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INTEGRATING SUSTAINABILITY PERFORMANCE INDICATORS INTO DIGITAL MATURITY MODELS: A SYSTEMATIC LITERATURE REVIEW

Abstract

Digital transformation and sustainability have emerged as two dominant and interrelated strategic imperatives for contemporary organizations. However, existing digital maturity models predominantly focus on technological capabilities while largely overlooking sustainability performance outcomes. This study addresses this gap by systematically reviewing the literature on integrating sustainability performance indicators into digital maturity models. A systematic literature review was conducted following Kitchenham's protocol and the PRISMA framework, covering peer-reviewed journal articles published between 2016 and 2026 and retrieved from the Web of Science and Scopus databases. The review synthesizes conceptual and empirical contributions, identifies commonly applied environmental, social, and governance (ESG) indicators, and examines methodological approaches for integration. The findings reveal three dominant integration approaches: combined maturity models, parallel assessment frameworks, and embedded dimensional models. Environmental indicators are most frequently operationalized, while social and governance dimensions remain comparatively underdeveloped. The analysis also highlights persistent challenges related to limited empirical validation, lack of standardization, data availability constraints, and SME applicability. The study contributes by providing a structured synthesis of integration mechanisms and proposing a conceptual foundation for integrated digital–sustainability maturity assessment, offering guidance for researchers and practitioners seeking to advance holistic organizational evaluation frameworks.

Key words: *digital transformation, maturity models, sustainable performance*

JEL classification: *M15, Q56*

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ИНТЕГРИСАЊЕ ПОКАЗАТЕЉА ОДРЖИВИХ ПЕРФОРМАНСИ У МОДЕЛЕ ДИГИТАЛНЕ ЗРЕЛОСТИ: СИСТЕМАТСКИ ПРЕГЛЕД ЛИТЕРАТУРЕ

Апстракт

Дигитална трансформација и одрживост постале су два доминантна и међусобно повезана стратешка императива савремених организација. Међутим, постојећи модели дигиталне зрелости претежно су усмерени на технолошке капацитете, док у великој мери занемарују концепт одрживих перформанси. Овај рад настоји да одговори на наведени јаз кроз систематски преглед литературе о интеграцији показатеља одрживих перформанси у моделе дигиталне зрелости. Систематски преглед литературе спроведен је применом Kitchenham протокола и PRISMA оквира, обухватајући рецензиране научне радове објављене у периоду 2016–2026. године и идентификоване у базама Web of Science и Scopus. Преглед синтетизује концептуалне и емпиријске доприносе, идентификује најчешће коришћене еколошке, социјалне и управљачке (ESG) индикаторе и анализира методолошке приступе њиховој интеграцији. Резултати указују на три доминантна приступа интеграцији: комбиноване моделе зрелости, паралелне оквире процене и моделе са уграђеном димензијом одрживости. Еколошки индикатори су најзаступљенији, док су социјална и управљачка димензија релативно слабије развијене. Анализа такође идентификује одређене изазове који се односе на ограничену емпиријску валидацију, недостатак стандардизације, ограничења у доступности података и применљивост у малим и средњим предузећима. Рад доприноси пружањем структуриране синтезе механизама интеграције и предлагањем концептуалне основе за процену интегрисане дигитално-одрживе зрелости, нудећи смернице истраживачима и практичарима за развој холистичких оквира организационе евалуације.

Кључне речи: *дигитална трансформација, модели зрелости, одрживе перформансе*

Introduction

There are two megatrends that have transformed the business landscape: digital transformation and the sustainability imperative, which have put pressure on organizations worldwide to increase their digital capabilities and simultaneously address environmental degradation, social inequality, and governance accountability (Singh et al., 2025; Šimberová et al., 2022). These dual challenges have catalyzed scholarly and practitioner interest in frameworks that can holistically assess organizational readiness and performance across both dimensions (Fortier et al., 2025; Martínez-Peláez et al., 2024).

While digital maturity and sustainability performance have traditionally been assessed as two separate areas using different frameworks and metrics, digital maturity models tend to focus on technological infrastructure, digital capabilities, business process transformation, and the creation of an innovation-oriented organizational culture (Merdin et al., 2022), whereas sustainability assessment frameworks tend to focus on environmental indicators (e.g., emissions and resource consumption), social metrics (e.g., employee well-being and community engagement), and governance practices (e.g., ethical leadership and transparency) (Sell, 2024).

Nevertheless, the increasing recognition of the interdependence between digitalization and sustainability has resulted in the development of integrated approaches, which acknowledge that digital technologies can enhance sustainability performance, while sustainability objectives can simultaneously shape and direct digital transformation strategies (Martínez-Peláez et al., 2024; Fatemi, 2024; Fortier et al., 2025).

The integration of sustainable performance indicators into digital maturity models represents a paradigm shift toward comprehensive organizational assessment (Fortier et al. 2025; Münnich et al., 2025) because sustainability considerations can inform more responsible and resilient digital transformation strategies (Eisner et al. 2022; Nicolau & Petcu, 2026), and digital technologies can be enablers of sustainability goals (Fatemi, 2024). Recent research shows that firms that pursue „twin transformation" or the simultaneous advancement of sustainability and digital agendas outperform firms that handle these imperatives separately (Fatemi, 2024).

This review synthesizes findings from over 30 highly relevant peer-reviewed journal articles published between 2016 and 2026, and provides researchers, practitioners, and policymakers with a comprehensive review of current knowledge, methodological approaches, and strategic pathways for advancing integrated assessment frameworks, contributing to both academic discourse and practical application in identifying best practices, persistent challenges, and charting directions for future research and development.

Despite the growing body of literature on digital maturity models and sustainability performance assessment, the integration of these two domains remains theoretically fragmented and methodologically inconsistent. Existing studies either integrate sustainability in a limited manner within digital frameworks or treat digitalization only as an enabling factor for sustainability outcomes. This study addresses this gap by systematically mapping existing models, critically comparing their integration mechanisms, and providing a clearer pathway for future research and practical implementation. Accordingly, the primary objective of this study is to systematically examine how sustainability performance indicators are incorporated into digital maturity models, identify dominant integration approaches, and synthesize existing conceptual and empirical contributions. To contextualize this research gap and establish a conceptual basis for the systematic review, the following section outlines the theoretical foundations related to digital maturity models, sustainability performance indicators, and the emerging twin transformation paradigm. Based on the identified research gap, the central research question guiding this study is: How are sustainability performance indicators integrated into digital maturity models, and what dominant approaches characterize this integration?

The remainder of the paper is structured as follows. The next section presents the theoretical background, outlining key concepts related to digital maturity models, sustainability performance indicators, and the twin transformation paradigm. This is followed by the methodology section, which describes the systematic literature review design and research procedures. The subsequent section presents the thematic analysis and synthesis of key findings from the reviewed studies. Finally, the paper concludes with a discussion of implications, limitations, and directions for future research.

1. Theoretical Background

1.1. Digital Maturity Models: Evolution and Concepts

Digital maturity models offer a structured approach to analyzing the digital capabilities of an organization and determining future growth opportunities. While originally rooted in early capability maturity models (CMM) that focused on evaluating software development processes, today, they have evolved into more holistic frameworks that examine strategy, culture, technology, and operations (Merdin et al., 2022). Digital maturity models typically evaluate organizations on a variety of dimensions, such as technological infrastructure (hardware, software, connectivity), digital competencies (employee skills, digital literacy), business process transformation (automation, optimization), data governance (data collection, analysis, and utilization), innovation capacity (experimentation, agility), and digital leadership (vision, managerial support) (Quenum et al., 2025).

The progression of digital maturity models parallels wider changes in organizational technology adoption patterns, from initial emphasis on information technology infrastructure and simple digitization of manual processes, to the more advanced capabilities of artificial intelligence, Internet of Things (IoT) integration, cloud computing, and data analytics (Lichtenthaler, 2020; Sira, 2025). While digital maturity models typically are applied to technology and the ability of an organization to adopt digital tools, research has shown that technological maturity is not sufficient to drive comprehensive organizational performance (Kahrović, 2021). In this regard, digital business transformation is viewed as an organizational process that involves the application of digital technologies but also requires a transformation of business models, operational processes, and strategic directions of the enterprise (Kahrović & Avdović, 2023). Thus, integrating sustainability metrics (economic, social, and environmental) into digital maturity frameworks allows for more holistic assessments of how digital transformation contributes to organizational performance and to its overall sustainable performance. Recent empirical research further confirms that technological quality and the achieved technological level of economic entities significantly influence sustainable business operations, positioning technological capability as a key determinant of long-term organizational sustainability (Miletić et al., 2025). However, understanding the role of sustainability within digital maturity assessment requires a clear conceptualization of sustainability performance measurement itself, which is discussed in the following subsection.

Digital maturity assessment serves a number of organizational functions, including being diagnostically useful to provide a baseline understanding of current capabilities and gaps relative to an industry benchmark or strategic goal, prescriptively useful to help prioritize resource allocation and digital initiatives, and strategically useful to align digital investments with business objectives and competitive positioning.

However, traditional digital maturity models have been criticized for being too narrowly focused on technological capabilities and not paying enough attention to the broader organizational and societal impacts (Djebbouri et al., 2025; Tiron-Tudor et al., 2024). In addition, empirical analyses suggest that most existing digital maturity models remain predominantly descriptive and linear, lack strong theoretical grounding, and are rarely empirically validated, thus demonstrating limited scientific robustness and prescriptive value (Kruljac & Knežević, 2019).

1.2. Sustainability Performance Indicators: The ESG Framework

Sustainability performance measurement has evolved from early environmental compliance metrics to more holistic ESG frameworks, which measure the multidimensional impacts of organizations on the environment, society, and governance (Singh et al., 2025). Within this framework, *environmental indicators* are typically operationalized through metrics that quantify resource intensity and ecological impact. These commonly include direct and indirect greenhouse gas emissions across operational boundaries, patterns of energy use and efficiency, water consumption profiles, waste treatment, and material recovery practices, as well as biodiversity and circularity-related initiatives. Such indicators are often aligned with internationally recognized reporting architectures including Global Reporting Initiative - GRI, Carbon Disclosure Project - CDP, and Task Force on Climate-related Financial Disclosures - TCFD (Babkin et al., 2021; Fan, 2025; Li et al., 2025; Radivojević et al., 2018). The *social indicators* focuses on how organizations manage relationships with internal and external stakeholders. Key measures frequently encompass occupational safety conditions, workforce development initiatives, equality and inclusiveness policies, responsible labor standards, protection of fundamental human rights, community-oriented programs, customer trust and data protection practices, and socially responsible supply chain management (Nasiri et al., 2022; Tiron-Tudor et al., 2024). *Governance indicators* capture organizational structures, policies, and practices that ensure accountability, transparency, and ethical conduct and include metrics like board composition and independence, executive compensation alignment, shareholder rights, business ethics and anti-corruption measures, regulatory compliance, and risk management frameworks, all of which are becoming integral to environmental and social performance (Sell, 2024, Al Jabri & Lahrech, 2026). While ESG frameworks provide structured mechanisms for evaluating sustainability performance, recent research increasingly emphasizes the need to integrate these metrics with digital transformation processes, giving rise to the concept of twin transformation discussed below.

1.3. The Convergence Imperative: Twin Transformation

The concept of „twin transformation" has emerged to describe the strategic integration of digital transformation and sustainability transition (Martínez-Peláez et al., 2024; Fortier et al., 2025). Multiple factors drive this convergence. First, digital technologies offer powerful tools for monitoring, controlling, and assessing sustainability performance. IoT sensors enable real-time environmental monitoring, artificial intelligence optimizes resource consumption, blockchain enhances supply chain transparency, and data analytics identify sustainability improvement opportunities (Nicolau & Petcu, 2026). Second, as businesses realize that adopting technology must be in line with their commitments to social responsibility and the environment, sustainability factors are becoming more and more important in shaping digital transformation strategies (Fatemi, 2024; Martínez-Peláez et al. in 2024). Sustainability is increasingly recognized not merely as a compliance requirement but as a driver of value creation, as integrating environmental and social considerations into business models enhances long-term competitiveness and stakeholder value (Milenković et al., 2025).

Several theoretical frameworks support twin transformation. The resource-based view theory states that the integrated digital-sustainability capabilities can be considered valuable, rare, and difficult to imitate resources that provide a competitive advantage (Al Jabri & Lahrech, 2026). According to stakeholder theory, businesses must balance the interests of different stakeholders,such as social and environmental ones, with their financial objectives. Finally, institutional theory explains how regulatory pressures, normative expectations, and mimetic processes lead to organizational adoption of integrated assessment frameworks that incorporate digital maturity and sustainability performance (Damnjanović et al., 2025; Jamwal et al., 2025; Li et al., 2025). Building upon these theoretical foundations, the study proceeds with a systematic literature review designed to identify, compare, and synthesize existing approaches for integrating sustainability indicators into digital maturity models.

2. Methodology

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021) and Kitchenham's protocol (2004) serve as the foundation for this study's systematic literature review. This strategy promotes methodological transparency, reproducibility, and thorough coverage of the relevant literature. Using the PICO model to formulate research questions, creating a structured search strategy across the Web of Science and Scopus databases, applying stringent inclusion and exclusion criteria, and formally evaluating the quality of eligible studies to ensure methodological rigor are the four main steps in the review process. Every stage is intended to reduce bias and improve the reliability of the results.

2.1. Research Questions

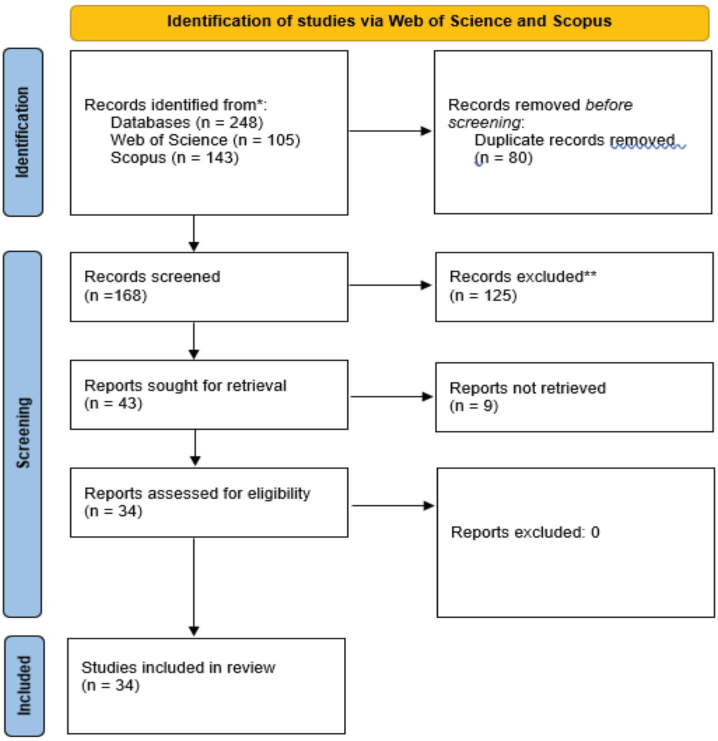
In order to systematically address the objectives of this study, the research questions were formulated using the PICO model, a widely recognized framework originally introduced by Richardson et al. (1995) for structuring systematic reviews and decomposing clinical questions into searchable components. PICO, which stands for Population, Intervention, Comparison, and Outcomes, provides a clear and rigorous approach for defining the scope of an investigation. In the context of this research, the *population* (P) comprises organizations across industries undergoing digital transformation and sustainability transitions. The *intervention* (I) refers to integrated digital maturity models that incorporate sustainability and ESG performance indicators. The *comparison* (C) involves traditional assessment approaches in which digital maturity and sustainability performance are evaluated separately through distinct frameworks. The *outcomes* (O) include organizational performance improvement, alignment between digital and sustainability strategies, transparency and accountability, and greater long-term resilience.

This literature review aims to explore what is known about the integration of sustainability performance indicators into digital maturity models, specifically (1) which conceptual and empirical frameworks exist for integrating sustainability into digital maturity assessment, (2) which environmental, social, and governance (ESG) indicators are most frequently used, (3) how sustainability indicators are methodologically integrated, and (4) what industry contexts and empirical applications support the development and implementation of integrated digital sustainability maturity models.

2.2. Search Strategy

This literature review employed a comprehensive and systematic search strategy to identify relevant scholarly publications examining the integration of sustainable performance indicators into digital maturity models (Martínez-Peláez et al., 2024). The search was carried out through the electronic databases Web of Science (WoS) and Scopus. According to Benavides et al., (2020, p. 3), "they are the most relevant scientific information platforms that access the scientific databases and the most significant publication of the different areas of knowledge" (p. 3). The structured search strategy employed to identify articles used the strings "digital maturity*" AND "sustainable performance*" and was conducted on 15 January 2026.

Figure 1: Search and selection strategies



The initial search retrieved 248 records (105 from WoS and 143 from Scopus). All references were imported into Zotero reference management software, where 80 duplicate entries papers were removed. After deduplication and quality checks, 34 unique records were retained for the screening phase. This structured search approach ensured that the selected studies systematically address the research questions and maintain methodological rigor.

2.3. Study Selection

Following the initial search, rigorous inclusion and exclusion criteria were applied to ensure the review focused on the most relevant and high-quality studies. Inclusion criteria specified: (1) peer-reviewed journal articles published in academic journals; (2) publication dates between 2016 and 2026, capturing the most recent decade of research; (3) substantive focus on digital maturity models, sustainability performance indicators, or their integration; (4) empirical studies, conceptual frameworks, or systematic reviews; and (5) English language publications. Exclusion criteria eliminated: (1) conference proceedings, book chapters, dissertations, and grey literature; (2) publications outside the specified time range; (3) studies lacking substantive discussion of either digital maturity or sustainability indicators; (4) purely technical papers without organizational or strategic focus; and (5) duplicate publications.

2.4. Quality Assessment

Kitchenham (2004) suggests that study quality relates to the extent to which bias is minimized and internal and external validity are maximized. Assessing the quality of primary studies is crucial in a systematic review for several reasons: to refine inclusion and exclusion criteria, to explore whether quality differences explain variations in findings, to weigh the importance of individual studies during synthesis, to guide the interpretation of results, and to strengthen recommendations for future research (p. 10).

In this review, the quality assessment was conducted during the eligibility evaluation phase. Studies were included only if they were published in journals indexed in the Journal Citation Reports 2024, which ensures that all sources meet rigorous international standards of academic quality. Articles were also expected to focus on fundamental aspects of digital maturity and sustainable performance, ensuring that only recent, peer-reviewed, high-impact studies contributed to the synthesis of findings; this approach ensured that the review would be of high methodological rigor and would minimize bias, which would ultimately increase the credibility and reliability of results.

The extracted data were organized into a comprehensive paper table with enriched columns capturing: (1) frameworks and models used, describing specific digital maturity models, sustainability frameworks, or integrated models; (2) sustainability indicator types, categorizing environmental, social, and governance metrics; and (3) integration approaches and methodologies, detailing how sustainability indicators were incorporated into maturity assessment frameworks.

Thematic analysis was conducted to extract common patterns, trends, and relationships in the literature, grouped papers based on themes such as framework types, indicator categories, integration methodologies, industry applications, and research gaps, compared frameworks, methodological approaches, and empirical findings, and synthesized findings across studies to provide a holistic understanding of the current knowledge, best practices, and research gaps in this area. The application of this methodological procedure resulted in a structured body of literature that was subsequently analyzed thematically, with the key findings presented in the following section.

3. Results and Discussion

3.1. Current Frameworks Integrating Sustainability into Digital Maturity

A review of the literature shows that frameworks that incorporate sustainability considerations into digital maturity assessment fall into three main categories: combined maturity models, parallel assessment frameworks, and embedded dimensional models (Fortier et al., 2025; Sell, 2024). To enhance clarity and reduce fragmentation in the presentation of findings, Table 1 provides a structured synthesis of these approaches, outlining their conceptual logic, integration mechanisms, and representative studies.

Table 1: Dominant Approaches to Integrating Sustainability into Digital Maturity Models

Integration Approach	COMBINED MATURITY MODELS	PARALLEL ASSESSMENT FRAMEWORKS	EMBEDDED DIMENSIONAL MODELS
Conceptual Logic	Digital and sustainability maturity assessed within a unified and structurally integrated framework	Digital maturity and sustainability performance assessed separately and analytically linked	Sustainability incorporated as an intrinsic dimension within digital maturity structures
Sector	SMEs; Manufacturing; Supply chains	Industrial ecosystems; Manufacturing; Industry 4.0 firms	Construction; General business; Industry 5.0; Smart cities
ESG Coverage	E (strong); S (moderate); G (variable)	E; S; G (separate projections)	E (strong); S (moderate); G (limited)
Methodological Type	Conceptual + empirical validation	Quantitative empirical (survey; modelling; PCA)	Design science; conceptual + sector case applications
Typical Integration Mechanism	Composite indices; weighted aggregation; ESG mapping	Correlation analysis; PCA; regression modelling	ESG indicators embedded into maturity dimensions
Representative Studies	Tiron-Tudor et al. (2024); Münnich et al. (2025); Fatemi (2024); Fortier et al. (2025); Trequattrini et al. (2025); Demir et al. (2022)	Babkin et al. (2021); Jamwal et al. (2025); Gladysz et al. (2024)	Sell (2024); Merdin et al. (2022); Han (2025); Djebbouri et al. (2025); Diaz Schery et al. (2025); Santana et al. (2019)

As shown in Table 1, combined maturity models represent the most structurally integrated approach, while parallel and embedded models reflect varying degrees of methodological coupling between digital and sustainability assessment. The following sections elaborate on each category in greater detail.

Combined Maturity Models represent the most integrated approach, treating digital and sustainability maturity as interconnected dimensions within a unified assessment framework. The Synergetic Digital Sustainable Development Maturity Model (SDSDMM) is an example of a combined maturity model developed for SMEs in Eastern Europe. The SDSDMM captures both digitalization and sustainability dimensions through a user-friendly tool validated via focus group sessions with experts who confirmed its transparency and practicality (Tiron-Tudor et al., 2024). Similarly, Münnich et al. (2025) developed a combined digitalization-sustainability maturity model for SMEs that systematically maps ESG metrics to digital maturity levels, validated through expert feedback and 37 case evaluations. Fatemi (2024) proposed a weighted maturity model for assessing digital–sustainability synergy within the twin transformation paradigm, applying composite scoring logic validated through multiple case applications. Fortier et al. (2025) developed an integrated framework for manufacturing SMEs that structurally embeds sustainable performance indicators within digital maturity assessment. Trequattrini et al. (2025) introduced a composite digital–sustainability readiness index linking ESG metrics to digital maturity levels through weighted scoring validated in SME contexts. The Smart and Sustainable Supply Chain Readiness and Maturity Model (S3RM) represents another significant combined framework, specifically designed for supply chain contexts. The S3RM employs a triple-bottom-line approach encompassing smartness dimensions (availability, integrity, adaptability) and sustainability dimensions (social, environmental, economic). The model calculates a composite Smart and Sustainable Readiness and Maturity Index by averaging sustainability scores' summation and smartness scores' multiplication, validated through automotive industry case studies (Demir et al., 2022).

Parallel Assessment Frameworks maintain separate but coordinated evaluation of digital maturity and sustainability performance. Babkin et al. (2021) developed a methodology for assessing industrial ecosystem maturity that extends the traditional ESG framework with a fourth projection: digital maturity. This approach employs principal component analysis and hierarchical agglomerative clustering to assess six maturity levels (very high, advanced, basic, elementary, zero, and minus one), demonstrating positive and significant correlations across all four assessment projections. The methodology was validated on Russia's national industrial ecosystem and metallurgy/mining sector. Jamwal et al. (2025) demonstrated positive associations between Industry 4.0 maturity and sustainability outcomes using quantitative modelling. Gladysz et al. (2024) assessed Industry 4.0 maturity and sustainability dimensions separately while identifying interdependencies.

Embedded Dimensional Models incorporate sustainability as an intrinsic dimension within digital maturity frameworks. Sell (2024) developed a maturity model for evaluating data-driven sustainability management that encompasses eight technical and organizational dimensions derived from theory and practitioner insights through design science research. The model progresses from basic implementation to real-time integration and cloud connectivity, emphasizing the role of data culture in sustainability management. Several frameworks target specific industry contexts (Gladysz et al., 2024; Criveanu, 2026). Han (2025) introduced an updated digital maturity assessment model for construction companies that directly correlates digital maturity levels to ESG performance enhancements. Diaz Schery et al. (2025) established a framework linking Building Information Modeling (BIM) maturity with Industry 4.0 and sustainability paradigms for construction digital transformation. Santana et al. (2019) developed a Sustainability Maturity Model (SMM) for smart cities using ISO 37122 sustainability indicators, following the CMMI maturity indices and COBIT process controls.

3.2. Types of Sustainable Performance Indicators Used

The literature suggests that many sustainability indicators are integrated into digital maturity models, but there is considerable variation in specificity, measurement approaches, and emphasis across the ESG dimensions.

Environmental indicators are the most prevalent sustainability metrics and reflect the climate change and resource depletion challenges facing organizations (Eisner et al., 2022; Fan, 2025; Li et al., 2025), and the most commonly cited environmental indicators include: 1. *Energy and Emissions*: Energy consumption and efficiency, renewable energy adoption, carbon intensity, and carbon emissions (Scope 1, 2, and 3) are mentioned in most frameworks (Babkin et al., 2021), and carbon emissions and energy efficiency metrics were included in the industrial ecosystem maturity assessment (Maghawry et al., 2025). 2. *Resource Management*: Water consumption and efficiency, waste generation and recycling rates, circular economy practices, and material efficiency are among the commonly cited metrics (Demir et al., 2022; Münnich et al., 2025). 3. *Environmental Impact*: Biodiversity impacts, pollution levels, environmental compliance, and ecosystem services metrics are included in more comprehensive frameworks (Sell, 2024).

While less emphasized than environmental metrics in most frameworks, *social indicators* address organizational relationships with employees, customers, suppliers, and communities: 1. *Employee Welfare*: Occupational health and safety, employee training and development, work-life balance, and employee satisfaction metrics are commonly included; Tiron-Tudor et al. (2024) included social dimensions such as employee welfare in the SDSDMM framework, Babkin et al. (2021) included social metrics as one of four assessment projections in their industrial ecosystem maturity model. 2. *Diversity and Inclusion*: Gender diversity, ethnic diversity, pay equity, and inclusive workplace practices appear; Demir et al. (2022) included social responsibility metrics in the sustainability dimensions of the S3RM model. 3. *Stakeholder Engagement*: Customer satisfaction, community engagement, stakeholder dialogue, and social impact assessment metrics appear; Sell (2024) highlighted the need for sustainability communication that is tailored for specific stakeholder groups. 4. *Supply Chain Social Responsibility*: Labor practices in supply chains, human rights due diligence, supplier diversity, and fair trade practices appear; Demir et al. (2022) incorporated supply chain social responsibility into the S3RM model validated through automotive industry applications.

Governance indicators focus on organizational structures, policies, and practices ensuring accountability, transparency, and ethical conduct: 1. *Board and Leadership*: Board composition and independence, executive compensation alignment, leadership diversity, and succession planning metrics appear in comprehensive ESG frameworks.

Babkin et al. (2021) included corporate governance as one of the core ESG projections in their maturity assessment methodology. 2. *Ethics and Compliance*: Business ethics policies, anti-corruption measures, regulatory compliance, whistleblower protections, and ethical supply chain practices feature prominently. Cenholt & Presser (2025) developed an ESG-Capability Maturity Model (ESG-CMM) that bridges ESG metrics with capability maturity frameworks, emphasizing governance accountability. 3. *Transparency and Reporting*: Sustainability reporting quality, data transparency, third-party verification, and stakeholder communication metrics appear increasingly. Sell (2024) emphasized the importance of transparent sustainability reporting and the challenges of formulating appropriate sustainability KPIs. 4. *Risk Management*: Climate risk assessment, social risk management, cybersecurity governance, and integrated risk frameworks appear in advanced maturity models (Sira, 2025; Koldovskiy et al., 2025). Sivaiah et al. (2025) developed a maturity-based adoption model for sustainability reporting in SMEs that emphasizes governance and transparency.

The literature reveals significant variation in indicator specificity. Some frameworks employ broad, qualitative indicators (e.g., „environmental performance", „social responsibility"), while others specify quantitative metrics with clear measurement protocols (e.g., „tons of CO2 equivalent emissions per unit of production", „percentage of renewable energy in total energy consumption"). This variation reflects different framework purposes, target audiences, and data availability constraints.

3.3. Integration Approaches and Methodologies

The literature reveals diverse methodological approaches for integrating sustainability indicators into digital maturity models, ranging from simple additive scoring to sophisticated weighted composite indices and embedded dimensional frameworks.

The most common integration method is to combine digital maturity and sustainability scores through weighted aggregation (Babkin et al., 2021; Fortier et al., 2025; Trequattrini et al., 2025), which involves assigning weights to different indicator categories based on their relative importance (Trequattrini et al., 2025), with the weighting scheme determined through expert judgment, AHP, or empirical validation (Trequattrini et al., 2025), allowing organizations to tailor the framework to their contexts and strategic priorities. A weighted maturity model for assessing digital-sustainability synergy in twin transformation (Fatemi, 2024) is another example of the weighting method applied to maturity dimensions that was validated by multiple case applications and deemed flexible and practical. Demir et al. (2022) used a mathematical integration method to calculate the S3RM index by averaging the summation of sustainability scores and the multiplication of smartness scores.

The parallel assessment with correlation analysis, which has separate pathways for digital maturity and sustainability performance and examines relationships between them, shows that all four assessment projections (environmental, social, governance, and digital maturity) are positively and significantly correlated, and that digital maturity advancement will lead to improvements in other dimensions, thus yielding insights into synergies and trade-offs without forcing artificial integration (Babkin et al. 2021). Industry 4.0 maturity and sustainability outcomes are also positively correlated, with the best sustainability performance achieved by firms that are more mature in Industry 4.0 (Jamwal et al. 2025).

Embedded dimensional integration treats sustainability as an intrinsic dimension within digital maturity frameworks rather than a separate assessment domain. Sell (2024) developed a maturity model with eight technical and organizational dimensions that inherently incorporate sustainability considerations. For example, the data handling dimension progresses from basic implementation to real-time sustainability data integration and cloud connectivity. This approach ensures that sustainability is considered at every stage of digital maturity progression. Merdin et al. (2022) developed a digital maturity model for Turkish businesses that includes environmental elements as one of seven core dimensions alongside strategy, customers, employees, process management, technology and data management, organizational culture, and innovation. This embedded approach treats sustainability as a fundamental component of digital maturity rather than an add-on consideration (Djebbouri et al., 2025).

Maturity Level Mapping explicitly defines sustainability performance expectations at each digital maturity level. Münnich et al. (2025) systematically mapped ESG metrics to digital maturity levels, specifying the sustainability capabilities expected at each stage of digital advancement. For example, organizations at basic digital maturity levels might track simple environmental metrics manually, while those at advanced levels employ real-time IoT-enabled monitoring and AI-driven optimization. Han (2025) directly mapped digital maturity levels to ESG performance improvements in construction companies, demonstrating how digital capabilities enable progressively sophisticated sustainability management. This approach provides clear roadmaps for organizations seeking to advance both digital and sustainability maturity simultaneously.

Validation Approaches vary significantly across frameworks, with important implications for framework credibility and practical utility: 1. *Case Study Validation*: Multiple frameworks employ single or multiple case studies to demonstrate practical applicability. Münnich et al. (2025) validated their combined model through 37 SME case evaluations. Demir et al. (2022) conducted automotive industry case studies to validate the S3RM model. Case studies provide rich contextual insights but limited generalizability. 2. *Expert Panel Validation*: Several frameworks employ expert judgment to validate indicator selection, weighting schemes, and maturity level definitions. Tiron-Tudor et al. (2024) validated the SDSDMM through focus group sessions with experts who confirmed its transparency and practicality. Münnich et al. (2025) incorporated expert feedback into their systematic indicator selection process. Expert validation enhances face validity but may reflect expert biases. 2. *Empirical Data Validation*: Advanced frameworks employ objective performance data to validate relationships between digital maturity and sustainability outcomes. Trequattrini et al. (2025) validated their composite index with empirical evidence from industrial SMEs. This approach provides the strongest evidence of framework validity but requires access to comprehensive organizational data.

3.4. Industry Applications and Case Studies

The literature reveals diverse industry applications of integrated digital-sustainability maturity frameworks, with significant concentration in manufacturing, supply chain management, construction, and smart cities. Manufacturing and

Industrial SMEs represent the most extensively studied context, reflecting both the sector's significant environmental footprint and the critical role of SMEs in economic development. Münnich et al. (2025) applied their combined digitalization-sustainability maturity model to 37 SME case evaluations across diverse manufacturing sectors. The study demonstrated that SMEs face unique challenges in resource-constrained digital transformation while simultaneously addressing sustainability imperatives. Fortier et al. (2025) specifically focused on integrating sustainable performance into digital maturity models for manufacturing SMEs, recognizing their distinct needs compared to large enterprises.

Tiron-Tudor et al. (2024) developed the SDSDMM specifically for SMEs in Eastern Europe operating within Industry 5.0 contexts. The framework addresses challenges in SME awareness, understanding, and resource constraints while providing a user-friendly assessment tool. The focus on Eastern European SMEs highlights regional variations in digital-sustainability maturity and the need for context-specific frameworks.

Babkin et al. (2021) applied their industrial ecosystem maturity assessment methodology to Russia's national industrial ecosystem and metallurgy/mining sector. The results showed that Russia's industrial ecosystem maturity level was "basic" with prospects for advancement to "advanced," while the metallurgy and mining ecosystem achieved "advanced" maturity. This application demonstrates the framework's utility for national-level industrial policy and sector-specific strategic planning.

Given the extensive environmental and social impacts of supply chains, Supply Chain Management emerges as a key application domain. The S3RM model was validated by Demir et al. (2022) through automotive industry supply chain case studies to show how the framework can recognize strengths, weaknesses, opportunities, and threats for supply chain operations, with the automotive application being especially relevant due to the complex global supply chains of the sector and the high sustainability challenges.

Another example is the digital sustainable maturity grid for supply chains that Silva et al. (2022) introduced, which integrates ESG metrics into definitions of maturity levels without empirical testing, but provides a conceptual basis for the assessment of supply chain sustainability, acknowledging that organizational sustainability performance is becoming more dependent on extended value chain management beyond direct operations.

Another major application domain is Construction Industry, which reflects large environmental impacts of the construction industry and the ongoing digitization of the construction industry using Building Information Modeling (BIM) and other technologies, Han (2025) developed an extended digital maturity assessment model for construction companies and directly mapped digital maturity levels to ESG performance improvements based on the construction-specific framework addressing the construction industry characteristics such as project-based organization, fragmented value chains, and regulatory complexity.

Diaz Schery et al. (2025) bridged BIM maturity with Industry 4.0 and sustainability paradigms, recognizing that construction digital transformation must integrate sustainability considerations from the outset. The framework embeds social and economic sustainability indicators into BIM maturity assessment, though it lacks empirical case validation.

Smart Cities represent an emerging application domain where digital technologies and sustainability imperatives naturally converge. Santana et al. (2019) developed a Sustainability Maturity Model (SMM) for smart cities based on ISO 37122 sustainability indicators. The framework was inspired by CMMI maturity indices and COBIT process controls, demonstrating how established maturity model methodologies can be adapted to urban sustainability contexts. A case study in a hypothetical city validated the framework's ability to classify cities by maturity level based on standardized sustainability indicators.

Cross-Sector Insights from comparative analysis of industry applications: First, frameworks need to be sector-specific, taking into account industry characteristics, regulatory environments, and stakeholder expectations; second, SMEs have different challenges than large enterprises, so tools should be simplified and resource requirements lower; third, a supply chain and ecosystem perspective is becoming more relevant, as it is recognized that organizational sustainability depends on extended value networks; and fourth, validation approaches are different by sector, with manufacturing and supply chain studies requiring more rigorous empirical validation than in the case of construction and smart city applications.

3.5. Challenges and Gaps in Current Research

Despite significant progress in integrating sustainability indicators into digital maturity models, the literature reveals persistent challenges and research gaps that limit framework effectiveness and adoption.

Lack of Standardization emerges as the most fundamental challenge. The literature reveals proliferation of diverse frameworks with limited convergence on common dimensions, indicators, or maturity level definitions. This fragmentation creates several problems. Organizations struggle to select appropriate frameworks for their contexts. Benchmarking across organizations and sectors becomes difficult or impossible. Longitudinal tracking of progress is complicated when frameworks evolve or organizations switch between frameworks. Regulatory and reporting alignment is hindered when frameworks do not map to established standards like GRI, SASB, or TCFD. Tiron-Tudor et al. (2024) acknowledged that their SDSDMM framework, while validated through focus groups, provides limited indicator detail and sector focus. Similarly, multiple studies note the absence of unified assessment standards that would enable cross-organizational and cross-sector comparison (Fortier et al., 2025; Silva et al., 2022).

Limited Empirical Validation represents a significant methodological gap. Many proposed frameworks lack rigorous empirical testing, relying instead on conceptual development, expert validation, or single case studies. Silva et al. (2022) explicitly acknowledged that their digital sustainable maturity grid for supply chains lacks empirical testing. Diaz Schery et al. (2025.) noted the absence of empirical case validation for their BIM-sustainability integration framework. Fortier et al. (2025) recognized limited empirical validation of their integrated framework for manufacturing SMEs. This validation gap creates uncertainty about framework reliability, validity, and practical utility. Organizations may hesitate to invest resources in implementing frameworks without strong evidence of their effectiveness. Researchers cannot build cumulative knowledge when frameworks remain untested or tested only in limited contexts.

Practical limitations: Data Availability and Quality Constraints (Sell 2024) make it difficult to collect sustainability background data across the whole product life cycle and to design suitable sustainability KPIs, especially for Scope 3 emissions, supply chain social indicators, and long-term environmental impacts; many organizations (especially SMEs) do not have the data infrastructure, measurement systems, and reporting capabilities to undertake sustainability assessments; and digital maturity limitations (low maturity organizations do not have the technological capabilities to collect and analyze sustainability data) creates a circular dependency: sustainability assessment needs digital capabilities, and digital maturity assessment needs sustainability considerations.

Sector-Specific Adaptation Difficulties limit framework transferability across industries. While some frameworks claim broad applicability, effective implementation typically requires substantial customization to address sector-specific characteristics, regulatory requirements, and stakeholder expectations. Han (2025) developed a construction-specific framework recognizing that generic models inadequately address industry particularities. Demir et al. (2022) validated their S3RM model in automotive supply chains but acknowledged limited generalizability to other sectors. The tension between framework generalizability and sector specificity remains unresolved. Highly generic frameworks may lack practical utility, while sector-specific frameworks limit knowledge transfer and comparative analysis across industries.

SME-Specific Challenges receive significant attention but remain incompletely addressed. Multiple studies recognize that SMEs face distinct challenges including limited financial resources, constrained human capital, lower digital maturity baselines, limited sustainability expertise, and reduced stakeholder pressure compared to large enterprises (Fortier et al., 2025; Münnich et al., 2025; Tiron-Tudor et al., 2024). However, most frameworks remain complex and resource-intensive, limiting SME adoption. Quenum et al. (2025) developed a self-audit tool for SME digital maturity assessment that embeds sustainability indicators, but noted limited empirical validation and sector detail. The challenge of creating frameworks that are simultaneously comprehensive, rigorous, and accessible to resource-constrained SMEs remains largely unresolved.

Integration Methodology Gaps persist despite diverse approaches. The literature lacks clear guidance on optimal integration methodologies for different contexts. Should sustainability be embedded as dimensions within digital maturity models, assessed in parallel with correlation analysis, or combined through weighted composite indices? What weighting schemes are most appropriate? How should trade-offs between digital advancement and sustainability performance be managed? Fatemi (2024) proposed a weighted maturity model but acknowledged that optimal weighting schemes remain context-dependent and require further research. The mathematical integration approach employed by Demir et al. (2022) averaging sustainability scores' summation and smartness scores' multiplication represents an innovative but untested methodology requiring validation across diverse contexts.

Temporal Dynamics and Longitudinal Assessment: Most frameworks focus on a point-in-time assessment rather than temporal dynamics, learning curves, or longitudinal progression. Organizations require direction on the expected timeline for maturity advancement, the sequencing of digital and sustainability initiatives, and how to manage transition periods. There is limited evidence in the literature as to how organizations move through maturity levels over time or what intervention strategies are most effective at accelerating advancement.

Emerging Technology Integration remains underdeveloped. While frameworks acknowledge the importance of advanced technologies like artificial intelligence, blockchain, and IoT for sustainability management, they provide limited guidance on how these technologies should be incorporated into maturity assessment. Sell (2024) emphasized real-time integration and cloud connectivity but did not fully specify how emerging technologies should be evaluated within maturity frameworks.

Global South and Emerging Economy Contexts receive insufficient attention. Most frameworks are developed and validated in European, North American, or developed Asian contexts. Maghawry et al. (2025) addressed emerging economy contexts through their CBAM digital readiness index but noted limited validation and sector-specific case studies. The applicability of existing frameworks to emerging economies with different institutional environments, resource constraints, and sustainability priorities remains largely unexplored. Taken together, these findings highlight both the progress achieved and the persistent limitations in the development of integrated digital–sustainability maturity frameworks, forming the basis for the concluding discussion and future research directions.

Conclusions and Implications

This study provided a comprehensive review of the literature on integrating sustainability performance indicators into digital maturity models, based on the analysis of 30 highly relevant peer-reviewed journal articles published between 2016 and 2026. The findings indicate that this research field is rapidly evolving, driven by the growing importance of digital transformation and increasing pressure on organizations to improve sustainability outcomes. As a result, the concept of „twin transformation", referring to the simultaneous advancement of digital capabilities and sustainability performance, has emerged as a key strategic priority for modern organizations.

The analysis demonstrates a clear shift in the literature toward integrated assessment frameworks that treat digital maturity and sustainability as interdependent dimensions rather than separate organizational domains. The most advanced models apply combined maturity frameworks, parallel evaluation approaches supported by correlation analysis, or embedded sustainability dimensions within digital maturity structures. However, substantial diversity remains in terms of integration methodologies, indicator selection, and validation techniques. Environmental indicators continue to dominate most frameworks, while social and governance dimensions are often less developed, highlighting the need for a more balanced and holistic assessment approach in future research.

This study makes several important theoretical contributions. First, it systematizes a fragmented body of research by providing a structured synthesis of how sustainability performance indicators are incorporated into digital maturity models. Second, it develops a conceptual categorization of dominant integration approaches, thereby clarifying the structural differences among combined, parallel, and embedded maturity frameworks. Third, by examining methodological patterns and validation practices, the study identifies key theoretical gaps that hinder the development of standardized and comparable digital–sustainability maturity assessments. In doing so, the paper strengthens the conceptual foundation of the twin transformation paradigm and provides a basis for the development of more coherent and integrative assessment models.

Methodologically, the study contributes by applying a rigorous systematic literature review protocol, ensuring transparency, replicability, and analytical consistency in mapping integration mechanisms across diverse research contexts.

From a practical perspective, the findings offer actionable insights for managers, policymakers, and organizational decision-makers seeking to align digital transformation initiatives with sustainability objectives. The identified integration approaches provide structured pathways for incorporating ESG indicators into digital maturity assessments, enabling organizations to move beyond technology-centric evaluation toward more comprehensive performance measurement systems.

The study also highlights critical implementation challenges, including limited data availability, lack of standardized metrics, and constraints faced by small and medium-sized enterprises (SMEs). By identifying these barriers, the paper informs practitioners about key considerations in designing and implementing integrated digital–sustainability strategies. Moreover, the findings suggest that integrated maturity frameworks can support evidence-based policymaking and the development of regulatory instruments that promote responsible and sustainable digital transformation.

Despite significant progress, several persistent challenges limit the broader applicability of integrated frameworks. The most critical issues include the lack of standardization across models, limited empirical and longitudinal validation, and the underrepresentation of emerging economies and Global South contexts. Future research should prioritize the development of unified and comparable assessment standards, the execution of rigorous longitudinal studies, and the incorporation of advanced technologies such as artificial intelligence and big data analytics into sustainability assessment processes. Furthermore, greater emphasis is needed on refining social and governance indicators and integrating circular economy and regenerative sustainability principles into digital maturity frameworks. Overall, integrating sustainability into digital maturity models is evolving from a conceptual aspiration into a strategic necessity. As organizations navigate increasing technological complexity and sustainability pressures, integrated maturity frameworks are becoming essential tools for enhancing long-term competitiveness, accountability, and organizational resilience.

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