist-based risk assessment model was developed using insights from the literature review and qualitative interviews. This tool enables procurement professionals to evaluate risk exposure across distinct stages of the sourcing process (Table 6).

Table 6. Checklist-Based Risk Assessment for Sustainable Procurement (Excerpt)

Considerations			Evaluation		
Procurement Cycle Stage (Horizon 4)	**Strategic Aspects**	**Tactical Aspects**	**Is it Defined?**	**Is it Implemented?**	**Does it Work? What Results Are Achieved?**
1. Supplier Identification	1.1. Is there sufficient diversification to avoid dependency on single suppliers?	1.1.1. Are AI tools used to ensure reliable data in identifying sustainable suppliers? 1.1.2. What is the reduction rate of suppliers per item or service due to the introduction of sustainable sourcing requirements (e.g., certifications, regulatory compliance)? Has this been analyzed? Is it considered acceptable? If not, what actions have been taken? 1.1.3. What is the increase rate of single-source suppliers due to the introduction of sustainable sourcing requirements?			
2. Onboarding New Suppliers	2.1. Are ESG risks assessed for new suppliers? 2.2. To what extent does the company support the development of alternative suppliers that, despite being competitive in quality and price, are disqualified due to sustainable sourcing requirements? 2.3. Does the company have visibility into the impact on SMEs caused by sustainable sourcing requirements?	2.2.1. Is there a risk mapping of critical secondary supply chains (key suppliers of my suppliers)? 2.3.1. Are action plans in place to mitigate the impact on affected SMEs? What is the on-time compliance rate of the milestones in these plans?			
3. Category Strategy Development	3.1. Have sustainability objectives been integrated into the category strategy? 3.2. Is it clear how the category strategy changed due to sustainable sourcing requirements?	3.1.1. Are specific metrics used to assess sustainable impact within the category? 3.2.1. Are the KPIs that worsen due to sustainability requirements but remain clearly acceptable identified (e.g., lower savings rate or increased payment terms)?			

Considerations			Evaluation		
Procurement Cycle Stage (Horizon 4)	**Strategic Aspects**	**Tactical Aspects**	**Is it Defined?**	**Is it Implemented?**	**Does it Work? What Results Are Achieved?**
4. Cost Modeling	4.1. How are sustainable costs balanced with strategic benefits?	44.1.1. Are additional costs from sustainable suppliers adequately modeled? 4.1.2. How does the introduction of sustainable sourcing requirements affect the "should cost" or "could cost" analysis?			
5. Spend Analysis	5.1. Does the analysis include a financial risk assessment related to sustainability?	5.1.1. Are automated analytics tools in place that incorporate sustainability parameters?			
6. Request for Quotations (RFQ)	6.1. Is the sustainable approach clearly communicated in the evaluation criteria?	6.1.1. Have RFQs been automated to reduce errors and processing times? 6.1.2. Is supplier alignment with the company's strategic sustainability priorities assessed?			
7. Supplier Negotiations	7.1. Are long-term commitments with sustainable suppliers considered?	7.1.1. Are data from Sustainable Development Indicators (SDIs) used to support negotiations?			
8. Contract Management	8.1. Do contracts include sustainability clauses with clear metrics?	8.1.1. Are SDIs used to analyze implicit risks in contracts?			
9. Purchase Order Management	9.1. Is the system configured to prioritize certified sustainable suppliers?	9.1.1. Does order processing include sustainability compliance validations?			
10. Catalog Management	10.1. Are available products and services aligned with sustainability goals?	10.1.1. Are catalogs automatically updated with certified sustainable products? 10.1.2. Are mechanisms in place to detect purchases that do not adhere to the catalog? 10.1.3. Are audit mechanisms implemented to verify catalog accuracy and updates (e.g., outdated prices)?			
11. Third-Party Risk Monitoring	11.1. Are sustainability-related risks assessed for selected suppliers?	11.1.1. Is advanced technology used to monitor ESG performance in real time? 11.1.2. Is technology used to monitor media in real time for brand reputation and "greenwashing" risks?			
12. Fraud Detection	12.1. Has the potential for ethical risks among sustainable suppliers been assessed?	12.1.1. Are fraud detection tools configured to mitigate sustainability-specific risks?			
13. Supplier Payments	13.1. Have payment policies been implemented to incentivize sustainable practices?	13.1.1. Are processes automated to ensure accurate and timely payments to sustainable suppliers?			
14. Sourcing Optimization	14.1. Are dynamic strategies used to align costs and sustainability?	14.1.1. Is digital platform usage optimized to reduce errors and processing times?			
15. Reverse E-Auctions	15.1. Is the participation of sustainable suppliers ensured without compromising competitiveness?	15.1.1. Are offers automatically validated to meet ESG criteria? 15.1.2. Is sustainability given specific weight in scoring and evaluation matrices?			
16. Post-Implementation Analysis	16.1. Is the sustainable impact of decisions measured across each phase of the procurement cycle?	16.1.1. Are analytics tools used to identify areas for sustainability improvements?			

Sources, authors own elaboration

Table 6 presents a framework to assess the maturity of sustainable procurement practices by examining whether key risk mitigation strategies are defined, implemented, and effective. The checklist covers areas such as supplier identification, onboarding, spend analysis, contract management, and risk monitoring.

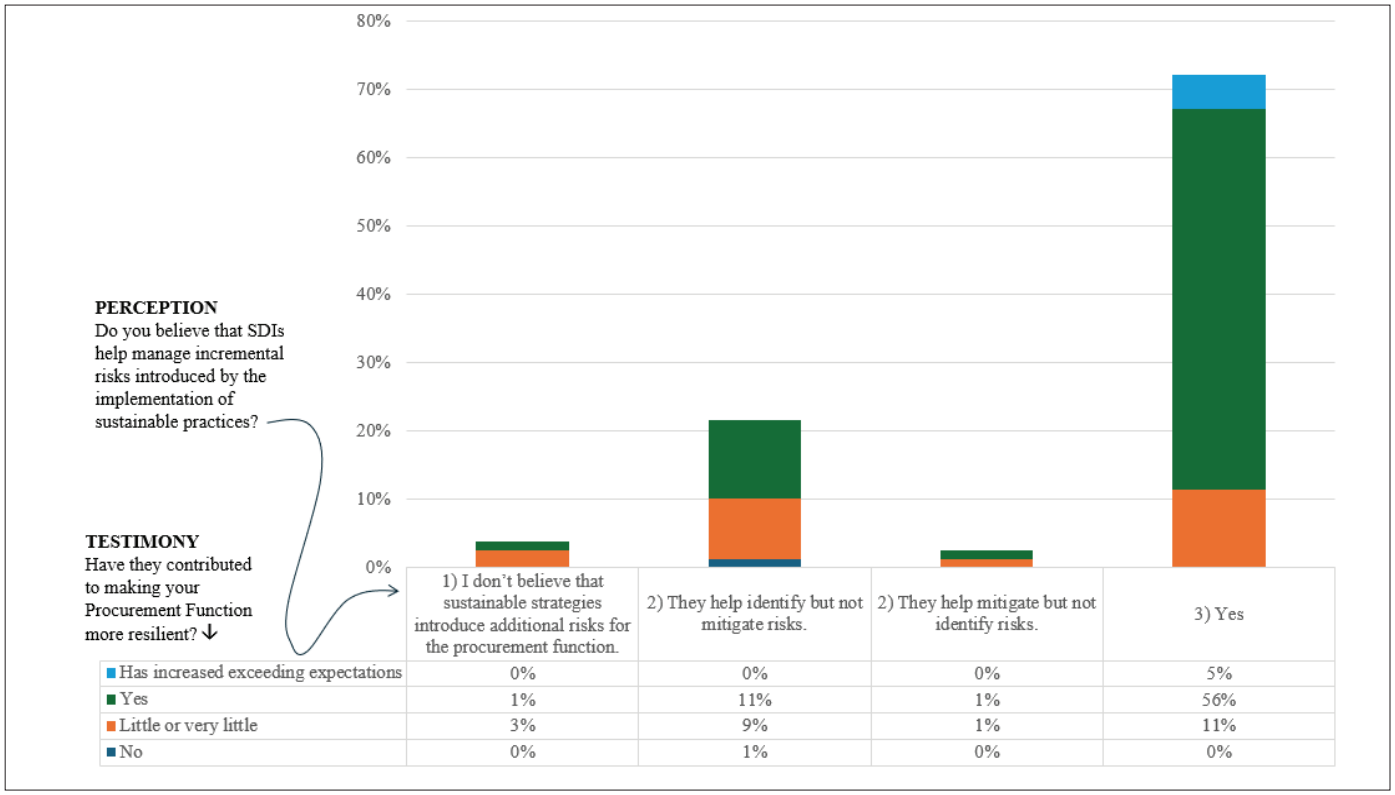
Key Takeaways from the Checklist:

- Helps procurement teams assess sustainability practices and identify improvement areas.
- The columns "Is it Defined?," "Is it Implemented?," and "Does it Work?" serve as a maturity evaluation framework.
- Organizations can track progress over time and benchmark against industry standards.

4.2 Subjective Perception of SDTs

Survey findings reveal that 100% of respondents acknowledge the existence of incremental risks in sustainable sourcing. Among them, 68% report that SDTs improve procurement resilience (Figure 3).

Figure 3. Perceived Effectiveness of SDTs in Risk Management and Procurement Resilience



Source, data tabulation from survey

Furthermore, 98% believe SDTs enhance effectiveness, though 42% consider the impact minimal. Likewise, 99% recognize efficiency gains, but 24% perceive them as marginal.

4.3 Awareness and Adoption of Smart Digitalization Technologies

Respondents rated their awareness of SDTs across different procurement phases on a scale of 1 (not aware) to 5 (fully implemented). The average awareness score is 2.9, indicating general recognition but limited active implementation (Table 7).

Table 7. Awareness Levels of SDTs Across Procurement Phases

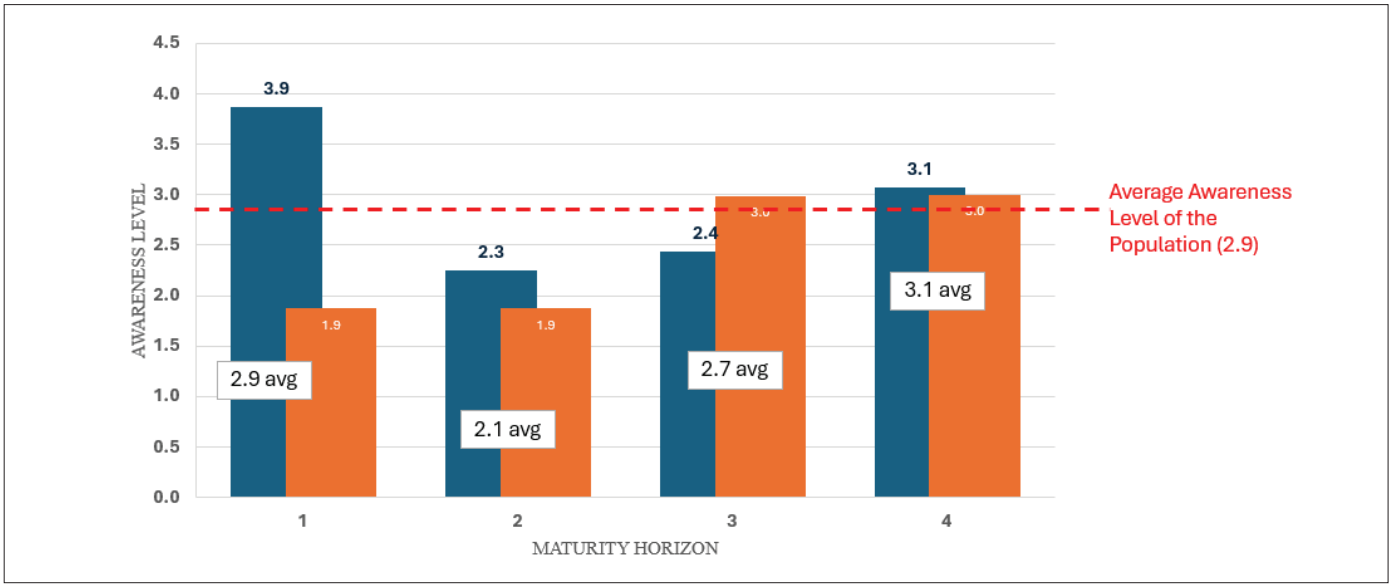
	I am not aware		I know something exists		I am / We are exploring options		Ongoing implementation		Implemented		Awareness
Supplier discovery	13%	15	34%	40	27%	32	17%	20	10%	12	**2.8**
Supplier onboarding	13%	15	28%	33	16%	19	13%	16	30%	36	**3.2**
Spend analytics	6%	7	29%	34	18%	21	13%	16	34%	41	**3.4**
Should Cost / Could Cost Modeling	18%	22	33%	39	24%	28	13%	15	13%	15	**2.7**
Scope of work elaboration assistance	29%	35	22%	26	18%	21	12%	14	19%	23	**2.7**
Bids analysis assistance	13%	15	23%	27	27%	32	11%	13	27%	32	**3.2**
Negotiation strategies analysis	20%	24	28%	33	21%	25	13%	15	18%	22	**2.8**
Legal assistance	28%	33	25%	30	15%	18	8%	9	24%	29	**2.8**
Average awareness	**17%**		**28%**		**21%**		**12%**		**22%**		**2.9**
Status	**1**		**2**		**3**		**4**		**5**		

Source, data tabulation from survey

A breakdown of awareness levels reveals three key insights (Figure 4):

- Professionals with 15+ years of experience report the highest awareness (3.0).
- Procurement functions with lower maturity (Horizons 1 and 2) exhibit below-average awareness (2.9).
- 69% of respondents report organizational intent to implement SDTs, with 97% of these professionals working in higher-maturity procurement functions (Horizons 3 and 4).

Figure 4. Awareness of SDTs by Experience Level and Procurement Maturity



Source, data tabulation from survey

4.4 Interview Findings Table

Table 8. Thematic Summary of Key Findings from Interviews with SDT Providers

Theme	Supporting Quote	Representative Company
ESG Risk Tracking	Our clients increasingly rely on automated ESG scoring to prioritize supplier relationships.	EcoVadis
Automation Limits	In crisis situations, humans still outperform AI in critical procurement decisions.	TechConnect
Data Dependency	Incomplete data has led to false positives in risk detection.	Fairmarkit
Supply Chain Visibility	"Clients demand insights not only into their suppliers, but also their suppliers' suppliers."	Thomson Reuters

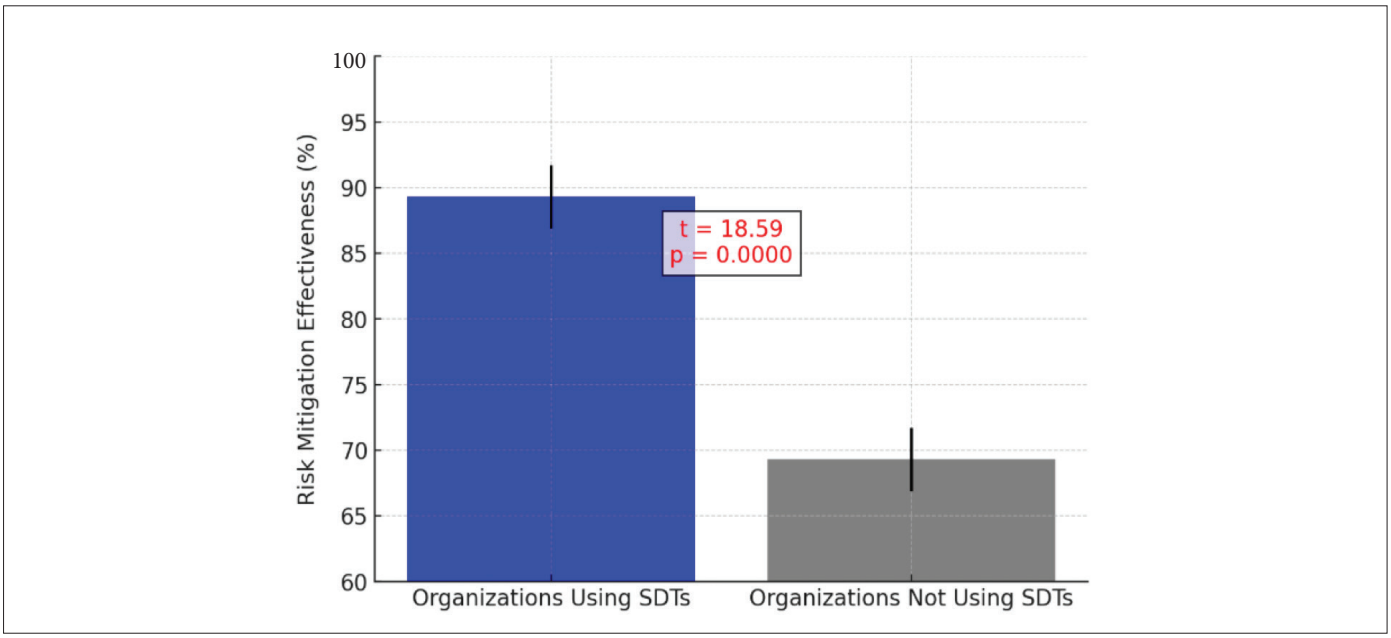
Source, data tabulation from interview

Concrete examples from interviews illustrate these risks. One expert noted that a multinational food supplier faced months of delay because local sourcing regulations required suppliers in Eastern Europe to comply with ESG reporting, which few could satisfy. Another example involved a company in the apparel industry that faced greenwashing accusations after choosing a vendor certified by an outdated sustainability standard (Table 8).

4.5 Correlation Between SDT Adoption and Risk Mitigation

A Student's T-test was conducted to assess whether SDT adoption significantly reduces incremental risks in sustainable sourcing. Results indicate a statistically significant difference in risk reduction among organizations that implement SDTs ($t = 18.59$, $p < 0.05$), supporting the hypothesis that SDTs positively impact procurement risk management (Figure 5).

Figure 5. Hypothesis Testing Results: SDT Adoption and Risk Mitigation



Source, data tabulation from survey

Annotated results confirm that organizations integrating digital risk assessment tools, AI-driven supplier monitoring, and real-time data analytics experience fewer disruptions in sustainable sourcing projects. These findings reinforce the potential of SDTs to enhance risk resilience and procurement efficiency.

5. Results discussion

5.1 Validation of the Hypothesis and Consensus on SDT Contribution

The research findings reveal a unanimous agreement among respondents that SDT contribute to managing the incremental risks associated with the implementation of sustainable sourcing practices. Given the absence of variability in responses, the proposed statistical analysis method (Student's t-test) was rendered inapplicable, leading to the conclusion that the hypothesis is validated by consensus. This establishes a sturdy foundation for further exploring the mechanisms and extent of SDT's impact on procurement functions.

5.2 Triangulation with SDT Provider Insights

To complement the survey findings, 17 in-depth interviews were conducted with senior representatives from leading SDT providers, including EcoVadis, Thomson Reuters, Fairmarkit, and TechConnect. Their insights confirmed that implementing sustainable sourcing practices can inadvertently introduce new risks, such as data dependency biases, unexpected cost escalations, secondary supply chain vulnerabilities, automation errors, and operational distractions due to compliance complexities. These findings not only align with existing literature but also contribute novel perspectives by identifying risks that were previously undocumented.

The surveyed population represents procurement functions within maturity Horizons 2, 3, and 4, as defined by Hallikas (2021). This corroborates prior theoretical discussions, affirming that advanced-stage procurement functions—characterized by data analytics capabilities—are better equipped to leverage SDT for risk mitigation, thereby enhancing supply chain resilience and sustainability (Escobar et al., 2023). The expert insights further reinforce this assertion, highlighting the essential role of SDT in risk identification, process automation, and supplier compliance monitoring. Triangulation of data confirms consistency between quantitative responses and qualitative expert insights. For example, 68% of survey participants reported improved resilience through SDTs, which aligns with interviewees' observations on the role of AI in supplier risk monitoring and early-warning alerts. Likewise, the limited perceived effectiveness in crisis response (reported by 30%) was echoed by experts who admitted that current SDTs struggle under volatile, high-pressure scenarios.

5.3 SDT's Role in Enhancing Operational Effectiveness, Efficiency, and Resilience

While survey responses unanimously acknowledged SDT's role in managing risks associated with sustainable sourcing practices, the degree of effectiveness remained a point of contention. Interview data confirm SDT's significant benefits, such as supplier segmentation, ESG risk assessment, and real-time monitoring of sustainability compliance across primary and secondary supply chains. Respondents also cited enhanced automation capabilities that facilitate corrective action, policy validation, and improved operational data integrity.

Platforms such as EcoVadis, Achilles, and Fairmarkit were specifically noted for their role in aligning procurement decisions with sustainability criteria. Additionally, Thomson Reuters' process standardization tools contributed to greater supply chain visibility and control. However, a notable limitation emerged—while SDT excels in proactive risk management, its effectiveness in crisis management remains limited. Interviewees consistently emphasized that human expertise in critical decision-making and emergency response still surpasses the current capabilities of SDT, indicating that these technologies are still in an evolutionary phase.

5.4 The Dichotomy Between Perceived and Actual Effectiveness

Despite unanimous recognition of SDT's risk management potential, 42% of the surveyed population reported minimal or very minimal contributions to organizational effectiveness, while 24% noted a limited impact on efficiency. Additionally, fewer than 70% of respondents considered SDT effective in mitigating supply chain disruptions. This divergence between perceived effectiveness and practical outcomes underscores key implementation challenges.

Interviews highlighted several factors constraining SDT's impact, including poor data quality, inadequately designed strategies, unrealistic leadership expectations, and insufficient change management initiatives. Consistent with the findings of Virkkala (2020) and Seppäläinen (2024), the research reinforces that SDT adoption is most effective within advanced maturity horizons, where procurement functions possess the requisite infrastructure and strategic alignment to fully leverage these technologies. Premature adoption in less mature procurement environments may expose organizations to unforeseen risks rather than mitigate them.

5.5 Practical Implications and Novel Contributions

The findings of this study present critical implications for both academic and practical domains. First, by identifying previously undocumented risks associated with sustainable sourcing, this research expands the current understanding of risk dynamics in digitalized procurement. Second, it offers empirical evidence on SDT's varying effectiveness, highlighting the need for a strategic, data-driven approach to implementation.

For practitioners, the study underscores the necessity of integrating SDT within a well-structured procurement maturity framework. Organizations must prioritize data accuracy, strategic alignment, and comprehensive change management to optimize SDT deployment. Additionally, while SDT enhances operational efficiency and compliance monitoring, its limitations in crisis response necessitate a hybrid approach that combines automation with human expertise in decision-making.

This research contributes to the ongoing discourse on sustainable procurement by demonstrating that while SDT is a critical enabler of risk mitigation, its impact is contingent upon organizational readiness and strategic execution. These insights provide a roadmap for procurement leaders seeking to balance sustainability objectives with risk resilience in increasingly complex supply chains.

6. Conclusions

This research confirms that SDT play a critical role in identifying and mitigating incremental risks introduced by the implementation of sustainable sourcing practices in procurement functions. The findings demonstrate that SDT positively impact organizational effectiveness, operational efficiency, and resilience. However, their contribution is contingent on several factors, including data quality, strategic implementation, and change management.

One of the key discoveries of this study is the near-universal acknowledgment (100% of relevant respondents) that SDT assist in managing the risks associated with sustainable sourcing. However, the extent of their effectiveness varies. While SDT enables supplier segmentation, ESG risk assessment, deeper visibility into multi-tier supply chains, and proactive identification of single-source dependencies, they are not a panacea for all procurement challenges. The study also reveals that SDT can function as a catalyst for sustainability adoption rather than merely responding to pre-existing sustainability initiatives. This suggests a reversed causality—organizations that integrate SDT effectively tend to strengthen their sustainability efforts as an outcome rather than as a prerequisite.

A significant contribution to this research is the confirmation that SDT adoption aligns with procurement functions at advanced maturity horizons. The findings corroborate previous literature (Hallikas, 2021; Escobar et al., 2023) by demonstrating that organizations with mature procurement capabilities are better positioned to harness SDT for sustainable sourcing. In contrast, premature adoption by less mature functions can lead to inefficiencies, increased exposure to risks, and failed implementation efforts.

Despite their advantages, the study identifies key barriers to the successful implementation of SDT. Poorly managed leadership expectations, unclear strategic objectives, inefficient change management, and the misconception that technology alone can resolve all challenges emerge as critical impediments. Furthermore, while SDT enhance operational efficiency, their effectiveness in managing unpredictable crises—such as black swan events (e.g., the COVID-19 pandemic)—remains limited. This underscores the necessity of human oversight, strategic planning, and adaptive decision-making alongside technological integration.

Another novel insight is the distinction between perceived and actual effectiveness. While 100% of respondents recognize SDT's risk management capabilities, 42% report limited contributions to

organizational effectiveness, and 24% note low contributions to operational efficiency. These discrepancies highlight the importance of aligning SDT implementations with well-defined procurement objectives and ensuring that technological adoption is not merely a superficial compliance measure but a strategic enabler.

The practical implications of this research are substantial. Organizations aiming to implement SDT for sustainable sourcing must prioritize data integrity, strategic foresight, and leadership alignment. Effective adoption requires a clear problem definition, robust change management frameworks, and ongoing evaluation of technological performance. Moreover, firms must recognize that SDT alone do not guarantee risk mitigation; rather, they function as tools that, when deployed within a well-structured procurement strategy, enhance resilience and sustainability.

This study provides a foundational basis for further research on optimizing SDT for sustainable procurement. Future research should explore advanced integration strategies, the role of AI in enhancing SDT capabilities, and the development of best practices to maximize their potential in diverse procurement environments. By addressing these areas, organizations can leverage digitalization to build more resilient, sustainable, and strategically agile supply chains.

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