


Chapter 2

Artificial Intelligence and Robotics in Smart Sustainable Warehouses: A Comprehensive Review

Mariem Mrad

 <https://orcid.org/0000-0002-2377-1401>

Faculty of Economics and Management of Sfax, University of Sfax, Tunisia

Younes Boujelbene

Faculty of Economics and Management of Sfax, University of Sfax, Tunisia

ABSTRACT

This chapter investigates the transformative role of artificial intelligence and robotics in advancing sustainable warehousing within green supply chains. Utilizing a bibliometric analysis of 122 documents from the Scopus database (2014–2024), it examines the intersection of AI, robotics, smart technologies, sustainability, and warehousing. The analysis reveals a 19.9% compound annual growth rate in publications, highlighting key sources, contributing countries, and thematic clusters such as AI-driven optimization and robotic automation. The chapter details applications in energy management, inventory optimization, logistics efficiency, and circular economy integration, supported by case studies of industry leaders. A proposed framework offers practical strategies for adopting these technologies, while addressing challenges like high costs and data integration. Aligned with the United Nations Sustainable Development Goals, this chapter provides actionable insights for warehouse managers, researchers, and policymakers committed to low-carbon, intelligent logistics.

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1. INTRODUCTION

Warehousing represents a critical node in global supply chains, serving as the backbone of storage, consolidation, and distribution activities. Conventional warehousing operations, however, are energy-intensive and contribute significantly to environmental degradation. Estimates suggest that warehouses account for nearly 10% of logistics-related greenhouse gas (GHG) emissions, primarily due to energy consumption in lighting, heating, ventilation, air conditioning (HVAC), and material handling processes (International Energy Agency, 2022). With intensifying concerns over climate change and the growing influence of international regulatory frameworks such as the Paris Agreement, warehouses are under increasing pressure to transition toward low-carbon operations and align with global sustainability agendas, notably the United Nations Sustainable Development Goals (SDGs).

Technological innovation offers viable pathways for sustainable transformation. AI, encompassing machine learning, predictive analytics, and optimization algorithms, enables warehouses to enhance energy management, optimize inventory systems, and streamline logistics planning (Yadav et al., 2024). In parallel, robotics, ranging from automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) to automated storage and retrieval systems (AS/RS), improves operational precision and reduces energy consumption (Zhen & Li, 2022). The integration of AI and robotics facilitates the emergence of smart and sustainable warehouses capable of minimizing environmental impact while simultaneously enhancing efficiency and productivity. Recent evidence suggests, for instance, that AI-optimized robotic systems can achieve 20–30% reductions in energy consumption through intelligent task allocation and path planning (DHL, 2023).

This chapter contributes to the literature by conducting a bibliometric analysis of 122 peer-reviewed documents indexed in Scopus between 2014 and 2024. While previous studies have often examined the role of digital technologies within broader supply chain contexts (Mrad et al., 2025), this analysis focuses specifically on warehousing, offering a targeted perspective. The chapter pursues five interrelated objectives:

1. To analyse publication trends, influential sources, and thematic clusters in sustainable warehousing research, highlighting their driving factors;
2. To examine applications of AI and robotics in energy optimization, inventory management, and circular economy integration;
3. To critically evaluate real-world implementations through balanced case studies of both successful initiatives and failed attempts;
4. To propose a comprehensive adoption framework incorporating lifecycle assessment, financial feasibility, and ethical considerations; and

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