



ORIGINAL RESEARCH ARTICLE

Modeling the Role of Business Risks, Capital Structure, Liquidity, and Credit Risk in ESG Sustainability with an Emphasis on Smart Control Solutions

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ABSTRACT

This study aimed to model the role of business risks, capital structure, liquidity, and credit risk in ESG sustainability, emphasizing smart control solutions. Given the exploratory nature of the topic, a qualitative approach and thematic analysis were employed. The research population consisted of experts in risk management, finance, corporate governance, and smart technologies, selected through purposive sampling until theoretical saturation was achieved. Ultimately, 16 experts participated in semi-structured interviews. Following full implementation, data were coded and analyzed using Braun and Clarke's six-stage thematic analysis framework. The findings revealed that business risk impacts an organization's ability to achieve environmental, social, and governance goals through market fluctuations, changing customer behavior, intense competition, and environmental uncertainty. Capital structure risk undermines sustainable decision-making and responsible investment via high leverage, capital costs, short-term debt dependence, and funding volatility. Liquidity risk, particularly regarding cash flow shortages, delayed receivables, and income-cost mismatches, threatens ESG policy implementation, while credit risk—characterized by defaults, poor creditworthiness, and delinquent receivables—affects stakeholder relationships and ESG reputation. Thematic analysis demonstrated that these risks possess systemic, synergistic links; management weaknesses in one area inevitably impact others. Conversely, intelligent control solutions based on artificial intelligence, machine learning, real-time data analysis, management dashboards, predictive algorithms, and early warning systems offer significant potential for improving risk monitoring and forecasting. Accordingly, the proposed conceptual model emphasizes the necessity of integrating financial risk management and ESG within a robust, data-driven, and intelligent governance framework to ensure long-term organizational sustainability. ©authors

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Introduction

In recent years, ESG sustainability has become a primary criterion for evaluating enterprises and financial institutions (Fabozzi, 2025). However, achieving true sustainability requires more than superficial compliance; it demands the intelligent identification, monitoring, and control of both financial and non-financial risks (Zervoudi et al, 2026). Business risks, capital structure, liquidity, and credit risk are decisive factors in balancing profitability and long-term resilience (Khardmand et al., 2025).

Business risks, driven by market changes, customer behavior, and technological uncertainty, are deeply intertwined with ESG dimensions. Climate change and social boycotts are now commercial risks that define sustainability (Mohaghegh et al., 2025; Issah et al, 2025). Companies that leverage ESG to reduce risk gain a competitive advantage, such as firms that successfully reduce energy consumption (Karimizadeh et al., 2025). Capital structure also dictates this path; while high leverage often forces short-term, unsustainable decisions, a balanced structure allows for long-term commitment (Mohseni et al., 2025). Properly managed debt, such as green bonds or sustainable loans, can align financial resources with ESG goals, whereas misuse of debt reduces ESG credibility (Hazrati et al., 2025).

Liquidity and credit risks further complicate this landscape. Weak liquidity prevents the necessary funding for green technology and pollution reduction (Hassan Nejad Nisi et al., 2025). Effective liquidity management, including cash flow forecasting and contingency reserves, is essential to maintain ESG commitments during crises (Bhattacharya et al., 2023). Simultaneously, credit risk—arising from defaults and delinquent receivables—depletes the resources needed for sustainability programs (Freivar Tanha et al., 2024).

In the context of digital transformation, “smart control”—utilizing AI, machine learning, big data, and predictive algorithms—enables real-time monitoring and rapid response to these complex risks. Smart systems can analyze market patterns to identify business risks earlier (Khodabakhsh et al., 2025; Bogdan et al, 2025), simulate financing scenarios to optimize capital structure (Mohseni et al., 2025), and forecast liquidity needs with precision (Khanpour Ali Kalayeh et al., 2025). By enabling integrated, data-driven decision-making, smart control transforms risk management into a tool for ESG advancement (Freivar Tanha et al., 2024; Antonius, 2026).

Given the critical need to integrate these digital tools into risk frameworks, this study aims to answer the following research question: How can a data-driven and intelligent control framework be modeled to optimize the impact of business risks, capital structure, liquidity, and credit risk on the ESG sustainability of organizations?

Literature Review

ESG sustainability achieves its conceptual maturity when an enterprise simultaneously pursues three strategic pillars: profitable continuity, mitigation of socio-environmental externalities, and transparent governance. While many organizations perceive ESG merely through the lens of compliance reporting or carbon footprint reduction, the qualitative essence of sustainability is fundamentally anchored in the management of core financial and operational risks (Zhou et al., 2025). Commercial instability, imbalanced capital structures, liquidity constraints, or high credit risks can jeopardize even the most robust social programs. Consequently, these financial risks must be viewed as the structural foundation of ESG, rather than peripheral issues (Adebayo et al., 2025). High business risk, in particular, can degrade ESG from a strategic priority to a marginal activity (Dimitrova et al., 2024).

However, business risk also acts as a catalyst for business model innovation. Contemporary market pressures—ranging from consumer sensitivity regarding product origins to investor preferences for climate-resilient firms—are increasingly ESG-centric. Organizations that analyze business risks through a sustainability lens can unlock new opportunities, such as resource efficiency and responsible supply chain design, which simultaneously mitigate risk

and enhance ESG standing (Gais et al., 2025). Although upgrading safety systems and digitalizing controls incur short-term costs, they significantly reduce “hidden” long-term liabilities (Ge et al., 2025). Within this framework, the capital structure serves as a strategic lever; while over-reliance on equity increases financing costs, excessive debt escalates insolvency risks (Haseeb et al., 2025). By linking interest rates to ESG benchmarks—such as energy reduction or board diversity—capital structure transcends accounting and becomes a tool for strategic guidance (Khan et al., 2025; Satriyono, 2025; Haque et al., 2026).

Liquidity remains the operational backbone of sustainability. An organization with illiquid assets may appear profitable but will fail to meet daily obligations to employees and suppliers, directly damaging the “Social” and “Governance” dimensions of ESG (Ongan et al., 2025). Adequate liquidity grants firms the “resilience buffer” needed to maintain ESG commitments during economic downturns, preventing reactive decisions like mass layoffs or environmental standard rollbacks (Liu et al., 2025; Quintiliani, 2025). Conversely, excess liquidity without productive ESG reinvestment signals inefficiency (Bhattacharya et al., 2023; Lu et al., 2024). Similarly, credit risk management is no longer just about receivables; it involves auditing the ESG profiles of business partners. High-pollution or non-transparent partners represent future credit liabilities due to potential regulatory fines or brand boycotts (Sardar et al., 2025; Ozkan et al., 2024; Salem, 2026). Integrating ESG into credit assessments not only secures the lender’s position but stabilizes the broader economy (Wang et al., 2024).

The novelty of this study lies in developing an integrated conceptual framework that simultaneously examines the effects of business risk, capital structure, liquidity, and credit risk on ESG sustainability while explicitly incorporating smart control solutions as a strategic mechanism for enhancing risk management effectiveness. Unlike existing ESG and financial risk management frameworks, which typically investigate these financial dimensions independently or focus primarily on conventional governance mechanisms, the proposed model adopts a holistic perspective by linking multiple financial risk factors with intelligent digital control capabilities. This integration provides a more comprehensive explanation of how organizations can strengthen ESG sustainability through data-driven monitoring, predictive risk assessment, and smart decision-support systems. Accordingly, the proposed framework extends the current literature by bridging the gap between financial risk management, ESG sustainability, and digital transformation, offering both theoretical advancement and practical guidance for organizations operating in increasingly technology-driven business environments.

Empirical Background

Empirical studies have further clarified these relationships. Karimizadeh (2025) demonstrated a significant negative correlation between ESG performance and the cost of capital, particularly in polluting industries, suggesting that sustainability directly influences market returns. Internationally, Cuonca et al. (2026) found that social disclosure significantly reduces non-performing loans (NPLs) in European banks, enhancing financial stability. Chen and Chang (2025) utilized Panel ARDL models to show that while environmental investments impact credit risk in the short term, corporate governance remains the key long-term driver of stability. Sahu et al. (2025) identified a “chain mediation” effect, where ESG improves financial performance and debt costs, thereby reducing default risks—a finding particularly evident during the COVID-19 recovery. However, Klymenko and Romanyuk (2025) offered a cautionary note, observing that post-2020, investors in certain markets (especially the US) have begun perceiving high ESG spending as a potential credit risk factor, indicating a shift in market sentiment.

Despite the growing body of literature, a significant knowledge gap exists regarding the integration of “Smart Control” mechanisms (AI, Big Data, and real-time monitoring) into the multifaceted relationship between financial risks and ESG. Most existing studies (e.g.,

Chen & Chang, 2025; Sahu et al., 2025; Kiss et al., 2025) focus on retrospective data and linear correlations. There is a lack of a comprehensive model that explains how digital transformation and intelligent systems can dynamically manage the synergistic links between business, liquidity, and credit risks to protect ESG integrity.

This research is necessary to bridge this gap by proposing an intelligent governance framework that moves beyond static reporting. By modeling these risks within a smart control environment, this study provides a roadmap for enterprises to transform traditional financial vulnerabilities into data-driven sustainability strengths, ensuring that ESG remains resilient even in volatile digital-first economies.

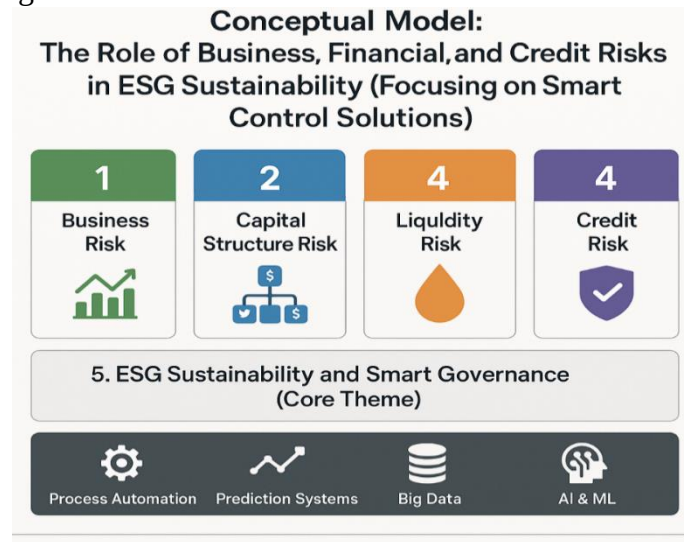


Figure 1. Basic model

The rapid advancement of digital transformation has fundamentally reshaped the way organizations identify, monitor, and manage financial risks. Smart control solutions based on artificial intelligence, machine learning, big data analytics, and digital monitoring systems enable firms to detect business, liquidity, capital structure, and credit risks in real time, thereby improving decision quality and strengthening ESG sustainability performance. As stakeholders increasingly demand greater transparency, accountability, and sustainability, integrating intelligent digital control mechanisms with financial risk management has become a strategic necessity rather than merely a technological option. Consequently, organizations that leverage smart digital control systems are better positioned to achieve resilient financial performance while simultaneously meeting environmental, social, and governance objectives.

Despite the growing body of literature on financial risk management and ESG sustainability, existing studies have largely examined business risk, capital structure, liquidity, and credit risk as separate determinants of corporate sustainability. Limited attention has been paid to developing an integrated framework that explains how these financial risk dimensions collectively influence ESG sustainability through the application of smart control technologies and digital transformation. This research addresses this gap by proposing and empirically testing a comprehensive model that incorporates financial risk factors within a digitally enabled control framework, thereby extending the existing literature and providing practical insights for organizations seeking to enhance ESG performance through intelligent monitoring and decision-support systems.

Method

In this study, a qualitative approach using thematic analysis was used to model the role of business risk, capital structure risk, liquidity risk, and credit risk in ESG sustainability with an emphasis on smart control solutions. The statistical population included experts in the fields of risk management, finance, corporate governance, and smart technologies, who were selected using purposive sampling. The criteria for selecting experts included having at least

10 years of relevant executive or research experience, mastery of ESG concepts, and familiarity with new risk management technologies. The sampling process continued until theoretical saturation was reached, and finally 16 experts were selected to conduct semi-structured interviews.

The data collection and analysis process was carried out simultaneously, and after each interview, the data were coded and analyzed. Theoretical saturation was assessed based on the absence of new codes, concepts, and categories in consecutive interviews. In such a way that after the twelfth interview, the number of new codes was minimized, and in the thirteenth to sixteenth interviews, no new concepts or categories that would expand the dimensions of the model or change the relationships between categories were extracted. At this stage, the resulting data were only used to confirm, complete, and enrich the existing categories; therefore, theoretical saturation was achieved in the sixteenth interview, and the sampling and data collection process was terminated.

Research data were collected through in-depth and semi-structured interviews. Interview questions were designed to identify types of business risk, capital structure risk, liquidity risk, and credit risk, how they affect environmental, social, and governance (ESG) dimensions, as well as smart control solutions and digital technologies. Interviews were conducted in person or online and were fully transcribed after recording.

In the data analysis section, thematic analysis method was used in the form of Brown and Clark's six steps. First, initial coding was performed on the raw data and concepts related to ESG risks and dimensions were extracted. Then, similar codes were categorized into sub-themes and finally main themes including "financial and structural risks", "ESG consequences", and "smart technology-based control solutions". Next, using selective coding, the relationships between the explanatory themes and the conceptual model of the research were designed. To increase reliability, the agreement method between coders and continuous review of the analysis process were used to ensure the coherence and validity of the findings.

Findings

In this study, the final sample consisted of 16 experts in the fields of risk management, finance, corporate governance, and smart technologies, who were selected purposively and until theoretical saturation was reached. In terms of demographic characteristics, 62.5 percent of the participants (10 people) were men and 37.5 percent (6 people) were women. In terms of education level, 56.25 percent (9 people) had a PhD in financial management, business management, economics, and industrial engineering, and 43.75 percent (7 people) had a master's degree in related fields. The average work or research experience of the experts was reported to be 14.2 years, ranging from 10 to 22 years. Also, in terms of job position, the sample composition included university faculty members (37.5%), senior managers and senior experts in the financial and banking industry (43.75%), and independent consultants in the field of risk management and new technologies (18.75%). This composition reflects the appropriate diversity in the participants' practical and scientific experience and has provided the opportunity to achieve comprehensive and multidimensional perspectives in analyzing the phenomenon under study. The interview protocol is also as follows:

1. In your opinion, what are the most important business risks that affect the sustainable performance of companies?
2. How can business risks affect the achievement of environmental, social and governance (ESG) goals?
3. What role does capital structure play in increasing or decreasing a company's ability to achieve ESG sustainability?
4. What features of capital structure make a company more resilient to financial risks?
5. How can adequate liquidity support the implementation of ESG-related programs?

6. What do you consider to be the most important factors that create liquidity risk in organizations?
7. How does credit risk affect a company's investment in sustainable activities?
8. What indicators do you consider to be most appropriate for assessing credit risk in companies?
9. What do you think is the relationship between business risk, capital structure, liquidity and credit risk?
10. Which of these factors has the greatest impact on ESG sustainability and why?
11. How do you define smart control solutions and what features should they have?
12. How can smart technologies such as artificial intelligence, big data, and machine learning improve financial risk management?
13. How do you assess the role of smart systems in predicting credit and liquidity risks?
14. What digital tools or smart systems can help improve ESG performance?
15. What are the most important barriers to implementing smart controls in corporate risk management?
16. What organizational or managerial factors facilitate the successful implementation of smart controls?
17. What indicators do you suggest for assessing the effectiveness of smart controls in risk management?
18. How do you think managers can balance profitability, risk management, and ESG objectives?
19. If you were to design a comprehensive model for the relationship between business risks, capital structure, liquidity, credit risk, and ESG sustainability, what components would you include in it?
20. Is there another important factor or variable that you think should be included in the final research model but was not mentioned in these questions?

The qualitative data were analyzed using a systematic thematic analysis procedure consisting of familiarization with the interview transcripts, initial open coding, code refinement, category development, and theme generation. Initially, each interview transcript was reviewed several times to ensure a comprehensive understanding of the participants' perspectives. Meaningful statements related to business risks, capital structure, liquidity, credit risk, ESG sustainability, and smart control solutions were assigned initial codes. Similar codes were subsequently grouped into higher-order categories and refined through iterative comparisons until coherent themes emerged. To enhance methodological rigor, two independent researchers coded the interview transcripts separately. The coding results were then compared, and disagreements were resolved through discussion until consensus was achieved. Inter-coder agreement exceeded 85%, indicating a high level of coding consistency. In addition, the trustworthiness of the findings was established using Lincoln and Guba's (1985) criteria, including credibility through member checking, dependability through maintaining an audit trail of coding decisions, confirmability through peer debriefing and documentation of analytical procedures, and transferability through providing detailed descriptions of the research context and participants. Table 1 shows an example of extracted codes:

Table 1. Example of extracted codes

Interview text	Extracted code
Severe market fluctuations have increased companies' business risk	Market volatility, increased business risk
Exchange rate changes have made financial planning difficult	Foreign exchange risk in financial planning
Lack of liquidity reduces ability to pay obligations	Liquidity constraints
Unbalanced capital structure increases financing costs	Capital structure imbalance
Lack of financial transparency increases credit risk	Reduced transparency → increased credit risk
Using smart data is effective in risk management	Use of smart data in risk
Non-transparent decisions undermine ESG	Weak ESG transparency
Competitive pressure has made it more difficult for new companies to enter	Intensity of market competition
Reliance on short-term debt increases liquidity risk	Dependence on short-term debt
Weak credit rating system leads to default	Weak creditworthiness
Artificial intelligence technologies increase the accuracy of risk analysis	The role of AI in risk analysis

Interview text	Extracted code
Changes in banking regulations affect capital structure	Regulatory risk
Delays in collecting receivables create liquidity risk	Delay in receivables
Lack of an integrated data system makes decision-making difficult	Lack of data integrity
Companies take a reactive approach to ESG risk management	Reactive approach to ESG
Increasing financing costs put pressure on capital structure	Pressure on the cost of financing
Credit risk in companies Small is more	SME credit risk
Unpredictable market makes planning difficult	Lack of market forecasting
Lack of smart tools hinders risk control	Lack of smart tools
Low quality of financial reporting increases credit risk	Weak financial reporting
Monetary policy changes affect liquidity	Effect of monetary policy on liquidity
Companies need real-time data to manage risk	Need for real-time data
Weak corporate governance exacerbates ESG risk	Weak corporate governance
Increasing foreign currency debt increases capital structure risk	Foreign exchange debt risk
Lack of accurate forecasting models causes wrong decision-making	Weak forecasting model
Digitalization of processes improves risk management	The role of digitalization
Lack of sufficient training in ESG causes management errors	Lack of ESG training
External risks cannot be controlled but can be predicted	Uncontrollable external risk
Lack of coordination between organizational units increases risk	Lack of organizational coordination
Shareholder pressure on financial performance changes risk appetite	Stakeholder pressure
Lack of working capital causes liquidity crisis	Working capital crisis
Increasing interest rates increase the cost of financing	Interest rate impact
Lack of early warning system increases risk	Lack of early warning
Using machine learning algorithms in Risk control is effective	ML in risk control
Weakness in financial scenario analysis limits decision-making	Weak scenario analysis
ESG risk affects company value in the long term	Long-term impact of ESG
Lack of ESG reporting unit standards is problematic	Lack of ESG standards
Dependence on external suppliers creates operational risk	Supply chain risk
Changing customer behavior affects business risk	Behavior change Client
Lack of transparency in liabilities increases credit risk	Lack of debt transparency
Use of management dashboards speeds up decision-making	Usage of management dashboard
External economic crises have a negative impact on liquidity	Effect of external crisis
Weakness in internal control increases financial risk	Weak internal control
Lack of sufficient historical data makes risk modeling difficult	Lack of historical data
Companies are moving towards predictive risk management	Predictive risk management
Lack of integration between ESG and finance creates problems	Lack of ESG-financial integration
Increasing cost of capital reduces investment	Reduction in investment
Systematic risks cannot be eliminated	Systematic risk
Using blockchain technology increases financial transparency	Role of blockchain in transparency
Lack of risk culture in the organization weakens decision-making	Weak risk culture

In the table provided, the frequency of concepts and themes is determined based on the number of times they were conceptualized from the expert interviews, and all extracted themes were raised and conceptualized by the participants at least more than twice. Therefore, the inclusion of each theme in the research model was not based solely on a single comment, but rather on repetition and confirmation in the qualitative data. Given that the aim of the present study is to identify and explain themes within the framework of thematic analysis and not to rank or prioritize factors, the use of an agreement coefficient to determine the relative importance of factors was not deemed necessary.

In this research, due to the exploratory nature of the study, a qualitative approach and thematic analysis method were used to model the role of business risks, capital structure, liquidity and credit risk in ESG sustainability. In the first stage, semi-structured interviews were conducted with experts in the fields of finance, risk management, corporate governance and smart technologies, and the resulting textual data were examined line by line. In this stage, initial coding was carried out and key concepts related to each type of risk, such as “market volatility”, “liquidity pressure”, “imbalanced capital structure” and “credit weakness”, were extracted. This stage led to the identification of a wide range of raw and initial concepts, which became the basis for subsequent analyses. In the second stage, the initial codes were reviewed and merged using a continuous comparison approach to organize similar codes into core codes or conceptual categories. In this process, semantic links between codes were revealed; For example, codes related to “market volatility” and “customer behavior change” were grouped under “environmental and business risks,” while concepts such as “liquidity shortage” and “dependence on short-term debt” were grouped under “structural liquidity risk.” In addition, the role of smart technologies as an intervention axis in controlling and

reducing the severity of risks was identified, indicating the importance of the technological dimension in ESG modeling. In the third step, by combining and interpreting the axis codes, sub-themes were extracted, each representing an important dimension of the phenomenon under study; including “macro-business risks,” “*financial structure instability*,” “*liquidity vulnerability*,” and “deficits in credit assessment.” These themes were then combined at a higher level, leading to the formation of constructive themes and ultimately overarching themes. Finally, the data analysis led to the development of a coherent thematic framework, which was presented in the form of a final table of themes, and presented the relationships between the four risks and ESG sustainability, along with the role of smart control solutions, in a structured manner.

Table 2. Final coding of the role of business risks, capital structure, liquidity and credit risk in ESG sustainability with an emphasis on smart control solutions

Overarching Theme	Constructive themes	Basic Theme
Business Risk	Market volatility and competitiveness	Changing Customer Demand
		Intensity of Industry Competition
		Entry of New Players
		Change in Business Model
	Business environment uncertainty	Regulatory Changes
		Economic Instability
		Sanctions
		Geopolitical Risks
	Smart business risk control solutions	Market Data Analysis with AI
		Demand Forecasting Systems
		Smart Decision-Making Dashboards
		Scenario Analysis
Capital Structure Risk	Inappropriate debt and equity mix	High Financial Leverage
		Cost of Capital
		Reliance on Short-Term Debt
		Financial Imbalance
	Financing volatility	Limited Access to Financial Resources
		Interest Rate Changes
		Decrease in Company Creditworthiness
		Fluctuations in Capital Flow
	Smart capital structure control	Capital Structure Optimization Algorithms
		Financial Risk Forecasting Models
		Digital Financial Scenario Analysis
		Intelligent Debt Management Systems
Liquidity Risk	Inability to meet short-term obligations	Cash Flow Shortage
		Delays in Receivables Collection
		Increase in Current Debt
		Operating Cash Pressure
	Cash flow management	Weakness in Cash Planning
		Cash Inflow and Outflow Fluctuations
		Income and Expense Mismatch
		Reliance on Short-Term Facilities
	Smart liquidity management solutions	Cash Flow Forecasting with AI
		Liquidity Alert Systems
		Analysis Real-time finance
		Treasury automation
Credit Risk	Default and non-repayment	Increasing customer defaults
		Weak creditworthiness
		Increasing outstanding receivables
		Risk of debtor insolvency
	Weakness of the credit rating system	Lack of accurate risk assessment models
		Incomplete customer information
		Weak credit data
		Failure to update credit rating
	Smart credit risk control	AI-based creditworthiness
		Machine learning models
		Customer behavior analysis
		Dynamic credit scoring systems
ESG Sustainability and Smart Governance	Environmental, social and governance performance	Emission reduction
		Social responsibility
		Governance transparency
		ESG compliance
	Risk integration and sustainability	Financial risk alignment with ESG
		Sustainable risk management
		ESG reporting

Overarching Theme	Constructive themes	Basic Theme
	Data-driven and smart governance	Non-financial impact assessment
		Use of Big Data
		Smart ESG dashboard
		Data-driven decision-making
		Digital monitoring systems

To improve the credibility, transparency, and interpretability of the qualitative findings, representative quotations from interview participants were incorporated throughout the findings section. These quotations provide direct evidence supporting the identified themes and allow readers to evaluate the consistency between the participants' experiences and the researchers' interpretations. To ensure confidentiality, participants were anonymized using identification codes (e.g., P1, P2, P3), and only quotations that clearly represented the underlying concepts were selected. The inclusion of verbatim quotations strengthens the authenticity of the thematic analysis and demonstrates how the extracted themes emerged directly from the participants' narratives. Based on the findings and identified codes, the following model is proposed:



Figure 2. Modeling the role of business risks, capital structure, liquidity and credit risk in ESG sustainability with an emphasis on smart control solutions

In the validation section of the present qualitative research findings, a set of accepted criteria in the thematic analysis methodology literature was used to ensure the reliability and trustworthiness of the results. First, the validity was strengthened through continuous data review, rereading of interviews and matching of codes with actual statements of experts. Also, the use of participants with practical and academic experience in the field of risk management and ESG ensured that the data had sufficient depth and richness and that the interpretations were based on professional realities.

Next, transferability was strengthened by providing a rich description of the research context, sample characteristics and coding process; in a way that allows the results to be used in other similar industries such as banking and investment firms. On the other hand, reliability or consistency was ensured by fully documenting the thematic analysis steps, including initial coding, code classification and extraction of sub-themes and overarching themes. In addition, confirmability was strengthened by relying on direct interview data and reducing researcher bias through continuous code comparison and the use of systematic analytical logic. Overall, the application of these criteria indicates that the research findings have reliable methodological support and that the results obtained from modeling the four risks in ESG sustainability can be trusted.

Discussion

The proposed model suggests that ESG sustainability is no longer driven solely by traditional financial management practices but increasingly depends on the integration of intelligent control solutions into corporate risk management processes. Conventional risk management frameworks are predominantly reactive, relying on historical financial statements, periodic reporting, and expert judgment to identify and respond to business risks. While these approaches have been effective in relatively stable environments, they are often inadequate for addressing the speed, complexity, and interconnected nature of contemporary financial and sustainability risks. The findings of this study indicate that the incorporation of smart control technologies fundamentally changes this paradigm by transforming risk management from a static monitoring process into a dynamic, data-driven, and predictive decision-making system.

Artificial intelligence plays a central role in this transformation by enabling organizations to recognize hidden patterns among business risks, capital structure decisions, liquidity conditions, and credit risk that may not be observable through conventional statistical analyses. Machine learning algorithms continuously improve their predictive capability as new financial and operational data become available, allowing firms to anticipate potential disruptions before they materialize (Dimitrova et al, 2024). Consequently, managers can implement preventive strategies rather than corrective actions, thereby reducing financial uncertainty while simultaneously improving ESG performance (Haseeb et al, 2025).

Big data analytics further strengthens this capability by integrating structured and unstructured information from multiple internal and external sources, including financial transactions, operational databases, market indicators, stakeholder feedback, regulatory disclosures, environmental reports, and digital communication platforms (Karimzadeh, 2025). Such comprehensive information integration provides a more holistic understanding of organizational risk exposure and enables decision-makers to evaluate financial and sustainability performance simultaneously instead of treating them as separate managerial objectives (Luo et al, 2024).

Predictive analytics represents another important mechanism through which the proposed model extends traditional risk management practices. Instead of estimating future conditions based solely on historical averages or deterministic financial ratios, predictive models continuously evaluate changing market conditions, macroeconomic variables, customer behavior, and organizational performance to estimate future liquidity shortages, credit defaults, operational disruptions, and sustainability-related risks. This forward-looking capability substantially enhances organizational resilience because managers are able to allocate financial resources proactively, optimize capital structure decisions, and maintain adequate liquidity buffers under uncertain economic conditions (Wang et al, 2024).

Moreover, intelligent decision support systems serve as the operational platform through which these advanced analytical capabilities are translated into managerial actions. These systems integrate artificial intelligence, predictive models, and real-time monitoring dashboards to provide managers with timely recommendations regarding financing strategies, risk mitigation alternatives, liquidity management, and ESG investment priorities. Consequently, managerial decisions become more evidence-based, adaptive, and responsive to rapidly changing business environments. Rather than replacing human expertise, intelligent decision support systems augment managerial judgment by processing large volumes of information that exceed human analytical capacity (Zhu et al, 2024; Ongan et al, 2025).

The interaction among business risks, capital structure, liquidity, and credit risk becomes significantly more manageable when supported by intelligent technologies. Business risks can be detected earlier through continuous monitoring systems; capital structure decisions can be optimized using predictive simulations; liquidity risks can be managed through real-

time cash flow forecasting; and credit risk assessment can be improved using artificial intelligence models capable of evaluating borrower behavior beyond traditional financial indicators. This integrated approach enhances financial stability while simultaneously supporting long-term ESG objectives by reducing uncertainty, improving transparency, and strengthening corporate governance.

Overall, the proposed conceptual framework demonstrates that smart control solutions should not be viewed merely as technological tools but as strategic capabilities that reshape the entire philosophy of corporate risk management. Their value lies not only in improving prediction accuracy but also in enabling continuous learning, adaptive governance, faster managerial responses, and stronger alignment between financial performance and ESG sustainability. Therefore, organizations seeking sustainable competitive advantage should consider digital intelligence as a core component of future risk management systems rather than an auxiliary technological investment.

The findings of this study redefine ESG sustainability not as a peripheral ethical obligation, but as a core operational capability that requires an intelligent, data-driven architecture. Our analysis indicates that the traditional, fragmented approach to managing business, capital structure, liquidity, and credit risks is increasingly obsolete in the age of digital transformation. To achieve true ESG resilience, organizations must transition from reactive, manual monitoring to a predictive, “Smart Control” framework that integrates seamlessly with digital ecosystems and virtualized business environments, such as the Metaverse.

The Dynamics of Business Risk in Digital Ecosystems

The study highlights that business risk is a primary disruptor of long-term ESG planning. In the era of digital transformation, this risk is compounded by the volatility of virtual markets and algorithmic competition. When faced with the uncertainty of the Metaverse—where brand reputation is subject to instantaneous, global, and often automated social scrutiny—managers often succumb to “survivalist” biases, neglecting sustainability for short-term cost-cutting. Our analysis suggests that organizations must leverage AI-powered predictive analytics to transform these market uncertainties into actionable insights. By simulating digital demand shifts and supply chain disruptions within virtual twins of their operations, firms can maintain ESG commitments even during periods of extreme volatility, effectively decoupling sustainability from crisis-induced operational paralysis.

Capital Structure and Liquidity: The Role of Digital Optimization

The research identifies capital structure and liquidity as the financial “nervous system” of ESG. Traditional reliance on static financial ratios is insufficient in a digital economy characterized by high-velocity transactions. We argue that smart control solutions—such as AI-driven capital allocation models and blockchain-enabled cash flow transparency—are essential for maintaining an optimal debt-equity mix. In the context of the Metaverse and digital business models, liquidity management must become real-time. Organizations that utilize autonomous predictive algorithms for cash flow forecasting can navigate the thin line between necessary liquidity buffers and unproductive idle capital. This dynamic optimization allows firms to channel resources into sustainable technology investments (e.g., green digital infrastructure) without sacrificing short-term solvency.

Credit Risk and Governance in a Data-Driven Paradigm

Finally, the findings underscore that credit risk management must evolve toward multidimensional, Big Data-driven models. Traditional credit scoring is often backward-looking and fails to capture the “ESG-risk” of business partners in complex digital supply chains. In a world where digital interoperability is the norm, an organization’s creditworthiness is inherently tied to its partner’s ESG data. We propose that organizations adopt AI-based reputational monitoring and sentiment analysis to assess the creditworthiness of suppliers and customers in real-time. By integrating these smart control solutions, credit risk management is transformed from a defensive compliance task into a strategic governance tool that protects the organization’s reputation and ESG integrity.

Toward a Metaverse-Integrated ESG Framework

Ultimately, this research demonstrates that the synergy between financial risk management and ESG sustainability is achievable only through digital-native governance. As organizations expand their footprint into the Metaverse and intensify their digital transformation, they must embed “smart control” directly into their financial core. This necessitates a shift from silos to an integrated data-driven framework where business, capital, liquidity, and credit risks are monitored, simulated, and controlled in real-time. Such a framework not only mitigates the risks identified in this study but also empowers organizations to turn sustainability into a tangible, scalable competitive advantage within the complex digital economy.

The findings of this study are generally consistent with previous research emphasizing the growing role of financial risk management in supporting ESG performance. Similar to earlier studies, the results confirm that effective management of business risks, capital structure, liquidity, and credit risk contributes significantly to organizational sustainability. However, the present study extends existing literature by introducing smart control solutions as an integrating mechanism that connects these financial dimensions with ESG sustainability. While previous studies have primarily examined financial risks independently, the proposed conceptual model highlights the synergistic role of artificial intelligence, predictive analytics, and intelligent governance systems in simultaneously improving financial resilience and sustainability performance. This integrated perspective represents an important theoretical contribution by demonstrating that digital intelligence functions not only as a technological resource but also as a strategic capability for sustainable organizational governance.

Conclusion

The findings of this study indicate that achieving long-term ESG sustainability requires a fundamental transformation in organizational risk management approaches. Rather than relying solely on conventional financial control mechanisms, organizations should integrate digital transformation initiatives with intelligent governance systems capable of continuously monitoring, predicting, and responding to emerging business risks. Artificial intelligence, big data analytics, predictive modeling, and intelligent decision support systems collectively enable organizations to improve transparency, optimize capital structure decisions, strengthen liquidity management, reduce credit risk exposure, and enhance corporate governance practices. Therefore, smart governance should be viewed not merely as a technological innovation but as a strategic organizational capability that aligns financial resilience with environmental, social, and governance objectives. The proposed model demonstrates that digital transformation serves as a key enabler of sustainable value creation by improving organizational adaptability, decision quality, stakeholder confidence, and long-term ESG performance under increasingly uncertain business environments. One of the most important results of the present study is that the four risks examined, namely business risk, capital structure risk, liquidity risk and credit risk, do not operate independently and separately from each other; rather, they affect ESG sustainability in the form of a dynamic, interconnected and synergistic system. Based on the findings, market fluctuations, reduced demand, changing customer behavior, unstable competitive environment and technological developments can weaken the organization's cash flow. Reduced cash flow may also increase the organization's dependence on short-term debt, raise the cost of capital and remove the capital structure from a balanced state. In addition, the financial pressures resulting from this situation can exacerbate credit risk, the possibility of default, reduce stakeholder trust and reduce the organization's ability to invest in environmental, social and governance programs.

From this perspective, ESG sustainability is not a separate concept from financial management, but rather the result of the quality of risk architecture, data-driven governance, and the organization's ability to make smart decisions. Organizations that manage risks in isolation

and solely at the level of financial, operational, or credit units will not be able to fully understand their chain and systemic effects on ESG performance. Therefore, the complexity of today's business environment, especially in the context of digital transformation and the formation of virtual ecosystems such as the metaverse, requires organizations to move beyond traditional and reactive approaches and move towards integrated, predictive, and intelligent risk management frameworks. In the era of digital transformation, organizational risks are not only formed in the physical environment and traditional markets, but are also reproduced in digital spaces, virtual platforms, smart supply chains, data-driven interactions, and even metaverse environments. As an emerging platform for economic, social, and organizational interactions, the metaverse can create opportunities such as improved transparency, decision simulation, virtual learning, value chain monitoring, and closer engagement with stakeholders; but at the same time, it creates new risks in the areas of digital trust, data security, organizational credibility, consumer behavior, digital identity, platform governance, and social responsibility. Therefore, organizations that intend to remain sustainable in the digital economy and metaverse must integrate ESG not only in formal reporting, but also in the design of their digital business model, data policies, capital structure, liquidity management, and credit rating system.

The research findings showed that smart control solutions can play an important role in promoting ESG sustainability. Technologies such as artificial intelligence, machine learning, big data analytics, management dashboards, real-time analytics, early warning systems, treasury automation, smart validation, cash flow forecasting models, and capital structure optimization algorithms are increasing an organization's ability to identify, analyze, and control risks. The main advantage of these technologies is that they move risk management from a retrospective and reactive state to a predictive, proactive, and evidence-based process. This evolution is especially important in the ESG field because many environmental, social, and governance outcomes are not visible in the short term and their effects become apparent over the long term. For example, weaknesses in liquidity management may initially only manifest as delayed payments, but can subsequently lead to reduced investment in clean technologies, decreased employee safety, reduced reporting quality, weakened investor confidence, and a loss of the organization's social legitimacy. In such circumstances, intelligent systems and digital simulations can reveal the financial and non-financial consequences of decisions before a crisis occurs by analyzing different scenarios.

In the metaverse, this capability is also of strategic importance. Organizations can use digital twins, simulated environments, interactive dashboards, and data-driven predictive models to assess the impact of financial and operational decisions on ESG indicators. For example, before implementing a financing policy, changing the supply chain, entering a new market, or investing in digital infrastructure, an organization can simulate its potential consequences on liquidity, debt, credit, carbon emissions, employee satisfaction, governance transparency, and stakeholder trust. This shows that the metaverse and digital transformation technologies are not just communication or marketing tools, but can become an infrastructure for smart governance, sustainable decision-making, and predictive risk control. Despite the importance of smart technologies, the research results showed that the success of implementing these solutions requires the provision of a set of organizational and technological prerequisites. Data quality and integrity, digital maturity, senior management support, evidence-based decision-making culture, human resource training, process transparency, data security, and the existence of appropriate technological infrastructure are among the main conditions for realizing smart risk control. Lack of sufficient historical data, fragmentation of information systems, weak ESG reporting standards, organizational resistance to change, lack of analytical skills, and misalignment between finance, technology, and sustainability units can reduce the effectiveness of smart control.

Therefore, technology alone does not guarantee ESG sustainability. Artificial intelligence, big data, blockchain, digital twins, or metaverse can help improve ESG performance when they

are implemented in the context of data-driven governance, appropriate organizational structure, information transparency, and a culture of accountability. In other words, digital transformation will create value when it is not limited to simply digitizing existing processes, but also transforms decision-making logic, control mechanisms, accountability systems, and risk management practices.

According to the conceptual model of the research, ESG sustainability is strengthened when an organization can establish a link between risk management, financial decision-making, smart governance and digital technologies. This model shows that business risks, capital structure, liquidity and credit affect ESG performance by affecting financial resources, stakeholder trust, decision-making quality, sustainable investment capacity and organizational transparency. In contrast, smart risk control can play a moderating and enabling role and reduce the severity of the negative effects of these risks. From this perspective, smart solutions are not only tools for risk reduction, but also mechanisms for creating sustainable value, increasing resilience, promoting transparency and improving organizational accountability. In summary, it can be concluded that achieving ESG sustainability is not possible without paying attention to the organization's risk architecture and without taking advantage of the capacities of digital transformation. Organizations that view ESG merely as a reporting requirement or a symbol of social responsibility will be vulnerable to financial, technological, credit, and environmental crises. In contrast, organizations that place ESG at the heart of their risk management system, capital structure, liquidity policies, smart creditworthiness, and digital transformation strategy will have a greater capacity for resilience, trust, and long-term value creation.

Therefore, the main achievement of this study is to provide an integrated view of the relationship between financial risks, ESG sustainability, and smart governance in the era of digital transformation. This view shows that the future of sustainable management depends on moving beyond traditional, sectoral, and retrospective approaches and moving toward smart governance, data-driven analytics, predictive risk management, and the strategic use of technologies such as artificial intelligence, big data, digital twins, and the metaverse. In such a framework, ESG will not be an additional cost, but rather part of the organization's overall strategy to reduce vulnerability, increase stakeholder trust, improve financial and non-financial performance, and ensure long-term survival in a complex, competitive, and digital environment.

Recommendations

According to the research results, it is recommended that organizations remove their risk management system from an island state and design an integrated framework for simultaneously managing business risk, capital structure risk, liquidity risk, and credit risk. In this framework, ESG indicators should be placed alongside financial and operational indicators so that organizational decisions are not based solely on short-term profitability and environmental, social, and governance impacts are also included in risk assessment.

Organizations should use intelligent tools such as artificial intelligence, machine learning, big data analytics, management dashboards, and early warning systems to monitor and predict risks. These tools can analyze market trends, customer behavior, cash flows, debt status, customer credit, and environmental changes in real time, enabling early identification of threats and making proactive decisions.

Financial managers need to seriously incorporate ESG sustainability considerations into capital structure design. Reducing reliance on short-term debt, controlling leverage, managing capital costs, and using sustainable financial resources can increase an organization's ability to invest in environmental, social, technological, and governance projects and prevent ESG programs from weakening under financial stress.

Organizations should implement intelligent liquidity management and cash flow forecasting systems. The use of early liquidity warning systems, treasury automation, financial scenario

analysis, and real-time monitoring of cash inflows and outflows can prevent liquidity crises and provide the necessary resources to implement ESG commitments at the right time. It is recommended that companies and financial institutions replace traditional credit models with data-driven, dynamic, and multidimensional models. AI-based credit assessment, customer behavior analysis, continuous credit rating updates, and the use of financial and non-financial data can reduce the risk of default and overdue receivables and strengthen the organization's credibility with stakeholders, banks, and investors. To succeed in intelligent risk control, organizations must strengthen their data infrastructure. Integrating financial, credit, operational, and ESG data, improving data quality, creating a historical database, developing reporting standards, ensuring data security, and increasing information transparency are essential requirements for this path. Without accurate and reliable data, intelligent algorithms cannot provide reliable output for management decision-making. Given the importance of the metaverse and emerging digital environments, it is recommended that organizations use the capacity of digital twins, virtual simulations, and interactive dashboards to assess the effects of financial and operational decisions on ESG indicators. These technologies can help managers see the possible consequences of their decisions before they are implemented and evaluate different scenarios in terms of financial, credit, environmental, social and governance. It is also necessary to strengthen training and culture in the field of ESG risk management, digital transformation and smart technologies at the level of managers and employees. Organizations should develop a culture of data-based decision-making, transparency, accountability and informed risk-taking. Holding training courses, creating interdisciplinary teams consisting of finance, IT, risk management and ESG experts, and senior management support for digital transformation can pave the way for the successful implementation of the smart risk management model and promoting ESG sustainability. Finally, it is recommended that policymakers and supervisory bodies also align ESG reporting standards with the requirements of the digital economy and metaverse environments. As organizations expand their activities in virtual spaces, it is necessary to develop frameworks for measuring data transparency, digital accountability, information security, algorithmic fairness, the environmental footprint of digital technologies, and stakeholder trust. Such an approach can pave the way for organizations to move from demonstrative sustainability to real, intelligent, and measurable sustainability.

Declaration of Competing Interest

The author declares that he has no competing financial interests or known personal relationships that would influence the report presented in this article.

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