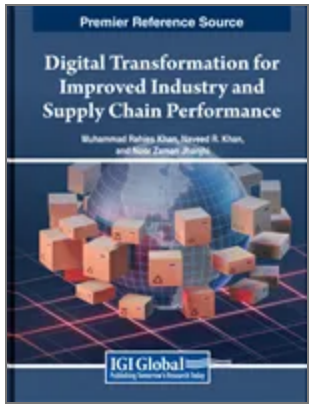

Industry 4.0: The Digital Revolution Unleashing Sustainable Supply Chains

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Abstract

Industry 4.0 is revolutionizing manufacturing and supply chain management through the integration of advanced digital technologies. This chapter provides an overview of Industry 4.0 and its implications for sustainable supply chains. Through interconnected systems, automation, artificial intelligence, and additive manufacturing, Industry 4.0 enhances efficiency, agility, and transparency in supply chain operations. The chapter explores how Industry 4.0 technologies contribute to resource efficiency, energy efficiency, waste reduction, transparency, and social responsibility in supply chains. Challenges and opportunities associated with implementing Industry 4.0 are discussed, along with best practices and case studies showcasing successful implementations. By embracing Industry 4.0, businesses can create more sustainable and efficient supply chains, contributing to a greener future.

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Introduction

A major revolution in manufacturing is coming; be ready. Driven by a wave of transformational digital technologies, Industry 4.0, the next phase of the industrial revolution, is here. However, this revolution is about more than just automation and efficiency; it's about paving the way for supply chains that are sustainable (Bag & Telukdarie, 2021; Devezas & Sarygulov, 2017). Before exploring it more, we briefly describe its definition and significance with respect to the industrial revolution.

Industry 4.0, also known as the Fourth Industrial Revolution, marks a significant shift in manufacturing and production processes. It is characterized by the integration of advanced digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and cyber-physical systems (CPS), into traditional industrial practices (Bartodziej & Bartodziej, 2017; Culot et al., 2019; El Jaouhari et al., 2022). This digital revolution is transforming supply chains across various industries, leading to increased efficiency, agility, and sustainability (Guban & Kov'acs, 2017; Mohamed, 2018).

The implications of Industry 4.0 for supply chain sustainability are multi- faceted. By enabling real-time data collection, analysis, and optimization, these technologies can significantly reduce waste, optimize resource utilization, and im- prove energy efficiency throughout the supply chain (Ghobakhloo, 2020; Gorecky et al., 2014). Additionally, Industry

4.0 can promote transparency and traceability, allowing for better monitoring of environmental and social impacts across the value chain (Mohamed, 2018; Muthusami & Srinivsan, 2018).

– Interconnectivity: Through the Internet of Things (IoT) and sensor networks, physical assets and machines across the supply chain are interconnected, enabling real-time data collection and communication. This transparency al- lows for optimized resource allocation, reduced waste, and improved visibility into environmental impact (Da Xu & Eric, 2018; Muthusami & Srinivsan, 2018; Ojo et al., 2018).
– Automation and Robotics: Advanced robotics and automation are automating repetitive tasks, enhancing efficiency and accuracy while reducing human error. This may result in less energy being used, less material waste, and in- creased workplace safety (Frank et al., 2019).
– Artificial Intelligence and Machine Learning: In order to forecast demand, improve logistics, and spot inefficiencies, massive volumes of data are analyzed by AI and machine learning algorithms. This data-driven strategy can minimize waste production, enhance inventory control, and lower transportation- related emissions (Gorecky et al., 2014; Tayyab et al., 2023).
– Additive production (3D Printing): This technology eliminates the need for conventional production methods, which frequently result in large waste, by enabling the creation of complicated parts on demand (Malik et al., 2022). Additionally, 3D printing enables localized production, minimizing transportation emissions and associated environmental impact (Jandyal et al., 2022). Figure (1) explains how Industry 4.0 will open up a sustainable future for supply chains.

Industry 4.0 technology' revolutionary potential to realize sustainable supply chain practices. We shall examine how these technologies specifically contribute to different facets of sustainability, such as:

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