REVISTA TÓPICOS
ISSN 2965-6672 | Qualis A2

ESG DIGITAL AS AN OPERATIONAL FRAMEWORK FOR INTEGRATING DIGITAL TRANSFORMATION, SUSTAINABILITY, AND PERFORMANCE

ESG DIGITAL COMO UMA ESTRUTURA OPERACIONAL PARA INTEGRAR TRANSFORMAÇÃO DIGITAL, SUSTENTABILIDADE E DESEMPENHO

Engenharias, Ciências Sociais Aplicadas • 25/07/2026

REGISTRO DOI: 10.70773/revistatopicos/784691740

Priscilla Maria De Luca Zaupa Costa[1]

Giane Gonçalves Lenzi[2]

Angelo Marcelo Tusset[3]

ABSTRACT

Digital transformation and ESG practices have become central to organizational competitiveness, but their integration remains fragmented in production systems. This article proposes ESG Digital as an operational framework for integrating digital technologies, sustainability practices, and performance indicators. Based on an integrative literature review and conceptual framework development, the study organizes ESG Digital into five interdependent dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance. The framework connects these dimensions to measurable indicators and explains how digital technologies can support operational efficiency, socio-environmental performance, stakeholder legitimacy, and adaptive governance. The study contributes to the literature by positioning ESG Digital as an organizational capability grounded in the Resource-Based View, Dynamic Capabilities, and the Triple Bottom Line. Practical implications include guidance for firms seeking to operationalize ESG through data-driven decision-making, especially in emerging economies and organizations with heterogeneous digital maturity.

Keywords: ESG Digital; digital transformation; sustainability; strategic management; performance indicators.

RESUMO

A transformação digital e as práticas ESG tornaram-se centrais para a competitividade organizacional, mas sua integração permanece fragmentada nos sistemas produtivos. Este artigo propõe o ESG Digital como um framework operacional para integrar tecnologias digitais, práticas de sustentabilidade e indicadores de desempenho. A partir de uma revisão integrativa da literatura e do desenvolvimento de um framework conceitual, o estudo organiza o

ESG Digital em cinco dimensões interdependentes: monitoramento em tempo real, otimização preditiva, transparência automatizada, engajamento digital e governança inteligente. O framework conecta essas dimensões a indicadores mensuráveis e explica como as tecnologias digitais podem apoiar a eficiência operacional, o desempenho socioambiental, a legitimidade perante stakeholders e a governança adaptativa. O estudo contribui para a literatura ao posicionar o ESG Digital como uma capacidade organizacional fundamentada na Visão Baseada em Recursos, nas Capacidades Dinâmicas e no Triple Bottom Line. As implicações práticas incluem orientações para empresas que buscam operacionalizar o ESG por meio da tomada de decisão orientada por dados, especialmente em economias emergentes e organizações com maturidade digital heterogênea.
Palavras-chave: ESG Digital; transformação digital; sustentabilidade; gestão estratégica; indicadores de desempenho.

1. INTRODUCTION

Digital transformation has become a structural force reshaping production systems, organizational routines, and value creation processes. Technologies such as artificial intelligence, the Internet of Things, cloud computing, advanced analytics, blockchain, and automation have expanded the capacity of firms to monitor operations, integrate data, improve decision-making, and respond to complex industrial and societal challenges (Schwab, 2016; Kagermann *et al.*, 2013). In this context, these technologies are particularly relevant because they affect process management, operational efficiency, performance measurement, quality control, supply chain coordination, and continuous improvement.

At the same time, Environmental, Social, and Governance (ESG) practices have become central to corporate legitimacy, stakeholder accountability, and long-term competitiveness. ESG has evolved from a financial and disclosure-oriented agenda into a broader managerial approach that affects environmental performance, occupational safety, governance routines, supplier relationships, and organizational resilience. Evidence suggests that firms with stronger sustainability and ESG-related practices tend to present superior organizational performance, lower risk exposure, and greater stakeholder trust (Friede *et al.*, 2015; Eccles *et al.*, 2014; Whelan *et al.*, 2021).

Despite the growing relevance of both digital transformation and ESG, their integration remains fragmented in the literature and in managerial practice. Digital transformation studies frequently emphasize automation, productivity, innovation, and data-driven decision-making, while treating sustainability as a secondary or indirect outcome. Conversely, ESG studies tend to focus on disclosure, compliance, stakeholder engagement, and legitimacy, with limited attention to the digital mechanisms that can operationalize ESG practices within production systems. As a result, there is still a need for frameworks capable of connecting digital technologies, ESG objectives, operational processes, and measurable performance indicators.

This gap is particularly relevant for organizations seeking to integrate digital transformation and sustainability agendas. Effective integration requires the alignment of people, technologies, materials, information, and organizational processes. Therefore, this represents an appropriate analytical domain for examining how digital technologies can transform ESG from a reporting-oriented

practice into an operational capability embedded in process management, performance measurement, risk mitigation, and strategic decision-making.

Recent studies have begun to address the convergence between digitalization and ESG. Puriwat and Tripopsakul (2022) introduced the term DESG from a marketing perspective, emphasizing customer attitudes and brand equity. Wang *et al.* (2023) examined how digital transformation may improve ESG performance in manufacturing contexts. Tan *et al.* (2025) mapped 455 publications on ESG and digitalization, showing the rapid expansion of the field, but also its conceptual fragmentation and the absence of unified theoretical frameworks. Although these contributions are relevant, the literature still lacks an operational framework that systematically connects digital technologies, ESG pillars, performance indicators, and sustainable competitive advantage from a strategic management perspective.

To address this gap, this article proposes ESG Digital as an operational framework for integrating digital transformation, sustainability practices, and performance indicators. ESG Digital is conceptualized as an organizational capability that uses digital technologies to monitor, optimize, automate, engage, and govern ESG-related processes. The proposed framework is structured around five interdependent dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance. These dimensions are connected to measurable indicators and grounded in the Resource-Based View, Dynamic Capabilities Theory, and the Triple Bottom Line.

The research question guiding this study is: how can digital transformation be systematically integrated with ESG practices to support operational performance, sustainability, and long-term competitiveness in organizations? To answer this question, the study adopts a theoretical-conceptual approach based on an integrative literature review and conceptual framework development.

The article contributes to the literature in three main ways. First, it advances the conceptualization of ESG Digital as an operational capability rather than a purely disclosure-oriented or reputational practice. Second, it connects digital technologies to ESG performance through measurable indicators applicable to production systems. Third, it provides a framework that can support organizations, especially in emerging economies and small and medium-sized enterprises, in structuring gradual and data-driven pathways for sustainable digital transformation.

The remainder of the article is organized as follows. Section 2 presents the methodological procedures adopted in the integrative literature review and framework development. Section 3 discusses the theoretical background on digital transformation, ESG, and sustainable competitive advantage. Section 4 presents the conceptualization of ESG Digital. Section 5 introduces the proposed framework and its operational dimensions. Section 6 discusses theoretical and practical implications for organizational and strategic management. Finally, Section 7 presents limitations, future research directions, and concluding remarks.

2. METHODOLOGY

This study adopts a theoretical-conceptual approach to develop an operational framework for integrating digital transformation, ESG practices, and performance indicators. The methodological design was organized into two stages: an integrative literature review and the development of a conceptual framework. This approach is appropriate because the relationship between digital transformation and ESG remains an emerging and fragmented research domain, requiring conceptual clarification and theoretical integration rather than immediate hypothesis testing.

This approach follows established guidelines for integrative literature reviews (Snyder, 2019) and for the development of theoretical-conceptual articles (Jaakkola, 2020), which support the synthesis and theoretical articulation of distinct bodies of knowledge into an original integrative framework.

2.1. Integrative Literature Review

The integrative literature review covered publications from 2010 to 2024, a period that captures the consolidation of Industry 4.0, digital transformation, and ESG as relevant managerial and technological paradigms. The review prioritized peer-reviewed studies and complementary institutional reports when relevant to the conceptual discussion.

The search focused on three interconnected streams: digital transformation, ESG and corporate sustainability, and digital–ESG convergence. The search terms included “digital transformation”, “Industry 4.0”, “artificial intelligence”, “Internet of Things”, “blockchain”, “ESG”, “corporate sustainability”, “digital sustainability”, “DESG”, and “performance indicators”.

Studies were included when they addressed digital transformation, ESG or sustainability, digital–ESG convergence, or theoretical foundations relevant to framework development, such as the Resource-Based View, Dynamic Capabilities Theory, Triple Bottom Line, and Stakeholder Theory. The final set of references comprised 36 sources and was analyzed through thematic synthesis to identify recurring concepts, theoretical gaps, operational mechanisms, and relationships among constructs.

Table 1 summarizes the inclusion and exclusion criteria adopted in the integrative literature review.

Table 1. Inclusion and exclusion criteria for the integrative literature review

Theme	Inclusion criteria	Exclusion criteria
Digital transformation	Studies on Industry 4.0, AI, IoT, blockchain, automation, analytics, and digital strategy in organizational or production contexts.	Purely technical studies without strategic, managerial, or operational implications.
ESG and sustainability	Studies on ESG practices, corporate sustainability, TBL, stakeholder management, governance, legitimacy, and sustainable competitive advantage.	Studies limited to financial-market indicators, investment screening, or compliance without organizational implications.
Digital–ESG convergence	Studies connecting digitalization, sustainability, ESG performance, digital sustainability, DESG, or technology-enabled sustainability management.	Studies addressing only digitalization or only ESG without conceptual or operational links.

Production systems and performance	Studies on operational performance, production systems, supply chains, process management, indicators, and data-driven decision-making.	Studies unrelated to organizational processes, production systems, performance measurement, or managerial decision-making.

Source: The authors.

2.2. Development Of The Conceptual Framework

The conceptual framework was developed through an iterative synthesis process. First, the reviewed literature was examined to identify the main theoretical lenses explaining the relationship between digital transformation, ESG practices, and competitive advantage. Second, the literature was analyzed to identify operational mechanisms through which digital technologies can support ESG practices in production systems. This process resulted in five interdependent dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance.

Third, these dimensions were connected to sustainable competitive advantage according to three analytical criteria: conceptual coherence, operational relevance, and applicability to organizational practice. The framework does not aim to provide a statistically validated model. Instead, it offers a theoretically grounded and operationally oriented structure that can guide future empirical studies, measurement efforts, and implementation across organizations, sectors, and levels of digital maturity.

3. THEORETICAL BACKGROUND

The theoretical foundation of this study is structured around three main pillars that support the proposition of ESG Digital as an operational and strategic construct: (i) the relationship between digital transformation and competitive advantage; (ii) the role of ESG as a driver of sustainable competitiveness; and (iii) the theoretical gap in the integration between digital transformation, ESG practices, and performance measurement in production systems. The convergence of these pillars provides the basis for developing the proposed framework.

3.1. Digital Transformation And Competitive Advantage

Digital transformation goes beyond the mere adoption of technologies. It represents a structural and organizational shift that redefines how firms create value, manage processes, and coordinate decision-making. Technologies such as artificial intelligence, Big Data, the Internet of Things, advanced automation, cloud computing, and blockchain reconfigure production systems and business models by enabling real-time monitoring, process integration, predictive analysis, and data-driven management (Schwab, 2016)

In organizational and operations management contexts, digital transformation is particularly relevant because it affects operational efficiency, quality management, supply chain coordination, maintenance systems, environmental monitoring, and performance measurement. From the perspective of advanced manufacturing, Kagermann *et al.* (2013) argue that Industry 4.0 introduces a new productive logic based on cyber-physical systems that integrate physical and digital environments, enabling real-time optimization, self-configuration, and adaptive control.

However, digital transformation does not automatically generate competitive advantage. Consistent with this view, Kane *et al.* (2019) argue that digital disruption is primarily about people and organizational routines rather than technology adoption itself. Carvalho *et al.* (2021) highlight that the concept still faces relevant challenges, especially regarding its boundaries, operational mechanisms, and implementation pathways. In the Brazilian context, Tortorella and Fettermann (2018) show that the adoption of Industry 4.0 and lean production practices may generate performance gains, but also depends on heterogeneous levels of digital maturity among organizations. These findings reinforce the need for integrative approaches capable of translating digital technologies into operational capabilities.

From a strategic perspective, the Resource-Based View argues that resources may generate sustainable competitive advantage when they are valuable, rare, inimitable, and non-substitutable (Barney, 1991). Dynamic Capabilities Theory complements this perspective by emphasizing the organizational ability to integrate, build, and reconfigure resources in changing environments (Teece *et al.*, 1997). Therefore, the competitive advantage derived from digital transformation does not stem from the isolated adoption of technologies, but from the organizational capability to integrate them into routines, processes, indicators, and decision-making systems. This premise supports the ESG Digital framework proposed in this study.

3.2. ESG as a Driver Of Sustainable Competitive Advantage

The ESG concept emerged in the financial sector and has evolved into a broader managerial framework for corporate sustainability. It

encompasses three interdependent dimensions: environmental practices, such as emissions management, energy efficiency, and resource optimization; social practices, such as occupational safety, diversity, training, and stakeholder engagement; and governance practices, such as transparency, ethics, compliance, and risk management. These dimensions have become central to organizational legitimacy, operational resilience, and long-term value creation (Suchman, 1995; Camilleri, 2025).

The relationship between ESG practices and organizational performance has been widely discussed in the literature. Friede *et al.* (2015) conducted a meta-analysis of more than 2,000 empirical studies and found predominantly positive associations between ESG performance and financial outcomes. Whelan *et al.* (2021) also show that ESG-related practices may contribute to improved financial performance, risk reduction, innovation, and operational efficiency. Similarly, Eccles *et al.* (2014) demonstrate that organizations with more advanced sustainability practices tend to develop stronger governance structures, greater stakeholder engagement, and a long-term strategic orientation.

In organizational management, ESG is relevant not only as a disclosure or compliance agenda, but also as a managerial approach that affects production systems, supply chains, quality management, occupational safety, environmental management, and performance measurement. Environmental indicators may support the reduction of energy consumption, emissions, waste, and resource inefficiencies. Social indicators may support safer work environments, employee engagement, and capability development. Governance indicators may strengthen process standardization, traceability, accountability, and risk control.

In the Brazilian context, however, relevant challenges persist. Morioka and Carvalho (2017) identify difficulties in translating sustainability into organizational practices and in measuring its outcomes. These challenges are particularly important for organizations with heterogeneous levels of digital maturity and limited resources for sustainability management. Nevertheless, recent evidence suggests progress in the Brazilian context, as Barbosa and Klann (2023) show that ESG performance contributes to the relevance of accounting information and may support competitive differentiation.

From a strategic perspective, Porter and van der Linde (1995) argue that environmental pressures may stimulate innovation and efficiency gains. Hart and Milstein (2003) also emphasize that socio-environmental challenges can become sources of value creation when integrated into business strategy. The Triple Bottom Line proposed by Elkington (1997) consolidates this perspective by evaluating organizational performance across economic, environmental, and social dimensions. In the context of ESG Digital, the Triple Bottom Line provides the value-based foundation for defining operational indicators and prioritizing the framework's dimensions.

3.3. Theoretical Gaps In The Integration Of ESG And Digital Transformation

Despite the growing relevance of digital transformation and ESG practices, the literature remains fragmented, with limited integration between these domains. Digital transformation studies have predominantly focused on automation, operational efficiency, innovation, and data-driven decision-making, while ESG research

has emphasized disclosure, sustainability performance, stakeholder engagement, legitimacy, and regulatory compliance. This separation limits the understanding of how digital technologies can effectively operationalize ESG practices within production systems.

From a theoretical standpoint, the convergence of the Resource-Based View (Barney, 1991), Dynamic Capabilities Theory (Teece *et al.*, 1997), and the Triple Bottom Line (Elkington, 1997), complemented by strategic perspectives on competitive advantage (Porter, 1985), provides a robust basis for explaining the integration between digital transformation and ESG. However, these theoretical perspectives are often applied separately. As a result, the literature still lacks structured approaches capable of explaining how digital resources, sustainability practices, and organizational routines interact to generate measurable operational and strategic outcomes.

This gap is particularly relevant for organizational management. Although digital technologies can support monitoring, optimization, traceability, automation, and decision-making, ESG practices are still frequently treated as reporting mechanisms rather than as operational capabilities embedded in processes, indicators, and management systems. Therefore, there is a need for frameworks capable of defining dimensions, performance indicators, and implementation pathways that connect digital capabilities to sustainable competitive advantage.

Recent reviews on digital transformation and sustainability reinforce this limitation, highlighting the fragmentation of the field and the absence of integrative frameworks capable of connecting digitalization and sustainability in a structured manner (Guandalini, 2022). In response to this gap, this article proposes ESG Digital as an

operational framework designed to connect digital technologies, ESG practices, production systems and performance measurement.

3.4. Multidimensional Challenges In ESG And Digital Transformation

The convergence between digital transformation and ESG creates opportunities for production systems, but also introduces managerial and governance challenges. Digital technologies can improve environmental monitoring, energy efficiency, waste reduction, supply chain traceability, occupational safety, and data-driven decision-making (George *et al.*, 2021; Karmaker *et al.*, 2023; Wang *et al.*, 2023).

However, these benefits are not automatic. Digital infrastructures may also increase energy consumption, electronic waste, technological dependence, digital exclusion, organizational surveillance, and labor-related risks. These challenges are particularly relevant in production systems, where digital technologies are increasingly embedded in operations, supply chains, maintenance routines, quality control, and performance measurement.

Therefore, digital technologies only contribute to sustainable outcomes when they are governed, measured, and integrated into organizational routines. This reinforces the need for frameworks capable of aligning technological efficiency, socio-environmental responsibility, and governance mechanisms. ESG Digital is proposed in this study as an operational approach for connecting digital capabilities with sustainability objectives and performance indicators.

3.5. Justification For The Proposed Framework And Critical Synthesis

The previous discussion shows that digital transformation and ESG remain insufficiently integrated in organizational and production contexts. While digital transformation studies emphasize efficiency, automation, and data-driven decision-making, ESG studies often focus on legitimacy, compliance, disclosure, and stakeholder accountability. This separation limits the understanding of how digital technologies can transform ESG objectives into measurable routines, indicators, and operational capabilities.

The integrative review identifies three main gaps: fragmentation between digital and ESG literatures, limited operationalization of ESG through digital systems, and restricted applicability of existing frameworks to emerging economies and organizations with heterogeneous digital maturity. Brazil illustrates the relevance of these gaps because of its industrial heterogeneity, renewable energy matrix, biodiversity, and strong presence of small and medium-sized enterprises.

In this context, ESG Digital is proposed as an integrative framework capable of connecting digital transformation, ESG practices, performance indicators, and competitive strategy within a unified operational perspective. Table 2 summarizes the main gaps and the contribution of ESG Digital.

Table 2. Integrative synthesis of digital transformation, ESG, and ESG Digital integration

Dimension	Main gap	ESG Digital contribution

Digital transformation	Sustainability often treated as an indirect outcome.	Connects digital capabilities to ESG objectives and indicators.
ESG / Sustainability	Digitalization often treated as a support tool.	Transforms ESG into measurable and data-driven routines.
Operations Management	Lack of operational frameworks linking technologies, ESG, and KPIs.	Integrates monitoring, optimization, transparency, engagement, and governance.

Source: The authors.

3.6. Theoretical Propositions Of ESG Digital

Following the critical synthesis of the literature, ESG Digital is theoretically grounded as a distinctive organizational capability that may generate sustainable competitive advantage. This conceptualization is supported by the integration of the Resource-Based View, Dynamic Capabilities Theory, the Triple Bottom Line, and Stakeholder Theory. Together, these perspectives explain how digital transformation and ESG practices can be systematically aligned to create operational, environmental, social, and governance-related value.

3.6.1. ESG Digital as a Dynamic Capability

Beyond static resource configurations, ESG Digital can be understood as a higher-order dynamic capability (Teece *et al.*, 1997; Teece, 2007). It enables organizations to continuously adapt to environmental, regulatory, technological, and market changes by integrating ESG objectives into data-driven routines and production systems.

Through the sensing-seizing-transforming cycle, ESG Digital supports three complementary functions. First, it allows firms to sense ESG-related risks and opportunities through real-time data, monitoring systems, and stakeholder information. Second, it enables firms to seize these opportunities by applying digital technologies to optimize resource allocation, reduce inefficiencies, and improve socio-environmental performance. Third, it supports the transformation of organizational routines by embedding ESG criteria into process management, performance indicators, governance systems, and strategic decision-making.

3.6.2. ESG Digital as a VRIN-Based Strategic Capability

The Resource-Based View argues that sustainable competitive advantage arises from resources and capabilities that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). However, digital technologies in isolation, such as IoT, artificial intelligence, blockchain, and robotic process automation, do not necessarily meet these criteria, since they are increasingly available in technology markets.

Theoretical Proposition 1: The integration of digital technologies with ESG practices constitutes a distinctive organizational capability that fulfills the VRIN criteria and supports sustainable competitive advantage.

This proposition is supported as follows. First, ESG Digital is valuable because it can simultaneously improve operational efficiency, reduce risks, strengthen transparency, and enhance socio-environmental legitimacy. Second, it is rare because the effective integration of digital technologies, ESG practices, performance

indicators, and organizational routines remains limited across firms, especially in contexts of heterogeneous digital maturity. Third, it is inimitable because ESG Digital capabilities are path-dependent, socially complex, and embedded in organizational learning, culture, data infrastructure, and stakeholder relationships. Fourth, it is non-substitutable because isolated digitalization or traditional ESG reporting cannot generate equivalent levels of efficiency, traceability, adaptability, and legitimacy.

3.6.3. ESG Digital And Multidimensional Value Creation

The Triple Bottom Line establishes that sustainable value arises from the integration of economic, environmental, and social dimensions (Elkington, 1997). Porter and Kramer (2011) extend this logic through the concept of shared value, emphasizing that firms may generate economic and societal benefits simultaneously.

Theoretical Proposition 2: Digital technologies act as integrative mechanisms across the Triple Bottom Line dimensions, enabling simultaneous and mutually reinforcing value creation through ESG Digital.

This proposition suggests that ESG Digital can connect economic, environmental, and social objectives within production systems. For example, data generated for energy optimization may also support emissions monitoring, operational transparency, cost reduction, and stakeholder accountability. Similarly, predictive systems designed to reduce failures may improve productivity, occupational safety, and governance quality. In this sense, ESG Digital transforms sustainability from a fragmented set of practices into a measurable and integrated management capability.

3.6.4. Transition To The Conceptual Framework

The theoretical fragmentation identified in the literature shows that digital transformation, sustainability, and competitive strategy are often treated separately. The propositions developed in this section provide the theoretical basis for integrating these domains into a single framework.

The following section presents the formal conceptualization of ESG Digital, including its constitutive definition, operational principles, distinctive aspects, and differentiation from related constructs.

4. CONCEPTUALIZATION OF ESG DIGITAL

4.1. Constitutive And Operational Definition Of ESG Digital

ESG Digital is defined as an organizational capability through which digital technologies are systematically integrated into ESG practices to support sustainable competitive advantage. It operates through the coordinated use of technologies, data, indicators, processes, and governance mechanisms oriented toward multidimensional value creation.

From a constitutive perspective, ESG Digital represents the integration between digital transformation and ESG as a strategic and operational construct. It differs from traditional ESG approaches because it does not focus only on disclosure, compliance, or reputational gains. Instead, it transforms ESG into a data-driven management system embedded in organizational routines, production systems, and decision-making processes.

From an operational perspective, ESG Digital uses technologies such as artificial intelligence, Internet of Things, analytics, blockchain, automation, and digital platforms to monitor, optimize, automate, engage, and govern ESG-related processes. This conceptualization is based on four principles: systemic integration, data-driven sustainability, multidimensional value creation, and dynamic adaptability.

4.2. Distinctive Aspects Of ESG Digital

ESG Digital differs from traditional ESG approaches by shifting ESG from reporting to operationalization, from fragmentation to integration, from compliance to strategy, from periodic evaluation to continuous management, and from qualitative assessment to measurable performance. These shifts show that ESG Digital is not merely the digitalization of ESG reports, but a transition toward integrated, measurable, and data-driven sustainability management.

By embedding ESG practices into production routines, digital infrastructures, indicators, analytics, and governance systems, ESG Digital allows organizations to monitor deviations, anticipate risks, improve transparency, and connect sustainability objectives to operational and strategic performance.

4.3. Conceptual Differentiation From Related Constructs

Although ESG Digital shares similarities with Green IT, Industry 4.0, Digital Corporate Sustainability, and DESG, it differs in scope, purpose, and theoretical grounding. Green IT focuses mainly on the environmental impact of information technologies. Industry 4.0 emphasizes automation and productive efficiency, but does not necessarily incorporate ESG objectives as a strategic priority. Digital

Corporate Sustainability addresses the use of digital technologies for sustainability, but often lacks explicit operationalization through ESG indicators and production-system mechanisms. DESG has been discussed in specific contexts such as marketing and manufacturing, but still requires broader integration with strategic capabilities, performance measurement, and sustainable competitive advantage.

Therefore, ESG Digital emerges as a distinct construct positioned at the intersection of digital transformation, sustainability, and strategic management. It proposes an integrated capability through which firms can transform ESG objectives into operational routines, measurable indicators, and data-driven governance mechanisms.

Table 3 synthesizes the main conceptual distinctions between ESG Digital and related constructs identified in the literature.

Table 3. Conceptual differentiation between ESG Digital and related constructs

Concept	Main focus	Main limitation	ESG Digital contribution
Green IT	IT environmental efficiency.	Mainly environmental.	Extends to ESG indicators.
Industry 4.0	Automation and connectivity.	ESG often secondary.	Embeds ESG in production systems.
Digital Corporate Sustainability	Digital tools for sustainability.	Limited KPI/routine focus.	Links technologies, indicators, and decisions.

DESG	Digitalized ESG in specific contexts.	Partial strategic integration.	Adds RBV, Dynamic Capabilities, TBL, and KPIs.
ESG Digital — proposed construct	Integrated digital–ESG capability.	Requires empirical validation.	Makes ESG measurable and operational.

Source: The authors.

As shown in Table 3, ESG Digital extends prior approaches by integrating digital transformation, ESG practices, performance indicators, and strategic management into a unified organizational capability capable of transforming sustainability objectives into measurable and operational management practices.

5. PROPOSED ESG DIGITAL FRAMEWORK

5.1. Traditional ESG Versus ESG Digital

The distinction between traditional ESG and ESG Digital can be understood through a set of operational dimensions that affect data management, transparency, measurement, organizational integration, and stakeholder engagement. While traditional ESG approaches are often based on periodic reporting and retrospective assessment, ESG Digital emphasizes continuous monitoring, digital traceability, real-time indicators, and data-driven decision-making. Table 4 summarizes these differences.

Table 4. Comparison between traditional ESG and ESG Digital

Criterion	Traditional ESG	ESG Digital

Data and measurement	Periodic reports and retrospective indicators.	Real-time data and quantitative KPIs.
Transparency and integration	Self-reporting and fragmented practices.	Automated auditing and integrated traceability.
Response capability	Reactive and compliance-oriented.	Predictive, proactive, and decision-oriented.
Strategic orientation	ESG as disclosure or regulatory requirement.	ESG as an operational capability for sustainable competitiveness.

Source: The authors.

In carbon emissions management, for example, traditional ESG relies mainly on annual estimates derived from energy consumption records. ESG Digital, in contrast, may combine IoT sensors for real-time monitoring, artificial intelligence for operational optimization, and blockchain technologies to track and record the carbon footprint of products and processes (Ben-Daya et al., 2019; Saberi et al., 2019; Frozza et al., 2023).

This example illustrates that ESG Digital extends beyond the adoption of advanced technologies. It represents a transformation in sustainability governance and management by replacing manual, fragmented, and retrospective procedures with intelligent systems, continuous data flows, and measurable indicators. As a result, sustainability can operate as a continuous mechanism for value creation, risk mitigation, operational improvement, and stakeholder accountability. In this perspective, the focus shifts from regulatory compliance toward dynamic competitive advantage, supported by high-frequency, reliable, and actionable information (George *et al.*, 2021; Wang *et al.*, 2023).

5.2. Framework Structure

The ESG Digital framework is structured into five interdependent operational dimensions that converge toward long-term strategic value creation. Each dimension represents a specific organizational mechanism through which digital technologies can support the monitoring, optimization, automation, engagement, and governance of ESG-related processes.

Dimension 1 — Real-time monitoring: This dimension is based on the use of IoT sensors, edge computing, and analytical dashboards for the continuous tracking of ESG indicators. It enables organizations to identify deviations, monitor operational conditions, and respond more rapidly to environmental, social, and governance-related risks (Kagermann *et al.*, 2013; Kolagar *et al.*, 2024).

Dimension 2 — Predictive optimization: This dimension is grounded in the application of artificial intelligence and machine learning to predict failures, optimize resource use, and anticipate ESG-related risks. It supports proactive decision-making and improves the ability of firms to align operational efficiency with sustainability objectives (Dhiman *et al.*, 2024; Wang *et al.*, 2023).

Dimension 3 — Automated transparency: This dimension relies on technologies such as blockchain, digital certification, and automated reporting systems to strengthen traceability, accountability, and stakeholder trust. It enables the continuous generation and verification of ESG-related information across organizational processes and supply chains (Wang *et al.*, 2023; Eccles *et al.*, 2014).

Dimension 4 — Digital engagement: This dimension is based on collaborative platforms, gamification strategies, and digital

interaction tools designed to mobilize internal and external stakeholders. It supports employee participation, stakeholder communication, and social engagement in sustainability-oriented initiatives (Freeman, 1984; George *et al.*, 2021; Kirchner-Krath *et al.*, 2026).

Dimension 5 — Intelligent governance: This dimension involves the use of robotic process automation, expert systems, and digital compliance tools to monitor risks, automate governance routines, and ensure regulatory coherence. It strengthens the capacity of organizations to integrate ESG criteria into decision-making, control systems, and corporate governance practices (Teece *et al.*, 1997; Wang *et al.*, 2023).

The interdependence among these five dimensions is the main differentiating feature of the ESG Digital framework. Isolated digital initiatives may improve specific processes, but their strategic value increases when monitoring, optimization, transparency, engagement, and governance are integrated into a coherent organizational capability. Together, these dimensions operationalize ESG Digital as a data-driven and measurable approach to sustainable competitive advantage.

5.3. Key Performance Indicators

The interpretation of ESG Digital indicators is associated with their ability to capture gains in operational efficiency, risk reduction, organizational legitimacy, and socio-environmental performance. In this sense, KPIs do not merely measure ESG practices. They function as mechanisms that translate sustainability objectives into measurable operational and strategic outcomes.

Table 5 presents a representative KPI for each dimension of the ESG Digital framework.

Table 5. Key performance indicators of the ESG Digital framework

Dimension	Proposed indicator
Real-time monitoring	Environmental incident detection rate (%)
Predictive optimization	AI-enabled energy reduction (%)
Automated transparency	Digital supply-chain traceability (%)
Digital engagement	ESG Digital engagement rate (%)
Intelligent governance	Automated compliance processes (%)

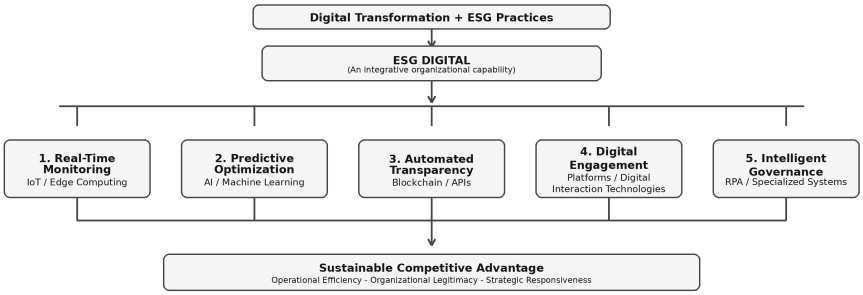
Source: The authors.

These indicators support continuous ESG performance monitoring and data-driven decision-making. They also reinforce the role of ESG Digital as a measurable organizational capability capable of linking sustainability practices, operational performance, and sustainable competitive advantage.

5.4. Visual Representation Of The Framework

Figure 1 illustrates the integrated structure of the ESG Digital framework. The figure shows how digital transformation and ESG practices converge into an organizational capability structured around five operational dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance. Together, these dimensions support the creation of sustainable competitive advantage through operational efficiency, organizational legitimacy, and strategic responsiveness.

Figure 1. ESG Digital framework for strategic sustainability integration.



Source: The authors.

5.5. Operating Dynamics And Link To Sustainable Competitive Advantage

The ESG Digital framework operates through three interdependent mechanisms: systemic integration, competitive amplification, and adaptive scalability. Systemic integration connects real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance into organizational routines, production systems, indicators, and decision-making processes.

Competitive amplification occurs when ESG Digital strengthens efficiency, transparency, risk detection, stakeholder legitimacy, and governance quality. Adaptive scalability refers to the possibility of implementing the framework progressively, according to organizational capabilities, sectoral conditions, and levels of digital maturity.

Together, these mechanisms position ESG Digital as an integrative capability based on the Efficiency–Legitimacy–Responsiveness triad. Efficiency refers to operational and resource performance;

legitimacy refers to stakeholder trust and accountability; and responsiveness refers to the ability to anticipate and respond to ESG-related risks and opportunities.

5.6. Detailed Operationalization: Predictive Optimization

Although the five dimensions of the ESG Digital framework are interdependent, this study further details predictive optimization because of its direct connection with dynamic capabilities, competitive differentiation, and data-driven sustainability management. Predictive optimization enables organizations to anticipate ESG-related risks and opportunities, allocate resources more efficiently, and adapt operational routines based on predictive information.

Within ESG Digital, predictive optimization is defined as the organizational ability to anticipate risks, failures, inefficiencies, opportunities, and performance deviations related to ESG pillars, and to prescribe actions that improve sustainability, operational performance, and governance outcomes. It is enabled by technologies such as machine learning, IoT-based analytics, optimization algorithms, digital twins, forecasting systems, and decision-support platforms.

Predictive optimization can be applied across the three ESG pillars. In the environmental dimension, it supports energy optimization, emission reduction, waste prevention, and resource efficiency. In the social dimension, it supports occupational safety, employee well-being, and workforce risk prevention. In the governance dimension, it strengthens anomaly detection, compliance monitoring, fraud prevention, and reputational risk management.

Table 6 presents representative applications of predictive optimization and associated ESG and operational outcomes.

Table 6. Applications of predictive optimization by ESG pillar

ESG pillar	Application	Expected outcomes
Environmental (E)	Energy-demand forecasting using machine learning.	Lower energy use, reduced emissions, and better resource planning.
Social (S)	Accident-risk prediction using operational and workforce data.	Improved occupational safety, risk prevention, and workforce planning.
Governance (G)	Anomaly detection using machine learning models.	Earlier detection of irregularities and stronger compliance controls.

Source: The authors.

The applications summarized in Table 6 show that predictive optimization operates as a cross-cutting mechanism across ESG pillars. Rather than indicating fixed performance gains, the table identifies expected outcomes that depend on sectoral conditions, data quality, technological maturity, organizational capabilities, and governance structures. Thus, predictive optimization strengthens ESG Digital by transforming ESG-related data into anticipatory and prescriptive mechanisms for efficiency, risk reduction, legitimacy, and sustainable competitive advantage.

6. THEORETICAL CONTRIBUTIONS

This study advances the literature through three main contributions. First, it develops ESG Digital as a distinctive theoretical construct

that connects digital technologies, ESG practices, performance indicators, and sustainable competitive advantage. By providing a constitutive and operational definition, the study differentiates ESG Digital from adjacent concepts such as Green IT, Industry 4.0, Digital Corporate Sustainability, and DESG.

Second, the study explains how digital–ESG integration may support sustainable competitive advantage. By articulating the Resource-Based View, Dynamic Capabilities Theory, the Triple Bottom Line, and Stakeholder Theory, the article positions ESG Digital as a capability that generates value through efficiency, legitimacy, and responsiveness. This theoretical integration clarifies how digital technologies can support ESG practices as mechanisms for operational improvement, risk mitigation, stakeholder accountability, and strategic adaptation.

Third, the study proposes an operationalization framework structured around five dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance. These dimensions translate ESG Digital into operational mechanisms, enabling technologies, and representative performance indicators, supporting future empirical validation and practical implementation in production systems.

6.1. Implications For Strategic Management

Strategic management is a relevant context for ESG Digital because it integrates people, technologies, materials, information, processes, and organizational systems. From an operational perspective, the framework can support process management, quality control,

supply chain coordination, environmental management, occupational safety, and governance routines.

In the Brazilian context, these implications are especially relevant because the transition toward advanced manufacturing occurs heterogeneously, with significant differences in digital maturity among organizations (Tortorella; Fettermann, 2018). ESG Digital addresses this challenge by offering an adaptable structure that can be implemented progressively according to organizational capabilities, sectoral conditions, and available resources.

The framework also contributes to sustainability measurement, a persistent challenge for Brazilian organizations (Morioka; Carvalho, 2017). By translating ESG practices into operational indicators, ESG Digital can support monitoring, comparison, decision-making, and continuous improvement.

6.2. ESG Digital And Small And Medium-Sized Enterprises (SMEs)

Small and medium-sized enterprises represent a relevant context for ESG Digital, especially in emerging economies. These firms often face resource constraints, limited technological infrastructure, lack of specialized personnel, and heterogeneous levels of digital maturity. At the same time, they may benefit from organizational flexibility and shorter decision-making cycles.

For SMEs, ESG Digital can be adopted gradually through selected indicators, service-based digital solutions, low-cost analytics tools, and collaborative ecosystems involving universities, industry associations, technology providers, and institutions such as SEBRAE. Thus, ESG Digital does not require full-scale digital transformation from the outset. It can be progressively implemented through

specific processes and scalable technologies, helping SMEs strengthen resilience, competitiveness, stakeholder legitimacy, and long-term value creation (Nunes *et al.*, 2024).

7. LIMITATIONS AND FUTURE RESEARCH

This study has limitations that should be considered when interpreting its contributions. First, the proposed ESG Digital framework remains conceptual and has not yet been empirically validated in organizational settings. Although it is theoretically grounded, its applicability and measurement structure require testing across different sectors, firm sizes, and levels of digital maturity.

Second, the reviewed literature remains partially concentrated in developed economies and technologically advanced contexts. Therefore, the implementation of ESG Digital may vary according to institutional conditions, technological infrastructure, regulatory pressures, organizational capabilities, and access to digital resources.

Third, the proposed KPIs should be interpreted as representative indicators rather than universal measures. Their application requires adaptation to sector-specific characteristics, organizational strategies, regulatory environments, and data availability. ESG Digital also raises ethical and socioeconomic challenges, including digital exclusion, technological dependence, organizational surveillance, data governance, labor displacement, and the environmental footprint of digital infrastructures.

Future research may advance the ESG Digital literature by empirically testing the framework, developing standardized and sector-specific indicators, comparing institutional environments, and

conducting systematic literature reviews with bibliometric analyses. These directions may help consolidate ESG Digital as an emerging organizational capability positioned at the intersection of digital transformation, sustainability, and competitive strategy.

8. CONCLUSION

This study proposed ESG Digital as an organizational capability that integrates digital technologies with Environmental, Social, and Governance practices to support sustainable competitive advantage. Based on an integrative literature review and conceptual framework development, the article argues that digital transformation can move ESG beyond disclosure and compliance, transforming sustainability into an operational, measurable, and data-driven management system.

The proposed framework is structured around five interdependent dimensions: real-time monitoring, predictive optimization, automated transparency, digital engagement, and intelligent governance. Together, these dimensions explain how digital technologies can support operational efficiency, socio-environmental performance, stakeholder legitimacy, and adaptive governance. By linking these dimensions to representative performance indicators, the framework positions ESG Digital as a bridge between sustainability objectives and measurable organizational outcomes.

Theoretically, the study contributes by articulating the Resource-Based View, Dynamic Capabilities Theory, the Triple Bottom Line, and Stakeholder Theory to explain ESG Digital as a strategic and operational capability embedded in routines, data infrastructure,

governance systems, and production processes. Practically, the framework may guide organizations in structuring sustainable digital transformation pathways, especially in emerging economies and firms with heterogeneous levels of digital maturity.

By connecting digital technologies, ESG practices, and performance indicators, ESG Digital offers a pathway for organizations seeking to strengthen sustainability, competitiveness, and long-term resilience in increasingly complex and data-intensive environments.

REFERENCES

Barbosa, I. de S., & Klann, R. C. (2023). Efeitos do desempenho ambiental, social e de governança na relevância das informações contábeis de empresas brasileiras. *Revista Contemporânea de Contabilidade, 20*(54), 1–15. https://doi.org/10.5007/2175-8069.2023.e86044

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. *International Journal of Production Research, 57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140

Camilleri, M. A. (2025). Sustainability accounting and disclosures of responsible restaurant practices in environmental, social and governance (ESG) reports. *International Journal of Hospitality Management, 126*, 104051. https://doi.org/10.1016/j.ijhm.2024.104051

Carvalho, R. B., Reis, A. M. P., Larieira, C. L. C., & Pinochet, L. H. C. (2021). Transformação digital: Desafios na formação de um constructo e cenários para uma agenda de pesquisa. *Revista de Administração Mackenzie, 22*(6), eRAMD210400. https://doi.org/10.1590/1678-6971/eRAMD210400

Dhiman, R., Miteff, S., Wang, Y., Ma, S.-C., Amirikas, R., & Fabian, B. (2024). Artificial intelligence and sustainability: A review. *Analytics, 3*(1), 140–164. https://doi.org/10.3390/analytics3010008

Eccles, R. G., Ioannou, I., & Serafeim, G. (2014). The impact of corporate sustainability on organizational processes and performance. *Management Science, 60*(11), 2835–2857. https://doi.org/10.1287/mnsc.2014.1984

Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century business*. Capstone Publishing.

Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Pitman.

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment, 5*(4), 210–233. https://doi.org/10.1080/20430795.2015.1118917

Frozza, T., Lima, E. P. de, & Costa, S. E. G. da. (2023). Knowledge management and blockchain technology for organizational sustainability: Conceptual model. *Brazilian Journal of Operations & Production Management, 20*(2), 1354. https://doi.org/10.14488/BJOPM.1354.2023

George, G., Merrill, R. K., & Schillebeeckx, S. J. D. (2021). Digital sustainability and entrepreneurship: How digital innovations are helping tackle climate change and sustainable development. *Entrepreneurship Theory and Practice, 45*(5), 999–1027. https://doi.org/10.1177/1042258719899425

Guandalini, I. (2022). Sustainability through digital transformation: A systematic literature review for research guidance. *Journal of Business Research, 148*, 456–471. https://doi.org/10.1016/j.jbusres.2022.05.003

Hart, S. L., & Milstein, M. B. (2003). Creating sustainable value. *Academy of Management Executive, 17*(2), 56–69. https://doi.org/10.5465/ame.2003.10025194

Jaakkola, E. (2020). Designing conceptual articles: Four approaches. *AMS Review, 10*(1–2), 18–26. https://doi.org/10.1007/s13162-020-00161-0

Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry*. National Academy of Science and Engineering.

Kane, G. C., Phillips, A. N., Copulsky, J. R., & Andrus, G. R. (2019). *The technology fallacy: How people are the real key to digital transformation*. MIT Press.

Karmaker, C. L., Al Aziz, R., Ahmed, T., Misbauddin, S. M., & Moktadir, M. A. (2023). Impact of Industry 4.0 technologies on sustainable supply chain performance: The mediating role of green supply chain management practices and circular economy. *Journal of Cleaner Production, 419*, 138249. https://doi.org/10.1016/j.jclepro.2023.138249

Kirchner-Krath, J., Dijkstra-Silva, S., Morschheuser, B., & von Korflesch, H. F. O. (2026). Gameful systems for corporate sustainability: Systematic review, conceptual framework and research agenda on gamification and sustainable employee behavior in companies. *Internet Research, 36*(2), 513–550. https://doi.org/10.1108/INTR-06-2024-1000

Kolagar, M., Parida, V., & Sjödin, D. (2024). Linking digital servitization and industrial sustainability performance: A configurational perspective on smart solution strategies. *IEEE Transactions on Engineering Management, 71*, 7743–7755. https://doi.org/10.1109/TEM.2024.3383462

Morioka, S. N., & Carvalho, M. M. (2017). Discutindo sustentabilidade no contexto de negócios e em relatórios de desempenho: Análise de estudos de caso brasileiros. *Gestão & Produção, 24*(3), 514–525. https://doi.org/10.1590/0104-530X2665-16

Nunes, E. N., Franqueira, A. da S., Bitencourt, C. A. L., Melo Júnior, H. G., Santos, S. M. A. V., & Viana, S. C. (2024). Transformação digital: Desafios e oportunidades para pequenas e médias empresas. *Observatorio de la Economía Latinoamericana, 22*(4), e4224. https://doi.org/10.55905/oelv22n4-128

Porter, M. E. (1985). *Competitive advantage: Creating and sustaining superior performance*. Free Press.

Porter, M. E., & Kramer, M. R. (2011). Creating shared value. *Harvard Business Review, 89*(1–2), 62–77.

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic*

Perspectives, 9(4), 97–118. https://doi.org/10.1257/jep.9.4.97

Puriwat, W., & Tripopsakul, S. (2022). From ESG to DESG: The impact of DESG (digital environmental, social, and governance) on customer attitudes and brand equity. *Sustainability, 14*(17), 10480. https://doi.org/10.3390/su141710480

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Suchman, M. C. (1995). Managing legitimacy: Strategic and institutional approaches. *Academy of Management Review, 20*(3), 571–610. https://doi.org/10.5465/amr.1995.9508080331

Tan, Q. L., Hashim, S., & Zheng, Z. (2025). Environmental social governance (ESG) in digitalization research: A bibliometric analysis. *SAGE Open, 15*(1), 21582440241310953. https://doi.org/10.1177/21582440241310953

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of sustainable enterprise performance. *Strategic Management Journal, 28*(13), 1319–1350. https://doi.org/10.1002/smj.640

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal, 18*(7), 509–533. https://doi.org/10.1002/(SICI)1097-0266(199708)18:7%3C509::AID-SMJ882%3E3.0.CO;2-Z

Tortorella, G. L., & Fettermann, D. (2018). Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research, 56*(8), 2975–2987. https://doi.org/10.1080/00207543.2017.1391420

Wang, J., Hong, Z., & Long, H. (2023). Digital transformation empowers ESG performance in the manufacturing industry: From ESG to DESG. *SAGE Open, 13*(4), 1–21. https://doi.org/10.1177/21582440231204158

Whelan, T., Atz, U., Van Holt, T., & Clark, C. (2021). *ESG and financial performance: Uncovering the relationship by aggregating evidence from 1,000 studies*. NYU Stern Center for Sustainable Business.

---

[1] PhD candidate in Production Engineering, Universidade Tecnológica Federal do Paraná (UTFPR), Ponta Grossa Campus. UTFPR – Ponta Grossa Campus, Av. Monteiro Lobato, Km 04, CEP 84016-210, Ponta Grossa-PR, Brazil. E-mail: acesse o artigo original para visualizar o e-mail.

[2] PhD in Chemical Engineering. Professor, Department of Chemical Engineering and Graduate Program in Production Engineering (PPGEP), Universidade Tecnológica Federal do Paraná (UTFPR), Ponta Grossa Campus. UTFPR – Ponta Grossa Campus, Av. Monteiro Lobato, Km 04, CEP 84016-210, Ponta Grossa-PR, Brazil. E-mail: acesse o artigo original para visualizar o e-mail.

[3] PhD in Mechanical Engineering. Associate Professor, Universidade Tecnológica Federal do Paraná (UTFPR), Ponta Grossa Campus, and Coordinator of the Graduate Program in Production Engineering (PPGEP). UTFPR – Ponta Grossa Campus, Av. Monteiro Lobato, Km 04, CEP 84016-210, Ponta Grossa-PR, Brazil. E-mail: acesse o artigo original para visualizar o e-mail.