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Sustainability in Industry 4.0 Context: A Meta-Analysis Review

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Abstract

Sustainability, encompassing social, economic, and environmental dimensions, is increasingly central in both academia and practice as organizations respond to global economic shifts and technological disruptions. The convergence of sustainability and Industry 4.0 (4IR) is transforming global business environments and prompting firms to embed sustainability into core operations to meet regulatory, environmental, and stakeholder expectations. Manufacturing remains critical to global development, contributing to employment, revenue, and social advancement. As manufacturing business models evolve, integration across functional domains is essential to maximize value and drive performance. Business processes, including maintenance, play a pivotal role in ensuring reliability, efficiency, and safety in production environments. However, organizations face challenges such as reducing emissions, energy use, and operational costs, while simultaneously adopting innovative technologies to support sustainable manufacturing. Despite growing interest in the 4IR-sustainability nexus, limited empirical research explores how digital technologies contribute to sustainability goals. This study addresses that gap through a meta-analysis of 1,398 peer-reviewed articles published between 2014 and 2025, examining the influence of Industry 4.0 technologies on sustainable manufacturing outcomes. Using bibliometric analysis, this study identifies major themes and research gaps, including integration challenges, application diversity, and the underrepresentation of comprehensive frameworks aligned with the Triple Bottom Line (TBL). Findings highlight the transformative potential of technologies such as IoT, AI, and digital twins in driving sustainable performance, while also underscoring the need for cross-disciplinary strategies and policy reforms. This research offers valuable insights for academics, practitioners, and policymakers seeking to leverage 4IR technologies for sustainable industrial transformation.

Keywords
Sustainability, Industry 4.0, Meta-Analysis